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May 11, 2006
BYR 2006-037

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555-001

References: (a) License No. DPR-3 (Docket No. 50-29)

(b) BYR 2004-133, Submittal of Revision 1 to the Yankee Nuclear Power Station's License Termination Plan

(c) Yankee Nuclear Power Station – Issuance of Amendment 158 Re: License Termination Plan

Subject: Submittal of YNPS-FSS-AUX01-00 and YNS-FSS-NSY12-00, the Final Status Survey Reports for Survey Areas AUX-01 and NSY-12, Respectively

Dear Madam/Sir:

This letter submits YNPS-FSS-AUX01-00, Final Status Survey Report for AUX-01, and YNPS-FSS-NSY12-00, Final Status Survey Report for NSY-12. These reports were written in accordance with Section 5 of the YNPS License Termination Plan, "Final Status Survey Plan," and are consistent with the guidance provided in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).

We trust that this information is satisfactory; however if you should have any questions or require any additional information, please contact Alice Carson at (301) 916-3995 or the undersigned at (413)-424-2261.

Sincerely,

YANKEE ATOMIC ELECTRIC COMPANY

Joseph Lynch
Regulatory Affairs Manager

Enclosure: YNPS-FSS-AUX01-00
YNPS-FSS-NSY12-00 (2 hard copies plus CD)

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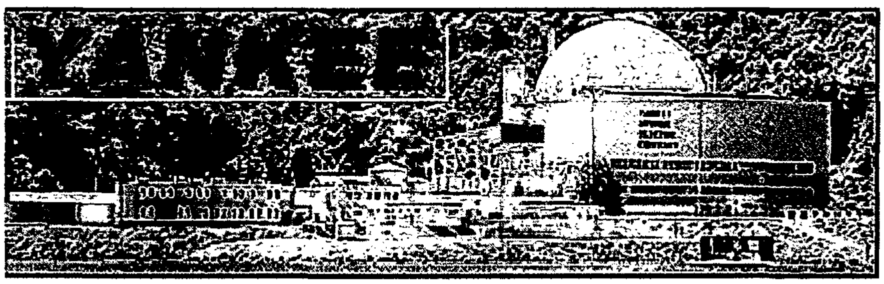
Yankee Nuclear Plant Station Final Status Survey Report For AUX-01



Yankee Atomic Electric Company

YANKEE NUCLEAR POWER STATION
FINAL STATUS SURVEY REPORT

REPORT NO.: YNPS-FSS-AUX-01-00

Prepared by: ______________________ Date: 5-8-06
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Approved by: ______________________ Date: 5/8/06
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List of Abbreviations and Acronyms

AL .... Action Level
ALARA .... As Low As Reasonably Achievable
c/d .... Counts per Disintegration
DCGL .... Derived Concentration Guideline Level
$DCGL_{EMC}$ .... DCGL for small areas of elevated activity
$DCGL_W$ .... DCGL for average concentration over a wide area, used with statistical tests
DQO .... Data Quality Objectives
EMC .... Elevated Measurement Comparison
ETD .... Easy-to-Detect
FSS .... Final Status Survey
FSSP .... Final Status Survey Plan
GPS .... Global Positioning System
H_o .... Null Hypothesis
HSA .... Historical Site Assessment
HTD .... Hard-to-Detect
ISOCS .... *In-situ* Object Counting System®
LBGR .... Lower Bound of the Grey Region
LTP .... License Termination Plan
MARSSIM .... Multi-Agency Radiation Survey and Site Investigation Manual
MDA .... Minimum Detectable Activity
MDC .... Minimum Detectable Concentration
PAB .... Primary Auxiliary Building
QAPP .... Quality Assurance Project Plan
QC .... Quality Control
RCA .... Radiological Controlled Area
RP .... Radiation Protection
RSS .... Reactor Support Structure
SFP .... Spent Fuel Pool
VC .... Vapor Container
VCC .... Vertical Concrete Cask
VSP .... Visual Sample Plan
YNPS .... Yankee Nuclear Power Station

1.0 EXECUTIVE SUMMARY

A Final Status Survey (FSS) was performed of Survey Area AUX-01 in accordance with Yankee Nuclear Power Station's (YNPS) License Termination Plan (LTP). This FSS was conducted as a building surface FSS with structure occupancy Derived Concentration Guideline Levels (DCGLs) even though the AUX-01 structure will be subsurface at license termination. This practice conservatively implements LTP criteria that subsurface structure surfaces be evaluated for the presence of contamination.

1.1 Identification of Survey Area and Units

AUX-01 consisted of the portion of the PAB (a structure constructed of reinforced concrete) designed to contain the radiological constituents resulting from operation of the primary (radioactive) systems of the YNPS. AUX-01 is bounded by NOL-01 on the north, NOL-02 on the east, NOL-05 on the south and AUX-02 on the west. The PAB structure was free released post operation and demolished. However, portions of AUX-01 were below grade and inaccessible for the free release survey until subsequently exposed during the demolition and excavation processes. The remaining walls and foundation comprise this Survey Area. AUX-01 is located within the Radiological Controlled Area (RCA) and has been classified as a MARSSIM Class 1 area due to initial HSA, surveys and remedial activities performed in adjacent areas.

Survey Area AUX-01 consists of four Survey Units, AUX-01-01 through AUX-01-04. Survey Unit AUX-01-01 consists of the remaining PAB walls that lie within the SFP Excavation footprint. Survey Unit AUX-01-02 encompasses the concrete walls and floor of the pit from the 1022' elevation down to and including the floor of the pit at the 1004' elevation. Survey Unit AUX-01-03 consists of remnant PAB walls and floor existing in the east side of the former structure. Survey Unit AUX-01-04 consists of remnant PAB walls and floor existing in the middle section of the former structure.

1.2 Dates(s) of Survey

The FSS of the AUX-01 Survey Area was performed between September 12th, 2005, and December 22nd, 2005.

AUX-01-01 was surveyed from September 12th, 2005 to September 19th, 2005

AUX-01-02 was surveyed from December 1st, 2005 to December 7th, 2005

AUX-01-03 was surveyed from December 14th, 2005 to December 22nd, 2005

AUX-01-04 was surveyed from December 14th, 2005 to December 22nd, 2005

1.3 Number and Types of Measurements Collected

Final Status Survey Plan (FSSP) was developed for this Survey Unit in accordance with YNPS LTP and FSS procedures using the MARSSIM protocol. The planning and design of the survey plan employed the Data Quality Objective (DQO) process, ensuring that the type, quantity and quality of data gathered was appropriate for the decision-making process and that the resultant decisions were technically sound and defensible. A total of 79 direct measurements were taken, providing data for the non-parametric testing of the Survey Area. In addition to the direct measurements, a total of 113 In-Situ Object Counting System (ISOCS) scans, supplemented by hand-held survey instrument scans, were performed to provide 100 percent coverage of the Survey Area.

1.4 Summary of Survey Results

Following the survey, the data were reviewed against the survey design to confirm completeness and consistency, to verify that the results were valid, to ensure that the survey plan objectives were met and to verify Survey Unit classification. Direct measurement surveys indicated that three Survey Units had measurements that exceeded the $DCGL_W$ but were less than the $DCGL_{EMC}$, therefore the Sign Test was used to evaluate the Survey Units. The Survey Units passed the Sign Test, depicted in Attachment B, and summarized in Table 5 Retrospective power curves were generated and demonstrated that adequate power was achieved. Therefore, the null hypothesis (H_o) (that the Survey Units exceeds the release criteria) is rejected.

1.5 Conclusions

Based upon the evaluation of the data acquired for the FSS, AUX-01 meets the release requirements set forth in the YNPS LTP. The Total Effective Dose Equivalent (TEDE) to the average member of the critical group does not exceed 25 mrem/yr, including that from groundwater. 10CFR20 Subpart E ALARA requirements have been met as well as the site release criteria for the administrative level DCGLs that ensure that the Massachusetts Department of Public Health's 10 mrem/yr limit will also be met.

2.0 FSS PROGRAM OVERVIEW

2.1 Survey Planning

The YNPS FSS Program employs a strategic planning approach for conducting final status surveys with the ultimate objective to demonstrate compliance with the DCGLs, in accordance with the YNPS LTP. The DQO process is used as a planning technique to ensure that the type, quantity, and quality of data gathered is appropriate for the decision-making process and that the resultant decisions are technically sound and defensible. Other key planning measures are the review of historical data for the Survey Unit and the use of peer review for plan development.

2.2 Survey Design

In designing the FSS, the questions to be answered are: "Does the residual radioactivity, if present in the Survey Unit, exceed the LTP release criteria?" and "Is the potential dose from this radioactivity ALARA?" In order to answer these questions, the radionuclides present in the Survey Units must be identified, and the Survey Units classified. Survey Units are classified with respect to the potential for contamination: the greater the potential for contamination, the more stringent the classification and the more rigorous the survey.

The survey design additionally includes the number, type and locations of fixed measurements/samples (as well as any judgmental assessments required), scanning requirements, and instrumentation selection with the required sensitivities or detection levels. DCGLs are developed relative to the surface/material of the Survey Unit and are used to determine the minimum sensitivity required for the survey. Determining the acceptable decision error rates, the lower bound of the gray region (LBGR), statistical test selection and the calculation of the standard deviation and relative shift allows for the development of a prospective power curve plotting the probability of the Survey Unit passing FSS.

2.3 Survey Implementation

Once the planning and development has been completed, the implementation phase of the FSS program begins. Completion of remediation and final characterization activities is followed by a final walk down of the Survey Unit. If the unit is determined to be acceptable (i.e. physical condition of the unit is suitable for FSS), it is turned over to the FSS team, and FSS isolation and control measures are established. After the Survey Unit isolation and controls are in place, grid points are identified for the fixed measurements/samples, using Global Positioning System (GPS) coordinates whenever possible, consistent with the Massachusetts State Plane System, and the area scan grid is identified. Data is collected and any required investigations are performed.

2.4 Survey Data Assessment

The final stage of the FSS program involves assessment of the data collected to ensure the validity of the results, to demonstrate achievement of the survey plan objectives, and to validate Survey Unit classification. During this phase, the DQOs and survey design are reviewed for consistency between DQO output, sampling design and other data collection documents. A preliminary data review is conducted to include: checking for problems or anomalies, calculation of statistical quantities and preparation of graphical representations for data comparison. Statistical tests are performed, if required, and the assumptions for the tests are verified. Conclusions are then drawn from the data, and any deficiencies or recommendations for improvement are documented.

2.5 Quality Assurance and Quality Control Measures

YNPS FSS activities are implemented and performed under approved procedures, and the YNPS Quality Assurance Project Plan (QAPP) assures plans, procedures and instructions have been followed during the course of FSS, as well as providing guidance for implementing quality control measures specified in the YNPS LTP.

3.0 SURVEY AREA INFORMATION

3.1 Survey Area Description

AUX-01 consisted of portion of the PAB designed to contain the radiological constituents resulting from operation of the primary (radioactive) systems of the YNPS. The design of the AUX-01 portion of the PAB provided for collection and control of radioactive liquid and gaseous spills or releases that occurred within this portion of the PAB. All areas within AUX-01 had floor drains that channeled liquids to the radioactive waste system and were ventilated through the Primary Ventilation Stack. The structure was constructed of reinforced concrete.

AUX-01 is bounded by NOL-01 on the north, NOL-02 on the east, NOL-05 on the south and AUX-02 on the west. AUX-01 consists of portions of the PAB structure which were below grade and inaccessible for the free release survey until subsequently exposed during the demolition and excavation processes. The remaining walls and foundation comprise this Survey Area.

3.2 History of Survey Area

The PAB was identified as a contaminated area shortly after the initial criticality of the YNPS reactor, as a result of a pipe leak. Over the operating history of the YNPS this portion of the plant has been maintained as a contaminated area.

The PAB structure was free released post operation and demolished. However, portions of AUX-01 were below grade and inaccessible for the free release survey until subsequently exposed during the demolition and excavation processes. The remaining walls and foundation comprise this Survey Area.

Notable events are listed in Table 1.

Table 1 Survey Area AUX-01 Events/Conditions

Date	Event/Condition
Various	Facility was used to collect and channel radioactive liquid waste
Late 1980's	Initial surface remediation
Post-HSA	Facility was demolished
Winter 2005	Final Remediation and FSS performed

3.3 Division of Survey Area into Survey Units

Survey Area AUX-01 consists of four Survey Units, AUX-01-01 through AUX-01-04. Survey Unit AUX-01-01 consists of the remaining PAB walls that lie within the SFP Excavation footprint. Survey Unit AUX-01-02 consists of reinforced concrete floor, foundations, and sub-grade structures of the PAB that are expected to remain buried on site. Survey Unit AUX-01-03 consists of remnant PAB walls and floor existing in the east side of the former structure (i.e. the portion that surrounds the "Pit"). Survey Unit AUX-01-04 consists of remnant PAB walls and floor existing in the middle section of the former structure.

3.4 Survey Unit Description

3.4.1 AUX-01-01 Description

Survey Unit AUX-01-01 consists of the remaining PAB walls that lie within the SFP Excavation footprint. Total Area is 59 m^2; the maximum length is 9.4 m and the maximum width: 4.9m.

3.4.2 AUX-01-02 Description

Survey Unit AUX-01-02 consists of reinforced concrete floor, foundations, and sub-grade structures of the PAB that are expected to remain buried on site. The structure has effectively been demolished down to the 1022' elevation. Due to the change in grade elevation between the north and south sides of the PAB the north wall has been removed to approximately the 1022' elevation and the south wall has been removed to approximately the 1035' elevation. Portions of the east and west end walls remain to provide support for the south wall. The west side of the PAB remnant contains a 24' by 15.5' pit that is 18' deep (waste tank cubicles). This survey (AUX-01-02) encompasses the concrete walls and floor of the pit from the 1022' elevation down to and including the floor of the pit at the 1004' elevation. Total Area is 173.81m^2; the maximum length is 18.3 m and the maximum width: 15.7m.

3.4.3 AUX-01-03 Description

Survey Unit AUX-01-03 consists of remnant PAB walls and floor existing in the east side of the former structure (i.e. the portion that surrounds the "Pit") and contains a total surface area of 152 m^2 (69m^2 floor area). The maximum length is 14.9 m and the maximum width: 9.7m.

3.4.4 AUX-01-04 Description

Survey Unit AUX-01-04 consists of remnant PAB walls and floor existing in the middle section of the former structure and contains a total surface area of 112.6 m^2 (69m^2 floor area). Total Area is 59 m^2. The maximum length is 14.9 m and the maximum width: 9.7m.

4.0 SURVEY UNIT INFORMATION

4.1 Summary of Radiological Data Since Historical Site Assessment (HSA)

4.1.1 Chronology and Description of Surveys Since HSA

Isolation and control measures were implemented for the FSS. The condition of AUX-01 Survey Units at the time of FSS was smooth to heavily remediated steel reinforced concrete.

4.1.2 Radionuclide Selection and Basis

During the initial DQO process, Co-60 was identified as the radiological nuclide of concern due to its more restrictive DCGL value when compared to Cs-137 (sampling of soil adjacent to the concrete indicated a relationship of approximately 80% Co-60 to 20% Cs-137). Adjacent soil characterization and survey data indicate no other LTP-specified radionuclides warrant consideration in the AUX-01 Survey Units.

4.1.3 Scoping & Characterization

The characterization for radionuclides-of-concern for units AUX-01-01 and AUX-01-02 were based on data acquired from the FSS of the adjacent Survey Unit, NOL-01-03.

The characterization for radionuclides-of-concern for units AUX-01-03 and AUX-01-04 were based on data acquired from the FSS of the adjacent Survey Units AUX-01-01 and AUX-01-02.

4.2 Basis for Classification

Based upon the radiological condition of this Survey Area identified in the operating history and as a result of the decommissioning activities performed to date, Survey Area AUX-01 is identified as a Class 1 Area.

4.3 Remedial Actions and Further Investigations

No further investigations or remedial actions were required for the AUX-01 Survey Area.

4.4 Unique Features of Survey Unit

Survey Unit AUX-01-01 through AUX-01-04 exhibited surface characteristics ranging from smooth surfaces to heavily remediated irregular surfaces. Most of the pits and irregularities increased the source-to-detector distance by approximately ¼ - ½ inch, although some increase it as much as 1 - 2 inches. These types of irregularities in the concrete surfaces were taken into account through the efficiency factor applied to the measurements collected with the HP-100. Technical report YA-REPT-00-015-04 (Appendix B) provides instrument efficiency factors (ε_i) for various source-to-detector distances. The ε_i value for a source-to-detector distance of 1 inch was selected as a representative efficiency for data collected with the HP-100 from the irregular surfaces because it accounts for the ½ inch stand-off and the most common depth of pits and surface irregularities (¼ - ½ inch). In contrast to the irregular surfaces, the vertical walls of the structures are relatively smooth. Table 4.2 of the YA-REPT-00-015-04 (Appendix B) provides instrument efficiency factors (ε_i) for various source-to-detector distances. Detector efficiencies (HP-100C) were applied as follows: smooth surface 0.0603 c/d, irregular surface 0.0373 c/d.

4.5 ALARA Practices and Evaluations

An ALARA evaluation was developed for each Survey Unit in the AUX-01 Survey Area which concluded that additional remediation was not warranted. These evaluations are found in Appendix D.

5.0 SURVEY UNIT FINAL STATUS SURVEY

5.1 Survey Planning

5.1.1 Final Status Survey Plan and Associated DQOs

The FSS for AUX-01 Survey Units was planned and developed in accordance with the LTP using the DQO process. Form DPF-8856.1, found in YNPS Procedure 8856, "*Preparation of Survey Plans*," was used to provide guidance and consistency during development of the FSS Plan.

The FSS Plans can be found in Appendix A. The DQO process allows for systematic planning and is specifically designed to address problems that require a decision to be made in a complex survey design and, in turn, provides alternative actions.

The DQO process was used to develop an integrated survey plan providing the Survey Unit identification, sample size, selected analytical techniques, survey instrumentation, and scan coverage. The Sign Test was specified for non-parametric statistical testing for this Survey Unit, if required. The design parameters developed are presented in Table 2.

Table 2 Survey Area AUX-01 Design Parameters

Survey Unit	Design Parameter	Value	Basis
AUX-01-01	Area	59 m^2	Class 1, ≤1000 m^2
	Number of Direct Measurements	15 (calculated) + 4 (added) Total: 19	α (Type I) = 0.05, β (Type II) = 0.05 σ: 571 Adjusted Relative Shift: 2 Adjusted LBGR:5266
	Sample Area	3.1 m^2	Area / Sample #
	Sample Grid Spacing, triangular pitch	1.86 m	$(Area/(0.866*Sample \#))^{1/2}$
	Scan Grid Area	ISOCS scans at 2 meters	2.6 m on center
	Scan area	59 m^2	Class 1 Area – 100%
	Scan Investigation Level	Co-60: 2.9E3 dpm/100cm^2 Cs-137 : 1.1E4 dpm/100cm^2	See Appendix C
AUX-01-02	Area	174 m^2	Class 1, ≤1000 m^2
	Number of Direct Measurements	15 (calculated) + 5 (added) Total: 20	α (Type I) = 0.05, β (Type II) = 0.05 σ: 571 Adjusted Relative Shift: 2 Adjusted LBGR:5266
	Sample Area	8.7 m^2	Area / Sample #
	Sample Grid Spacing, triangular pitch	3.2 m	$(Area/(0.866*Sample \#))^{1/2}$
	Scan Grid Area	ISOCS scans at 2 meters	2.6 m on center
	Scan area	174 m^2	Class 1 Area – 100%
	Scan Investigation Level	Co-60: 2.9E3 dpm/100cm^2 Cs-137 : 1.1E4 dpm/100cm^2	See Appendix C
AUX-01-03	Area	152 m^2	Class 1, ≤1000 m^2
	Number of Direct Measurements	15 (calculated) + 5 (added) Total: 20	α (Type I) = 0.05, β (Type II) = 0.05 σ: 636 Adjusted Relative Shift: 2 Adjusted LBGR:5028
	Sample Area	7.6 m^2	Area / Sample #
	Sample Grid Spacing, triangular pitch	3 m	$(Area/(0.866*Sample \#))^{1/2}$
	Scan Grid Area	ISOCS scans at 2 meters	2.6 m on center

Survey Unit	Design Parameter	Value	Basis
	Scan area	152 m^2	Class 1 Area – 100%
	Scan Investigation Level	Co-60: 2.9E3 dpm/100cm^2 Cs-137 : 1.1E4 dpm/100cm^2	See Appendix C
AUX-01-04	Area	113 m^2	Class 1, ≤1000 m^2
	Number of Direct Measurements	15 (calculated) + 5 (added) Total: 20	α (Type I) = 0.05, β (Type II) = 0.05 σ: 636 Adjusted Relative Shift: 2 Adjusted LBGR:5028
	Sample Area	5.6 m^2	Area / Sample #
	Sample Grid Spacing, triangular pitch	2.6 m	(Area/(0.866*Sample #))$^{1/2}$
	Scan Grid Area	ISOCS scans at 2 meters	2.6 m on center
	Scan area	113 m^2	Class 1 Area – 100%
	Scan Investigation Level	Co-60: 2.9E3 dpm/100cm^2 Cs-137 : 1.1E4 dpm/100cm^2	See Appendix C

5.1.2 Deviations from the FSS Plan as Written in the LTP

The null hypothesis (H_o) is stated and tested in the negative form: "Residual licensed radioactive materials in Survey Units exceed the release criterion." This null hypothesis is designed to protect the health of the public as well as to demonstrate compliance with the requirements set forth in the Yankee Rowe LTP. The tolerable limits established for this survey plan set the probability of Type I errors (*a*) at 0.05 and the probability of Type II errors (β) at 0.05. Investigation levels for the fixed measurements were set at a greater than three sigma from the mean and >$DCGL_W$ or >$DCGL_{EMC}$. The scan MDCs for the ISOCS measurements were set at the $DCGL_{EMC}$. All MDCs for the surveys of AUX-01 were met in accordance with YNPS LTP. DCGL values and the associated MDC values can be found in Table 3.

Table 3 $DCGL_W$, $DCGL_{EMC}$ and Investigation Level for ISOCS measurements

	$DCGL_W$	**$DCGL_{EMC}$ (ISOCS based on source area = 1m^2)**	**Investigation Level (ISOCS Based on source area = 1m^2, 2m 90d collimated)**
Nuclide	Bldg Surface (dpm/100 cm^2) at 8.73 mrem/y	Bldg Surface (dpm/100 cm^2)	Bldg Surface (dpm/100 cm^2)
Co-60	6.3E+03 (Smooth=379 cpm) (Irregular=232 cpm)	4.6E+04	2.9E+03
Cs-137	2.2E+04	1.7E+05	1.1E+04

The FSSP design was performed to the criteria of the LTP; therefore, no subsequent LTP deviations with potential impact to this Survey Area need to be evaluated.

5.1.3 DCGL Selection and Use

It must be noted that for the final evaluation of the AUX-01 Survey Units and throughout this report, the acceptance criteria of Building Surface LTP-listed DCGL values has been applied. However, given that all of the remaining slab and foundation structure will be at least a few feet subsurface before site grading is complete and will be in such a state at license termination, the LTP, section 5.6.3.1.2, "Exterior Surfaces of Building Foundations," establishes the applicable guidance, as it addresses methods that may be applied to determine if subsurface structure surfaces will be acceptable by meeting LTP-required concrete volumetric DCGLs.

With the established LTP guidance, given that Co-60 and Cs-137 have been found to be the only radionuclides of significance in the area of concern, and given the ISOCS ability to readily detect either constituent to acceptable levels and conventional hand-held instrument survey criteria techniques being conservatively based on Co-60 beta emissions, performing a Class 1 survey applying Building Surface DCGLs has led to a very conservative approach in determining the final status of the Survey Unit. However, in applying this approach, in addition to evaluating subsurface conditions, there is no unanswered concern should the question of future subsurface structure occupancy arise.

5.1.4 Measurements

Error tolerances and characterization sample population statistics drove the selection of the number of direct measurements. Professional judgment was exercised adding additional direct measurements despite the use of ISOCS scanning to achieve a tighter sampling grid building conservatism into the sampling design.

The direct measurement grid was developed as a systematic grid with spacing consisting of a triangular pitch pattern with a random starting point. With the aid of a GPS and AutoCAD-generated Survey Unit map, the systematic random start grid was developed using Visual Sample Plan software. Sample measurement locations are provided in Attachment D.

The ISOCS scan grid used a 2.6-m point-to-point grid with no perimeter points farther than 1.3 m from the Survey Unit boundary providing 100 percent coverage of the Survey Area. The ISOCS scan grid did not require a random start. ISOCS scans were performed at a height of 2 m from the surface positioned perpendicular to the scan point using a 90-

degree collimator. The adjusted investigation levels, referenced in Table 2, for the ISOCS were derived by multiplying the $DCGL_{EMC}$ ($DCGL_W$ * AF for a 1-m^2 elevated area) by the ratio of MDCs obtained from the 12.6-m^2 field of view relative to the MDC obtained for a 1-m^2 area at the edge of the 12.6-m^2 field of view, as this leads to a conservative model. The values developed for the 1-m^2 elevated area at the edge of the field of view used for the ISOCS scan investigative levels are sensitive enough to detect the elevated comparison values for the 12.6-m^2 area. MDC values for the Portable ISOCS scans were set at the $DCGL_{EMC}$ for the individual radionuclides. The technical basis for the use of the ISOCS is documented in Technical Report YA-REPT-00-018-05, "*Use of In-situ Gamma Spectrum Analysis to Perform Elevated Measurement Comparison in Support of Final Status Surveys.*" (Appendix C).

5.2 Survey Implementation Activities

Table 4 provides a summary of daily activities performed during the Final Status Survey of Survey Units in AUX-01.

Table 4 Survey Unit FSS Activity Summary

Survey Unit	Date	Activity
AUX-01-01	09-12-05	Performed walk-down of Survey Unit, established Isolation and Controls
	09-14-05	Performed Job Hazard Analysis, and Unit Classification
	09-15-05	Performed Sample Quantity Calculations, established DQOs
	09-15-05	Generated FFS Sample Plans
	09-15-05	Initiated Scans, and Static measurements.
	09-19-05	FSS Complete
AUX-01-02	12-01-05	Performed walk-down of Survey Unit, established Isolation and Controls
	12-01-05	Performed Job Hazard Analysis, and Unit Classification
	12-01-05	Performed Sample Quantity Calculations, established DQOs
	12-01-05	Generated FFS Sample Plans
	12-02-05	Initiated Scans, and Static measurements.
	12-07-05	FSS Complete

Survey Unit	Date	Activity
AUX-01-03	12-14-05	Performed walk-down of Survey Unit, established Isolation and Controls
	12-14-05	Performed Job Hazard Analysis, and Unit Classification
	12-15-05	Performed Sample Quantity Calculations, established DQOs
	12-15-05	Generated FFS Sample Plans
	12-15-05	Initiated Scans, and Static measurements.
	12-22-05	FSS Complete
AUX-01-04	12-14-05	Performed walk-down of Survey Unit, established Isolation and Controls
	12-14-05	Performed Job Hazard Analysis, and Unit Classification
	12-15-05	Performed Sample Quantity Calculations, established DQOs
	12-15-05	Generated FFS Sample Plans
	12-15-05	Initiated Scans, and Static measurements.
	12-22-05	FSS Complete

5.3 Surveillance Surveys

5.3.1 Periodic Surveillance Surveys

Upon completion of the FSS of Survey Area AUX-01, the Survey Units were placed into the program for periodic surveillance surveys on a quarterly basis in accordance with YNPS procedure DP-8860, "*Area Surveillance Following Final Status Survey.*" These surveys provide assurance that areas with successful FSS remain unchanged until license termination.

5.3.2 Resurveys

No resurveys were required for this Survey Unit.

5.3.3 Investigations

No additional investigations were required for this Survey Unit.

5.4 Survey Results

Direct measurement surveys indicated that three Survey Units had measurements that exceeded the $DCGL_W$ but were less than the $DCGL_{EMC}$, therefore the Sign Test was used to evaluate the Survey Units. The Survey Units passed the Sign Test, depicted in Attachment B. Retrospective power curves were generated and demonstrated that adequate power was achieved. Therefore, the null hypothesis (H_o) (that the Survey Units exceeds the release criteria) is rejected.

Table 5 Direct Measurement Summary

Survey Unit	AUX-01-01	AUX-01-02	AUX-01-03	AUX-01-03
Number of Samples	19	20	20	20
Samples Above $DCGL_W$	5	0	1	2
Critical Value	13	14	14	14
Samples Above $DCGL_{EMC}$	0	0	0	0
Pass Sign Test	Yes	Yes	Yes	Yes

The ISOCS scan results were compared to the respective Investigation Levels (Table 3) and where multiple nuclides were positively identified a fractional $DCGL_{EMC}$ sum-of-fractions was performed. A summary of the ISOCS scans is provided below in Table 6, the detailed ISOCS results are provided in Attachment A.

Table 6 ISOCS Scan Summary

Unit Number	Number of Scans	Investigation Levels Exceeded	Sum of Fractions ≥ 1
AUX-01-01	21	No	No
AUX-01-02	30	No	No
AUX-01-03	36	No	No
AUX-01-04	26	No	No

5.5 Data Quality Assessment

The Data Quality Assessment phase is the part of the FSS where survey design and data are reviewed for completeness and consistency, ensuring the validity of the results, verifying that the survey plan objectives were met, and validating the classification of the Survey Unit.

The sample design and the data acquired were reviewed and found to be in accordance with applicable YNPS procedures DP-8861, "*Data Quality Assessment*"; DP-8856, "*Preparation of Survey Plans*"; DP-8853, "*Determination of the Number and Locations of FSS Samples and Measurements*"; DP-8857, "*Statistical Tests*"; DP-8865, "*Computer Determination of the Number of FSS Samples and Measurements*" and DP-8852, "*Final Status Survey Quality Assurance Project Plan*".

The Data Quality Assessments, Power Curves, and Plots are found in Attachment B.

6.0 QUALITY ASSURANCE AND QUALITY CONTROL

6.1 Instrument QC Checks

Operation of the portable ISOCS was in accordance with DP-8871,"*Operation of the Canberra Portable ISOCS System,*" with QC checks performed in accordance with DP-8869,"*In-situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure*" and DP-8871, "*Operation of the Canberra Portable ISOCS System.*" Operation of the E-600 w/SPA-3 was in accordance with DP-8535,"*Setup and Operation of the Eberline E-600 Digital Survey Instrument,*" with QC checks preformed in accordance with DP-8504, "*Control and Accountability of Radiation Protection Portable Survey Instruments.*" Instrument response checks were performed prior to and after use for the E-600 w/SPA-3 and once per shift for the Portable ISOCS. Any flags (i.e. anomalies in the QC results) encountered during the ISOCS QC Source Count were corrected/ resolved prior to surveying. All instrumentation involved with the FSS of AUX-01 satisfied the above criteria for the survey. QC records are found in Attachment C.

6.2 Split Samples and Recounts

DP-8864,"*Split Sample Assessment for Final Status Survey*" deals strictly with soil samples and provides no criteria for direct measurements therefore no measurement comparison were made.

6.3 Self-Assessments

No self-assessments were performed during the FSS of AUX-01.

7.0 CONCLUSION

The FSS of AUX-01 has been performed in accordance with YNPS LTP and applicable FSS procedures. Evaluation of the direct measurement data has shown 8 of the direct measurements exceeded the $DCGL_W$ but were less than the $DCGL_{EMC}$, therefore the Sign Test was used to evaluate the Survey Unit. The Survey Unit passed the Sign Test, depicted in Attachment B. Retrospective power curves were generated and demonstrated that adequate power was achieved. Therefore, the null hypothesis (H_o) is rejected.

AUX-01 meets the objectives of the Final Status Survey.

Based upon the evaluation of the data acquired for the FSS, AUX-01 meets the release requirements set forth in the YNPS LTP. The Total Effective Dose Equivalent (TEDE) to the average member of the critical group does not exceed 25 mrem/yr, including that from groundwater. 10CFR20 Subpart E ALARA requirements have been met as well as the site release criteria for the administrative level DCGLs that ensure that the Massachusetts Department of Public Health's 10 mrem/yr limit will also be met.

List of Appendices

List of Attachments

(In the electronic version, every Table of Contents, Figures, Appendices and Attachments, as well as every mention of a Table, Figure, Appendix or Attachment is a hyperlink to the actual location or document.)

Attachments A through C have been provided electronically on the enclosed CD.

Attachment D – Maps and Posting Plots

List of Figures

Figure Page

Figure 1 AUX-01 Relative to Structures

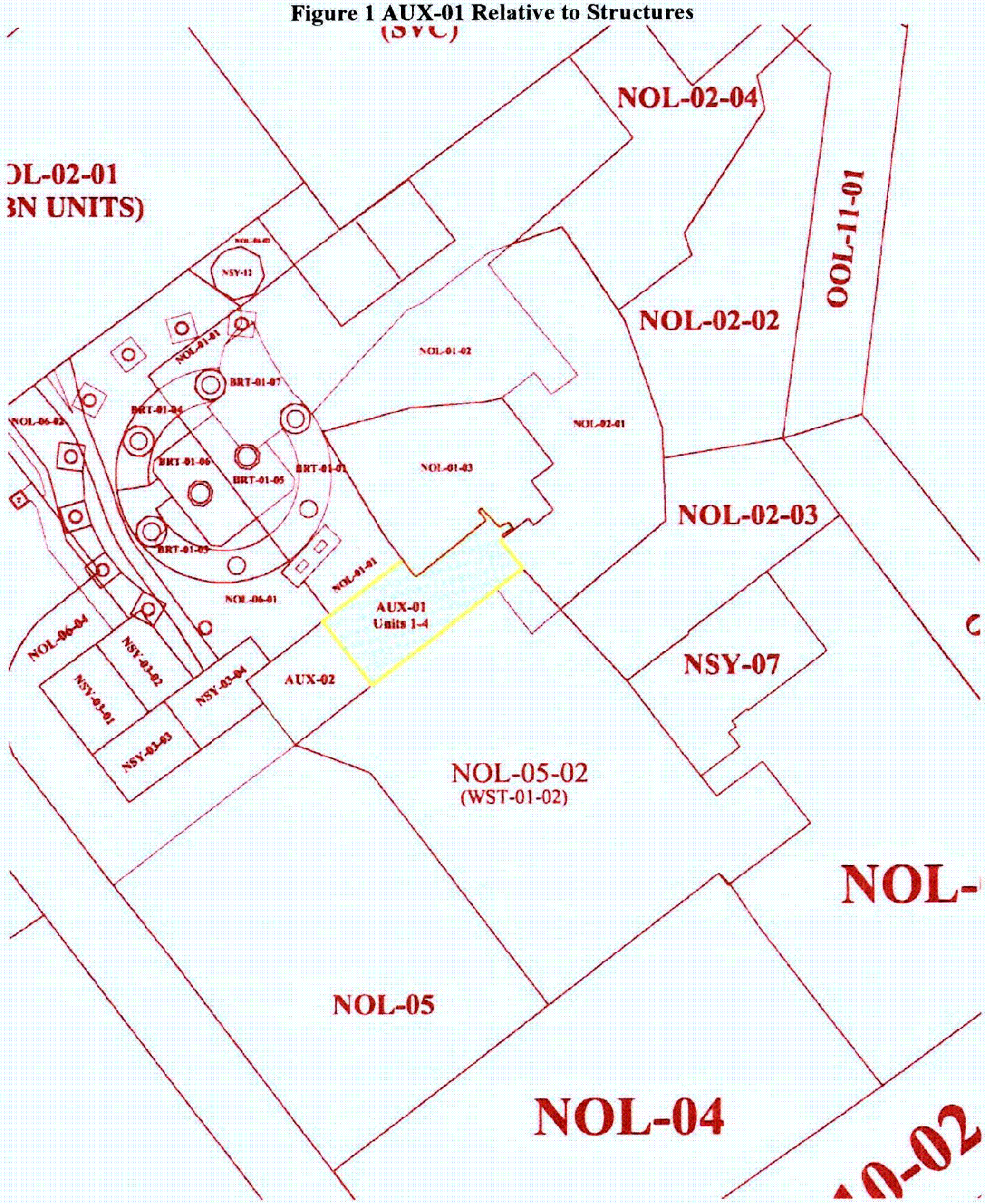


Figure 2 AUX-01-01 Posting Plot

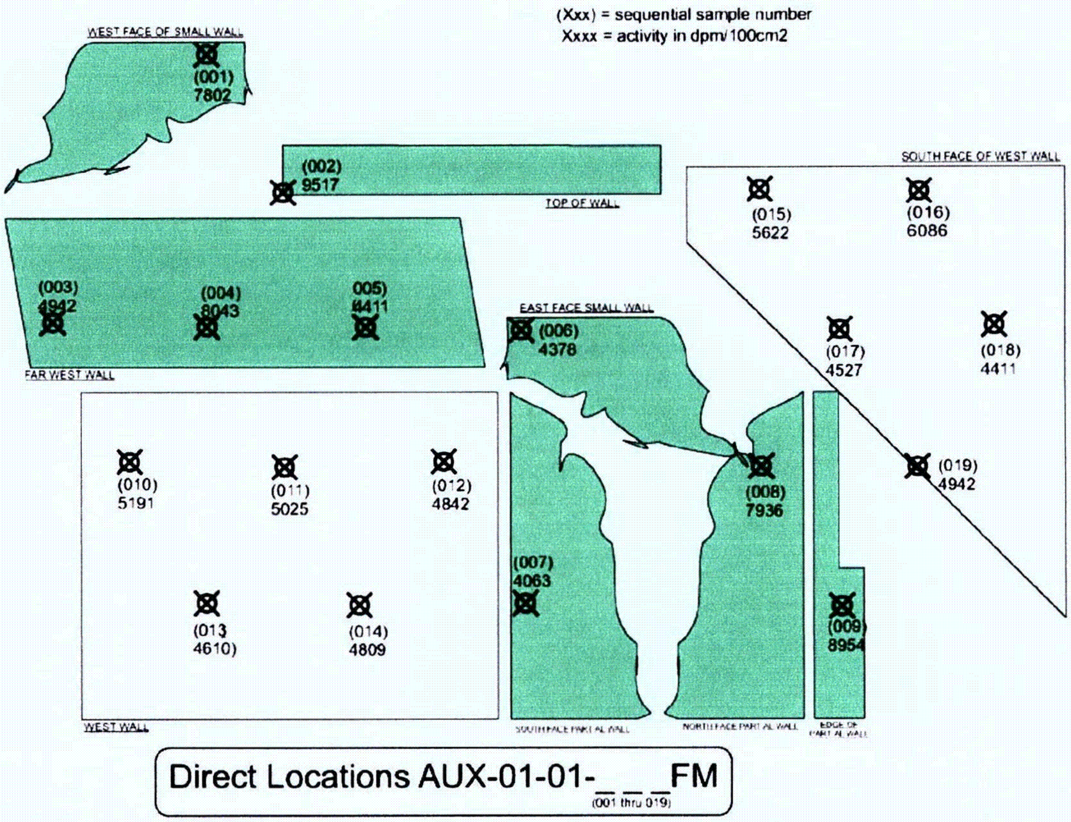


Figure 3 AUX-01-02 Posting Plot

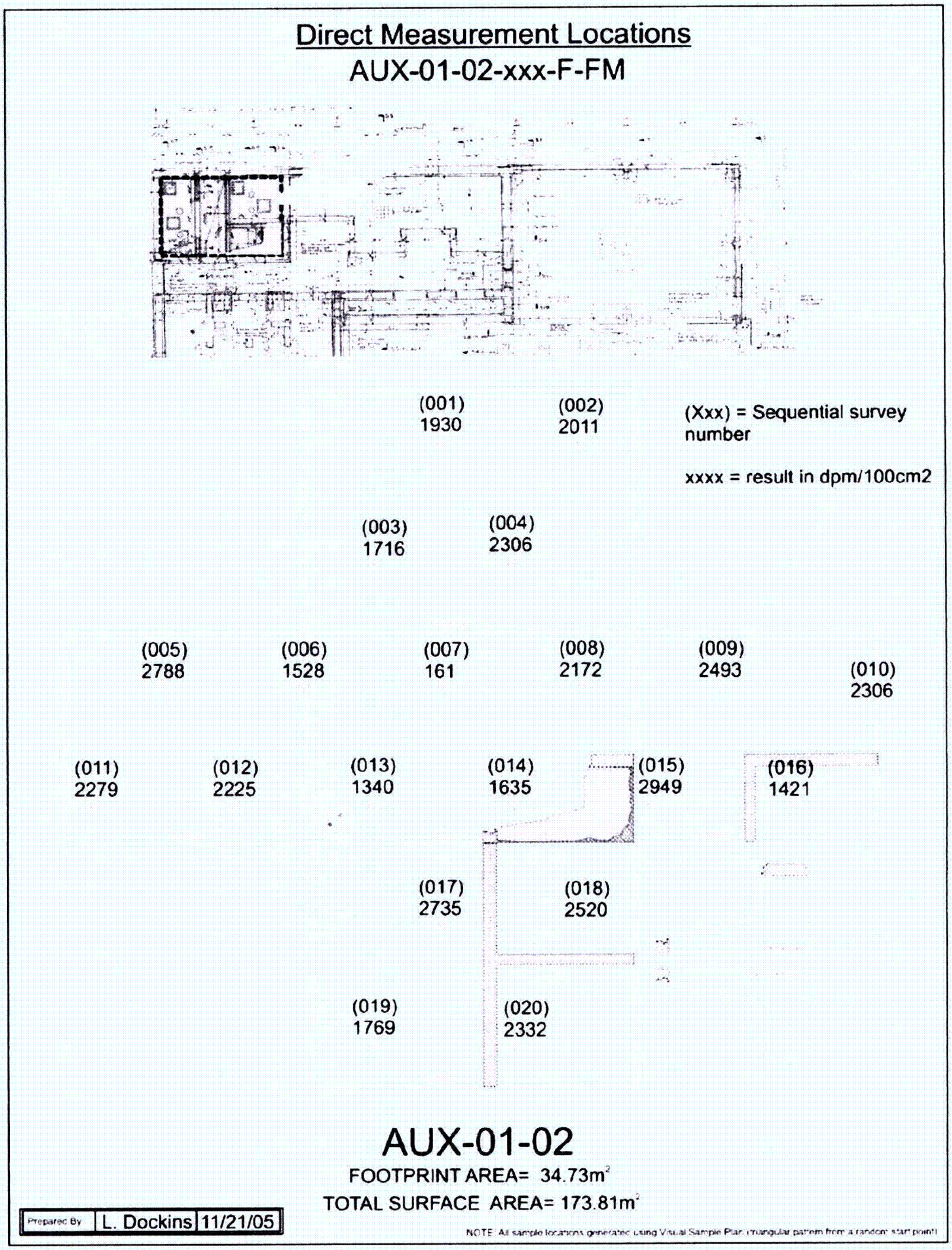
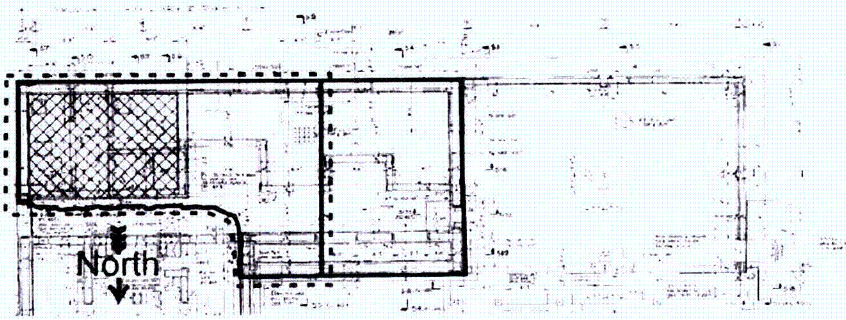


Figure 4 AUX-01-03 Posting Plot



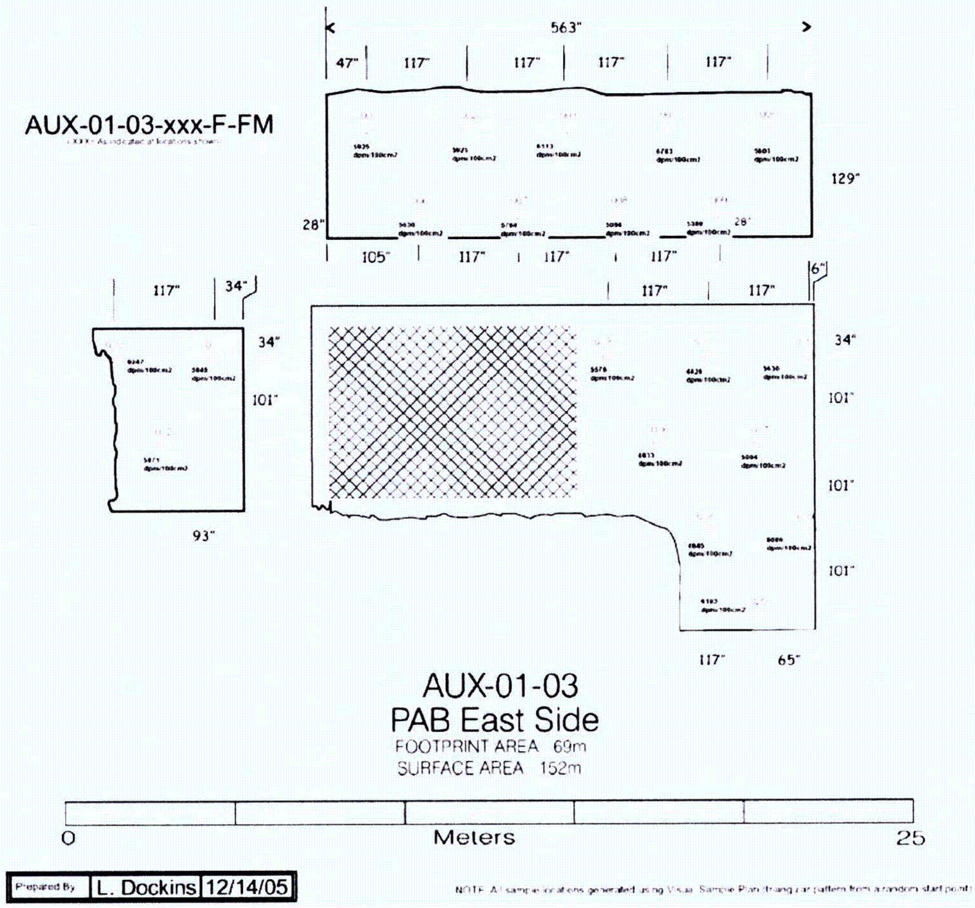


Figure 5 AUX-01-04 Posting Plot

YANKEE ATOMIC ELECTRIC COMPANY

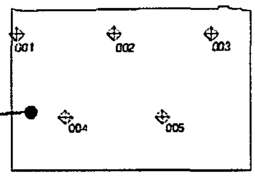
RADIATION PROTECTION SURVEY FORM

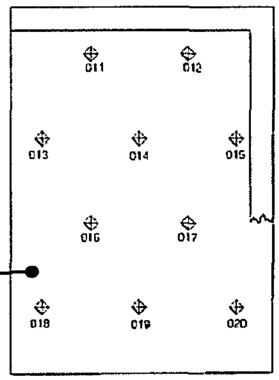
AUX-01-04 Posting Plot

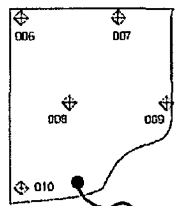
South Wall

Location	Results (cpm)	I/S*
AUX-01-04-001-F-FM	293	I
AUX-01-04-002-F-FM	273	I
AUX-01-04-003-F-FM	285	I
AUX-01-04-004-F-FM	280	S
AUX-01-04-005-F-FM	242	S

*Surface Condition: I=Irregular(Rough) S=Smooth







Floor

Location	Results (cpm)	I/S*
AUX-01-04-011-F-FM	229	I
AUX-01-04-012-F-FM	261	I
AUX-01-04-013-F-FM	244	S
AUX-01-04-014-F-FM	227	S
AUX-01-04-015-F-FM	194	I
AUX-01-04-016-F-FM	224	I
AUX-01-04-017-F-FM	262	I
AUX-01-04-018-F-FM	244	I
AUX-01-04-019-F-FM	211	S
AUX-01-04-020-F-FM	222	I

*Surface Condition: I=Irregular(Rough) S=Smooth

West Wall

Location	Results (cpm)	I/S*
AUX-01-04-006-F-FM	218	I
AUX-01-04-007-F-FM	287	S
AUX-01-04-008-F-FM	258	S
AUX-01-04-009-F-FM	244	S
AUX-01-04-010-F-FM	205	S

*Surface Condition: I=Irregular(Rough) S=Smooth

Final Status Survey Planning Worksheet

GENERAL SECTION	
Survey Area #: AUX-01	Survey Unit #: 01
Survey Unit Name: SFP Excavation Subsurface Structures	
FSSP Number: YNPS-FSSP-AUX 01-01-**01** (changes shown in bold print)	

PREPARATION FOR FSS ACTIVITIES

Check marks in the boxes below signify affirmative responses and completion of the action.

1.1 Files have been established for survey unit FSS records. ☒

1.2 ALARA review has been completed for the survey unit. ☒

1.3 The survey unit has been turned over for final status survey. ☒

1.4 An initial DP-8854 walkdown has been performed and a copy of the completed Survey Unit Walkdown Evaluation is in the survey area file. ☒

1.5 Activities conducted within area since turnover for FSS have been reviewed. ☒

Based on reviewed information, subsequent walkdown: ☒ not warranted ☐ warranted

If warranted, subsequent walkdown has been performed and documented per DP-8854. ☐

OR

The basis has been provided to and accepted by the FSS Project Manager for not performing a subsequent walkdown. ☒ No additional work has been performed on this area since the initial turnover of the Spent Fuel Pool excavation area (see NOL-01 & 02 survey units).

1.6 A final classification has been performed. ☒

Classification: CLASS 1 ☒ CLASS 2 ☐ CLASS 3 ☐

DATA QUALITY OBJECTIVES (DQO)

1.0 State the problem:

Survey Unit AUX-01-01 consists of the remaining PAB walls that lie within the SFP Excavation footprint. These walls, in conjunction with the rest of the remaining PAB walls, were originally part of a "free release" effort prior to demolition of the PAB structure. However, portions of AUX-01-01 were below grade and inaccessible for the "free release" survey until subsequently exposed during the demolition and excavation processes. The identities of the radionuclides-of-concern were based on data acquired from the FSS of the adjacent area. Although FSS data from NOL-01-03 (the adjacent survey area) has shown both Co-60 and Cs-137 present, the $DCGL_W$ chosen for this plan was based upon Co-60 since this would be the most conservative approach. Data used to determine the number of samples were taken from the free release effort and can be found in YA-REPT-00-017-04. The number of direct survey points were determined to be 15, however four additional samples were added to add power to the survey plan. Soil was used in this plan for nuclide identification because the soil would have been the source of, or in direct communication with any wall contamination.

The problem, therefore, is to determine and demonstrate that residual licensed radioactive materials, if present in AUX-01-01, meets the LTP release criterion

The planning team for this effort consists of the FSS Project Manager, FSS Radiological make primary decisions with the concurrence of the FSS Project Manager.

2.0 Identify the decision:

The decision to be made can be stated "Does residual plant-related radioactivity, if present in the survey unit, exceed the release criteria?"

Alternative actions that may be employed are investigation, re-survey and remediation or disposal.

3.0 Identify the inputs to the decision:

Sample media: Concrete substructures.

Types of measurements: Systematic measurements, scans and concrete sampling.

Radionuclides-of-concern: All nuclides listed in LTP Table 6-1 will be included in analysis.

DCGLs:

(1) Applicable $DCGL_w$: 6.3E3 dpm/100cm^2 (Co-60 assumed as a conservative measure)
Note: the $DCGL_w$ value corresponds to 8.73 mrem/y.

Some surfaces contain pits and irregular surfaces, which will increase the source-to-detector distance for some localized areas under the 100cm^2 window of the detector. Most of the pits and irregularities increase the source-to-detector distance as much as 1 inches. These types of irregularities in the concrete surfaces will be taken into account through the efficiency factor applied to the measurements collected with the HP-100. Technical report YA-REPT-00-015-04 provides instrument efficiency factors (ϵ_i) for various source-to-detector distances. The ϵ_i value for a source-to-detector distance of 1 inch was selected as a representative efficiency for data collected with the HP-100 on irregular surfaces. The ϵ_i value for a distance of ½ inch will be applied to HP-100 data collected from smooth concrete surfaces. The efficiency factors provided in YA-REPT-00-015-04 are used below:

- ϵ_i = 0.2413 c/e for smooth concrete surfaces (reflects a source to detector distance = ½ inch), and
  = 0.149 c/e for pitted/irregular surfaces (reflects a source to detector distance = 1 inch)
- ϵ_s = 0.25 e/d (consistent with the Co-60 assumption)
- total efficiency for smooth surface = $\epsilon_i \cdot \epsilon_s$ = 0.2413 c/e · 0.25 e/d = 0.0603 c/d
- total efficiency for pitted/irregular surfaces = $\epsilon_i \cdot \epsilon_s$ = 0.149 c/e · 0.25 e/d = 0.0373 c/d

(2) Gross measurement $DCGL_w$ (for HP-100): 6.3E3 dpm/100cm^2

- for smooth concrete surface: 6.3E3 dpm/100cm^2 * 0.0603 c/d = 3.8E2 cpm/100cm^2
- for pitted/irregular surface: 6.3E3 dpm/100cm2 * 0.0373 c/d = 2.3E2 cpm/100cm^2

(3) Applicable $DCGL_{EMC}$ for fixed-point measurements: $DCGL_w$ * AF = 6.3E3 dpm/100cm^2 *2.4 = 1.5E4 dpm/100cm^2

- for smooth concrete surface: 1.5E4 dpm/100cm^2 * 0.0603 c/d = 9.0E2 cpm/100cm^2
- for pitted/irregular surface: 1.5E4 dpm/100cm2 * 0.0373 c/d = 5.6E2 cpm/100cm^2.

Note: the DCGL and $DCGL_{EMC}$ value refer to above-background radioactivity.

Investigation Level for fixed-point measurement:

- for smooth (i.e., vertical side) concrete surface: >9.0E2 cpm/100cm^2 above background
- for pitted/irregular (i.e., top) concrete surface: >5.6E2 cpm/100cm^2 above background

Investigation Level for SPA-3 scan: Reproducible indication above background using the audible feature with headphones

Investigation Level for ISOCS scans: 1m scan height: 1.7E4 dpm/100cm^2 (Co-60).
2m scan height: 2.91E3 dpm/100cm^2 (Co-60).

Note: The investigation levels for the ISOCS scans were derived by multiplying the $DCGL_{EMC}$ associated with a 1m^2 area by the ratio of the MDC for the full field of view (12.6m^2 for 2m scan height and 3.14m^2 for 1m scan height) to the MDC for a 1m^2 area at the edge of the full field of view. The investigation levels developed in this manner are sensitive enough to detect the Co-60 $DCGL_{EMC}$ value based on the grid area (1.5E4 dpm/100cm^2). If other LTP-listed gamma-emitting radionuclides are identified in the ISOCS assays, the investigation level will be evaluated using the same criteria applied in the development of the investigation level for Co-60.

MDCs forISOCS measurements:

Nuclide	MDC (dpm/100cm^2)	Nuclide	MDC (dpm/100cm^2)	Nuclide	MDC (dpm/100cm^2)
Co-60	1.5E3	Sb-125	8.4E3	Eu-152	3.1E3
Nb-94	2.2E3	Cs-134	2.5E3	Eu-154	2.8E3
Ag-108m	2.1E3	Cs-137	5.5E3	Eu-155	5.7E4

Note: The MDCs listed in the above table are 10% of the $DCGL_{EMC}$ values (based on concrete surface DCGLs & nuclide-specific AF value for 4m^2 from LTP, Appendix 6S). If the MDC values in the above table cannot be achieved in a reasonable count time, then an MDC no greater than 5X the table value must be achieved.

Scan coverage: ISOCS scan measurements providing 100% coverage of all surfaces.

QC checks and measurements: QC checks for the survey instruments will be performed in accordance with DP-8534 and DP-8540. Pre- and post-use instrument QC checks will be performed. QC checks for the ISOCS will be in accordance with DP-8869 and DP-8871.

MDC_{fixed}: Refer to Attachments 1 and 1A.

Investigation level for SPA-3 scans: Reproducible indication above background using an audible signal. A shielded SPA-3 probe should be used for these scans due to the close proximity to the ISFSI.

Note: ISOCS scans satisfy the requirements for scanning in this survey plan. SPA-3 scans are in addition and therefore no MDCR and MDC (fDCGL) are developed for these scans.

MDCs for analysis of any concrete core bore samples:

Table 1

For Pulverized Material counted on site.

Radionuclide	Soil MDC (pCi/gm)
H^{3}	130
Co^{60}	1.4
Nb^{94}	2.5
Ag^{108m}	2.5
Sb^{125}	11
Cs^{134}	1.7
Cs^{137}	3.0
Eu^{152}	3.5
Eu^{154}	3.3
Eu^{155}	140
C^{14}	1.9
Fe^{55}	1.0E04
Ni^{63}	280
Sr^{90}	0.6
Tc^{99}	4.8
Pu^{238}	11
$Pu^{239, 240}$	10
Pu^{241}	340
Am^{241}	10
$Cm^{243, 244}$	11

Table 2
For Sample sent to GEL Labs.

Radionuclide	10% of values listed in LTP Table 6-1 (pCi/gm)
H^3	13.5
C-14	243
Cs-137	145
Co-60	345
Ni-63	6160
Sr-90	1.39

4.0 Define the boundaries of the survey:

AUX-01-01 is comprised of walls of the former PAB structure that lie in the SFP Excavation on the southwest and west side. Only these walls will be surveyed in AUX-01-01. Other remaining walls of the PAB structure will be addressed in other Survey Plans.

Note: A random-start systematic grid has been developed to identify the fixed-point measurement locations. The random start was developed using a set of random numbers taken from Appendix I, Table I.6 of the MARSSIM Manual. The X-axis was found by multiplying the longest length, (31 feet) by the random number 0.165133. The Y-axis was found by multiplying the longest width (16 feet) by the random number 0.281668.

Surveying of AUX-01-01 will be performed during daylight hours when weather conditions will not adversely affect the data acquisition.

5.0 Develop a decision rule:

a. If all of the data show that the concentrations of all plant-related nuclides are below the DCGLs and the sum of their DCGL fractions are less than unity then reject the null hypothesis (i.e. the Survey Unit meets the release criteria).

b. If the action levels are exceeded, then perform an investigation survey.

c. If the average of the FSS measurements is below the $DCGL_w$, but some individual measurements exceed the $DCGL_w$, then apply a statistical test as the basis for accepting or rejecting the null hypothesis.

d. If the average concentration exceeds the DCGL then accept the null hypothesis (i.e. the Survey Area does not meet the release criteria).

6.0 Specify tolerable limits on decision errors:

Null hypothesis: The null hypothesis (H_o), as required by MARSSIM, is stated and tested in the negative form: "Residual licensed radioactive materials in Survey Unit AUX-01-01 exceeds the release criterion".

Probability of type I (α) error: 0.05
Probability of type II (β) error: 0.05

LBGR: $DCGL_w/2$ = 3150 dpm/100cm^2 (systematic measurements)

7.0 Optimize Design:

Type of statistical test: **Sign Test**

Number of measurements: 19 (Systematic grid from a random start point.)

Biased measurements: 2ea. core bores. (One from the base of each of the two largest scan surfaces. "South Face of West Wall" and "West Wall").

GENERAL INSTRUCTIONS

1. Notify QA of date and time of the pre-survey briefing, commencement of sampling and any other scheduled activities subject to QA notification that are currently known.

2. Survey instrument: Operation of the E-600 w/SPA-3 will be in accordance with DP-8535, with QC checks preformed in accordance with DP-8540. Operation and source checking of the E-600 w/HP-100 will be in accordance with DP-8534. The instrument response checks shall be performed before issue and after use

3. Collect ISOCS measurements in accordance with DP-8871.

4. The job hazards associated with the FSS in Survey Unit 04 are addressed in the accompanying JHA for AUX-01-01.

5. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. Grid AUX-01-01 for 100% scan coverage by placing parallel rows of markers forming a square pattern at a maximum distance of 2.6 meters apart and a maximum of 1.3 meters from the edge of each surface area (add additional scan points closer than 2.6 meters apart as necessary). Sequentially number each scan location starting with number **020**. Indicate the approximate ISOCS scan location and the sequence number (AUX-01-01-### [sequence number]-F-G) on the maps. Using the 90° collimator, position the ISOCS detector directly at each marker 2 meters from the surface to be scanned. Angle the detector as necessary perpendicular to the scan surface and perform an analysis in accordance with DP-8871 employing a preset count time sufficient to meet the MDAs referenced in this survey plan. Review the report to verify that the MDAs have been met for the nuclides. Identify

radionuclides representing licensed radioactive material and compare their concentration to their respective $DCGL_{EMC}$ value.

2. If any ISOCS scan measurement is equal to or greater than the action (investigation) level then an investigation of that scan area footprint shall be performed as follows:

a. Using the SPA-3 at a slow speed scan rate (approximately 2-3" per second), scan the entire ISOCS footprint. Scanning will be performed in the rate-meter mode with the audible feature "on".

Note:If the background level exceeds 24000 cpm, contact the FSS Engineer prior to continuing.

b. Mark (outline on the surface) locations where detectable-above-background readings are found. Identify each outlined areas on a survey map.

c. Measure the total area (square centimeters) of each outlined elevated area. Indicate on the map (and with black marker on the actual location) the location of the highest indicated activity spot. Record the highest SPA-3 reading observed for each outlined area.

d. On the spot indicating the highest SPA-3 reading observed for each outlined area, perform and record a 1 minute scaler reading using the E600/SHP100.

Note: Should further investigative measures be required (i.e. concrete core sampling) a specific investigative sample plan will be developed.

Detailed descriptions of investigative actions will be recorded on form DPF-8856.2 and the location of the investigation analyses will be recorded on the survey map. The location description must provide ample detail to allow revisiting the spot at a later time.

3. For the fixed-point measurements, mark the grid locations as shown on the maps using small, but readily visible marks.

a. Collect and record the 19 measurements with the E-600/SHP-100 in accordance with DP-8534 and DP-8535 using the scalar mode (1 minute). Record each fixed-point measurement "as read" (in units of cpm) on the Form 2.

b. Designation for fixed-point measurements: AUX-01-01-001-**F-M** through AUX-01-01-019-**F-M** corresponding to FSS measurement locations 001 through 019.

Note: Any grid point that falls at a location that is unsuitable for a fixed measurement should be relocated in accordance with DP-8856 to the nearest suitable location within one meter.

4. Core Bore Samples: Collect 2ea. core bore samples. One from the base of the "South Face of West Wall" and one from the base of the "West Wall"). Indicate the location of each sample on a copy of the appropriate maps.

Core Bore collection:

a) Attempt to collect the cores intact, at a four-inch depth. If the core falls apart, it will be counted as a volumetric sample for which a minimum of 500 ml is required after it is pulverized. One liter would be preferable.

b) Seal each core in a Ziploc bag as soon as it is free. Each core will be sliced so it is necessary to assign two numbers to each core: AUX-01-01-001-C and AUX-01-01-002-C for the first core; AUX-01-01-003-C and AUX-01-01-004-C for the second core. In each case, the lower number (odd) applies to the surface slice, and the higher number (even) applies to the remainder.

Core Bore analysis:

a) If core is intact:
   1) Cut a one-inch slice from the outside surface of the concrete.
   2) Bag and seal the slice and remainder separately, immediately after cutting. The slice, representing the outside inch of the sample should be given the odd number of the two numbers on the original sample. The remainder should be assigned the even number.
   3) Count the slice and the remaining piece using a "hockey puck" geometry.

b) If any core falls apart to the degree that the hockey puck geometry is not appropriate, pulverize enough of the sample to provide 1-liter (preferred) or 500-ml of pulverized material. Count as a volumetric sample, using soil MDCs **(see section 3 table 1).**

c) The FSS Rad Engineer will select one concrete sample to be sent to an off-site lab for hard-to-detect analysis. Pulverize and rebag this sample before shipment. **Instruct GEL Labs to achieve minimum detectable levels of 10% of the values listed in LTP Table 6-1 (see section 3 table 2).**

NOTIFICATION POINTS

QA notification point(s) (y/n) y* QA Signature/Date:

(1) Date/time of initial pre-survey briefing ____ / ____

(2) Date/time of commencement of fixed measurement ____ / ____

(3) Date/time of first ISOCS scan measurement ____ / ____

(4) Date/time of first SPA-3 scan measurement ____ / ____

* Email notification to trudeau@yankee.com with a copy to calsyn@yankee.com satisfies this step

FSI point(s) (y/n) n FSS Radiological Engineer Signature/Date:

(1) ____ ____ / ____

(2) ____ ____ / ____

Prepared by [signature] Date 9/19/05
FSS Radiological Engineer

Reviewed by [signature] Date 9/19/05
FSS Radiological Engineer

Approved by G. Hummer for D. Smith Date 9-19-05
FSS Project Manager

Attachment 1 (Smooth)

MDCR/MDC Table for AUX-01-01	
Background (cpm)	MDC fixed
100	821
200	1140
300	1385
400	1591
500	1773
600	1938
700	2089
800	2230
900	2362
1000	2487

$$MDC_{fixed} = \frac{3 + 4.65\sqrt{B}}{Kt}$$

where:

B = background counts in time "t"
K = e_i*e_s(A/100)
A = Probe area (cm^2)
e_i = instrument efficiency
e_s = source efficiency
t = time interval (min)

Rb = background count rate
A = 100 cm^2
e_i = 0.2413
e_s = 0.25
t = 1 min

Attachment 1A (Irregular)

MDCR/MDC Table for AUX-01-01	
Background (cpm)	MDC fixed
100	1329
200	1846
300	2243
400	2577
500	2872
600	3138
700	3383
800	3611
900	3826
1000	4028

$$MDC_{fixed} = \frac{3 + 4.65\sqrt{B}}{Kt}$$

where:

B = background counts in time "t"
K = e_i*e_s(A/100)
A = Probe area (cm^2)
e_i = instrument efficiency
e_s = source efficiency
t = time interval (min)

Rb = background count rate
A = 100 cm^2
e_i = 0.149
e_s = 0.25
t = 1 min

Final Status Survey Planning Worksheet

GENERAL SECTION	
Survey Area #: AUX-01	Survey Unit #: 02
Survey Unit Name: Primary Auxiliary Building #1	
FSSP Number: YNPS-FSSP-AUX01-02-00	

PREPARATION FOR FSS ACTIVITIES

Check marks in the boxes below signify affirmative responses and completion of the action.

1.1 Files have been established for survey unit FSS records. ☒

1.2 ALARA review has been completed for the survey unit. ☒

1.3 The survey unit has been turned over for final status survey. ☒

1.4 An initial DP-8854 walkdown has been performed and a copy of the completed Survey Unit Walkdown Evaluation is in the survey area file. ☒

1.5 Activities conducted within area since turnover for FSS have been reviewed. ☒

Based on reviewed information, subsequent walkdown: ☒ not warranted ☐ warranted

If warranted, subsequent walkdown has been performed and documented per DP-8854. ☐

OR

The basis has been provided to and accepted by the FSS Project Manager for not performing a subsequent walkdown. ☐

1.6 A final classification has been performed. ☒

Classification: CLASS 1 ☒ CLASS 2 ☐ CLASS 3 ☐

DATA QUALITY OBJECTIVES (DQO)

1.0 State the problem:

Survey Unit AUX-01 consists of reinforced concrete floor, foundations, and sub-grade structures of the PAB that are expected to remain buried on site. The structure has effectively been demolished down to the 1022' elevation. Due to the change in grade elevation between the north and south sides of the PAB the north wall has been removed to approximately the 1022' elevation and the south wall has been removed to approximately the 1035' elevation. Portions of the east and west end walls remain to provide support for the south wall. The west side of the PAB remnant contains a 24' by 15.5' pit that is 18' deep (waste tank cubicles). This survey (AUX-01-02) encompasses the concrete walls and floor of the pit from the 1022' elevation down to and including the floor of the pit at the 1004' elevation. These structure surfaces, in conjunction with the rest of the remaining PAB, were originally part of a "free release" effort prior to demolition of the PAB structure. However, portions of remaining structure were left exposed within the confines of the Radiological Control area during demolition of adjacent contaminated structures.

The problem, therefore, is to determine and demonstrate that residual licensed radioactive materials, if present in AUX-01-02, meets the LTP release criterion

The planning team for this effort consists of the FSS Project Manager, FSS Radiological Engineer, FSS Field Supervisor, and FSS Technicians. The FSS Radiological Engineer will make primary decisions with the concurrence of the FSS Project Manager.

2.0 Identify the decision:

The decision to be made can be stated "Does residual plant-related radioactivity, if present in the survey unit, exceed the release criteria?"

Alternative actions that may be employed are investigation, re-survey and remediation or disposal.

3.0 Identify the inputs to the decision:

Sample media: Concrete substructures.

Types of measurements: Systematic measurements, scans (concrete sampling if required).

Radionuclides-of-concern: All nuclides listed in LTP Table 6-1.

DCGLs:

(1) Applicable $DCGL_W$: 6.3E3 dpm/100cm^2 (Co-60 assumed as a conservative measure)

Note: the $DCGL_w$ value corresponds to 8.73 mrem/y.

Some surfaces contain pits and irregular surfaces, which will increase the source-to-detector distance for some localized areas under the 100cm^2 window of the detector. Most of the pits and irregularities increase the source-to-detector distance as much as 1 inches. These types of irregularities in the concrete surfaces will be taken into account through the efficiency factor applied to the measurements collected with the HP-100. Technical report YA-REPT-00-015-04 provides instrument efficiency factors (ϵ_i) for various source-to-detector distances. The ϵ_i value for a source-to-detector distance of 1 inch was selected as a representative efficiency for data collected with the HP-100 on irregular surfaces. The ϵ_i value for a distance of ½ inch will be applied to HP-100 data collected from smooth concrete surfaces. The efficiency factors provided in YA-REPT-00-015-04 are used below:

- ϵ_i = 0.2413 c/e for smooth concrete surfaces (reflects a source to detector distance = ½ inch), and

  = 0.149 c/e for pitted/irregular surfaces (reflects a source to detector distance = 1 inch)
- ϵ_s = 0.25 e/d (consistent with the Co-60 assumption)
- total efficiency for smooth surface = $\epsilon_i \cdot \epsilon_s$ = 0.2413 c/e · 0.25 e/d = 0.0603 c/d
- total efficiency for pitted/irregular surfaces = $\epsilon_i \cdot \epsilon_s$ = 0.149 c/e · 0.25 e/d = 0.0373 c/d

(2) Gross measurement $DCGL_w$ (for HP-100): 6.3E3 dpm/100cm^2

- for smooth concrete surface: 6.3E3 dpm/100cm^2 * 0.0603 c/d = 3.8E2 cpm/100cm^2

- for pitted/irregular surface: 6.3E3 dpm/100cm2 * 0.0373 c/d = 2.3E2 cpm/100cm^2

<u>(3) Applicable $DCGL_{EMC}$ for fixed-point measurements</u>: $DCGL_w$ * AF = 6.3E3 dpm/100cm^2 *1.4 = 1.5E4 dpm/100cm^2

- for smooth concrete surface: 8820 dpm/100cm^2 * 0.0603 c/d = 532 cpm/100cm^2
- for pitted/irregular surface: 8820 dpm/100cm2 * 0.0373 c/d = 329 cpm/100cm^2.

Note: the DCGL and $DCGL_{EMC}$ value refer to above-background radioactivity.

Investigation Level for fixed-point measurement:

- for smooth (i.e., vertical side) concrete surface: >532cpm/100cm^2 above background
- for pitted/irregular (i.e., top) concrete surface: >329cpm/100cm^2 above background

Investigation Level for SPA-3 scan: Reproducible indication above background using the audible feature with headphones

Investigation Level for ISOCS scans: 1m scan height: 1.7E4 dpm/100cm^2 (Co-60).
2m scan height: 2.91E3 dpm/100cm^2 (Co-60).

Note: The investigation levels for the ISOCS scans were derived by multiplying the $DCGL_{EMC}$ associated with a 1m^2 area by the ratio of the MDC for the full field of view (12.6m^2 for 2m scan height and 3.14m^2 for 1m scan height) to the MDC for a 1m^2 area at the edge of the full field of view. The investigation levels developed in this manner are sensitive enough to detect the Co-60 $DCGL_{EMC}$ value based on the grid area (1.5E4 dpm/100cm^2). If other LTP-listed gamma-emitting radionuclides are identified in the ISOCS assays, the investigation level will be evaluated using the same criteria applied in the development of the investigation level for Co-60.

MDAs for ISOCS measurements: Equal to or less than $DCGL_{EMC}$ values (based on concrete surface DCGLs & nuclide-specific AF value for 10m^2 from LTP, Appendix 6S).

Scan coverage: ISOCS scan measurements providing 100% coverage of all surfaces.

QC checks and measurements: QC checks for the survey instruments will be performed in accordance with DP-8534 and DP-8540. Pre- and post-use instrument QC checks will be performed. QC checks for the ISOCS will be in accordance with DP-8869 and DP-8871.

MDC_{fixed}: Refer to Attachments 1 and 1A.

Investigation level for SPA-3 scans: Reproducible indication above background using an audible signal. A shielded SPA-3 probe should be used for these scans due to the close proximity to the ISFSI.

Note: ISOCS scans satisfy the requirements for scanning in this survey plan. SPA-3 scans are in addition and therefore no MDCR and MDC (fDCGL) are developed for these scans.

4.0 Define the boundaries of the survey:

AUX-01-02 encompasses the concrete walls and floor of the pit from the 1022' elevation down to and including the floor of the pit at the 1004' elevation.

The fixed-point measurement locations will be defined by a random-start systematic grid. The ISOCS scans are 100% of the concrete slab surface.

5.0 Develop a decision rule:

a. If all of the data show that the concentrations of all plant-related nuclides are below the DCGLs and the sum of their DCGL fractions are less than unity then reject the null hypothesis (i.e. the Survey Unit meets the release criteria).

b. If the action levels are exceeded, then perform an investigation survey.

c. If the average of the FSS measurements is below the $DCGL_w$, but some individual measurements exceed the $DCGL_w$, then apply a statistical test as the basis for accepting or rejecting the null hypothesis.

d. If the average concentration exceeds the DCGL then accept the null hypothesis (i.e. the Survey Area does not meet the release criteria).

6.0 Specify tolerable limits on decision errors:

Null hypothesis: The null hypothesis (H_o), as required by MARSSIM, is stated and tested in the negative form: "Residual licensed radioactive materials in Survey Unit AUX-01-02 exceeds the release criterion".

Probability of type I (α) error: 0.05
Probability of type II (β) error: 0.05

LBGR: $DCGL_w/2$ = 3150 dpm/100cm^2 (systematic measurements)

7.0 Optimize Design:

Type of statistical test: **Sign Test**

Number of measurements: 20 (Systematic grid from a random start point.)

Biased measurements: none

GENERAL INSTRUCTIONS

1. Notify QA of date and time of the pre-survey briefing and any other scheduled activities subject to QA notification that are currently known.

2. Survey instrument: Operation of the E-600 w/SPA-3 will be in accordance with DP-8535, with QC checks preformed in accordance with DP-8540. Operation and source checking of the E-600 w/HP-100 will be in accordance with DP-8534. The instrument response checks shall be

performed before issue and after use

3. Collect ISOCS measurements in accordance with DP-8871.

4. The job hazards associated with this FSS are addressed in the accompanying JHA for AUX-01-02.

5. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. Mark the scan locations as indicated on the Scan Coverage maps. ISOCS scan locations are sequentially numbered starting with number **101**. Indicate additional scans by marking the approximate location and the sequence number (AUX-01-02-### [sequence number]-F-G) on the maps. Using the 90° collimator, position the ISOCS detector directly at each mark 2 meters from the surface to be scanned. Angle the detector as necessary perpendicular to the scan surface and perform an analysis in accordance with DP-8871 employing a preset count time sufficient to meet the MDAs referenced in this survey plan. Review the report to verify that the MDAs have been met for the nuclides. Identify radionuclides representing licensed radioactive material and compare their concentration to their respective $DCGL_{EMC}$ value.

2. If any ISOCS scan measurement is equal to or greater than the action (investigation) level then an investigation of that scan area footprint shall be performed as follows:

   a. Using the SPA-3 at a slow speed scan rate (approximately 2-3" per second), scan the entire ISOCS footprint. Scanning will be performed in the rate-meter mode with the audible feature "on".

   Note:If the background level exceeds 17000 cpm, contact the FSS Engineer prior to continuing.

   b. Mark (outline on the surface) locations where detectable-above-background readings are found. Identify each outlined areas on a survey map.

   c. Measure the total area (square centimeters) of each outlined elevated area. Indicate on the map (and with black marker on the actual location) the location of the highest indicated activity spot. Record the highest SPA-3 reading observed for each outlined area.

   d. On the spot indicating the highest SPA-3 reading observed for each outlined area, perform and record a 1 minute scaler reading using the E600/SHP100.

Note: Should further investigative measures be required (i.e. concrete core sampling) a specific investigative sample plan will be developed.

Detailed descriptions of investigative actions will be recorded on form DPF-8856.2 and the location of the investigation analyses will be recorded on the survey map. The location description must provide ample detail to allow revisiting the spot at a later time.

3. For the fixed-point measurements, mark the grid locations as shown on the maps using small, but readily visible marks.

   a. Collect and record the 20 measurements with the E-600/SHP-100 in accordance with DP-8534 and DP-8535 using the scalar mode (1 minute). Record each fixed-point measurement "as read" (in units of cpm) on the Form 2.

b. Designation for fixed-point measurements: AUX-01-02-001-**F-FM** through AUX-01-02-020-**F-FM** corresponding to FSS measurement locations 001 through 020.

Note: Any grid point that falls at a location that is unsuitable for a fixed measurement should be relocated in accordance with DP-8856 to the nearest suitable location within one meter.

4. Document a background survey on a standard survey form with a map of the area showing the survey locations. Readings can be tabulated outside the map area using references to the locations.

4.1 Cover the detector with 1/8-inch Lucite shield, or equivalent, and collect a series of one-minute background readings according to the following plan:

A) Near each corner of the room (pit), determine a location that is 1 meter from each wall and 1 meter above the floor as nearly as possible. Take 4 readings: one reading facing each of the two near walls, one directed at the center of the room (pit) and one facing the floor.

B) At the approximate center of the room take a set of readings as follows: one facing each wall and one facing the floor.

NOTIFICATION POINTS

QA notification point(s) (y/n) y* QA Signature/Date:

(1) Date/time of initial pre-survey briefing /

(2) Date/time of commencement of fixed measurement /

(3) Date/time of first scan measurement /

(4) Date/time of E600 data download, if performed /

* Email notification to trudeau@yankee.com and Marchi@cyapo.com satisfies this step

FSI point(s) (y/n) n

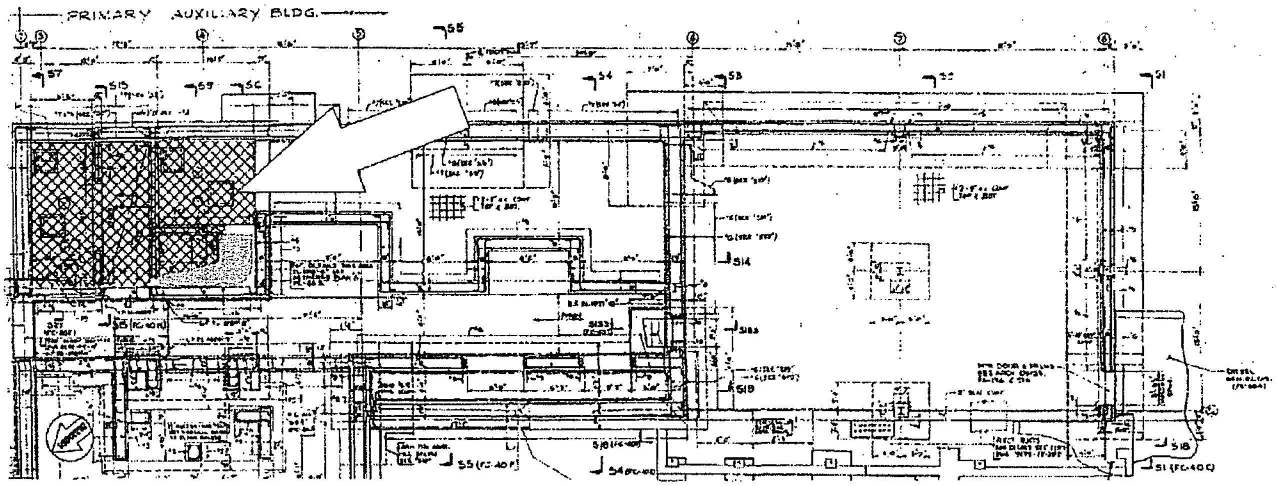
Prepared by [signature] Date 1 DEC. 05
FSS Radiological Engineer

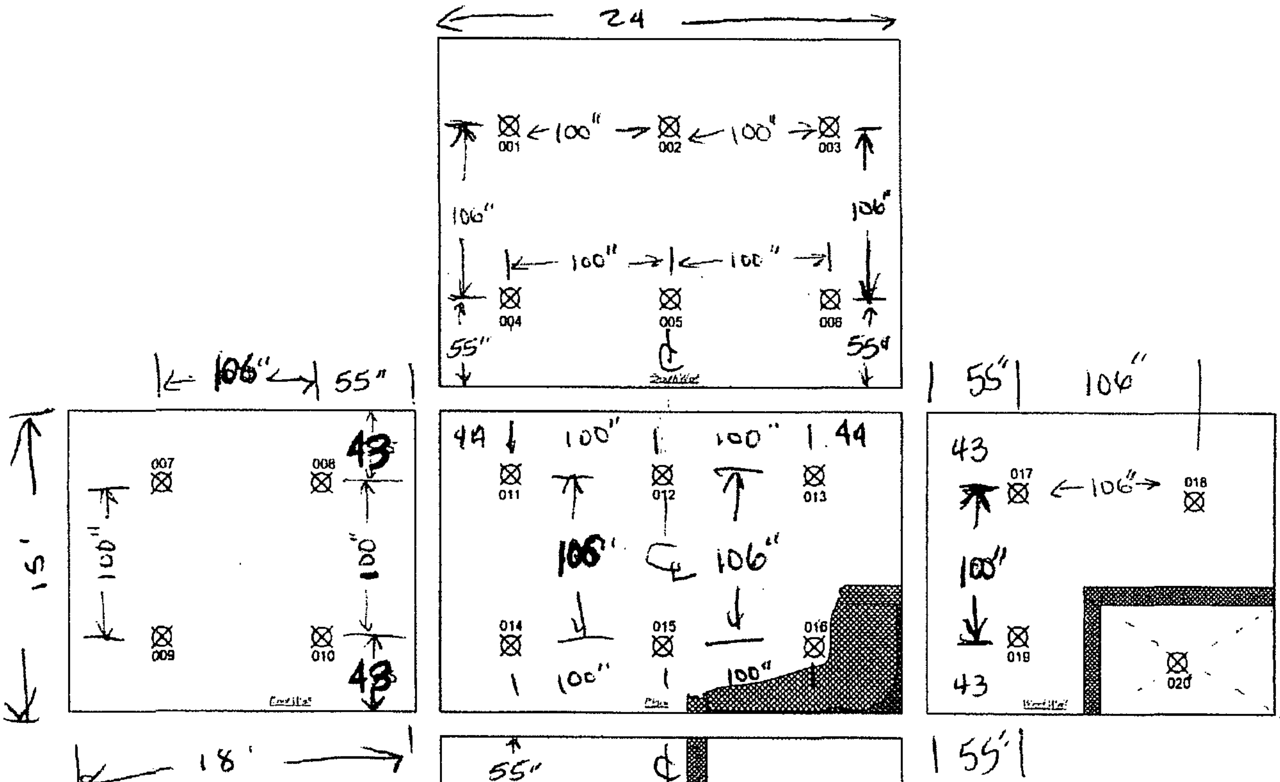
Reviewed by [signature] Date 12/1/05
FSS Radiological Engineer

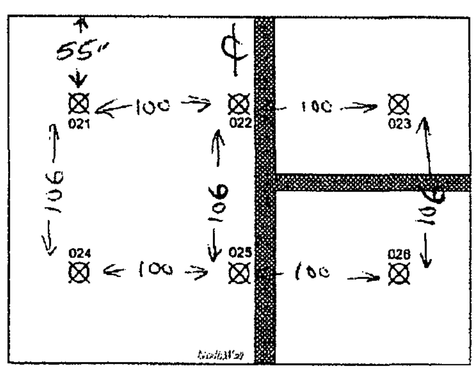
Approved by [signature] LORRIE FOR D. SMITH Per Telecon Date 12/1/05
FSS Project Manager

Scan Measurement Locations

AUX-01-02-xxx-F-G







AUX-01-02

FOOTPRINT AREA= 34.73m²

TOTAL SURFACE AREA= 173.81m²

Prepared By:	L. Dockins	11/21/05

Attachment 1 (Smooth)

MDCR/MDC Table for AUX-01-02	
Background (cpm)	MDC fixed
100	821
200	1140
300	1385
400	1591
500	1773
600	1938
700	2089
800	2230
900	2362
1000	2487

$$MDC_{fixed} = \frac{3 + 4.65\sqrt{B}}{Kt}$$

where:

B = background counts in time "t"
K = $e_i * e_s$(A/100)
A = Probe area (cm^2)
e_i = instrument efficiency
e_s = source efficiency
t = time interval (min)

Rb = background count rate
A = 100 cm^2
e_i = 0.2413
e_s = 0.25
t = 1 min

Attachment 1A (Irregular)

MDCR/MDC Table for AUX-01-02	
Background (cpm)	MDC fixed
100	1329
200	1846
300	2243
400	2577
500	2872
600	3138
700	3383
800	3611
900	3826
1000	4028

$$MDC_{fixed} = \frac{3 + 4.65\sqrt{B}}{Kt}$$

where:

B = background counts in time "t"
K = e_i*e_s(A/100)
A = Probe area (cm^2)
e_i = instrument efficiency
e_s = source efficiency
t = time interval (min)

Rb = background count rate
A = 100 cm^2
e_i = 0.149
e_s = 0.25
t = 1 min

Final Status Survey Planning Worksheet

GENERAL SECTION	
Survey Area #: AUX-01	Survey Unit #: 03
Survey Unit Name: PAB East Side	
FSSP Number: YNPS-FSSP-AUX01-03-00	

PREPARATION FOR FSS ACTIVITIES

Check marks in the boxes below signify affirmative responses and completion of the action.

1.1 Files have been established for survey unit FSS records. ☒

1.2 ALARA review has been completed for the survey unit. ☒

1.3 The survey unit has been turned over for final status survey. ☒

1.4 An initial DP-8854 walkdown has been performed and a copy of the completed Survey Unit Walkdown Evaluation is in the survey area file. ☒

1.5 Activities conducted within area since turnover for FSS have been reviewed. ☒

Based on reviewed information, subsequent walkdown: ☒ not warranted ☐ warranted

If warranted, subsequent walkdown has been performed and documented per DP-8854. ☐

OR

The basis has been provided to and accepted by the FSS Project Manager for not performing a subsequent walkdown.

1.6 A final classification has been performed. ☒

Classification: CLASS 1 ☒ CLASS 2 ☐ CLASS 3 ☐

DATA QUALITY OBJECTIVES (DQO)

1.0 State the problem:

Survey Unit AUX-01-03 consists of remnant PAB walls and floor existing in the east side of the former structure (i.e. the portion that surrounds the "Pit") and contains a total surface area of 152 m^2 (69m^2 floor area).

These walls, in conjunction with the the remaining PAB walls, were originally part of a "free release" effort prior to demolition of the PAB structure.

The identities of the radionuclides-of-concern for this survey effort, as well as the statistical data, are based on results acquired from the FSS of the adjacent survey units AUX-01-01 and AUX-01-02 as well as information provided in the "free release" effort. Pre-remediation and investigation data has indicated a 70/30 to 80/20 Cs-137 \ Co-60 ratio. In addition to the pre-remediation data, ISOCS assays of AUX-01-02 have indicated the major isotopic contributor to be Cs-137. If a weighted $DCGL_W$ were to be calculated utilizing this data the resultant values would be considerably higher than using the DCGL value for Co-60 alone. In keeping with the previous conservative approach to the PAB concrete surfaces (i.e. protocols used for AUX-01-01 and AUX-01-02), this survey plan will use the DCGL values for the most limiting isotope Co-60 for AUX-01-03 FSSP calculations.

Data used to determine the number of samples are derived from the FSS of the adjacent survey unit AUX-01-02.

Initial HSA and surveys prompted a LTP MARSSIM Classification of 1 for AUX-01, and due to remedial activities performed in adjacent areas, AUX-01-03 will remain a Class 1 area.

The problem, therefore, is to determine and demonstrate that residual licensed radioactive materials, if present in AUX-01-03, meets the LTP release criterion

The planning team for this effort consists of the FSS Project Manager, FSS Radiological Engineer, FSS Field Supervisor, and FSS Technicians. The FSS Radiological Engineer will make primary decisions with the concurrence of the FSS Project Manager.

2.0 Identify the decision:

The decision to be made can be stated "Does residual plant-related radioactivity, if present in the survey unit, exceed the release criteria?"

Alternative actions that may be employed are investigation, re-survey and remediation or disposal.

3.0 Identify the inputs to the decision:

Sample media: Concrete surfaces.

Types of measurements: Systematic measurements, scans and concrete sampling (if required for investigations).

Radionuclides-of-concern: All nuclides listed in Table 1 of this FSSP will be included in analysis with the primary emphasis on Co-60.

DCGLs:

Applicable DCGL$_w$: 6.3E3 dpm/100cm^2 (Co-60 assumed as a conservative measure)

__Note:__ the DCGL$_w$ value corresponds to 8.73 mrem/y.

Some surfaces contain pits and irregular surfaces, which will increase the source-to-detector distance for some localized areas under the 100cm^2 window of the detector. Most of the pits and irregularities increase the source-to-detector distance as much as 1 inch. These types of irregularities in the concrete surfaces will be taken into account through the efficiency factor applied to the measurements collected with the HP-100. Technical report YA-REPT-00-015-04 provides instrument efficiency factors (ε_i) for various source-to-detector distances. The ε_i value for a source-to-detector distance of 1 inch was selected as a representative efficiency for data collected with the HP-100 on irregular surfaces. The ε_i value for a distance of ½ inch will be applied to HP-100 data collected from smooth concrete surfaces. The efficiency factors provided in YA-REPT-00-015-04 are used below:

- ε_i = 0.2413 c/e for smooth concrete surfaces (reflects a source to detector distance = ½ inch), and

  = 0.149 c/e for pitted/irregular surfaces (reflects a source to detector distance = 1 inch)
- ε_s = 0.25 e/d (consistent with the Co-60 assumption)
- total efficiency for smooth surface = $\varepsilon_i \cdot \varepsilon_s$ = 0.2413 c/e · 0.25 e/d = 0.0603 c/d

- total efficiency for pitted/irregular surfaces = $\varepsilon_i \cdot \varepsilon_s$ = 0.149 c/e · 0.25 e/d = 0.0373 c/d

Gross measurement $DCGL_W$ (for HP-100): 6.3E3 dpm/100cm^2

- for smooth concrete surface: 6.3E3 dpm/100cm^2 * 0.0603 c/d = 3.8E2 cpm/100cm^2
- for pitted/irregular surface: 6.3E3 dpm/100cm2 * 0.0373 c/d = 2.3E2 cpm/100cm^2

Applicable $DCGL_{EMC}$ for fixed-point measurements*:* $DCGL_w$ * AF = 6.3E3 dpm/100cm^2 *1.6 = 1.0E4 dpm/100cm^2

- for smooth concrete surface: 1.0E4 dpm/100cm^2 * 0.0603 c/d = 6.0E2 cpm/100cm^2
- for pitted/irregular surface: 1.0E4 dpm/100cm2 * 0.0373 c/d = 3.7E2 cpm/100cm^2.

Note: the $DCGL_W$ and $DCGL_{EMC}$ values refer to above-background radioactivity.

Investigation Level for fixed-point measurement:

- for smooth concrete surface: >6.0E2 cpm/100cm^2 above background
- for pitted/irregular concrete surface: >3.7E2 cpm/100cm^2 above background

Investigation Level for HP-100 scans: Reproducible indication above background using an audible signal. Refer to Attachment 3 for HP-100 MDCR and MDCf($DCGL_{EMC}$) values.

Investigation Level for ISOCS scans: 1m90d scan height: 1.7E4 dpm/100cm^2 (Co-60).
2m90d scan height: 2.91E3 dpm/100cm^2 (Co-60).

<u>Note</u>: The investigation levels for the ISOCS scans were derived by multiplying the $DCGL_{EMC}$ associated with a 1m^2 area by the ratio of the MDC for the full field of view (12.6m^2 for 2m scan height and 3.14m^2 for 1m scan height) to the MDC for a 1m^2 area at the edge of the full field of view. The investigation levels developed in this manner are sensitive enough to detect the Co-60 $DCGL_{EMC}$ value based on the grid area (1.0E4 dpm/100cm^2). If other LTP-listed gamma-emitting radionuclides are identified in the ISOCS assays, the investigation level will be evaluated using the same criteria applied in the development of the investigation level for Co-60 and in turn the *f*($DCGL_{EMC}$) will be compared to Unity (i.e. SOF<1).

MDCs for ISOCS measurements:

Table 1

MDC values for LTP ISOCS Measurements

Nuclide	MDC (dpm/100cm^2)	Nuclide	MDC (dpm/100cm^2)	Nuclide	MDC (dpm/100cm^2)
Co-60	1.0E3	Sb-125	5.6E3	Eu-152	1.9E3
Nb-94	1.5E3	Cs-134	1.6E3	Eu-154	1.9E3
Ag-108m	1.4E3	Cs-137	3.5E3	Eu-155	3.6E4

<u>**Note:**</u> The MDCs listed in the above table are 10% of the $DCGL_{EMC}$ values (based on concrete surface DCGLs & nuclide-specific AF value for 8m^2 from LTP, Appendix 6S). If the MDC values in the above table cannot be achieved in a reasonable count time, then an MDC no greater than 5X the table value must be achieved.

MDC_{fixed}: Refer to Attachments 1 and 1A.

Scan coverage: ISOCS and/or HP-100/Spa-3 scan measurements providing 100% coverage of all AUX-01-03 surfaces.

QC checks and measurements: QC checks for the survey instruments will be performed in accordance with DP-8534 and DP-8540. Pre and post-use instrument QC checks will be performed. QC checks for the ISOCS will be in accordance with DP-8869 and DP-8871.

Investigation level for SPA-3 scans: Reproducible indication above background using an audible signal. A shielded SPA-3 probe should be used for these scans due to the close proximity to the ISFSI.

<u>Note</u>: If ISOCS scans are utilized then SPA-3 gamma scans are not applicable. If beta scans are used then the MDCR and $f(DCGL_{EMC})$ developed for the SPA-3 scans will be implemented for those Spa-3 scans. (Refer to Attachment 2).

4.0 Define the boundaries of the survey:

AUX-01-03 is comprised of remnant walls and floor of the former PAB structure that lie in the eastern side as indicated on the attached map. Only these walls and floor will be surveyed in AUX-01-03. Other remaining walls and floors of the PAB structure will be addressed in other Survey Plans.

Note: A random-start systematic grid has been developed to identify the fixed-point measurement locations.

Surveying of AUX-01-03 will be performed when weather conditions will not adversely affect the data acquisition.

5.0 Develop a decision rule:

(a) If all of the data show that the concentrations of all plant-related nuclides are below the $DCGL_W$ and the sum of their DCGL fractions are less than unity then reject the null hypothesis (i.e. the Survey Unit meets the release criteria).

(b) If the action levels are exceeded, then perform an investigation survey.

(c) If the average of the FSS measurements is below the $DCGL_w$, but some individual measurements exceed the $DCGL_w$, then apply a statistical test as the basis for accepting or rejecting the null hypothesis.

(d) If the average concentration exceeds the $DCGL_W$ then accept the null hypothesis (i.e. the Survey Area does not meet the release criteria).

6.0 Specify tolerable limits on decision errors:

Null hypothesis: The null hypothesis (H_o), as required by MARSSIM, is stated and tested in the negative form: "Residual licensed radioactive materials in Survey Unit AUX-01-03 exceeds the release criterion".

Probability of type I (α) error: 0.05
Probability of type II (β) error: 0.05

LBGR: $DCGL_w/2$ = 3150 dpm/100cm^2 (systematic measurements)

7.0 Optimize Design:

Type of statistical test: **Sign Test**

Number of measurements: 20 (Systematic grid from a random start point.)

GENERAL INSTRUCTIONS

1. Notify QA of date and time of the pre-survey briefing, commencement of sampling and any other scheduled activities subject to QA notification that are currently known.

2. Survey instrument: Operation of the E-600 w/SPA-3 will be in accordance with DP-8535, with QC checks preformed in accordance with DP-8540. Operation and source checking of the E-600 w/HP-100 will be in accordance with DP-8534. The instrument response checks shall be performed before issue and after use

3. Collect ISOCS measurements in accordance with DP-8871.

4. The job hazards associated with the FSS in Survey Unit 03 are addressed in the accompanying JHA for AUX-01-03.

5. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. Grid AUX-01-03 for 100% scan coverage by placing parallel rows of markers forming a square pattern at a maximum distance of 2.6 meters apart and a maximum of 1.3 meters from the edge of each surface area (add additional scan points closer than 2.6 meters apart as necessary to achieve 100% scan coverage). Sequentially number each scan location starting with number 001. Indicate the approximate ISOCS scan location and the sequence number (AUX-01-03-xxx [sequential number starting at 101]-F-G) on the maps. Using the 90° collimator, position the ISOCS detector directly at each marker 2 meters from the surface to be scanned. Angle the detector as necessary perpendicular to the scan surface and perform an analysis in accordance with DP-8871 employing a preset count time sufficient to meet the MDAs referenced in this survey plan. Review the report to verify that the MDAs have been met for the nuclides. Identify radionuclides representing licensed radioactive material and compare their concentration to their respective $DCGL_{EMC}$ value.

<u>Note:</u> If multiple radionuclides are identified in any single ISOCS assay, then, in addition to comparing each individual nuclide to it's action (investigation) level; the assay will be compared to unity (SOF<1).

2. If any ISOCS scan measurement is equal to or greater than the action (investigation) level, or the SOF ≥1, then an investigation of that scan area footprint shall be performed as follows:

   (a) Using the SPA-3 at a slow speed scan rate (approximately 4" per second), scan the entire ISOCS footprint. Scanning will be performed in the rate-meter mode with the audible feature "on".

Note: If the background level exceeds 19000 cpm, contact the FSS Engineer prior to continuing.

(b) Mark (outline on the surface) locations where detectable-above-background readings are found. Identify each outlined areas on a survey map.

(c) Measure the total area (square centimeters) of each outlined elevated area. Indicate on the map (and with black marker on the actual location) the location of the highest indicated activity spot. Record the highest SPA-3 reading observed for each outlined area.

(d) On the spot indicating the highest SPA-3 reading observed for each outlined area, perform and record a 1-minute scaler reading using the E600/SHP100.

Note: Should further investigative measures be required (i.e. concrete core sampling) a specific investigative sample plan will be developed.

Detailed descriptions of investigative actions will be recorded on form DPF-8856.2 and the location of the investigation analyses will be recorded on the survey map. The location description must provide ample detail to allow revisiting the spot at a later time.

3. If performing beta scans execute the following:

(a) Perform the HP-100 scans by moving the detector at a speed no greater than 2 inches per second, using a ½ inch standoff.

(b) FSS Technicians will wear headphones while scanning and the survey instrument will be in the rate-meter mode. Surveyors will listen for upscale readings and respond to readings that exceed the investigation level.

Note: Contact FSS Engineer if HP-100 background levels exceed 1000 cpm prior to or during scans.

(c) If the HP-100 scan investigation level is exceeded:

(1) Confirm that the above background indication is reproducible and cannot be attributed to a nearby source.

(2) If a nearby source is identified, have it removed or shielded, document the finding on DP-8856.2, and repeat the scan,

(3) If reproducible and not caused by a nearby source, collect a fixed-point measurement at the location of the highest reading observed during the scan,

(4) The designation for a fixed-point measurement collected during a first-level investigation will continue in sequence beginning with AUX-01-03-021-F-FM-I. Record all investigation fixed-point measurements "as read" (in units of cpm) on the attached Form 1 (even if the measurement was logged).

(5) Clearly mark the location of any fixed-point measurement collected during this level of investigation. The FSS Radiological Engineer is responsible for assessing the need for further investigation. If further investigation is required, it will be conducted under a separate survey plan.

Note: The FSS Field Supervisor will record information relevant to the HP-100 scans on DPF-8856.2 accompanied by a survey map of the area scanned.

4. If beta scans are performed then gamma scans will be performed on irregular surfaces and cracks in the concrete as follows:

(a) Perform SPA-3 scans on the irregular surfaces and over cracks by moving the detector slowly (no greater than 0.09m/s) and keeping it < 3 inches from the surface.

Note: If background levels exceed 19000 cpm contact the Radiological Engineer prior to starting the scan or continuing scans.

Note: When performing Spa-3 scans, (investigations not included) no less than 50% of the time will be monitored and timed by the FSS Field Supervisor.

(b) FSS Technicians will wear headphones while scanning with the survey instrument in the rate-meter mode. Surveyors will listen for upscale readings and respond to readings that exceed the SPA-3 investigation level.

(c) If a SPA-3 reading exceeds the investigation level:

(1) Confirm that the above-background indication is reproducible and cannot be attributed to a nearby source,

(2) If a nearby source is identified, have it removed or shielded, document the finding on DP-8856.2, and repeat the scan,

(3) If the reading is reproducible and not caused by a nearby source, collect a fixed-point measurement with the HP-100 at the highest reading observed during the scan and clearly mark that location. Designate the investigation fixed-point measurement as describe in step 3(c)(4) above. Record all investigation fixed-point measurements "as read" (in units of cpm) on the attached Form 1 (even if the measurement was logged). The FSS Radiological Engineer is responsible for assessing the need for further investigation. If further investigation is required, it will be conducted under a separate survey plan.

5. For the statistical fixed-point measurements perform the following:

(a.) Locate and mark the measurement points at the locations shown in the attached map using small, but readily visible marks. Use the distances (from edge of survey unit footprint) shown on Map 2 to locate the fixed-point measurements on the vertical walls.

Note: If a measurement location is obstructed such that a measurement cannot be collected, select the nearest suitable location within one meter in accordance with DP-8856.

(b.) Collect and record the 20 measurements with the E-600/SHP-100 in accordance with DP-8534 and DP-8535 using the scalar mode (1 minute). Record each fixed-point measurement "as read" (in units of cpm) on the Form 1 indicating whether the concrete surface was smooth (S) or irregular (I).

(c.) Designation for fixed-point measurements: AUX-01-03-001-FM through AUX-01-03-020-FM corresponding to FSS measurement locations 001 through 020.

6. Perform a background survey as follows:

(a) Cover the detector with 1/8-inch Lucite shield, or equivalent, and collect a series of one-minute background readings according to the following plan:

(1) At each corner location of AUX-01-03 as indicated on the attached map, determine a location that is 1 meter from any wall present and 1 meter above the floor as nearly as possible. Take 4 readings: one each facing plant north, south, east and west and one reading facing the floor.

(2) At the approximate center of the room, as indicated on the attached map, take a set of readings as follows: one each facing plant north, south, east and west and one facing the floor

(3) Record each background measurement "as read" (in units of cpm) on the background survey map attached to this survey plan.
NOTIFICATION POINTS
QA notification point(s) (y/n) __y*__ QA Signature/Date:
(1) Date/time of initial pre-survey briefing ____ / ____
(2) Date/time of commencement of fixed measurement ____ / ____
(3) Date/time of first ISOCS scan measurement ____ / ____
(4) Date/time of first SPA-3 scan measurement ____ / ____
* Email notification to trudeau@yankee.com with a copy to Marchi@cyapco.com satisfies this step
FSI point(s) (y/n) _ n FSS Radiological Engineer Signature/Date:
(1)____ ____ / ____
(2)____ ____ / ____

Prepared by [signature] Date 12/15/05
FSS Radiological Engineer

Reviewed by [signature] Date 12/15/05
FSS Radiological Engineer

Approved by D.C.Smith [signature] Date 12/15/05
FSS Project Manager

Final Status Survey Planning Worksheet

GENERAL SECTION	
Survey Area #: AUX-01	Survey Unit #: 04
Survey Unit Name: PAB Mid Section	
FSSP Number: YNPS-FSSP-AUX01-04-00	

PREPARATION FOR FSS ACTIVITIES

Check marks in the boxes below signify affirmative responses and completion of the action.

1.1 Files have been established for survey unit FSS records. ☒

1.2 ALARA review has been completed for the survey unit. ☒

1.3 The survey unit has been turned over for final status survey. ☒

1.4 An initial DP-8854 walkdown has been performed and a copy of the completed Survey Unit Walkdown Evaluation is in the survey area file. ☒

1.5 Activities conducted within area since turnover for FSS have been reviewed. ☒

Based on reviewed information, subsequent walkdown: ☒ not warranted ☐ warranted

If warranted, subsequent walkdown has been performed and documented per DP-8854. ☐

OR

The basis has been provided to and accepted by the FSS Project Manager for not performing a subsequent walkdown.

1.6 A final classification has been performed. ☒

Classification: CLASS 1 ☒ CLASS 2 ☐ CLASS 3 ☐

DATA QUALITY OBJECTIVES (DQO)

1.0 State the problem:

Survey Unit AUX-01-04 consists of remnant PAB walls and floor existing in the middle section of the former structure and contains a total surface area of 112.6 m^2 (69m^2 floor area).

These walls, in conjunction with the remaining PAB walls, were originally part of a "free release" effort prior to demolition of the PAB structure.

The identities of the radionuclides-of-concern for this survey effort, as well as the statistical data, are based on results acquired from the FSS of survey units AUX-01-01 and AUX-01-02 as well as information provided in the "free release" effort. Pre-remediation and investigation data has indicated a 70/30 to 80/20 Cs-137 \ Co-60 ratio. In addition to the pre-remediation data, ISOCS assays of AUX-01-02 have indicated the major isotopic contributor to be Cs-137. If a weighted $DCGL_W$ were to be calculated utilizing this data the resultant values would be considerably higher than using the DCGL value for Co-60 alone. In keeping with the previous conservative approach to the PAB concrete surfaces (i.e. protocols used for AUX-01-01 and AUX-01-02), this survey plan will use the DCGL values for the most limiting isotope Co-60 for AUX-01-04 FSSP calculations.

Data used to determine the number of samples are derived from the FSS of survey unit AUX-01-02.

Initial HSA and surveys prompted a LTP MARSSIM Classification of 1 for AUX-01, and due to remedial activities performed in adjacent areas, AUX-01-04 will remain a Class 1 area.

The problem, therefore, is to determine and demonstrate that residual licensed radioactive materials, if present in AUX-01-04, meets the LTP release criterion

The planning team for this effort consists of the FSS Project Manager, FSS Radiological Engineer, FSS Field Supervisor, and FSS Technicians. The FSS Radiological Engineer will make primary decisions with the concurrence of the FSS Project Manager.

2.0 Identify the decision:

The decision to be made can be stated "Does residual plant-related radioactivity, if present in the survey unit, exceed the release criteria?"

Alternative actions that may be employed are investigation, re-survey and remediation or disposal.

3.0 Identify the inputs to the decision:

Sample media: Concrete surfaces.

Types of measurements: Systematic measurements, scans and concrete sampling (if required for investigations).

Radionuclides-of-concern: All nuclides listed in Table 1 of this FSSP will be included in analysis with the primary emphasis on Co-60.

DCGLs:

Applicable $DCGL_w$: 6.3E3 dpm/100cm^2 (Co-60 assumed as a conservative measure)

Note: the $DCGL_w$ value corresponds to 8.73 mrem/y.

Some surfaces contain pits and irregular surfaces, which will increase the source-to-detector distance for some localized areas under the 100cm^2 window of the detector. Most of the pits and irregularities increase the source-to-detector distance as much as 1 inch. These types of irregularities in the concrete surfaces will be taken into account through the efficiency factor applied to the measurements collected with the HP-100. Technical report YA-REPT-00-015-04 provides instrument efficiency factors (ε_i) for various source-to-detector distances. The ε_i value for a source-to-detector distance of 1 inch was selected as a representative efficiency for data collected with the HP-100 on irregular surfaces. The ε_i value for a distance of ½ inch will be applied to HP-100 data collected from smooth concrete surfaces. The efficiency factors provided in YA-REPT-00-015-04 are used below:

- ε_i = 0.2413 c/e for smooth concrete surfaces (reflects a source to detector distance = ½ inch), and

  = 0.149 c/e for pitted/irregular surfaces (reflects a source to detector distance = 1 inch)
- ε_s = 0.25 e/d (consistent with the Co-60 assumption)
- total efficiency for smooth surface = $\varepsilon_i \cdot \varepsilon_s$ = 0.2413 c/e · 0.25 e/d = 0.0603 c/d
- total efficiency for pitted/irregular surfaces = $\varepsilon_i \cdot \varepsilon_s$ = 0.149 c/e · 0.25 e/d = 0.0373 c/d

Gross measurement $DCGL_W$ (for HP-100): 6.3E3 dpm/100cm^2

- for smooth concrete surface: 6.3E3 dpm/100cm^2 * 0.0603 c/d = 3.8E2 cpm/100cm^2
- for pitted/irregular surface: 6.3E3 dpm/100cm2 * 0.0373 c/d = 2.3E2 cpm/100cm^2

Applicable $DCGL_{EMC}$ for fixed-point measurements: $DCGL_w$ * AF = 6.3E3 dpm/100cm^2 *1.9 = 1.2E4 dpm/100cm^2

- for smooth concrete surface: 1.2E4 dpm/100cm^2 * 0.0603 c/d = 7.2E2 cpm/100cm^2
- for pitted/irregular surface: 1.2E4 dpm/100cm2 * 0.0373 c/d = 4.5E2 cpm/100cm^2.

Note: the $DCGL_W$ and $DCGL_{EMC}$ values refer to above-background radioactivity.

Investigation Level for fixed-point measurement:

- for smooth concrete surface: >7.2E2 cpm/100cm^2 above background
- for pitted/irregular concrete surface: >4.5E2 cpm/100cm^2 above background

Investigation Level for HP-100 scans: Reproducible indication above background using an audible signal. Refer to Attachment 3 for HP-100 MDCR and MDCf($DCGL_{EMC}$) values.

Investigation Level for ISOCS scans: 1m90d scan height: 1.7E4 dpm/100cm^2 (Co-60).
2m90d scan height: 2.91E3 dpm/100cm^2 (Co-60).

__Note__: The investigation levels for the ISOCS scans were derived by multiplying the $DCGL_{EMC}$ associated with a 1m^2 area by the ratio of the MDC for the full field of view (12.6m^2 for 2m scan height and 3.14m^2 for 1m scan height) to the MDC for a 1m^2 area at the edge of the full field of view. The investigation levels developed in this manner are sensitive enough to detect the Co-60 $DCGL_{EMC}$ value based on the grid area (1.2E4 dpm/100cm^2). If other LTP-listed gamma-emitting radionuclides are identified in the ISOCS assays, the investigation level will be evaluated using the same criteria applied in the development of the investigation level for Co-60 and in turn the f($DCGL_{EMC}$) will be compared to Unity (i.e. SOF<1).

MDCs for ISOCS measurements:

Table 1

MDC values for LTP ISOCS Measurements

Nuclide	MDC (dpm/100cm^2)	Nuclide	MDC (dpm/100cm^2)	Nuclide	MDC (dpm/100cm^2)
Co-60	1.2E3	Sb-125	6.7E3	Eu-152	2.5E3
Nb-94	1.7E3	Cs-134	1.9E3	Eu-154	2.3E3
Ag-108m	1.7E3	Cs-137	4.2E3	Eu-155	4.3E4

__**Note:**__ The MDCs listed in the above table are 10% of the $DCGL_{EMC}$ values (based on concrete surface DCGLs & nuclide-specific AF value for 6m^2 from LTP, Appendix 6S). If the MDC values in the above table cannot be achieved in a reasonable count time, then an MDC no greater than 5X the table value must be achieved.

MDC_{fixed}: Refer to Attachments 1 and 1A.

Scan coverage: ISOCS and/or HP-100/Spa-3 scan measurements providing 100% coverage of all AUX-01-04 surfaces.

QC checks and measurements: QC checks for the survey instruments will be performed in accordance with DP-8534 and DP-8540. Pre and post-use instrument QC checks will be performed. QC checks for the ISOCS will be in accordance with DP-8869 and DP-8871.

Investigation level for SPA-3 scans: Reproducible indication above background using an audible signal. A shielded SPA-3 probe should be used for these scans due to the close proximity to the ISFSI.

<u>Note</u>: If ISOCS scans are utilized then SPA-3 gamma scans are not applicable. If beta scans are used then the MDCR and $f(DCGL_{EMC})$ developed for the SPA-3 scans will be implemented for those Spa-3 scans. (Refer to Attachment 2).

4.0 Define the boundaries of the survey:

AUX-01-04 is comprised of remnant walls and floor of the former PAB structure that lie in the middle portion as indicated on the attached map. Only these walls and floor will be surveyed in AUX-01-04. Other remaining walls and floors of the PAB structure will be addressed in other Survey Plans.

Note: A random-start systematic grid has been developed to identify the fixed-point measurement locations.

Surveying of AUX-01-04 will be performed when weather conditions will not adversely affect the data acquisition.

5.0 Develop a decision rule:

(a) If all of the data show that the concentrations of all plant-related nuclides are below the $DCGL_W$ and the sum of their DCGL fractions are less than unity then reject the null hypothesis (i.e. the Survey Unit meets the release criteria).

(b) If the action levels are exceeded, then perform an investigation survey.

(c) If the average of the FSS measurements is below the $DCGL_w$, but some individual measurements exceed the $DCGL_w$, then apply a statistical test as the basis for accepting or rejecting the null hypothesis.

(d) If the average concentration exceeds the $DCGL_W$ then accept the null hypothesis (i.e. the Survey Area does not meet the release criteria).

6.0 Specify tolerable limits on decision errors:

Null hypothesis: The null hypothesis (H_o), as required by MARSSIM, is stated and tested in the negative form: "Residual licensed radioactive materials in Survey Unit AUX-01-04 exceeds the release criterion".

Probability of type I (α) error: 0.05
Probability of type II (β) error: 0.05

LBGR: $DCGL_w/2$ = 3150 dpm/100cm^2 (systematic measurements)

7.0 Optimize Design:

Type of statistical test: **Sign Test**

Number of measurements: 20 (Systematic grid from a random start point.)

GENERAL INSTRUCTIONS

1. Notify QA of date and time of the pre-survey briefing, commencement of sampling and any other scheduled activities subject to QA notification that are currently known.

2. Survey instrument: Operation of the E-600 w/SPA-3 will be in accordance with DP-8535, with QC checks preformed in accordance with DP-8540. Operation and source checking of the E-600 w/HP-100 will be in accordance with DP-8534. The instrument response checks shall be performed before issue and after use

3. Collect ISOCS measurements in accordance with DP-8871.

4. The job hazards associated with the FSS in Survey Unit 03 are addressed in the accompanying JHA for AUX-01-04.

5. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. Grid AUX-01-04 for 100% scan coverage by placing parallel rows of markers forming a square pattern at a maximum distance of 2.6 meters apart and a maximum of 1.3 meters from the edge of each surface area (add additional scan points closer than 2.6 meters apart as necessary to achieve 100% scan coverage). Sequentially number each scan location starting with number 001. Indicate the approximate ISOCS scan location and the sequence number (AUX-01-04-xxx [sequential number starting at 101]-F-G) on the maps. Using the 90° collimator, position the ISOCS detector directly at each marker 2 meters from the surface to be scanned. Angle the detector as necessary perpendicular to the scan surface and perform an analysis in accordance with DP-8871 employing a preset count time sufficient to meet the MDAs referenced in this survey plan. Review the report to verify that the MDAs have been met for the nuclides. Identify radionuclides representing licensed radioactive material and compare their concentration to their respective $DCGL_{EMC}$ value.

__Note:__ If multiple radionuclides are identified in any single ISOCS assay, then, in addition to comparing each individual nuclide to it's action (investigation) level; the assay will be compared to unity (SOF<1).

2. If any ISOCS scan measurement is equal to or greater than the action (investigation) level, or the SOF ≥1, then an investigation of that scan area footprint shall be performed as follows:

   (a) Using the SPA-3 at a slow speed scan rate (approximately 5" per second), scan the entire ISOCS footprint. Scanning will be performed in the rate-meter mode with the audible feature "on".

__Note:__ If the background level exceeds 19000 cpm, contact the FSS Engineer prior to continuing.

(b) Mark (outline on the surface) locations where detectable-above-background readings are found. Identify each outlined areas on a survey map.

(c) Measure the total area (square centimeters) of each outlined elevated area. Indicate on the map (and with black marker on the actual location) the location of the highest indicated activity spot. Record the highest SPA-3 reading observed for each outlined area.

(d) On the spot indicating the highest SPA-3 reading observed for each outlined area, perform and record a 1-minute scaler reading using the E600/SHP100.

Note: Should further investigative measures be required (i.e. concrete core sampling) a specific investigative sample plan will be developed.

Detailed descriptions of investigative actions will be recorded on form DPF-8856.2 and the location of the investigation analyses will be recorded on the survey map. The location description must provide ample detail to allow revisiting the spot at a later time.

3. If performing beta scans execute the following:

(a) Perform the HP-100 scans by moving the detector at a speed no greater than 2 inches per second, using a ½ inch standoff.

(b) FSS Technicians will wear headphones while scanning and the survey instrument will be in the rate-meter mode. Surveyors will listen for upscale readings and respond to readings that exceed the investigation level.

Note: Contact FSS Engineer if HP-100 background levels exceed 1000 cpm prior to or during scans.

(c) If the HP-100 scan investigation level is exceeded:

(1) Confirm that the above background indication is reproducible and cannot be attributed to a nearby source.

(2) If a nearby source is identified, have it removed or shielded, document the finding on DP-8856.2, and repeat the scan,

(3) If reproducible and not caused by a nearby source, collect a fixed-point measurement at the location of the highest reading observed during the scan,

(4) The designation for a fixed-point measurement collected during a first-level investigation will continue in sequence beginning with AUX-01-04-021-F-FM-I. Record all investigation fixed-point measurements "as read" (in units of cpm) on the attached Form 1 (even if the measurement was logged).

(5) Clearly mark the location of any fixed-point measurement collected during this level of investigation. The FSS Radiological Engineer is responsible for assessing the need for further investigation. If further investigation is required, it will be conducted under a separate survey plan.

Note: The FSS Field Supervisor will record information relevant to the HP-100 scans on DPF-8856.2 accompanied by a survey map of the area scanned.

4. If beta scans are performed then gamma scans will be performed on irregular surfaces and cracks in the concrete as follows:

(a) Perform SPA-3 scans on the irregular surfaces and over cracks by moving the detector slowly (no greater than 0.13m/s) and keeping it < 3 inches from the surface.

Note: If background levels exceed 19000 cpm contact the Radiological Engineer prior to starting the scan or continuing scans.

Note: When performing Spa-3 scans, (investigations not included) no less than 50% of the time will be monitored and timed by the FSS Field Supervisor.

(b) FSS Technicians will wear headphones while scanning with the survey instrument in the rate-meter mode. Surveyors will listen for upscale readings and respond to readings that exceed the SPA-3 investigation level.

(c) If a SPA-3 reading exceeds the investigation level:

(1) Confirm that the above-background indication is reproducible and cannot be attributed to a nearby source,

(2) If a nearby source is identified, have it removed or shielded, document the finding on DP-8856.2, and repeat the scan,

(3) If the reading is reproducible and not caused by a nearby source, collect a fixed-point measurement with the HP-100 at the highest reading observed during the scan and clearly mark that location. Designate the investigation fixed-point measurement as describe in step 3(c)(4) above. Record all investigation fixed-point measurements "as read" (in units of cpm) on the attached Form 1 (even if the measurement was logged). The FSS Radiological Engineer is responsible for assessing the need for further investigation. If further investigation is required, it will be conducted under a separate survey plan.

5. For the statistical fixed-point measurements perform the following:

(a.) Locate and mark the measurement points at the locations shown in the attached map using small, but readily visible marks. Use the distances (from edge of survey unit footprint) shown on Map 2 to locate the fixed-point measurements on the vertical walls.

Note: If a measurement location is obstructed such that a measurement cannot be collected, select the nearest suitable location within one meter in accordance with DP-8856.

(b.) Collect and record the 20 measurements with the E-600/SHP-100 in accordance with DP-8534 and DP-8535 using the scalar mode (1 minute). Record each fixed-point measurement "as read" (in units of cpm) on the Form 1 indicating whether the concrete surface was smooth (S) or irregular (I).

(c.) Designation for fixed-point measurements: AUX-01-04-001-FM through AUX-01-04-020-FM corresponding to FSS measurement locations 001 through 020.

6. Perform a background survey as follows:

(a) Cover the detector with 1/8-inch Lucite shield, or equivalent, and collect a series of one-minute background readings according to the following plan:

(1) At each corner location of AUX-01-04 as indicated on the attached map, determine a location that is 1 meter from any wall present and 1 meter above the floor as nearly as possible. Take 4 readings: one each facing plant north, south, east and west and one reading facing the floor.

(2) At the approximate center of the room, as indicated on the attached map, take a set of readings as follows: one each facing plant north, south, east and west and one facing the floor

(3) Record each background measurement "as read" (in units of cpm) on the

background survey map attached to this survey plan.
NOTIFICATION POINTS
QA notification point(s) (y/n) y* QA Signature/Date:
(1) Date/time of initial pre-survey briefing /
(2) Date/time of commencement of fixed measurement /
(3) Date/time of first ISOCS scan measurement /
(4) Date/time of first SPA-3 scan measurement /
* Email notification to trudeau@yankee.com with a copy to Marchi@cyapco.com satisfies this step
FSI point(s) (y/n) n FSS Radiological Engineer Signature/Date:
(1) /
(2) /

Prepared by [signature] Date 12/15/05
FSS Radiological Engineer

Reviewed by [signature] Date 12/15/05
FSS Radiological Engineer

Approved by [signature] / DC Smith Date 12/15/05
FSS Project Manager

TECHNICAL REPORT TITLE PAGE

COPY

Instrument Efficiency Determination for Use in Minimum Detectable Concentration Calculations in Support of the Final Status Survey at Yankee Rowe

Title

YA-REPT-00-015-04
REV. 0

Technical Report Number

Approvals	(Print & Sign Name)		
Preparer:	[signature]	Date:	10-7-04
Reviewer:	James R. Hummer	Date:	10/7/04
Approver (Cognizant Manager):	[signature]	Date:	10/7/04

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Tables

Appendix

1.0 Executive Summary:

The minimum detectable concentration (MDC) of the field survey instrumentation is an important factor affecting the quality of the final status survey (FSS). The efficiency of an instrument inversely impacts the MDC value. The objective of this report is to determine the instrument and source efficiency values used to calculate MDC. Several factors were considered when determining these efficiencies and are discussed in the body of this report. Instrument efficiencies (ε_i), and source efficiencies (ε_s), for alpha beta detection equipment under various field conditions, and instrument conversion factors (E_i), for gamma scanning detectors were determined and the results are provided herein.

2.0 Introduction:

Before performing Final Status Surveys of building surfaces and land areas, the minimum detectable concentration (MDC) must be calculated to establish the instrument sensitivity. Table 5.4 of the License Termination Plan (LTP) [8.6] lists the available instrumentation and nominal detection sensitivities; however for the purposes of this basis document, efficiencies for the 100cm^2 gas proportional and the 2"x2" NaI (Tl) detectors will be determined. Efficiencies for the other instrumentation listed in the LTP shall be determined on an as needed basis. The 100 cm^2 gas proportional probe will be used to perform surveys (i.e. fixed point measurements). A 2" x2" NaI (Tl) detector will be used to perform gamma surveys (i.e., surface scans) of portions of land areas and possibly supplemental structural scans at the Yankee Rowe site. Although surface scans and fixed point measurements can be performed using the same instrumentation, the calculated MDCs will be quite different. MDC is dependent on many factors and may include but is not limited to:

- instrument efficiency
- background
- integration time
- surface type
- source to detector geometry
- source efficiency

A significant factor in determining an instrument MDC is the total efficiency, which is dependent on the instrument efficiency, the source efficiency and the type and energy of the radiation. MDC values are inversely affected by efficiency, as efficiencies increase, MDC values will decrease. Accounting for both the instrument and source components of the total efficiency provides for a more accurate assessment of surface activity.

3.0 Calibration Sources:

For accurate measurement of surface activity it is desirable that the field instrumentation be calibrated with source standards similar to the type and energy of the anticipated contamination. The nuclides listed in Table 3.1 illustrate the nuclides found in soil and building surface area DCGL results that are listed in the LTP.

Instrument response varies with incident radiations and energies; therefore, instrumentation selection for field surveys must be modeled on the expected surface activity. For the purposes of this report, isotopes with max beta energies less than that of C-14 (0.158 MeV) will be considered difficult to detect (reference table 3.1). The detectability of radionuclides with max beta energies less than 0.158 MeV, utilizing gas proportional detectors, will be negligible at typical source to detector distances of approximately 0.5

inches. The source to detector distance of 1.27 cm (0.5 inches) is the distance to the detector with the attached standoff (DP-8534 "Operation and Source Checks of Proportional Friskers")[8.5]. Table 3.1 provides a summary of the LTP radionuclides and their detectability using Radiological Health Handbook [8.4] data.

Table 3.1
Nuclides and Major Radiations: Approximate Energies (Reference 8.4)

Nuclide	α Energy (MeV)	$E_{\beta max}$ (MeV)	Average E_β (MeV)	Photon Energy (MeV)	α Detectable w/ Gas Proportional	β Detectable w/ Gas Proportional	γ Detectable w/ NaI 2x2"
H-3		0.018	0.005				
C-14		0.158	0.049				
Fe-55				0.23 (0.004%) bremsstrahlung			
Co-60		0.314	0.094	1.173 (100%), 1.332 (100%)		√	√
Ni-63		0.066	0.017				
Sr-90		0.544 2.245 (Y-90)	0.200 0.931			√	
Nb-94		0.50	0.156	0.702 (100%), 0.871 (100%)		√	√
Tc-99		0.295	0.085			√	
Ag-108m		1.65 (Ag-108)	0.624 (Ag-108)	0.434 (0.45%), 0.511 (0.56%) 0.615 (0.18%), 0.632 (1.7%)			√
Sb-125		0.612	0.084	0.6, 0.25, 0.41, 0.46, 0.68, 0.77, 0.92, 1.10, 1.34		√	√
Cs-134		1.453	0.152	0.57 (23%), 0.605 (98%) 0.796 (99%), 1.038 (1.0%) 1.168 (1.9%), 1.365 (3.4%)		√	√
Cs-137		1.167	0.195	0.662 (85%) Ba-137m X-rays		√	√
Eu-152		1.840	0.288	0.122 (37%), 0.245 (8%) 0.344 (27%), 0.779 (14%) 0.965 (15%), 1.087 (12%) 1.113 (14%), 1.408 (22%)		√	√
Eu-154		1.850 (10%)	0.228				
Eu-155		0.247	0.044	0.087 (32%), 0.105 (20%)		√	
Pu-238	5.50 (72%) 5.46 (28%)			0.099 (8E-3%) 0.150 (1E-3%) 0.77 (5E-5%)	√		
Pu-239	5.16 (88%) 5.11 (11%)			0.039 (0.007%), 0.052 (0.20%), 0.129 (0.005%)...	√		
Pu-241	4.90 (0.0019%) 4.85 (0.0003%)	0.021	0.005	0.145 (1.6E-4%)			
Am-241	5.49 (85%) 5.44 (13%)			0.060 (36%), 0.101 (0.04%)...	√		
Cm-243	6.06 (6%) 5.99 (6%) 5.79 (73%) 5.74 (11.5%)			0.209 (4%), 0.228 (12%), 0.278 (14%)	√		

NUREG-1507 and ISO 7503-1 provide guidance for selecting calibration sources and their use in determining total efficiency. It is common practice to calibrate instrument efficiency for a single beta energy; however the energy of this reference source should not be significantly greater than the beta energy of the lowest energy to be measured.

Tc-99 (0.295 MeV max) and Th-230 (4.68 MeV at 76% and 4.62 MeV at 24%) have been selected as the beta and alpha calibration standards respectively, because their energies conservatively approximate the beta and alpha energies of the plant specific radionuclides.

4.0 Efficiency Determination:

Typically, using the instrument 4π efficiency exclusively provides a good approximation of surface activity. Using these means for calculating the efficiency often results in an under estimate of activity levels in the field. Applying both the instrument 2π efficiency and the surface efficiency components to determine the total efficiency allows for a more accurate measurement due to consideration of the actual characteristics of the source surfaces. ISO 7503-1 [8.2] recommends that the total surface activity be calculated using:

$$A_s = \frac{R_{S+B} - R_B}{(\varepsilon_i)(W)(\varepsilon_s)},$$

where:
A_s is the total surface activity in dpm/cm^2,
R_{S+B} is the gross count rate of the measurement in cpm,
R_B is the background count rate in cpm,
ε_i is the instrument or detector 2π efficiency
ε_s is the efficiency of the source
W is the area of the detector window (cm^2)

4.1 Alpha and Beta Instrument Efficiency (ε_i):

Instrument efficiency (ε_i) reflects instrument characteristics and counting geometry, such as source construction, activity distribution, source area, particles incident on the detector per unit time and therefore source to detector geometry. Theoretically the maximum value of ε_i is 1.0, assuming all the emissions from the source are 2π and that all emissions from the source are detected. The ISO 7503-1 methodology for determining the instrument efficiency is similar to the historical 4π approach; however the detector response, in cpm, is divided by the 2π surface emission rate of the calibration source. The instrument efficiency is calculated by dividing the net count rate by the 2π surface emission rate ($q_{2\pi}$) (includes absorption in detector window, source detector geometry). The instrument efficiency is expressed in ISO 7503-1 by:

$$\varepsilon_i = \frac{R_{S+B} - R_B}{q_{2\pi}}$$

where:
R_{S+B} is the gross count rate of the measurement in cpm,
R_B is the background count rate in cpm,
$q_{2\pi}$ is the 2π surface emission rate in reciprocal seconds

Note that both the 2π surface emission rate and the source activity are usually stated on the certification sheet provided by the calibration source manufacturer and certified as National Institute of Standards and Technology (NIST) traceable. Table 4.1 depicts instrument efficiencies that have been determined during calibration using the 2π surface emission rate of the source.

Table 4.1
Instrument Efficiencies (ε_i)

Source	**Emission**	**Active Area of Source (cm^2)**	**Effective Area of Detector**	**100 cm^2 Gas Proportional HP-100 Instrument Efficiency (ε_i) (Contact)**
Tc-99	β	*15.2*	100 cm^2	0.4148
Th-230	α	*15.2*	100 cm^2	0.5545

4.2 Source to Detector Distance Considerations:
A major factor affecting instrument efficiency is source to detector distance. Consideration must be given to this distance when selecting accurate instrument efficiency. The distance from the source to the detector shall to be as close as practicable to geometric conditions that exist in the field. A range of source to detector distances has been chosen, taking into account site specific survey conditions. In an effort to minimize the error associated with geometry, instrument efficiencies have been determined for source to detector distances representative of those survey distances expected in the field. The results shown in Table 4.2 illustrate the imposing reduction in detector response with increased distance from the source. Typically this source to detector distance will be 0.5 inches for fixed point measurements and 0.5 inches for scan surveys on flat surfaces, however they may differ for other surfaces. Table 4.2 makes provisions for the selection of source to detector distances for field survey conditions of up to 2 inches. If surface conditions dictate the placement of the detector at distances greater than 2 inches instrument efficiencies will be determined on an as needed basis.

4.2.1 Methodology:
The practical application of choosing the proper instrument efficiency may be determined by averaging the surface variation (peaks and valleys narrower than the length of the detector) and adding 0.5 inches, the spacing that should be maintained between the detector and the highest peaks of the surface. Select the source to detector distance from Table 4.2 that best reflects this pre-determined geometry.

Table 4.2
Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters

Source to Detector Distance (cm)	**Instrument Efficiency (ε_i)**	
	Tc-99 Distributed	**Th-230 Distributed**
Contact	0.4148	0.5545
1.27 (0.5 in)	0.2413	0.1764
2.54 (1 in)	0.1490	0.0265
5.08 (2 in)	0.0784	0.0002

4.3 Source (or Surface) Efficiency (ε_s) Determination:

Source efficiency (ε_S), reflects the physical characteristics of the surface and any surface coatings. The source efficiency is the ratio between the number of particles emerging from surface and the total number of particles released within the source. The source efficiency accounts for attenuation and backscatter. ε_s is nominally 0.5 (no self-absorption/attenuation, no backscatter)--backscatter increases the value, self-absorption decreases the value. Source efficiencies may either be derived experimentally or simply selected from the guidance contained in ISO 7503-1. ISO 7503-1 takes a conservative approach by recommending the use of factors to correct for alpha and beta self-absorption/attenuation when determining surface activity. However, this approach may prove to be too conservative for radionuclides with max beta energies that are marginally lower than 0.400 MeV, such as Co-60 with a βmax of 0.314 MeV. In this situation, it may be more appropriate to determine the source efficiency by considering the energies of other beta emitting radionuclides. Using this approach it is possible to determine weighted average source efficiency. For example, a source efficiency of 0.375 may be calculated based on a 50/50 mix of Co-60 and Cs-137. The source efficiencies for Co-60 and Cs-137 are 0.25 and 0.5 respectively, since the radionuclide fraction for Co-60 and Cs-137 is 50% for each, the weighted average source efficiency for the mix may be calculated in the following manner:

$$(0.25)(0.5)+(0.5)(0.5)=0.375$$

Table 4.3 lists guidance on source efficiencies from ISO 7503-1.

Table 4.3
Source Efficiencies as listed in ISO 7503-1

	> 0.400 MeV_{max}	≤ 0.400 MeV_{max}
Beta emitters	$\varepsilon_s = 0.5$	$\varepsilon_s = 0.25$
Alpha emitters	$\varepsilon_s = 0.25$	$\varepsilon_s = 0.25$

It should be noted that source efficiency is not typically addressed for gamma detectors as the value is effectively unity.

5.0 Instrument Conversion Factor (E) (Instrument Efficiency for Scanning):

Separate modeling analysis (Microshield™) was conducted using the common gamma emitters with a concentration of 1 pCi/g of uniformly distributed contamination throughout the volume. MicroShield is a comprehensive photon/gamma ray shielding and dose assessment program, which is widely used throughout the radiological safety community. An activity concentration of 1 pCi/g for the nuclides was entered as the source term. The radial dimension of the cylindrical source was 28 cm, the depth was 15 cm, and the dose point above the surface was 10 cm with a soil density of 1.6 g/cm^3. The instrument efficiency when scanning, E_i, is the product of the modeled exposure rate (MicroShield™) in mRhr^{-1}/pCi/g for and the energy response factor in cpm/mR/hr as derived from the energy response curve provided by Eberline Instruments (Appendix O). Table 5.1 demonstrates the derived efficiencies for the major gamma emitting isotopes listed in Table 3.1.

TABLE 5.1

Energy Response and Efficiency for Photon Emitting Isotopes

Isotope	Calculations for E_i See appendix A through L	E_i (cpm/pCi/g)
Co-60	See Appendix Aand B	**379**
Nb-94	See Appendix C and D	**416**
Ag-108m	See Appendix E and F	**637**
Sb-125	See Appendix G and H	**210**
Cs-134	See Appendix I and J	**506**
Cs-137	See Appendix K and L	**188**
Eu-152	See Appendix M and N	**344**

When performing gamma scan measurements on soil surfaces the effective source to detector geometry is as close as is reasonably possible (less than 3 inches).

6.0 Applying Efficiency Corrections Based on the Effects of Field Conditions for Total Efficiency:

The total efficiency for any given condition can now be calculated from the product of the instrument efficiency ε_i and the source efficiency ε_s.

$$\varepsilon_{tot} = \varepsilon_i \times \varepsilon_s$$

The following example illustrates the process of determining total efficiency. For this example we will assume the following:

- Surface activity readings need to be made in the Primary Auxiliary Building (PAB) on the concrete wall surfaces using the E-600 and C-100 gas proportional detector.
- Data obtained from characterization results from the PAB indicate the presence of beta emitters with energies greater than 0.400 Mev.
- The source (activity on wall) to detector distance is 1.27 cm (0.5 in detector stand off). To calculate the total efficiency, ε_{tot}, refer to Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters" to obtain the appropriate ε_i value.
- Contamination on all surfaces is distributed relative to the effective detector area.

- When performing fixed point measurements with gas proportional instrumentation the effective source to detector geometry is representative of the calibrated geometries listed in Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters".
- Corrections for temperature and pressure are not substantial.

In this example, the value for ε_i is 0.2413 as depicted in Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α- β Emitters". The ε_s value of 0.5 is chosen refer to Table 4.3 "Source Efficiencies as listed in ISO 7503-1". Therefore the total efficiency for this condition becomes $\varepsilon_{tot} = \varepsilon_i \times \varepsilon_s = 0.2413 \times 0.5 = 0.121$ or 12.1%.

7.0 Conclusion:

Field conditions may significantly influence the usefulness of a survey instrument. When applying the instrument and source efficiencies in MDC calculations, field conditions must be considered. Tables have been constructed to assist in the selection of appropriate instrument and source efficiencies. Table 4.2 "Source to Detector Distance Effects on Instrument Efficiencies for α-β Emitters" lists instrument efficiencies (ε_i) at various source to detector distances for alpha and beta emitters. The appropriate ε_i value should be applied, accounting for the field condition, i.e. the relation between the detector and the surface to be measured.

Source efficiencies shall be selected from Table 4.3 "Source Efficiencies as listed in ISO 7503-1". This table lists conservative ε_s values that correct for self-absorption and attenuation of surface activity. Table 5.1 "Energy Response and Efficiency for Photon Emitting Isotopes" lists E_i values that apply to scanning MDC calculations. The Microshield™ model code was used to determine instrument efficiency assuming contamination conditions and detector geometry cited in section 5.6.2.4.4 "MDCs for Gamma Scans of Land Areas" of the License Termination Plan [8.6].

Detector and source conditions equivalent to those modeled herein may directly apply to the results of this report.

8.0 References

8.1 NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions," 1998

8.2 ISO 7503-1, "Evaluation of Surface Contamination – Part I: Beta Emitters and Alpha Emitters," 1988-08-01.

8.3 ISO 8769, "Reference Sources for the Calibration of Surface Contamination Monitors-Beta-emitters (maximum beta energy greater 0.15MeV) and Alpha-emitters," 1988-06-15.

8.4 "Radiological Health Handbook," Revised Edition 1970.

8.5 DP-8534, "Operation and source Checks of Portable Friskers".

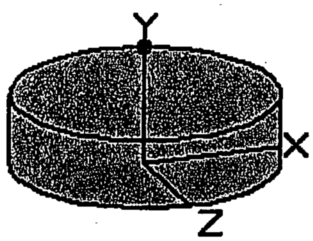
8.6 Yankee Nuclear Plant Site License Termination Plan, Rev.0, November 2003.

APPENDIX A

MicroShield v6.02 (6.02-00253)

Page	:1		**File Ref**	:
DOS File	:SPA3-EFF-Co-60.ms6		**Date**	:
Run Date	: September 10, 2004		**By**	:
Run Time	: 8:56:50 AM		**Checked**	:
Duration	: 00:00:00			

Case Title: SPA3-EFF-Co-60
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Co-60
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Co-60	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	2.230e-01	9.055e-06	1.590e-05	1.748e-08	3.070e-08
1.1732	1.367e+03	1.098e-01	1.669e-01	1.962e-04	2.982e-04
1.3325	1.367e+03	1.293e-01	1.904e-01	2.244e-04	3.303e-04
Totals	**2.734e+03**	**2.391e-01**	**3.573e-01**	**4.205e-04**	**6.286e-04**

APPENDIX B

Co-60
Microsoft Excel E_i Calculation Sheet

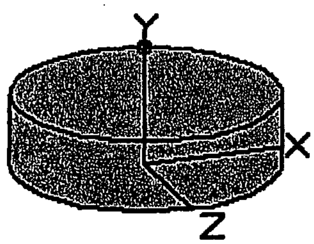
	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	E_i (cpm/pCi/g)
694	0.6938	694	3.07E-08	1,112,630	0
1173	1.1732	1,173	2.98E-04	660,557	197
1333	1.3325	1,333	3.30E-04	552,233	182
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	379

APPENDIX C

MicroShield v6.02 (6.02-00253)

Page	:1	**File Ref**	:
DOS File	:SPA3-EFF-Nb-94.ms6	**Date**	:
Run Date	: September 16, 2004	**By**	:
Run Time	: 3:22:38 PM	**Checked**	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Nb-94
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Nb-94
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Nb-94	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0023	9.067e-02	1.391e-10	1.430e-10	1.861e-10	1.913e-10
0.0174	4.834e-01	8.762e-09	9.129e-09	4.729e-10	4.927e-10
0.0175	9.260e-01	1.719e-08	1.792e-08	9.104e-10	9.491e-10
0.0196	2.720e-01	7.924e-09	8.356e-09	2.925e-10	3.085e-10
0.7026	1.367e+03	5.643e-02	9.872e-02	1.088e-04	1.904e-04
0.8711	1.367e+03	7.464e-02	1.228e-01	1.405e-04	2.312e-04
Totals	**2.736e+03**	**1.311e-01**	**2.216e-01**	**2.493e-04**	**4.216e-04**

APPENDIX D

Nb-94					
	Energy MeV	Energy keV	Exposure Rate (mR/hr-1pCi/g)	Energy Response (cpm/mR/h)	E_i (cpm/pCi/g)
2	0.0023	2	1.91E-10		0
17	0.0174	17	4.93E-10		0
18	0.0175	18	9.49E-10		0
20	0.0196	20	3.09E-10		0
703	0.7026	703	1.90E-04	1,110,370	211
871	0.8711	871	2.31E-04	884,689	205
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	416

APPENDIX E

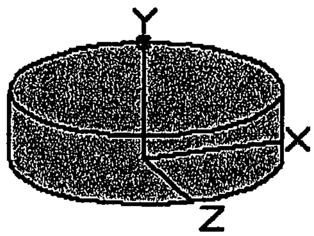
MicroShield v6.02 (6.02-00253)

Page	:1	**File Ref**	:
DOS File	:SPA3-EFF-Ag-108m.ms6	**Date**	:
Run Date	: September 16, 2004	**By**	:
Run Time	: 3:30:40 PM	**Checked**	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Ag-108m
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Ag-108m
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)



Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ag-108m	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0028	6.580e+01	1.252e-07	1.287e-07	1.351e-07	1.388e-07
0.003	7.853e+00	1.568e-08	1.612e-08	1.612e-08	1.657e-08
0.021	2.491e+02	9.534e-06	1.015e-05	2.824e-07	3.007e-07
0.0212	4.727e+02	1.862e-05	1.985e-05	5.389e-07	5.744e-07
0.022	7.024e+00	3.202e-07	3.434e-07	8.233e-09	8.831e-09
0.0222	1.330e+01	6.251e-07	6.714e-07	1.568e-08	1.685e-08
0.0238	1.501e+02	9.273e-06	1.010e-05	1.863e-07	2.029e-07
0.0249	4.289e+00	3.145e-07	3.464e-07	5.492e-09	6.050e-09
0.0304	2.902e-04	4.431e-11	5.248e-11	4.230e-13	5.010e-13
0.0792	9.687e+01	2.008e-04	4.802e-04	3.190e-07	7.629e-07
0.4339	1.229e+03	2.705e-02	5.514e-02	5.294e-05	1.079e-04
0.6144	1.236e+03	4.282e-02	7.808e-02	8.347e-05	1.522e-04
0.7229	1.237e+03	5.300e-02	9.194e-02	1.019e-04	1.768e-04
Totals	**4.768e+03**	**1.231e-01**	**2.257e-01**	**2.398e-04**	**4.389e-04**

APPENDIX F

Ag-108m
Microsoft Excel E_i Calculation Sheet

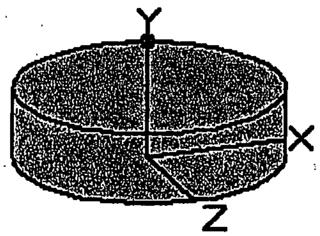
	Energy MeV	Energy keV	Exposure Rate (mR/hr /pCi/g)	Energy Response cpm/(mR/h)	Ei (cpm/pCi/g)
3	0.0028	3	1.39E-07		0
3	0.003	3	1.66E-08		0
21	0.021	21	3.01E-07		0
21	0.0212	21	5.74E-07		0
22	0.022	22	8.83E-09		0
22	0.0222	22	1.69E-08		0
24	0.0238	24	2.03E-07		0
25	0.0249	25	6.05E-09		0
30	0.0304	30	5.01E-13	1086720	0
79	0.0792	79	7.63E-07	11696000	9
434	0.4339	434	1.08E-04	2061265	222
614	0.6144	614	1.52E-04	1402440	213
723	0.7229	723	1.77E-04	1086291	192
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	637

APPENDIX G

MicroShield v6.02 (6.02-00253)

Page	:1		**File Ref**	:
DOS File	:SPA3-EFF-Sb-125.ms6		**Date**	:
Run Date	: September 16. 2004		**By**	:
Run Time	: 3:34:07 PM		**Checked**	:
Duration	: 00:00:00			

Case Title: SPA3-EFF-Sb-125
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Sb-125
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	Becquerels	μCi/cm³	Bq/cm³
Sb-125	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0038	6.762e+01	1.708e-07	1.756e-07	1.388e-07	1.427e-07
0.0272	1.748e+02	1.785e-05	2.020e-05	2.376e-07	2.689e-07
0.0275	3.262e+02	3.453e-05	3.922e-05	4.461e-07	5.067e-07
0.031	1.132e+02	1.857e-05	2.221e-05	1.670e-07	1.997e-07
0.0355	5.693e+01	1.492e-05	1.918e-05	9.090e-08	1.169e-07
0.117	3.568e+00	1.380e-05	3.715e-05	2.146e-08	5.778e-08
0.159	9.531e-01	5.634e-06	1.499e-05	9.416e-09	2.505e-08
0.1726	2.478e+00	1.634e-05	4.295e-05	2.787e-08	7.326e-08
0.1763	9.422e+01	6.392e-04	1.674e-03	1.096e-06	2.870e-06
0.2041	4.410e+00	3.630e-05	9.230e-05	6.435e-08	1.636e-07
0.2081	3.324e+00	2.805e-05	7.103e-05	4.994e-08	1.264e-07
0.2279	1.796e+00	1.708e-05	4.229e-05	3.098e-08	7.670e-08
0.321	5.701e+00	8.474e-05	1.899e-04	1.620e-07	3.632e-07
0.3804	2.045e+01	3.792e-04	8.052e-04	7.364e-07	1.564e-06
0.408	2.486e+00	5.051e-05	1.049e-04	9.853e-08	2.047e-07
0.4279	4.009e+02	8.668e-03	1.774e-02	1.695e-05	3.470e-05
0.4435	4.130e+00	9.356e-05	1.894e-04	1.832e-07	3.709e-07
0.4634	1.415e+02	3.395e-03	6.781e-03	6.658e-06	1.330e-05
0.6006	2.430e+02	8.174e-03	1.501e-02	1.595e-05	2.930e-05
0.6066	6.864e+01	2.340e-03	4.283e-03	4.564e-06	8.355e-06
0.6359	1.548e+02	5.609e-03	1.012e-02	1.091e-05	1.967e-05
0.6714	2.478e+01	9.640e-04	1.710e-03	1.867e-06	3.311e-06
Totals	**1.916e+03**	**3.060e-02**	**5.901e-02**	**6.046e-05**	**1.158e-04**

APPENDIX H

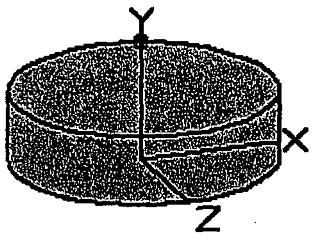
Sb-125					
	Energy Mev	Energy keV	Exposure Rate (mR/hr-1pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
4	0.0038	4	1.43E-07	6,618,312	0
27	0.0272	27	2.69E-07	510,290	0
28	0.0275	28	5.07E-07	554,334	0
31	0.031	31	2.00E-07	1,219,281	0
36	0.0355	36	1.17E-07	2,418,948	0
117	0.117	117	5.78E-08	9,167,000	1
159	0.159	159	2.51E-08	8917000	0
173	0.1726	173	7.33E-08	6859000	1
176	0.1763	176	2.87E-06	6192600	18
204	0.2041	204	1.64E-07	6011300	1
208	0.2081	208	1.26E-07	4073050	1
228	0.2279	228	7.67E-08	3110500	0
321	0.321	321	3.63E-07	3000500	1
380	0.3804	380	0.000001564	2348000	4
408	0.408	408	2.047E-07	2155800	0
428	0.4279	428	0.0000347	2083165	72
444	0.4435	444	3.709E-07	2026225	1
463	0.4634	463	0.0000133	1953590	26
601	0.6006	601	0.0000293	1452810	43
607	0.6066	607	0.000008355	1430910	12
636	0.6359	636	0.00001967	1323965	26
671	0.6714	671	0.000003311	1194390	4
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	210

APPENDIX I

MicroShield v6.02 (6.02-00253)

Page	:1	**File Ref**	:
DOS File	:SPA3-EFF-Cs-134.ms6	**Date**	:
Run Date	: September 16, 2004	**By**	:
Run Time	: 3:39:09 PM	**Checked**	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Cs-134
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Cs-134
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Cs-134	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.222e+00	3.658e-09	3.760e-09	2.507e-09	2.577e-09
0.0318	2.931e+00	5.271e-07	6.386e-07	4.391e-09	5.320e-09
0.0322	5.407e+00	1.014e-06	1.236e-06	8.157e-09	9.943e-09
0.0364	1.968e+00	5.611e-07	7.321e-07	3.188e-09	4.160e-09
0.2769	4.839e-01	5.931e-06	1.391e-05	1.113e-08	2.610e-08
0.4753	1.996e+01	4.950e-04	9.808e-04	9.712e-07	1.924e-06
0.5632	1.146e+02	3.545e-03	6.648e-03	6.940e-06	1.302e-05
0.5693	2.109e+02	6.619e-03	1.237e-02	1.295e-05	2.421e-05
0.6047	1.334e+03	4.529e-02	8.300e-02	8.836e-05	1.619e-04
0.7958	1.167e+03	5.668e-02	9.564e-02	1.079e-04	1.820e-04
0.8019	1.193e+02	5.852e-03	9.853e-03	1.113e-05	1.874e-05
1.0386	1.367e+01	9.377e-04	1.472e-03	1.717e-06	2.696e-06
1.1679	2.461e+01	1.964e-03	2.990e-03	3.514e-06	5.349e-06
1.3652	4.156e+01	4.055e-03	5.936e-03	6.993e-06	1.024e-05
Totals	**3.058e+03**	**1.254e-01**	**2.189e-01**	**2.405e-04**	**4.202e-04**

APPENDIX J

Cs-134

Microsoft Excel E Calculation Sheet

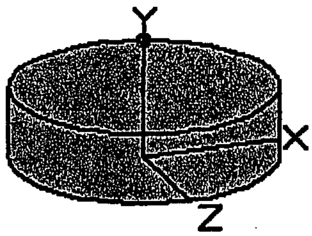
	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
5	0.0045	5	2.58E-09		0
32	0.0318	32	5.32E-09	1,406,947	0
32	0.0322	32	9.94E-09	1,505,273	0
36	0.0364	36	4.16E-09	2,696,122	0
277	0.2769	277	2.61E-08	3,637,000	0
475	0.4753	475	1.92E-06	1,910,155	4
563	0.5632	563	1.30E-05	1,589,320	21
569	0.5693	569	2.42E-05	1,567,055	38
605	0.6047	605	1.62E-04	1,437,845	233
796	0.7958	796	1.82E-04	998,082	182
802	0.8019	802	1.87E-05	939,149	18
1039	1.0386	1,039	2.70E-06	752,085	2
1168	1.1679	1,168	5.35E-06	664,161	4
1365	1.3652	1,365	1.02E-05	573,136	6
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E) Total:	**506**

APPENDIX K

MicroShield v6.02 (6.02-00253)

Page	:1	**File Ref**	:
DOS File	:*SPA3-EFF-Cs-137.ms6*	**Date**	:
Run Date	: September 10, 2004	**By**	:
Run Time	: 8:52:18 AM	**Checked**	:
Duration	: 00:00:00		

Case Title: SPA3-EFF-Cs-137
Description: SPA-3 Soil scan - 28 cm radius 1pCi/cm3 Cs-137 and Daughters
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Actual Photon Energies

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Ba-137m	3.4950e-008	1.2932e+003	9.4600e-007	3.5002e-002
Cs-137	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	1.342e+01	4.020e-08	4.133e-08	2.755e-08	2.833e-08
0.0318	2.677e+01	4.815e-06	5.834e-06	4.011e-08	4.860e-08
0.0322	4.939e+01	9.260e-06	1.129e-05	7.452e-08	9.084e-08
0.0364	1.797e+01	5.126e-06	6.688e-06	2.912e-08	3.800e-08
0.6616	1.164e+03	4.442e-02	7.913e-02	8.611e-05	1.534e-04
Totals	**1.271e+03**	**4.444e-02**	**7.915e-02**	**8.628e-05**	**1.536e-04**

APPENDIX L

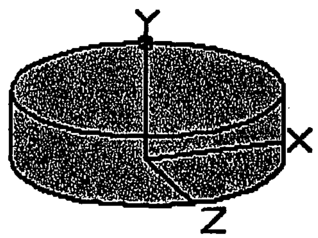
Cs-137 Microsoft Excel E Calculation Sheet					
	Energy MeV	Energy kev	Exposure Rate (mR/hr / 1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
5	0.0045	5	2.83E-08		0
32	0.0318	32	4.86E-08	1,406.947	0
32	0.0322	32	9.08E-08	1,505.273	0
36	0.0364	36	3.80E-08	2,696.122	0
662	0.6616	662	1.53E-04	1,228.700	188
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E) Total:	188

APPENDIX M

MicroShield v6.02 (6.02-00253)

Page	:1		**File Ref**	:
DOS File	:SPA3-EFF-Eu-152.ms6		**Date**	:
Run Date	: October 7, 2004		**By**	:
Run Time	: 11:25:11 AM		**Checked**	:
Duration	: 00:00:00			

Case Title: SPA-3-EFF-Eu-152
Description: SPA-3 Soil scan - 28cm radius 1 pCi/cm3 Eu-152
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions:

Height	15.0 cm	(5.9 in)
Radius	28.0 cm	(11.0 in)

Dose Points

A	X	Y	Z
# 1	0 cm	25 cm	0 cm
	0.0 in	9.8 in	0.0 in

Shields

Shield N	Dimension	Material	Density
Source	3.69e+04 cm³	Concrete	1.6
Air Gap		Air	0.00122

Source Input : Grouping Method - Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Eu-152	3.6945e-008	1.3670e+003	1.0000e-006	3.7000e-002

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.077e+02	2.087e-06	2.146e-06	1.790e-07	1.841e-07
0.04	8.088e+02	3.131e-04	4.331e-04	1.385e-06	1.916e-06
0.05	2.022e+02	1.507e-04	2.467e-04	4.014e-07	6.572e-07
0.1	3.887e+02	1.189e-03	3.118e-03	1.819e-06	4.770e-06
0.2	1.024e+02	8.207e-04	2.097e-03	1.448e-06	3.700e-06
0.3	3.696e+02	5.029e-03	1.151e-02	9.540e-06	2.184e-05
0.4	8.590e+01	1.701e-03	3.555e-03	3.314e-06	6.926e-06
0.5	7.711e+00	2.043e-04	3.984e-04	4.010e-07	7.819e-07
0.6	5.797e+01	1.948e-03	3.579e-03	3.802e-06	6.985e-06
0.8	2.434e+02	1.190e-02	2.005e-02	2.263e-05	3.813e-05
1.0	5.849e+02	3.820e-02	6.058e-02	7.042e-05	1.117e-04
1.5	3.171e+02	3.490e-02	4.999e-02	5.871e-05	8.411e-05
Totals	**3.376e+03**	**9.635e-02**	**1.556e-01**	**1.740e-04**	**2.817e-04**

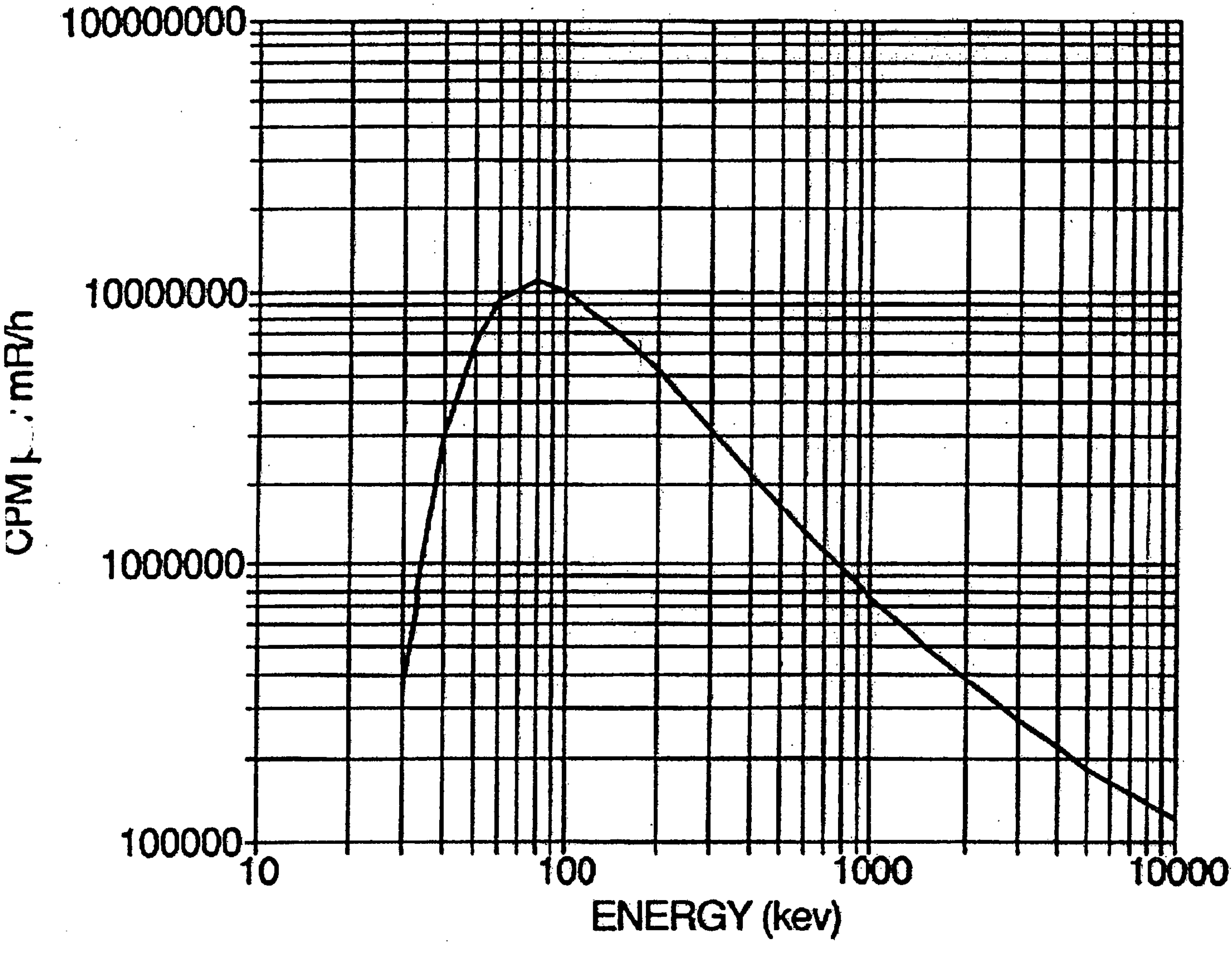
APPENDIX N

Eu-152					
	Energy MeV	Energy keV	Exposure Rate (mR/h-1 pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
15	0.015	15	1.84E-07		0
40	0.04	40	1.92E-06	3,897,600	7
50	0.05	50	6.57E-07	6,500,000	4
100	0.1	100	4.77E-06	9,958,333	48
200	0.2	200	3.70E-06	4,850,000	18
300	0.3	300	2.18E-05	3,200,000	70
400	0.4	400	6.93E-06	2,185,000	15
500	0.5	500	7.82E-07	1,820,000	1
600	0.6	600	6.99E-06	1,455,000	10
800	0.8	800	3.81E-05	993,000	38
1000	1	1,000	1.12E-04	783,019	87
1500	1.5	1,500	8.41E-05	530,000	45
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E) Total:	**344**

APPENDIX O

Calculated Energy Response
(Eberline Instruments)

CPM/mR/h



Use Of In-Situ Gamma Spectrum Analysis To Perform Elevated Measurement Comparisons In Support Of Final Status Surveys

YA-REPT-00-018-05

Approvals	**(Print & Sign Name)**	
Preparer: Greg Astrauckas/	G. P. Astrauckas	Date: 10/10/05
Preparer: Gordon Madison, CHP/	[signature]	Date: 10/11/05
Reviewer: Jim Hummer, CHP/	J. Hummer	Date: 10/18/05
Approver (FSS Manager): Dann Smith, CHP/	[signature]	Date: 11/4/05

Rev. 0

Technical Report YA-REPT-00-018-05, Rev. 0

Use Of In-Situ Gamma Spectrum Analysis To Perform
Elevated Measurement Comparisons In Support Of Final Status Surveys

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1.0 REPORT

1.1 Introduction

The ISOCS In-Situ Gamma Spectrum detector system manufactured by Canberra Industries is being employed to perform elevated measurement comparison (EMC) surveys in support of the Final Status Surveys at Yankee Atomic's Yankee Rowe facility. This system uses an HPGe detector and specialized efficiency calibration software designed to perform in-situ gamma-spectroscopy assays. The ISOCS system will primarily be employed to evaluate survey units for elevated measurement comparisons. The ISOCS system can obtain a static measurement at a fixed distance from a pre-determined location. Count times can be tailored to achieve required detection sensitivities. Gamma spectroscopy readily distinguishes background activity from plant-related licensed radioactivity. This attribute is particularly beneficial where natural radioactivity introduces significant investigation survey efforts. Additionally, background subtraction or collimation can be employed where background influences are problematic due to the presence of stored spent fuel (ISFSI).

This technical report is intended to outline the technical approach associated with the use of ISOCS for implementing a MARSSIM-based Final Status Survey with respect to scanning surveys for elevated measurement comparisons for both open land areas and building surfaces. While the examples and discussions in this report primarily address open land areas, the same approach and methodology will be applied when deriving investigation levels, grid spacing and measurement spacing for evaluating building surfaces.

Validation of the ISOCS software is beyond the scope of this technical report. Canberra Industries has performed extensive testing and validation on both the MCNP-based detector characterization process and the ISOCS calibration algorithms associated with the calibration software. The full MCNP method has been shown to be accurate to within 5% typically. ISOCS results have been compared to both full MCNP and to 119 different radioactive calibration sources. In general, ISOCS is accurate to within 4-5% at high energies and 7-11% at 1 standard deviation for low energies. Additionally, the ISOCS technology has been previously qualified in Yankee Atomic Technical Report YA-REPT-00-022-04, "Use Of Gamma Spectrum Analysis To Evaluate Bulk Materials For Compliance With License Termination Criteria."

1.2 Discussion

1.2.1 Detector Description

Two ISOCS-characterized HPGe detectors manufactured by Canberra Industries have been procured. Each detector is a reverse-electrode HPGe detector rated at 50% efficiency (relative to a NaI detector). Resolution for these detectors is 2.2 keV @ 1332 keV. As the project progresses, other ISOCS detectors (e.g. standard electrode coaxial), if available, may be used to increase productivity. The key element regarding the use of other types of ISOCS® detectors is that specific efficiency calibrations will be developed to account for each detector's unique characteristics.

The HPGe detector is mounted on a bracket designed to hold the detector / cryostat assembly and associated collimators. This bracket may be mounted in a wheeled cart or in a cage-like frame. Both the wheeled cart and frame permit the detector to be oriented (pointed) over a full range from a horizontal to vertical position. The frame's design allows the detector to be suspended above the ground. Photographs of the frame-mounted system are presented in Attachment 1. During evaluations of Class1 areas for elevated radioactivity, the detector will generally be outfitted with the 90-degree collimator. Suspending the detector at 2 meters above the target surface yields a nominal field-of-view of 12.6 m^2.

The InSpector (MCA) unit that drives the signal chain and the laptop computer that runs the acquisition software (Genie-2000) are mounted either in the frame or on the wheeled cart. These components are battery powered. Back-up power supplies (inverter or UPS) are available to support the duty cycle. A wireless network has been installed at the site so that the laptop computers used to run the systems can be completely controlled from any workstation at the facility. This configuration also enables the saving of data files directly to a centralized file server. Radio communication will be used to coordinate system operation.

1.2.2 Traditional Approach

With respect to Class 1 Survey Units, small areas of elevated activity are evaluated via the performance of scan surveys. The size of the potential area of elevated activity affects the $DCGL_{EMC}$ and is typically determined by that area bounded by the grid points used for fixed measurements. This area in turn dictates the area factor(s) used for deriving the associated $DCGL_{EMC}$.

These scan surveys are traditionally conducted with hand-held field instruments that have a detection sensitivity sufficiently low to identify areas of localized activity above the $DCGL_{EMC}$. Occasionally, the detection sensitivity of these instruments is greater than the $DCGL_{EMC}$. In order to increase the $DCGL_{EMC}$ to the point where hand-held instrumentation can be reasonably employed, the survey design is augmented to require additional fixed-point measurements. The effect of these additional measurement points is to tighten the fixed measurement grid spacing, thus reducing the area applied to deriving the $DCGL_{EMC}$ and increasing the detection sensitivity criteria.

Background influences (from the ISFSI) and natural terrestrial sources further impact the sensitivity of these instruments. To address these impacts, the fixed-point grid spacing would again need to be reduced (requiring even more samples) in order to increase the $DCGL_{EMC}$ to the point where hand-held instrumentation can be used. Generally, the collection of additional fixed measurements (i.e. samples) increases project costs.

Survey designs for Class 2 and Class 3 survey units are not driven by the elevated measurement comparison because areas of elevated activity are not expected. In Class 2 areas, any indication of activity above the $DCGL_W$ requires further investigation. Similarly, in Class 3 areas, any positive indication of licensed radioactivity also requires further investigation. Because the $DCGL_{EMC}$ is not applicable to Class 2 or Class 3 areas, adjustments to grid spacing do not occur. However, the increased field-of-view associated with the in-situ gamma spectroscopy system improves the efficiency of the survey's implementation.

1.2.3 Innovative Approach

In-situ assays allow fixed-point grid spacing to be uncoupled from the derivation of applicable investigation levels. In contrast to the traditional approach where the $DCGL_{EMC}$ (based on grid size) determines both investigation levels and detection sensitivities, the use of this technology provides two independent dynamics as follows:

- Detection sensitivity is determined by the $DCGL_{EMC}$ associated with the (optimal) fixed-point grid spacing.
- Investigation levels are based on the detector's field-of-view and adjusted for the smallest area of concern (i.e. 1 m^2).

1.2.4 Investigation Level

Development of the investigation (action) levels applied to in-situ assay results is a departure from the traditional approach for implementing a MARSSIM survey. Examples are provided for both open land areas (i.e. soil) and for building surfaces, however the approach for both is identical.

To support the use of in-situ spectroscopy to evaluate areas of elevated activity the HPGe detector's field-of-view was characterized. Attachment 2 presents data from the field-of-view characterization for a detector configured with a 90-degree collimator positioned 2 meters from the target surface. Alternate configurations will be evaluated in a similar manner before being employed. As exhibited in Attachment 2, when the detector is positioned at 2 meters above the target surface the field-of-view has a radius of at least 2.3

meters. This value was rounded down to 2.0 meters for implementation purposes, introducing a conservative bias (approximately 9%) in reported results. The example provided in this technical report assumes a 2-meter source-to-detector distance, yielding a nominal field-of-view surface area of 12.6 m^2.

Occasionally, alternate source-to-detector distances (using the 90-degree collimator) may be employed, particularly in a characterization or investigation capacity. In such cases, the detector's field-of-view will be calculated by setting the radius equal to the source-to-detector distance, thereby maintaining the conservative attribute previously described. If alternative collimator configurations are used to perform elevated measurement comparisons, then specific evaluations will be documented in the form of a technical evaluation or similar. Associated investigation levels will be derived using the same approach and methodology outlined below in this section.

After the detector's field-of-view is determined, an appropriate investigation level is developed to account for a potential one-meter square area of elevated activity. $DCGL_{EMC}$ values for a one-square meter area are presented in Table 1.

TABLE 1, SOIL $DCGL_{EMC}$ FOR 1 m^2

	Soil $DCGL_W$ (pCi/g) (NOTE 1)	Soil $DCGL_W$ (pCi/g) (NOTE 2)	Area Factor for 1 m^2 (NOTE 3)	$DCGL_{EMC}$ for 1 m^2 (pCi/g) (NOTE 4)
Co-60	3.8	1.4	11	15
Ag-108m	6.9	2.5	9.2	23
Cs-134	4.7	1.7	16	28
Cs-137	8.2	3.0	22	66

NOTE 1 – LTP Table 6-1
NOTE 2 – Adjusted to 8.73 mRem/yr
NOTE 3 – LTP Appendix 6Q
NOTE 4 – Soil $DCGL_W$ (adjusted to 8.73 mRem/yr) for a 1 m^2 area

The $^{1m2}DCGL_{EMC}$ values listed in Table 1 do not account for a source positioned at the edge of the field-of-view. Therefore, the $^{1m2}DCGL_{EMC}$ values are adjusted via a correction factor. To develop this correction factor, a spectrum free of plant-related radioactivity was analyzed using two different efficiency calibrations (i.e. geometries). The first scenario assumes radioactivity uniformly distributed over the detector's 12.6 m^2 field-of-view. The second scenario assumes radioactivity localized over a 1 m^2 situated at the edge of the detector's field-of-view. The resultant MDC values were compared to characterize the difference in detection efficiencies between the two scenarios. As expected, the condition with localized (1 m^2) radioactivity at the edge of the detector's field-of-view yielded higher MDC values. The ratio between the reported MDC values for the two scenarios is used as a correction factor. This correction factor is referred to as the offset geometry adjustment factor. The investigation levels for soils presented in Table 2 were calculated as follows:

$$\text{Nuclide Investigation Level (pCi/g)} = (DCGL_{EMC}) * CF$$

Where: $DCGL_{EMC} = (DCGL_W \text{ or } DCGL_{SURR}) * AF_{(1\,m^2)}$, and
CF = Mean offset geometry adjustment factor

TABLE 2, SOIL INVESTIGATION LEVEL DERIVATION

	MDC pCi/g (NOTE 1)	MDC pCi/g (NOTE 2)	RATIO (NOTE 3)	$DCGL_{EMC}$ for 1 m² (NOTE 5)	INVESTIGATION LEVEL pCi/g (NOTE 6)
Co-60	0.121	1.86	0.0651	15	1.0
Ag-108m	0.184	2.82	0.0652	23	1.5
Cs-134	0.189	2.90	0.0652	28	1.8
Cs-137	0.182	2.78	0.0655	66	4.3
Offset Geometry Adjustment Factor (NOTE 4)			**0.0653**		

NOTE 1 – Assumed activity distributed over the 12.6 m² field-of-view.
NOTE 2 – Efficiency calibration modeled for a 1 m² area situated (off-set) at the edge of the detector's field-of-view. The model assumes that all activity is distributed within the 1 m².
NOTE 3 – Ratio = (12.6 m² MDC ÷ 1 m² MDC).
NOTE 4 – The mean value of the ratios is applied as the off-set geometry adjustment factor.
NOTE 5 – $DCGL_{EMC}$ values for 1 m² (from Table 1)
NOTE 6 – Investigation levels derived by applying of the off-set geometry adjustment factor (e.g. 0.0653) to the $DCGL_{EMC}$ for a 1 m² area for each radionuclide.

With respect to building surfaces, the development of the investigation level is identical to that for soil surfaces. The one-meter square $DCGL_{EMC}$ for building surfaces are presented in Table 3.

TABLE 3, BUILDING SURFACE $DCGL_{EMC}$ FOR 1 m²

	Bldg $DCGL_W$ (dpm/100m²) (NOTE 1)	Bldg $DCGL_W$ (dpm/100cm²) (NOTE 2)	Area Factor For 1 m² (NOTE 3)	$DCGL_{EMC}$ For 1 m² (dpm/100cm²) (NOTE 4)
Co-60	18,000	6,300	7.3	46,000
Ag-108m	25,000	8,700	7.2	62,600
Cs-134	29,000	10,000	7.4	74,000
Cs-137	63,000	22,000	7.6	167,000

NOTE 1 – LTP Table 6-1
NOTE 2 – Adjusted to 8.73 mRem/yr
NOTE 3 – LTP Appendix 6S
NOTE 4 – Building $DCGL_W$ (adjusted to 8.73 mRem/yr) for a 1 m² area

Using the same approach described for soils, a correction factor to account for efficiency differences due to geometry considerations is developed the one-meter square $DCGL_{EMC}$. ISOCS efficiency calibrations for activity distributed over the detector's field-of-view and for activity within one-square meter located at the edge of the detector's field-of-view were developed. The MDC values for these two geometries were compared to characterize the difference in detection efficiencies. As expected, the condition with localized (1 m²) radioactivity at the edge of the detector's field-of-view yielded higher MDC values. The ratio between the reported MDC values for the two scenarios is used as the offset geometry adjustment factor. The MDC values, the associated ratios, and the derived investigation level for building surfaces are presented in Table 4.

TABLE 4, BUILDING SURFACE INVESTIGATION LEVEL DERIVATION

	12.6 m² MDC (dpm/100cm²) (NOTE 1)	1 m² MDC (dpm/100cm²) (NOTE 2)	RATIO (NOTE 3)	$DCGL_{EMC}$ For 1 m² (dpm/100cm²) (NOTE 5)	BUILDING SURFACE INVESTIGATION LEVEL (dpm/100cm²) (NOTE 6)
Co-60	785	12,400	0.0633	46,000	2,900
Ag-108m	839	13,000	0.0645	62,600	3,900
Cs-134	900	14,200	0.0634	74,000	4,700
Cs-137	922	14,600	0.0632	167,000	10,600
Offset Geometry Adjustment Factor (NOTE 4)			**0.0636**		

NOTE 1 – Assumed activity distributed over the 12.6 m² field-of-view.
NOTE 2 – Efficiency calibration modeled for a 1 m² area situated (off-set) at the edge of the detector's field-of-view. The model assumes that all activity is distributed within the 1 m².
NOTE 3 – Ratio = (12.6 m² MDC ÷ 1 m² MDC).
NOTE 4 – The mean value of the ratios is applied as the off-set geometry adjustment factor.
NOTE 5 – $DCGL_{EMC}$ values for 1 m² (from Table 3)
NOTE 6 – Investigation levels derived by applying of the off-set geometry adjustment factor (e.g. 0.0636) to the one-square meter $DCGL_{EMC}$.

In summary, effective investigation levels for both open land areas (i.e. soils) and for building surfaces can be derived and applied to in-situ gamma spectroscopy results. Note the MDC values associated with the detector's field-of-view were well below the derived investigation levels.

The investigation levels presented in Table 2 and Table 4 do not address the use of surrogate DCGLs. Use of surrogate DCGLs will be addressed in Final Status Survey Plans, particularly where it is necessary to evaluate non-gamma emitting radionuclides on building surfaces. When surrogate DCGLs are employed, investigation levels will be developed on a case-by-case basis using the approach outlined in this document. Similarly, the offset geometry adjustment factor presented in Table 2 and Table 4 will vary for different geometries. Although unlikely, if different geometries are employed, this value will be determined on a case-by-case basis using the methodology reflected in Table 2 and will be documented in the applicable Final Status Survey Plan.

For both open land areas and for building surfaces, when an investigation level is encountered, investigatory protocols will be initiated to evaluate the presence of elevated activity and bound the region as necessary. Such evaluations may include both hand-held field instrumentation as well as the in-situ HPGe detector system. After investigation activities are completed, subsequent (follow-up) scanning evaluations will most likely be conducted using the in-situ gamma spectroscopy system.

1.2.5 Detector Sensitivity

For Class 1 scan surveys, the minimum detectable concentration is governed by the $DCGL_{EMC}$ associated with the grid area used to locate fixed-point measurements. The system's count time can be controlled to achieve the required detection sensitivity. Therefore, the grid spacing for the fixed-point measurements can be optimized thus eliminating unnecessary increases to the number of fixed-point measurements while ensuring that elevated areas between fixed measurement locations can be identified and evaluated.

Based on preliminary work, it has been determined that a count time of 900 seconds will yield an acceptable sensitivity for many areas on the site. This count time provides MDC values well below the investigation levels presented in Table 2 and Table 4. Count times will be adjusted as necessary as survey unit-specific investigation levels are derived or where background conditions warrant to ensure that detection sensitivities are below the applicable investigation level. Since each assay report includes a report of the MDC values achieved during the assay, this information is considered technical support that required MDC values were met.

1.2.6 Area Coverage

Based on the nominal 12.6 m^2 field-of-view, a 3-meter spacing between each survey point will result in well over 100% of the survey unit to be evaluated for elevated activity. This spacing convention typically employs a grid pattern that is completely independent from the grid used to locate fixed-point measurements. An example of the grid pattern and spacing is presented in Attachment 3.

Alternate spacing conventions may be applied on a case-by-case basis. For instance, spacing may be decreased when problematic topographies are encountered. Note that decreased grid spacing in this context is not associated to the fixed-point measurements. Occasionally it may be necessary to position the detector at one meter or less from the target surface to evaluate unusual (e.g. curved) surfaces or to assist in bounding areas of elevated activity. In cases where it may be desirable to increase the field-of-view via collimator or source-to-detector distances, grid-spacing conventions (and applicable investigation levels) will be determined using the approach described in this document.

1.2.7 Moisture Content in the Soil Matrix

In-situ gamma spectroscopy of open land areas is inherently subject to various environmental variables not present in laboratory analyses. Most notably is the impact that water saturation has on assay results. This impact has two components. First, the total activity result for the assay is assigned over a larger, possibly non-radioactive mass introduced by the presence of water. Secondly, water introduces a self-absorption factor.

The increase in sample mass due to the presence of water is addressed by the application of a massimetric efficiency developed by Canberra Industries. Massimetric efficiency units are defined as [counts per second]/[gammas per second per gram of sample]. Mathematically, this is the product of traditional efficiency and the mass of the sample. When the efficiency is expressed this way, the efficiency asymptotically approaches a constant value as the sample becomes very large (e.g. infinite). Under these conditions changes in sample size, including mass variations from excess moisture, have little impact on the counting efficiency. However, the massimetric efficiency does not completely address attenuation characteristics associated with water in the soil matrix.

To evaluate the extent of self-absorption, (traditional) counting efficiencies were compared for two densities. Based on empirical data associated with the monitoring wells, typical nominally dry in-situ soil is assigned a density of 1.7 g/cc. A density of 2.08 g/cc, obtained from a technical reference publication by Thomas J. Glover, represents saturated soil. A density of 2.08 g/cc accounts for a possible water content of 20%. A summary of this comparison is presented in Table 5.

TABLE 5, COUNTING EFFICIENCY COMPARISONS

keV	Efficiencies 1.7 g/cc	Efficiencies 2.08 g/cc	Deviation due to density increase (excess moisture)
434	3.3 E-6	2.7 E-6	-18.7%
661.65	2.9 E-6	2.4 E-6	-17.5%
1173.22	2.5 E-6	2.1 E-6	-15.4%
1332.49	2.4 E-6	2.1 E-6	-14.8%

In cases when the soil is observed to contain more than "typical" amounts of water, potential under-reporting can be addressed in one of two manners. One way is to adjust the investigation level down by 20%. The second way is to reduce the sample mass by 20%. Either approach achieves the same objective: to introduce a conservative mechanism for triggering the investigation level where the presence of water may inhibit counting efficiency. The specific mechanism to be applied will be prescribed in implementing procedures.

The presence of standing water (or ice or snow) on the surface of the soil being assayed will be accounted for in customized efficiency calibrations applied during data analysis activities.

1.2.8 Discrete Particles in the Soil Matrix

Discrete particles are not specifically addressed in the License Termination Plan. However, an evaluation was performed assuming all the activity in the detector's field-of-view, to a depth of 15 cm, was situated in a discrete point-source configuration. A concentration of 1.0 pCi/g (Co-60), corresponding to the investigation level presented in Table 2, correlates to a discrete point-source of approximately 3.2 μCi. This activity value is considered as the discrete particle of concern. Since the presence of any discrete particles will most likely be accompanied by distributed activity, the investigation level may provide an opportunity to detect discrete particles below 3.2 μCi.

Discrete particles exceeding this magnitude would readily be detected during characterization or investigation surveys. The MDCs associated with hand-held field instruments used for scan surveys are capable of detecting very small areas of elevated radioactivity that could be present in the form of discrete point sources. The minimum detectable particle activity for these scanning instruments and methods correspond to a small fraction of the TEDE limit provided in 10CFR20 subpart E. Note that the MDC values presented in Table 2 are significantly lower than those published in Table 5-4 of the License Termination Plan.

When the investigation level in a Class 1 area is observed, subsequent investigation surveys will be performed to include the use of hand-held detectors. The detection sensitivities of instruments used for these surveys have been previously addressed in the LTP. Furthermore, discrete point sources do not contribute to the uniformly distributed activity of the survey unit. It is not expected that such sources at this magnitude would impact a survey unit's ability to satisfy the applicable acceptance criteria.

Noting that Class 2 or Class 3 area survey designs do not employ elevated measurement comparisons, associated investigation levels are based on positive indications of licensed radioactivity above the $DCGL_W$ or above background. Because such areas are minimally impacted or disturbed, potential discrete particles would most likely be situated near the soil surface where detection efficiencies are highest.

1.2.9 Procedures And Guidance Documents

General use of the portable ISOCS system is administrated by departmental implementing procedures that address the calibration and operation activities as well as analysis of the data. These procedures are listed as follows:

- DP-8869, "In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure."
- DP-8871, "Operation Of The Canberra Portable ISOCS Assay System."
- DP-8872, "ISOCS Post Acquisition Processing And Data Review."

Where the portable ISOCS® system is used for Final Status Surveys, the applicable FSS Plan will address detector and collimator configurations, applicable (surrogated) investigation levels, MDC requirements, and appropriate Data Quality Objectives, as applicable.

A secondary application of the portable ISOCS® system is to assay surfaces or bulk materials for characterization or unconditional release evaluations. Use of the portable ISOCS® system for miscellaneous evaluations will be administrated under a specific guidance document (e.g. Sample Plan, etc.). Operating parameters such as physical configuration, efficiency calibrations, count times, and MDCs will be applied so as to meet the criteria in the associated controlling documents. Such documents will also address any unique technical issues associated with the application and may provide guidance beyond that of procedure AP-0052, "Radiation Protection Release of Materials, Equipment and Vehicles."

1.2.10 Environmental Backgrounds

If background subtraction is used, an appropriate background spectrum will be collected and saved. Count times for environmental backgrounds should exceed the count time associated with the assay. In areas where the background radioactivity is particularly problematic (e.g. ISFSI), the background will be characterized to the point of identifying gradient(s) such that background subtractions are either appropriate or conservative. Documentation regarding the collection and application of environmental backgrounds will be provided as a component of the final survey plan.

1.2.11 Quality Control

Quality Control (QC) activities for the ISOCS system ensure that the energy calibration is valid and detector resolution is within specifications. A QC file will be set up for each detector system to track centroid position, FWHM, and activity. Quality Control counts will be performed on a shiftly basis prior to the system's use to verify that the system's energy calibration is valid. The Na-22 has a 1274.5 keV photon which will be the primary mechanism used for performance monitoring. If the energy calibration is found to be out of an acceptable tolerance (e.g. greater than ±4 channels), then the amplifier gain may be adjusted and a follow-up QC count performed. If the detector's resolution is found to be above the factory specification, then an evaluation will be performed to determine if the detector should be removed from service and/or if the data is impacted. Evaluations associated with QC counts shall be documented. Such documentation may be limited to a remark directly on the applicable QC report or in a logbook if the resolution does not render the system out of service. Otherwise the evaluation should be separately documented (e.g. Condition Report, etc.) so as to address the impact of any assay results obtained since the last acceptable QC surveillance.

Where it is determined that background subtraction is necessary, a baseline QC background will be determined specific to that area or region. When background subtraction is required, a QC background surveillance will be performed before a set of measurements are made to verify the applicability of the background to be subtracted. Due to the prevailing variability of the background levels across the site, the nature and extent of such surveillances will be on a case-by-case basis and should be addressed in the documentation associated with the applicable survey plan(s).

In addition to the routine QC counts, each assay report is routinely reviewed with respect to K-40 to provide indications where amplifier drift impacts nuclide identification routines. This review precludes the necessity for specific (i.e. required) after-shift QC surveillances. It also minimizes investigations of previously collected data should the system fail a before-use QC surveillance on the next day of use.

1.2.12 Data Collection

Data collection to support FSS activities will be administered by a specific Survey Plan. Survey Plans may include an index of measurement locations with associated spectrum filenames to ensure that all the required measurements are made and results appropriately managed. Personnel specifically trained to operate the system will perform data collection activities.

Data collection activities will address environmental conditions that may impact soil moisture content. Logs shall be maintained so as to provide a mechanism to annotate such conditions to ensure that efficiency calibration files address the in-situ condition(s). In extreme cases (e.g. standing water, etc.) specific conditions will be addressed to ensure that analysis results reflect the conditions. As previously discussed with respect to water, when unique environmental conditions exist that may impact analysis results, conservative compensatory factors will be applied to the analysis of the data.

1.2.13 Efficiency Calibration

The central feature of the portable ISOCS technology is to support in-situ gamma spectroscopy via the application of mathematically derived efficiency calibrations. Due to the nature of the environment and surfaces being evaluated (assayed), input parameters for the ISOCS efficiency calibrations will be reviewed on a case-by-case basis to ensure the applicability of the resultant efficiency. Material densities applied to efficiency calibrations will be documented. In practice, a single efficiency calibration file may be applied to the majority of the measurements.

The geometry most generally employed will be a circular plane assuming uniformly distributed activity. Efficiency calibrations will address a depth of 15 cm for soil and a depth up to 5 cm for concrete surfaces to account for activity embedded in cracks, etc. Other geometries (e.g. exponential circular plane, rectangular plane, etc.) will be applied if warranted by the physical attributes of the area or surface being evaluated. Efficiency calibrations are developed by radiological engineers who have received training with respect to the ISOCS® software. Efficiency calibrations will be documented in accordance with procedure DP-8869, "In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure."

1.2.14 Data Management

Data management will be implemented in various stages as follows:

- An index or log will be maintained to account for each location where evaluations for elevated activity are performed. Raw spectrum files will be written directly or copied to a central file server.
- Data Analysis – After the spectrum is collected and analyzed, a qualified Radiological Engineer will review the results. The data review process includes application of appropriate background, nuclide libraries, and efficiency calibrations. Data reviews also verify assay results with respect to the applicable investigation levels and the MDCs achieved. Data reviews may include monitoring system performance utilizing K-40. When the data analysis is completed, the analyzed data file will be archived to a unique directory located on a central file server.
- Data Reporting – The results of data files whose reviews have been completed and are deemed to be acceptable may be uploaded to a central database for subsequent reporting and statistical analysis.

- Data Archiving – Routinely (daily) the centralized file server(s) where the raw and analyzed data files are maintained will be backed up to tape.

1.3 Conclusions/Recommendations

The in-situ gamma spectroscopy system is a cost-effective technology well-suited to replace traditional scanning survey techniques to evaluate areas for elevated radioactivity. The static manner in which this system is operated eliminates many variables and limitations inherent to hand-held detectors moving over a surface. This system provides a demonstrably lower detection sensitivity than those offered by hand-held field instruments. This attribute qualifies this system as an alternative technology in lieu of hand-held NaI field instruments in areas where background radiation levels would prohibit the use of such detectors to evaluate for elevated gross activity. The MDC to which this system will be operated satisfies (or exceeds) criteria applied to traditional scan surveys using hand-held field instruments.

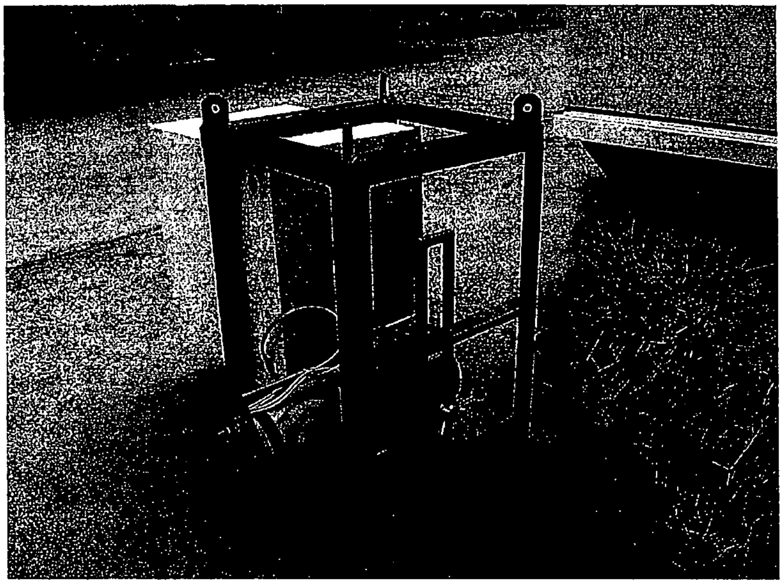
Effective investigation levels for both open land areas (i.e. soils) and for building surfaces can be derived and applied to in-situ gamma spectroscopy results. Where surrogate DCGLs are employed, investigation levels will developed on a case-by-case basis using the approach outlined in this document.

The manner in which investigation levels are derived employs several conservative decisions and assumptions. Additionally, adequate spacing applied to scanning survey locations yields an overlap in surface coverage providing 100-percent coverage of Class 1 areas and redundant opportunities in a significant portion of the survey area to detect localized elevated activity.

1.4 <u>References</u>

1. YNPS License Termination Plan, Revision 1
2. Multi-Agency Radiation Survey And Site Investigation Manual (MARSSIM) Revision 1, 2000
3. Canberra User's Manual Model S573 ISOCS Calibration Software, 2002
4. Decommissioning Health Physics - A Handbook for MARSSIM Users, E.W. Abelquist, 2001
5. Canberra's Genie 2000 V3.0 Operations Manual, 2004
6. In-Situ (ISOCS) Gamma Spectrum Assay System Calibration Procedure DP-8869, Revision 0
7. Operation of the Canberra Portable ISOCS Assay System DP-8871 Revision 0
8. Technical Ref., by Thomas J. Glover.

Attachment 1
Portable ISOCS® Detector System Photos



Attachment 2
Field-Of-View Characterization

Generally, the HPGe detector will be outfitted with a 90-degree collimator situated at 2 meters perpendicular to the surface being evaluated. Note that characterizing the detector's field-of-view could be performed without a source by comparing ISOCS-generated efficiencies for various geometries. If a different collimator configuration is to be employed, a similar field-of-view characterization will be performed.

To qualify the field-of-view for this configuration, a series of measurements were made at various off-sets relative to the center of the reference plane. The source used for these measurements was a 1.2 μCi Co-60 point-source with a physical size of approximately 1 cm^3. Each spectrum was analyzed as a point source both with and without background subtract. It was observed that the detector responded quite well to the point source.

Figure 1 presents the results with background subtraction applied. Note that there is a good correlation with the expected nominal activity and that outside the 2-meter radius of the "working" field-of-view (i.e. at 90 inches) some detector response occurs. This validates that the correct attenuation factors are applied to the algorithms used to compute the efficiency calibration.

FIGURE 1

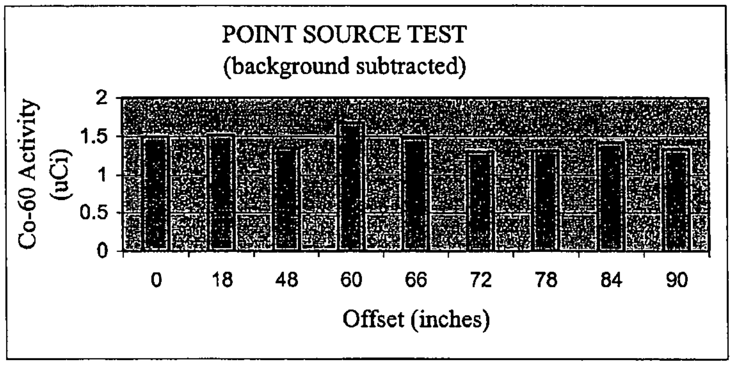
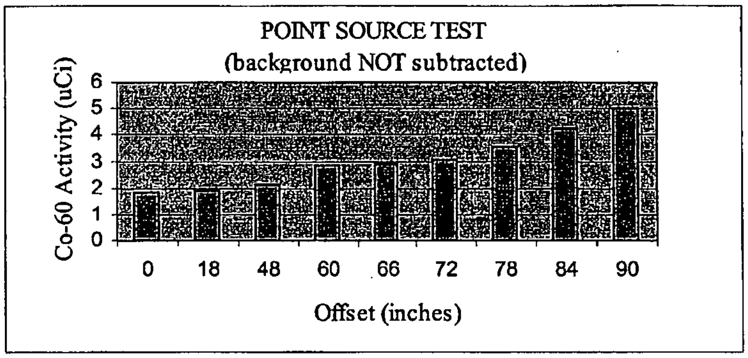
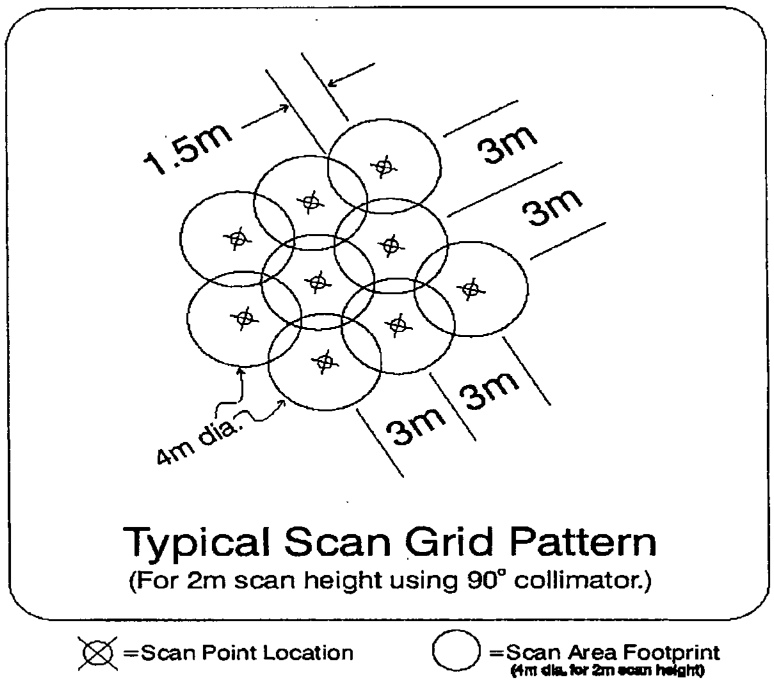


Figure 2 shows the effect of plant-derived materials present in the reference background, which indicates an increasing over-response the further the point source is moved off center. Detector response outside the assumed (i.e. 2-meter) field-of-view would yield conservative results. Normally, source term adjacent to the survey units should be reduced to eliminate background interference.

FIGURE 2


POINT SOURCE TEST
(background NOT subtracted)
Co-60 Activity (uCi)
6
5
4
3
2
1
0
0
18
48
60
66
72
78
84
90
Offset (inches)

Attachment 3
Typical Grid Pattern For In-Situ Gamma Spectroscopy



ALARA Action Levels

Calculation of ALARA Action Level (AL)
1. Removable fraction for remediation action being evaluated 1
2. Monetary discount rate 0.07 y^{-1}
3. Number of years over which the collective dose is calculated 70 y
4. Population density for the critical group 0.09 people/m^2
5. Survey unit area 1 m^2

Radionuclide	AL
H-3	<MDA
C-14	<MDA
Fe-55	<MDA
Co-60	1.21E+02
Ni-63	<MDA
Sr-90	<MDA
Nb-94	<MDA
Tc-99	<MDA
Ag-108m	<MDA
Sb-125	<MDA
Cs-134	<MDA
Cs-137	2.35E+01
Eu-152	<MDA
Eu-154	<MDA
Eu-155	<MDA
Pu-238	<MDA
Pu-239/240	<MDA
Pu-241	<MDA
Am-241	<MDA
Cm-243/244	<MDA

Sum of Als	1.45E+02

DCGL Fraction < ALARA AL?	YES

11. Decision Criteria: If the sum of the DCGL fractions < AL, then additional remediation is not cost beneficial. If the sum of the fractions > AL, then additional remediation is cost

Check one: Additional remediation **IS NOT** cost beneficial ✔

Additional remediation **IS** cost beneficial ______

Prepared by: ____________________
FSS Radiological Engineer

Independent Review by: ____________________
FSS Project Manager/ Radiation Protection Manager

Survey Area: AUX01	Survey Unit: 01 E02
1. Cost of performing remediation work ($Cost_R$)	$3,840
2. Cost of waste disposal ($Cost_{WD}$)= (2.a) * (2.b) a. estimated waste volume 1 m^3 b. cost of waste disposal 810 $\$/m^3$	$810
3. Cost of workplace accident ($Cost_{ACC}$) = $3,000,000 $person^{-1}$ * 4.2 x 10^{-8} h^{-1} * (3.a) a. time to perform remediation action 32 person-hours	$4
4. Cost of traffic fatality ($Cost_{TF}$) = {$3,000,000 * 3.8 x 10^{-8} km^{-1} * (2.a) * (4.a)}/(4.b) a. total distance traveled per shipment 1481 km b. waste volume per shipment 13.6 m^3, if unknown, use 13.6m^3 as a default value	$12
5. Cost of worker dose ($Cost_{WDose}$) = $2,000 per person-rem * (5.a) * (5.b) a. worker TEDE 0.00001 rem/h b. remediation exposure time 32 person-hour	$0
$Cost_T$	$4,666

DCGL Fractions

Radionuclide	Ave. Conc *pci*/gm	DCGL *pci*/gm	Relative Fractio	DCGL Fraction
H-3	0.00E+00	135	0	0.0000
C-14	0.00E+00	2340	0.00E+00	0.0000
Fe-55	0.00E+00		0.00E+00	#DIV/0!
Co-60*	3.45E+03	3450	7.04E-01	1.0000
Ni-63	0.00E+00	61600	0.00E+00	0.0000
Sr-90	0.00E+00	13.9	0.00E+00	0.0000
Nb-94	0.00E+00		0.00E+00	#DIV/0!
Tc-99	0.00E+00		0.00E+00	#DIV/0!
Ag-108m	0.00E+00		0.00E+00	#DIV/0!
Sb-125	0.00E+00		0.00E+00	#DIV/0!
Cs-134	0.00E+00		0.00E+00	#DIV/0!
Cs-137*	1.45E+03	1450	2.96E-01	1.0000
Eu-152	0.00E+00		0.00E+00	#DIV/0!
Eu-154	0.00E+00		0.00E+00	#DIV/0!
Eu-155	0.00E+00		0.00E+00	#DIV/0!
Pu-238	0.00E+00		0.00E+00	#DIV/0!
Pu-239	0.00E+00		0.00E+00	#DIV/0!
Pu-241	0.00E+00		0.00E+00	#DIV/0!
Am-241	0.00E+00		0.00E+00	#DIV/0!
Cm-243	0.00E+00		0.00E+00	#DIV/0!
	Total Concentration	4.90E+03		

Total DCGL Fraction	2.00

* Co-60 and Cs-137 concentrations assumed to be at the worst case (I.e. at their DCGL values). Concentrations at or above these levels automatically warrant remediation.

ALARA Action Levels

Calculation of ALARA Action Level (AL)

1. Removable fraction for remediation action being evaluated 1
2. Monetary discount rate 0.07 y^{-1}
3. Number of years over which the collective dose is calculated 70 y
4. Population density for the critical group 0.09 people/m^2
5. Survey unit area 1 m^2

Radionuclide	AL
H-3	<MDA
C-14	<MDA
Fe-55	<MDA
Co-60	1.21E+02
Ni-63	<MDA
Sr-90	<MDA
Nb-94	<MDA
Tc-99	<MDA
Ag-108m	<MDA
Sb-125	<MDA
Cs-134	<MDA
Cs-137	2.35E+01
Eu-152	<MDA
Eu-154	<MDA
Eu-155	<MDA
Pu-238	<MDA
Pu-239/240	<MDA
Pu-241	<MDA
Am-241	<MDA
Cm-243/244	<MDA

Sum of Als	1.45E+02

DCGL Fraction < ALARA AL?	**YES**

11. **Decision Criteria:** If the sum of the DCGL fractions < AL, then additional remediation is not cost beneficial. If the sum of the fractions > AL, then additional remediation is cost

Check one: Additional remediation **IS NOT** cost beneficial ✔

Additional remediation **IS** cost beneficial __________

Prepared by: ____________________
FSS Radiological Engineer

Independent Review by: ____________________
FSS Project Manager/ Radiation Protection Manager

DCGL Fractions

Radionuclide	Ave. Conc *pci*/gm	DCGL *pci*/gm	Relative Fractio	DCGL Fraction
H-3	0.00E+00		0	#DIV/0!
C-14	0.00E+00		0.00E+00	#DIV/0!
Fe-55	0.00E+00		0.00E+00	#DIV/0!
Co-60*	3.45E+03	3450	7.04E-01	1.0000
Ni-63	0.00E+00		0.00E+00	#DIV/0!
Sr-90	0.00E+00		0.00E+00	#DIV/0!
Nb-94	0.00E+00		0.00E+00	#DIV/0!
Tc-99	0.00E+00		0.00E+00	#DIV/0!
Ag-108m	0.00E+00		0.00E+00	#DIV/0!
Sb-125	0.00E+00		0.00E+00	#DIV/0!
Cs-134	0.00E+00		0.00E+00	#DIV/0!
Cs-137*	1.45E+03	1450	2.96E-01	1.0000
Eu-152	0.00E+00		0.00E+00	#DIV/0!
Eu-154	0.00E+00		0.00E+00	#DIV/0!
Eu-155	0.00E+00		0.00E+00	#DIV/0!
Pu-238	0.00E+00		0.00E+00	#DIV/0!
Pu-239	0.00E+00		0.00E+00	#DIV/0!
Pu-241	0.00E+00		0.00E+00	#DIV/0!
Am-241	0.00E+00		0.00E+00	#DIV/0!
Cm-243	0.00E+00		0.00E+00	#DIV/0!
	Total Concentration	4.90E+03		

Total DCGL Fraction	2.00

* Co-60 and Cs-137 concentrations assumed to be at the worst case (i.e. at their DCGL values). Concentrations at or above these levels automatically warrant remediation.

Survey Area: AUX01	Survey Unit: 03 & 04
1. Cost of performing remediation work ($Cost_R$)	$3,840
2. Cost of waste disposal ($Cost_{WD}$)= (2.a) * (2.b) a. estimated waste volume ___1___ m^3 b. cost of waste disposal ___810___ $/$m^3$	$810
3. Cost of workplace accident ($Cost_{ACC}$) = $3,000,000 $person^{-1}$ * 4.2 x 10^{-8} h^{-1} * (3.a) a. time to perform remediation action ___32___ person-hours	$4
4. Cost of traffic fatality ($Cost_{TF}$) = {$3,000,000 * 3.8 x 10^{-8} km^{-1} * (2.a) * (4.a)}/(4.b) a. total distance traveled per shipment ___1481___ km b. waste volume per shipment ___13.6___ m^3, if unknown, use 13.6m^3 as a default value	$12
5. Cost of worker dose ($Cost_{WDose}$) = $2,000 per person-rem * (5.a) * (5.b) a. worker TEDE ___0.00001___ rem/h b. remediation exposure time ___32___ person-hour	$0
$Cost_T$	$4,666