YANKEE ATOMIC ELECTRIC COMPANY Telephone (413) 424-5261

49 Yankee Road, Rowe, Massachusetts 01367

September 26, 2006
BYR 2006-086

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-OOL13-00, the Final Status Survey Report for Survey Area OOL-13

Dear Madam/Sir:

This letter submits YNPS-FSS-OOL13-00, Final Status Survey Report for OOL-13. This report was written in accordance with Section 5 of the YNPS License Termination Plan, "Final Status Survey Plan," and is 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.

Sincerely,

YANKEE ATOMIC ELECTRIC COMPANY

Joseph R. Lynch
Regulatory Affairs Manager

Enclosure: YNPS-FSS-OOL13-00 (2 hard copies plus CDs) cc (w/o encl):

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Yankee Nuclear Plant Station Final Status Survey Report For OOL-13

Yankee Atomic Electric Company

YANKEE NUCLEAR POWER STATION
FINAL STATUS SURVEY REPORT

REPORT NO.: YNPS-FSS-OOL-13-00

Prepared by: _______________ Date: 9-13-06
Michael D. Rennhack, FSS Radiological Engineer

Reviewed by: _______________ Date: 9/21/06
Robert Tozzie, FSS Radiological Engineer

Approved by: _______________ Date: 9/21/06
Martin Erickson, FSS Manager

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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_0	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 OOL-13 in accordance with Yankee Nuclear Power Station's (YNPS) License Termination Plan (LTP). This FSS was conducted as an open land area FSS with soil DCGLs.

1.1 Identification of Survey Area and Units

OOL-13 has a single Survey Unit, OOL-13-01 which is a Class 1 Survey Unit. OOL-13-01 is a section of the Sherman Reservoir bank near the rail spur terminus. It is located adjacent to and down slope of the location of the Radiologically Controlled Area (RCA) at the time of characterization. The land was owned by U. S. Gen at the time that the License Termination Plan (LTP) was written and is currently owned by TransCanada.

1.2 Dates(s) of Survey

Table 1 Date of Surveys

Survey Unit	Survey Start Date	Survey End Date	DQA Date
OOL-13-01	7/17/2006	7/26/2006	8/29/2006

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 15 systematic direct measurement measurements were taken in the Survey Unit, providing data for the non-parametric testing of the Survey Area. In addition to the direct measurement samples, ISOCS 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 none of the systematic measurements exceeded the $DCGL_W$, depicted in Attachment B. Retrospective power curves were generated and demonstrated that an adequate number of samples were collected to support the Data Quality Objectives. Therefore, the null hypothesis (H_0) (that the Survey Unit exceeds the release criteria) is rejected.

1.5 Conclusions

Based upon the evaluation of the data acquired for the FSS, OOL-13 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 direct 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. Upon completion of remediation and final characterization activities, a final walk down of the Survey Unit is performed. 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 direct 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

Survey Area OOL-13 consists of a land area and contains about 926 square meters of surface area. Survey Area OOL-13 is bounded by OOL-01 on the north, OOL-15 on the east, OOL-14 on the south, and OOL-12 and OOL-02 on the west. There are no subsurface systems that traverse or connect within Survey Area OOL-13. OOL-13-01 is a section of the Sherman Reservoir bank near the rail spur terminus. It is located adjacent to and down slope of the location of the Radiologically Controlled Area (RCA) at the time of characterization. The land was owned by U. S. Gen at the time that the License Termination Plan (LTP) was written and is currently owned by TransCanada.

3.2 History of Survey Area

The bounds of OOL-13 were established because this area was used for road and rail transportation of radioactive waste that included spent fuel and irradiated hardware (control rods). Survey Area OOL-13 is located down slope from the RCA and was susceptible to contamination by surface water run-off from the RCA. The western boundary of OOL-13 is the property line between USGen and YAEC. The land was owned by U. S. Gen at the time that the License Termination Plan (LTP) was written and is currently owned by TransCanada.

Railroad service to the plant was terminated during the early 1970s. The railroad tracks within the YNPS site and two flat bed cars remained in service to support plant operations.

After construction of the service building annex in the mid-1970s, vehicle traffic had to drive east, around the end of the warehouse/garage structure in order to access the east end of the RCA. The area east of the warehouse/garage structure lies within OOL-13.

Events and activities causing contamination within the RCA are notable because some of that contamination may have migrated into Survey Area OOL-13.

3.3 Division of Survey Area into Survey Units

OOL-13 has a single Survey Unit, OOL-13-01 which is a Class 1 Survey Unit.

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

Survey Unit	Date	Activity
OOL-13-01	5-16-06	Performed walk-down of Survey Unit
	7-17-06	Established Isolation and Controls
	5-16-06	Performed Unit Classification
	5-15-06	Performed Sample Quantity Calculations, established DQOs
	5-31-06	Performed Job Hazard Analysis
	7-14-06 & 7-24-06	Generated FFS Sample Plans
	7-17-06 to 7-26-06	Initiated Scans, and Direct measurements.
	8-29-06	Performed DQA, FSS Complete

4.1.2 Radionuclide Selection and Basis

During the initial DQO process, Cs-137 was identified as the radiological nuclide of concern. Characterization survey data from the HSA data indicated no other LTP-specified radionuclides warrant consideration in the OOL-13 Survey Area, however, the soil samples were evaluated for all LTP listed nuclides.

4.1.3 Scoping & Characterization

The characterization data in the HSA was sufficient to support FSS planning. Based on a review of the HSA data, Cs-137, Cs-134 and Ag-108m were detected at greater than minimum detectable concentrations, with Cs-137 at the highest concentrations and most frequently detected. No samples showed activity greater than 10% of DCGL.

It is noted that the characterization data did not include analyses for hard-to-detect (HTD) nuclides such as H-3, Sr-90, and TRUs. However, the gamma analysis did not detect Am-241 in any of the characterization soil samples, suggesting that TRUs are not present in Survey Unit OOL-13-01. HTD nuclides were included in the assessment for OOL-13-01. Five percent of the FSS soil samples were sent to an independent laboratory for complete analyses.

Based on the characterization data, a representative nuclide mix for OOL-13-01 (i.e., nuclides that would contribute to a SPA-3 reading) includes naturally occurring gamma-emitting radionuclides (e.g., K-40, Ac-228, Bi-212 & 214) plus Cs-137 as the only probable plant-related nuclide. However, all LTP-listed radionuclides will be included in the analyses of soil samples from OOL-13-01.

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 OOL-13 is identified as a Class 1 Area.

4.3 Remedial Actions and Further Investigations

Neither remedial actions nor investigations were required for OOL-13-01.

4.4 Unique Features of Survey Area

Survey Area OOL-13 is an open land area containing soils having a steep waterfront covered by dense brush.

4.5 ALARA Practices and Evaluations

An ALARA evaluation was developed for Survey Area OOL-13 which concluded that additional remediation was not warranted. This evaluation is found in Appendix C.

5.0 SURVEY UNIT FINAL STATUS SURVEY

5.1 Survey Planning

5.1.1 Final Status Survey Plan and Associated DQOs

The FSS for OOL-13 Survey Unit 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 Plan 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 below.

Table 2 Survey Area OOL-13 Design Parameters

Survey Unit	Design Parameter	Value	Basis
OOL-13-01	Area	926 m2	Class 1, ≤2,000 m2
	Number of Direct Measurements	15 (calculated)	α (Type I) = 0.05 β (Type II) = 0.05 σ: 0.0305
		Bias Samples: 2	Relative Shift: 2 Adjusted LBGR: 2.939 (Cs-137)
	Sample Area	61.7m2	Area / Sample #
	Sample Grid Spacing: Triangular	8.4m	Square Root (Area/(0.866*Sample #))
	Scan area	926 m2	Class 1 Area – 100%
	Scan Investigation Level	Co-60: 15pCi/gm Cs-137 : 66pCi/gm	See Appendix D

5.1.2 Deviations from the FSS Plan as Written in the LTP

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

5.1.3 DCGL Selection and Use

For the final evaluation of the OOL-13 Survey Area and throughout this report, the administrative acceptance criterion of 8.73 mRem/yr has been set for Soil LTP-listed radionuclides.

Table 3 Soil DCGL Values

Nuclide	Soil 8.73 mr/yr (pCi/g)	Nuclide	Soil 8.73 mr/yr (pCi/g)
Co-60	1.4E+00	H-3	1.3E+02
Nb-94	2.5E+00	C-14	1.9E+00
Ag-108m	2.5E+00	Fe-55	1.0E+04
Sb-125	1.1E+01	Ni-63	2.8E+02
Cs-134	1.7E+00	Sr-90	6.0E-01
Cs-137	3.0E+00	Tc-99	5.0E+00
Eu-152	3.6E+00	Pu-238	1.2E+01
Eu-154	3.3E+00	Pu-239	1.1E+01
Eu-155	1.4E+02	Pu-241	3.4E+02
Am-241	1.0E+01	Cm-243	1.1E+01

5.1.4 Measurements

Error tolerances and characterization sample population statistics drove the selection of the number of fixed point measurements. 15 measurements were needed in the event the Sign test may have been used. In addition to the 15 statistical measurements needed, 2 biased, 1 recount, and 1 split sample was also collected.

The direct measurement sampling grid was developed as a systematic grid with spacing consisting of a triangular pitch pattern with a random starting point. Sample measurement locations are provided in Attachment A.

5.2 Survey Implementation Activities

The Table below provides a summary of daily activities performed during the Final Status Survey of OOL-13.

Table 4 FSS Activity Summary for OOL-13

Survey Unit	Date	Activity
OOL-13-01	5-16-06	Performed walk-down of Survey Unit
	7-17-06	Established Isolation and Controls
	5-16-06	Performed Unit Classification
	5-15-06	Performed Sample Quantity Calculations, established DQOs
	5-31-06	Performed Job Hazard Analysis
	7-14-06 & 7-24-06	Generated FFS Sample Plans
	7-17-06 to 7-26-06	Initiated Scans, and Direct measurements.
	8-29-06	Performed DQA, FSS Complete

5.3 Surveillance Surveys

5.3.1 Periodic Surveillance Surveys

Upon completion of the FSS of Survey Area OOL-13, the Survey Unit was 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 performed in OOL-13-01.

5.3.3 Investigations

No additional investigations were required for this Survey Unit due to surveillance surveys.

5.4 Survey Results

Direct measurement surveys indicated that OOL-13-01 had no systematic measurements that exceeded the $DCGL_W$, depicted in Attachment B. Retrospective power curves were generated and demonstrated that an adequate number of samples were collected to support the Data Quality Objectives. Therefore, the null hypothesis (H_o) (that the Survey Unit exceeds the release criteria) is rejected.

Table 5 Direct Measurement Summary

Sample Description	Sum of Fractions
OOL-13-01-001-F	0.1
OOL-13-01-002-F	0.1
OOL-13-01-003-F	0.0
OOL-13-01-004-F	0.0

Sample Description	Sum of Fractions
OOL-13-01-005-F	0.1
OOL-13-01-006-F	0.1
OOL-13-01-007-F	0.1
OOL-13-01-008-F	0.1
OOL-13-01-009-F	0.1
OOL-13-01-010-F	0.1
OOL-13-01-011-F	0.0
OOL-13-01-012-F	0.2
OOL-13-01-013-F	0.1
OOL-13-01-014-F	0.1
OOL-13-01-015-F	0.1

Maximum Sum of Fractions	0.2
Standard Deviation	0.04

Table 6 ISOCS Scan Summary

Sample Title	Unity	Sample Title	Unity	Sample Title	Unity
OOL-13-01-101-F-R	0.08	OOL-13-01-155-F-G	0.00	OOL-13-01-214-F-G	0.00
OOL-13-01-102-F-R	0.00	OOL-13-01-156-F-G	0.00	OOL-13-01-215-F-G	0.00
OOL-13-01-103-F-G-R	0.00	OOL-13-01-157-F-G	0.00	OOL-13-01-216-F-G	0.00
OOL-13-01-104-F-G	0.00	OOL-13-01-158-F-G	0.00	OOL-13-01-217-F-G	0.00
OOL-13-01-105-F-G	0.00	OOL-13-01-159-F-G	0.00	OOL-13-01-218-F-G	0.00
OOL-13-01-106-F-G	0.00	OOL-13-01-160-F-G	0.00	OOL-13-01-219-F-G	0.00
OOL-13-01-107-F-G	0.00	OOL-13-01-161-F-G	0.00	OOL-13-01-220-F-G	0.00
OOL-13-01-108-F-G	0.00	OOL-13-01-162-F-G	0.00	OOL-13-01-221-F-G	0.00
OOL-13-01-109-F-R	0.00	OOL-13-01-163-F-G	0.00	OOL-13-01-222-F-G	0.00
OOL-13-01-110-F-G	0.00	OOL-13-01-165-F-G	0.00	OOL-13-01-223-F-G	0.00
OOL-13-01-111-F-G	0.00	OOL-13-01-166-F-G	0.00	OOL-13-01-224-F-G	0.00
OOL-13-01-112-F-G	0.00	OOL-13-01-167-F-G	0.00	OOL-13-01-225-F-G	0.00
OOL-13-01-113-F-G	0.00	OOL-13-01-169-F-G	0.00	OOL-13-01-226-F-G	0.00
OOL-13-01-114-F-G	0.00	OOL-13-01-170-F-G	0.00	OOL-13-01-227-F-G	0.00
OOL-13-01-115-F-G	0.00	OOL-13-01-171-F-G	0.00	OOL-13-01-228-F-G	0.00
OOL-13-01-116-F-G-R	0.00	OOL-13-01-173-F-G	0.00	OOL-13-01-229-F-G	0.00
OOL-13-01-117-F-G	0.00	OOL-13-01-174-F-G	0.00	OOL-13-01-230-F-G	0.00
OOL-13-01-118-F-G	0.00	OOL-13-01-175-F-G	0.00	OOL-13-01-231-F-G	0.00
OOL-13-01-119-F-G	0.00	OOL-13-01-177-F-G	0.00	OOL-13-01-232-F-G	0.00
OOL-13-01-120-F-G	0.00	OOL-13-01-178-F-G	0.00	OOL-13-01-233-F-G	0.00
OOL-13-01-121-F-G	0.00	OOL-13-01-179-F-G	0.00	OOL-13-01-234-F-G	0.00
OOL-13-01-122-F-G	0.00	OOL-13-01-181-F-G	0.00	OOL-13-01-235-F-G	0.00
OOL-13-01-123-F-G	0.00	OOL-13-01-182-F-G	0.00	OOL-13-01-236-F-G	0.00
OOL-13-01-124-F-G	0.00	OOL-13-01-183-F-G	0.00	OOL-13-01-237-F-G	0.00
OOL-13-01-125-F-G	0.00	OOL-13-01-185-F-G	0.00	OOL-13-01-238-F-G	0.00
OOL-13-01-126-F-G	0.00	OOL-13-01-186-F-G	0.00	OOL-13-01-239-F-G	0.00
OOL-13-01-127-F-R	0.00	OOL-13-01-187-F-G	0.00	OOL-13-01-240-F-G	0.00
OOL-13-01-128-F-G	0.00	OOL-13-01-188-F-G	0.00	OOL-13-01-241-F-G	0.00
OOL-13-01-129-F-G	0.00	OOL-13-01-189-F-G	0.00	OOL-13-01-242-F-G	0.00

Sample Title	Unity	Sample Title	Unity	Sample Title	Unity
OOL-13-01-130-F-G	0.00	OOL-13-01-190-F-G	0.00	OOL-13-01-243-F-G	0.00
OOL-13-01-131-F-G	0.00	OOL-13-01-191-F-G	0.00	OOL-13-01-245-F-G	0.00
OOL-13-01-132-F-G	0.00	OOL-13-01-192-F-G	0.00	OOL-13-01-246-F-G	0.00
OOL-13-01-133-F-G	0.00	OOL-13-01-193-F-G	0.00	OOL-13-01-247-F-G	0.00
OOL-13-01-134-F-G	0.00	OOL-13-01-194-F-G	0.00	OOL-13-01-249-F-G	0.00
OOL-13-01-135-F-G	0.00	OOL-13-01-195-F-G	0.00	OOL-13-01-250-F-G	0.00
OOL-13-01-136-F-G	0.00	OOL-13-01-196-F-G	0.00	OOL-13-01-251-F-G	0.00
OOL-13-01-137-F-G	0.00	OOL-13-01-197-F-G	0.00	OOL-13-01-260-F-G	0.00
OOL-13-01-138-F-G	0.00	OOL-13-01-198-F-G	0.00	OOL-13-01-261-F-G	0.00
OOL-13-01-139-F-G	0.00	OOL-13-01-199-F-G	0.00	OOL-13-01-262-F-G	0.00
OOL-13-01-140-F-G	0.00	OOL-13-01-200-F-G	0.00	OOL-13-01-263-F-G	0.00
OOL-13-01-141-F-G	0.00	OOL-13-01-201-F-G	0.00	OOL-13-01-264-F-G	0.00
OOL-13-01-142-F-G	0.08	OOL-13-01-202-F-G	0.00	OOL-13-01-265-F-G	0.00
OOL-13-01-143-F-G	0.00	OOL-13-01-203-F-G	0.00	OOL-13-01-266-F-G	0.00
OOL-13-01-144-F-G	0.00	OOL-13-01-204-F-G	0.00	OOL-13-01-267-F-G	0.00
OOL-13-01-145-F-G	0.00	OOL-13-01-205-F-G	0.00	OOL-13-01-268-F-G	0.00
OOL-13-01-146-F-G	0.09	OOL-13-01-206-F-G	0.00	OOL-13-01-269-F-G	0.00
OOL-13-01-147-F-G	0.03	OOL-13-01-207-F-G	0.00	OOL-13-01-270-F-G	0.00
OOL-13-01-148-F-G	0.00	OOL-13-01-208-F-G	0.00	OOL-13-01-271-F-G	0.00
OOL-13-01-149-F-G	0.00	OOL-13-01-209-F-G	0.00	OOL-13-01-272-F-G	0.00
OOL-13-01-150-F-G	0.09	OOL-13-01-210-F-G	0.00	OOL-13-01-273-F-G	0.00
OOL-13-01-151-F-G	0.04	OOL-13-01-211-F-G	0.00	OOL-13-01-274-F-G	0.00
OOL-13-01-152-F-G	0.00	OOL-13-01-212-F-G	0.00	OOL-13-01-275-F-G	0.00
OOL-13-01-153-F-G	0.00	OOL-13-01-213-F-G	0.00	OOL-13-01-276-F-G	0.00
OOL-13-01-154-F-G	0.00				

The following locations were removed from the initial survey plan, as they were located outside the Survey Unit and in the Sherman Reservoir: 164, 168, 172, 176, 180, 184, 244, 248, 252, 253, 254, 255, 256, 257, 258, and 259.

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.

A data set review was performed on OOL-13-01. The data range was within three standard deviations and exhibited a normal variance about the arithmetic mean. The frequency plot exhibited a Poisson distribution with the exception of one data point skewed slightly high; however this data point was a small fraction of the DCGLw and a review of the posting plot did not clearly reveal any systematic spatial trends. The quantile plot did not display noticeable asymmetry. The power function, shown by the retrospective power curve, was adequate to pass the FSS of the Survey Unit and the retrospective standard deviation was approximately equal the prospective standard deviation. The data set verified the assumptions of the statistical test.

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 Assessment power curves, scatter, quantile and frequency plots are found in Attachment B. Posting Plots are found in Attachment A.

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.*" Instrument response checks were performed 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 OOL-13 satisfied the above criteria for the survey. QC records are found in Attachment C.

6.2 Split Samples and Recounts

One recount and one split 'QC" sample was gathered and within tolerable limits in accordance with DP-8864,"*Split Sample Assessment for Final Status Survey*".

6.3 Self-Assessments

No self-assessments were performed during the FSS of OOL-13.

7.0 CONCLUSION

The FSS of OOL-13 has been performed in accordance with YNPS LTP and applicable FSS procedures. Evaluation of the direct measurement data has shown none of the systematic direct measurements exceeded the $DCGL_W$, depicted in Attachment B Retrospective power curves were generated and demonstrated that an adequate number of samples were collected to support the Data Quality Objectives. Therefore, the null hypothesis (H_0) is rejected.

OOL-13 meets the objectives of the Final Status Survey.

Based upon the evaluation of the data acquired for the FSS, OOL-13 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 Figure, Appendix or Attachment is a hyperlink to the actual location or document.)

Final Status Survey Planning Worksheet

GENERAL SECTION

Survey Area #: OOL-13	Survey Unit #: 01

Survey Unit Name: Sherman Reservoir Bank – Rail Spur Terminus

FSSP Number: YNPS-FSSP-OOL13-01-01 **(Note: Revision comments in *__Bold Italics and Underlined__*)**

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. ☑ (YA-REPT-00-003-05)

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 __Statement of problem__:

Survey Unit 01 is a section of the Sherman Reservoir bank near the rail spur terminus. It is located adjacent to and down slope of the location of the Radiologically Controlled Area (RCA) at the time of characterization. The land was owned by U. S. Gen at the time that the License Termination Plan (LTP) was written and is currently owned by TransCanada. The LTP classified it as Class 1, because of its historical use and radiological conditions. The problem at hand is to demonstrate that the years of plant operation did not result in an accumulation of plant-related radioactivity that exceeds the release criteria.

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__:

Does residual plant-related radioactivity, if present in the survey unit, exceed LTP release criteria? Alternative actions that may be implemented in this effort are investigation, remediation, reclassification and resurvey.

3.0 __Identify the inputs to the decision__:

Sample medium:	Soil
Types of measurements:	Soil samples, ISOCS Assays and gamma scans
Radionuclide of concern:	Cs-137
Applicable DCGL (8.73 mrem/y):	$DCGL_W$: 3.0 pCi/g $DCGL_{EMC}$: 8.7 pCi/g

The characterization data in the HSA is sufficient to support FSS planning. Based on a review of the HSA data, Cs-137, Cs-134 and Ag-108m were detected at greater than minimum detectable concentrations, with Cs-137at the highest concentrations and most frequently detected. No samples showed activity greater than 10% of DCGL.

It is noted that the characterization data do not include analyses for hard-to-detect (HTD) nuclides such as H-3, Sr-90, and TRUs. However, the gamma analysis did not detect Am-241 in any of the characterization soil samples, suggesting that TRUs are not present in Survey Unit OOL-13-01. HTD nuclides will be included in the assessment for Survey Unit 01. At least five percent of the FSS soil samples will be sent to an independent laboratory for complete analyses (HTD nuclides).

Based on the characterization data, a representative nuclide mix for survey unit 01 (i.e., nuclides that would contribute to a SPA-3 reading) includes naturally occurring gamma-emitting radionuclides (e.g., K-40, Ac-228, Bi-212 & 214) plus Cs-137 as the only probable plant-related nuclide. However, all LTP-listed radionuclides will be included in the analyses of soil samples from Survey Unit 01.

Survey Design / Release Criteria

Classification:	Class 1
Average Cs-137 concentration:	0.0468pCi/g
Standard deviation (σ) for Cs-137:	0.0305 pCi/g
Surrogate DCGL:	N/A (a surrogate DCGL will not be used)
Number of Samples:	15
Survey Unit Area:	926 m^2
Investigation Level for soil samples:	• >$DCGL_{EMC}$ for any LTP radionuclide -or- • A sum of $DCGL_{EMC}$ fractions>1.0 -or- • >$DCGL_W$ for any LTP radionuclide and a statistical outlier as defined by the LTP Note: The Cs-137 concentrations detected in the soil samples collected under this survey plan will not be adjusted to account for background Cs-137 (i.e., Cs-137 that can be attributed to fallout from nuclear weapons testing) because the average Cs-137 concentration in the characterization samples is lower than the decay-adjusted average Cs-137 background in the reference area (i.e., 0.82 pCi/g).
Radionuclides for analysis:	All LTP-listed nuclides with the focus on Cs-137.
MDCs for soil samples:	Table 1 shows the preferred and required MDC values that will be conveyed to the processing laboratories.

Table 1: MDCs for Soil Samples

Radionuclide	Preferred MDC (10% of DCGL)	Required MDC (50% of DCGL)	ETD or HTD
H-3	1.3E+01	6.4E+01	HTD
C-14	1.9E-01	9.7E-01	HTD
Fe-55	1.0E+03	5.1E+03	HTD
Co-60	1.4E-01	7.0E-01	ETD
Ni-63	2.8E+01	1.4E+02	HTD
Sr-90	6.0E-02	3.0E-01	HTD
Nb-94	2.5E-01	1.3E+00	ETD
Tc-99	5.0E-01	2.5E+00	HTD
Ag-108m	2.5E-01	1.3E+00	ETD
Sb-125	1.1E+00	5.6E+00	ETD
Cs-134	1.7E-01	8.7E-01	ETD
Cs-137	3.0E-01	1.5E+00	ETD
Eu-152	3.6E-01	1.8E+00	ETD
Eu-154	3.3E-01	1.7E+00	ETD
Eu-155	1.4E+01	6.9E+01	ETD
Pu-238	1.2E+00	5.8E+00	HTD
Pu-239	1.1E+00	5.3E+00	HTD
Pu-241	3.4E+01	1.7E+02	HTD
Am-241	1.0E+00	5.1E+00	HTD
Cm-243	1.1E+00	5.6E+00	HTD

ISOCS Assay Coverage:

100 % of the ***cleared land*** surface area, ensured by overlapping field-of-views using ISOCS in the 1m detector height with 180° open collimation configuration. ***100% of foliage covered surface area accessible to ISOCS, ensured by 100% overlapping field-of views using ISOCS in the 2m detector height with 90° collimation configuration. 2m, 90° ISOCS assays to be spaced on 2m centers.***

As determined by the FSSE, ISOCS assays in additional configurations (i.e. 1m, 90° collimation configuration) may be used to perform investigations of ISOCS assay measurements exceeding investigation criteria.

Investigation Level for ISOCS Measurements:

Table 2: ISOCS Investigation Levels

1m, 180° Open Collimation Configuration					
Nuclide	Inv. Level (pCi/g)	Nuclide	Inv. Level (pCi/g)	Nuclide	Inv. Level (pCi/g)
Co^{60}	1.8E-01	Sb^{125}	1.0E+00	Eu^{152}	4.1E-01
Nb^{94}	2.6E-01	Cs^{134}	3.0E-01	Eu^{154}	3.8E-01
Ag^{108m}	2.5E-01	Cs^{137}	7.0E-01	Eu^{155}	1.1E+01
2m, 90° Collimation Configuration					
Co^{60}	***1.01E+00***	***Sb^{125}***	***6.71E+00***	***Eu^{152}***	***2.21E+00***
Nb^{94}	***1.54E+00***	***Cs^{134}***	***1.83E+00***	***Eu^{154}***	***2.08E+00***
Ag^{108m}	***1.53E+00***	***Cs^{137}***	***4.32E+00***	***Eu^{155}***	***7.82E+01***
Note: These values were obtained from ***YA-REPT-00-018-05 and*** YA-EVAL-00-001-06 and .					

MDCs for ISOCS Measurements:

MDCs for ISOCS measurements are equal to the investigation levels in Table 2, above.

SPA-3 Scan Coverage:	***SPA-3 scans will be performed in areas where restricted access prevents the use of ISOCS. These scans will cover 100% of the surface area that is not covered by ISOCS scans.*** SPA-3 scans **may** be performed for surface soil within the field-of-view of an ISOCS assay or surrounding an FSS sample location that exceeds the investigation criteria. The SPA-3 scan will cover 100% of the ISOCS assay total field-of-view area (38.5m^2 ***or 12.6m^2*** as appropriate) or a 1-m radius around the FSS sample location (3.14m^2).
Investigation Level for SPA-3 Scans:	Reproducible indication above background using SPA-3 and audible discrimination.
Expected background range for SPA-3 scan:	7,000 cpm to 12,000 cpm, depending on the presence of rocks in the immediate vicinity of the measurement location and also the influence of the ISFSI dose rate.
MDCR for SPA-3:	The accompanying MDCR/MDC table in Attachment 1 provides MDCR values by various background levels.
MDC(fDCGL) for SPA-3 scans:	The accompanying MCDR/MDC table in Attachment 1 provides MDC values, as a fraction of DCGL, by various background levels. The table shows that scanning can be done effectively at the speed planned (0.5 m/s) in backgrounds up to 13,000 cpm. No background levels higher than this are anticipated.
QC checks and measurements:	• QC checks for the Leica GPS will be performed in accordance with DP-8859. • QC checks for the SPA-3 will be performed in accordance with DP-8504. • One QC split sample will be collected. • The YNPS Chemistry Lab will perform a QC recount of one soil sample.

4.0 Define the boundaries of the survey:

Boundaries of Survey Unit 01 are as shown on the attached map. The northern boundary is the Sherman Reservoir shore and Survey Area OOL-15. To the south are Survey Unit OOL-14-01 and Survey Unit OOL-12-01. To the west is Survey Unit OOL-03-02. Survey Unit OOL-15-01 is to the east. There are no structures present in the Survey Unit 01. The survey will be performed under appropriate weather conditions (as defined by instrumentation limitations and human tolerance).

5.0 Develop a decision rule:

Upon review of the FSS data collected under this survey plan:

(a) If all the sample data show that the soil concentrations of all plant-related nuclides and the sum of the fractions of these nuclides are below the 8.73-mrem/y DCGLs, reject the null hypothesis (i.e., Survey Unit OOL-13-01 meets the release criteria).
(b) If an investigation level is exceeded, then perform an investigation survey.
(c) If the average concentration of any LTP-listed nuclide exceeds the DCGL or the average sum of the fractions exceeds one, then accept the null hypothesis (i.e., Survey Unit OOL-13-01 fails to meet the release criteria).
(d) If the average concentration of an identified LTP-listed nuclide is less than $DCGL_w$ and the sum of their $DCGL_w$ fractions are less than 1, but some individual measurements exceed the $DCGL_w$, then apply the statistical test as the basis for accepting or rejecting the null hypothesis.

Note: Alternate actions include investigations, reclassification, remediation and resurvey.

6.0 Specify tolerable limits on decision errors:

Null hypothesis:	Residual plant-related radioactivity in Survey Unit OOL-13-01

	exceeds the release criteria.
Probability of type I error:	0.05
Probability of type II error:	0.05
LBGR:	2.94 pCi/g (Adjusted LBGR from DPF-8853..1)

7.0 Optimize Design:

Type of statistical test: WRS Test ☐ Sign Test ☑ (background will not be subtracted)

Note: 15 FSS soil samples will be collected in locations based on a triangular grid with a random start location to support the application of the Sign test, if necessary.

Basis including background reference location (if WRS test is specified): N/A

Number of systematic samples: 15. (Refer to the completed DPF-8853.1 in the survey package file.)

Biased samples: Two from the level area where the most vehicular traffic has occurred.

Location of samples: Shown on the map included in the package file.

Rev. 1 Supplement to OOL-13-01 FSS Plan

This revision provides instructions for use of ISOCS in the 2m-90° collimation configuration. Use of ISOCS in this configuration is necessitated due to a large portion of the area having foliage cover. Evaluation of use of ISOCS in areas with foliage cover indicates that the 2m-90° configuration is the most appropriate geometry. To enhance coverage, ISOCS assays in the 2m-90° configuration will be spaced on 2-m centers.

This revision also provides instructions for performance of investigation surveys of ISOCS assays. ISOCS assays that exceed the investigation criteria (stated in Section 3.0 of this plan) or other measurements selected by the FSSE will be investigated. Due to foliage cover and steep embankments in the survey unit, it is difficult, and unsafe in some areas, to perform SPA-3 scans. Use the ISOCS in a collimated geometry will be used as appropriate for investigations.

GENERAL INSTRUCTIONS

1. Where possible, identify soil sample locations using GPS in accordance with DP-8859. Mark each location to assist in identifying the location. Relocate any locations that are not suitable for soil sampling to a suitable location and document it in the field log in accordance with DP-8856.
2. Collect soil samples in accordance with DP-8120.
3. Use Chain of Custody forms in accordance with DP-8123 for all soil samples sent to an off-site laboratory.
4. Receive and prepare all soil samples in accordance with DP-8813.
   Note: Split and biased samples to be sent to an off-site lab will not be dried prior to counting on site or shipping.
5. ***For areas of cleared land (no foliage)***, mark centerline ISOCS locations on a square grid pattern with a maximum spacing of 4 meters apart and 2 meters from the edges of the survey unit, covering 100% of the survey unit area ***as appropriate. For areas with foliage cover, mark centerline ISOCS locations on a square grid pattern with a maximum spacing of 2 meters apart and 1 meter from the edges of the survey unit.*** Show the ISOCS grid layout, at least approximately, on a map entitled "ISOCS Scans" of the survey unit.
6. Collect ISOCS measurements in accordance with DP-8871.
7. Survey instrument: Operate the E-600 w/SPA-3 in accordance with DP-8535 with QC checks performed in accordance with DP-8504. The instrument response checks shall be performed before issue and after use.

6. SPA-3 ***scans of areas inaccessible to ISOCS*** and investigation scans:
   - Scan the area of concern with the SPA-3 in rate-meter mode moving the detector no faster than of 0.5 m/s, keeping the probe no more than 3" from the surface and following a serpentine path that includes at least

3 passes across each square meter.

- Surveyors will listen for upscale readings, to which they will respond by slowing down or stopping the probe to distinguish between random fluctuations in the background and greater than background readings.
- A first level investigation may be done with the SPA-3/E-600 to determine if the observed increase in the scan measurement is due to the presence of a rock. SPA-3 scans performed in non-impacted areas have shown that rock formations accounted for increased count rates. If it can be demonstrated that the presence of a rock is the cause of an increased count rate during a SPA-3 scan, record that finding on form DPF-8856.2 and close the investigation. Instructions on investigations where the source of the elevated count rate can not be attributed to a rock are given in Specific Instructions #6 and #7.

7. The job hazards associated with the survey described in this package are addressed in the accompanying Job Hazard Assessment (JHA) for OOL-13-01.
8. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. Identify all designated sample locations by GPS per DP-8859 or by use of reference points, compass and tape measure as necessary. If a designated sample location is obstructed for any reason, the FSS Radiological Engineer or the FSS Field Supervisor will select an alternate location in accordance with DP-8856. Record a detailed description of the alternate location on form DPF-8856.2. Provide information to the RSS Rad Engineer so that the survey unit map can be annotated appropriately. Conspicuously post the alternate location to facilitate re-visiting to identify and record the coordinates with GPS in accordance with DP-8859 or by measurement from a known reference point when GPS is not available. Soil sample locations are shown on map "FSS Samples".
2. Sample Requirements:
   - Collect 15 systematic 1-liter soil samples and two biased location samples in accordance with DP-8820. One of the random samples will be analyzed as a QC split sample to fulfill the QC requirement of DP-8852. The QC split sample will also be analyzed for Hard-to-Detect nuclides in accordance with section 5.6.3.2.1 of the LTP and DP-8856.
3. Soil Sample Designations:

Systematic FSS soil samples:	OOL-13-01-001-F through OOL-13-01-015-F corresponding to FSS sample locations 001 through 015. Analyzed by gamma spectroscopy by YNPS Chemistry.
Biased FSS soil samples:	OOL-13-01-016-F-B and OOL-13-01-017-F-B corresponding to samples locations 016 and 017. Analyzed by YNPS by gamma spectroscopy.
QC split sample:	OOL-13-01-009-F-S, collected at FSS sample location 009 is a QC split sample. Analyzed by off-site laboratory for all LTP radionuclides, including gamma emitters. Note: Sample OOL-13-01-009-F-S will be sent to the off-site laboratory as collected from the field (i.e., without drying) for HTD analysis. It may be counted wet for shipping purposes.
Recount sample:	Soil sample OOL-13-01-003-F will be counted twice and the results compared in accordance with DP-8864. The second count will be designated OOL-13-01-003-F-RC and will be analyzed by YNPS by gamma spectroscopy. Only the count designated OOL-13-01-003-F will be used as a measure of soil activity for that location.

4. Sample Analysis:
   - If any of the gamma analyses show that an investigation level has been exceeded, an investigation survey

will be conducted at that sample location as directed in Specific Instruction #6.

- All analyses will achieve the required MDC values stated in the DQO section of this plan.

5. ISOCS Assays:

   - ***For cleared land areas,*** set the ISOCS detector one meter above each of the marked ISOCS locations, using the 180° collimator unless otherwise directed by the FSS Engineer. ***For areas of foliage cover, set the ISOCS detector two meters above each of the ISOCS locations, using the 90° collimator. The area of the survey unit along the Sherman Reservoir has a steep embankment, to allow for physical control of ISOCS positioning, it may be necessary to align the ISOCS vertically.*** Make note on the daily survey journal (DPF-8856.2) if other geometries are used.
   - Collect ISOCS assays in accordance with DP-8871 to provide 100% scan coverage, as possible, of the survey unit. ***Areas inaccessible to ISOCS will be scanned using SPA-3.***
   - ISOCS assays are designated as OOL-13-01-xxx-F-G where xxx corresponds to the 3-digit location indicated on survey map "ISOCS Scans."
   - Perform QC checks at least once per shift in accordance with DP-8869 and DP-8871. Resolve flags encountered prior to survey.
   - Remove standing water prior to performance of ISOCS assays. Contact the FSS Engineer for directions if conditions are such that standing water cannot be removed.
   - Make note of any conditions within the ISOCS field of view that may affect analysis of ISOCS assay data such as mud, concrete, etc.
   - Designate any additional assay locations in continuing sequence from the last number assigned to an FSS measurement. Record detailed information about additional assay locations on the daily survey journal.
   - If the results on any ISOCS assay exceed an investigation level, investigate the area within the field of view (7m diameter – 38.5m^2 area for 180°-1m) for that assay as directed in Specific Instruction # 7.

6. If the result of any FSS sample (systematic and/or biased points) analysis exceeds an investigation level, perform a first level investigation as follows :

   Note: Detailed descriptions of investigation actions shall be recorded in the daily survey journal (DPF-8856.2).

   - Review ISOCS data for assays in which the sample requiring investigation may have been in the field of view.
   - Scan a 1m radius footprint around the sample location with a SPA-3 as described in the General Instructions section. The area of scan should be increased as necessary to bound any areas of elevated activity identified.
   - Mark the boundaries around any detected elevated areas in the soil and identify the boundaries on a survey map. Measure the total area of each outlined area in square centimeters.
   - Mark the location of the highest identified activity for each of the elevated areas in the soil and on the survey map.
   - At each identified area:
     - Perform and record a 1-minute scaler mode SPA-3 measurement. Designate the reading as "OOL-13-01-xxx-F-SC-I" where "xxx" continues sequentially from the last number assigned to an FSS measurement.
     - Obtain a soil sample at the location. Designate the sample as "OOL-13-01-xxx-F-I" where "xxx" continues sequentially from the last number assigned to an FSS measurement.
     - Perform and record a post sample 1-minute SPA-3 measurement. Designate the reading as described above, using the next sequential xxx.

7. If the results of an ISOCS assay exceed an investigation level, perform a ISOCS investigation as follows:

   Note: Detailed descriptions of investigation actions shall be recorded in the daily survey journal (DPF-8856.2).

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Note: As determined by the FSSE, ISOCS assays in the 1m, 90° collimation configuration may be used to perform investigations of ISOCS assays exceeding investigation criteria or may be used in addition to SPA-3 scans.

Use of ISOCS for investigation:

- ***Perform ISOCS scan measurements at each investigation location as follows:***
  - ***Perform ISOCS scans at 1m height with 90° collimation***
  - ***Perform ISOCS scans at 5 locations within a 4-m grid centered over the original ISOCS scan location – One centered over the original scan location and one in each corner of the grid centered at 1.4 m from the center of the grid. ISOCS Scan Investigation Map #1 (to be prepared as necessary) shows the proper positioning for ISOCS investigation scans.***
  - ***Identify investigation ISOCS scans using the convention: OOL-13-01-xxx-F-G-I, where xxx indicates the next sequential location number starting with 301 (i.e. the first investigation ISOCS scan performed will be OOL-13-01-301-F-G-I).***
  - ***Indicate any observations in the daily survey journal. Locations of ISOCS scans should be recorded by use of GPS when available.***
- ***The FSSE will review investigation ISOCS scans and will direct performance of SPA-3 scans as set forth in the following steps.***

Use of SPA-3 for investigation

- Scan the ISOCS footprint (7-m diameter, ***or 4-m diameter as appropriate***) with a SPA-3 as described in the General Instructions section.
- Mark the boundaries around any detected elevated areas in the soil and identify the boundaries on a survey map. Measure the total area of each outlined area in square centimeters.
- Mark the location of the highest identified activity for each of the elevated areas in the soil and on the survey map.
- At each of the highest identified activity area:
  - Perform and record a 1-minute scaler mode SPA-3 measurement. Designate the reading as "OOL-13-01-xxx-F-SC-I" where "xxx" continues sequentially from the last number assigned to an FSS measurement.
  - Obtain a soil sample at the location. Designate the sample as "OOL-13-01-xxx-F-I" where "xxx" continues sequentially from the last number assigned to an FSS measurement.
  - Perform and record a post-sample 1-minute SPA-3 measurement. Designate the reading as described above.

NOTIFICATION POINTS

None.

Prepared by [signature] Date 7/24/06
FSS Radiological Engineer

Reviewed by [signature] Date 7/24/06
FSS Radiological Engineer

Approved by [signature] Date 7/24/06
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 $100 cm^2$ 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

	$> 0.400\ MeV_{max}$	$\leq 0.400\ MeV_{max}$
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.

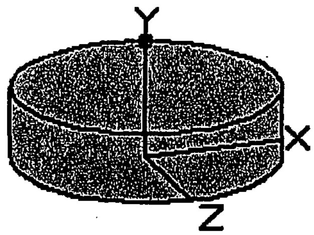
8.5 DP-8534, "Operation and source Checks of Portable Friskers".

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

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

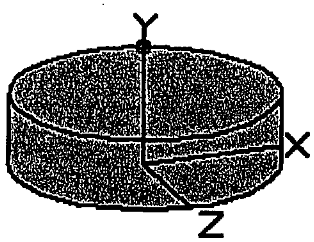
Co-60
Microsoft Excel E_i Calculation Sheet

	Energy MeV	Energy kev	Exposure Rate (mR/hr /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**

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**

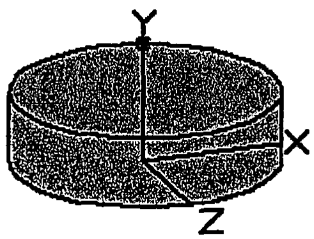
Nb-94					
	Energy MeV	Energy keV	Exposure Rate (mR/hr-1/pCi/g)	Energy Response (cpm/mR/h)	E (cpm/pCi/g)
2	0.0023	2	1.91E-10		0
17	0.0174	17	4.93E-10		0
18	0.0175	18	9.49E-10		0
20	0.0196	20	3.09E-10		0
703	0.7026	703	1.90E-04	1,110,370	211
871	0.8711	871	2.31E-04	884,689	205
0		0			0
0		0			0
0		0	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

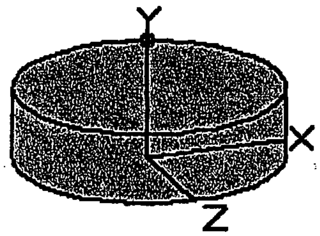
	Energy Mev	Energy kev	Exposure Rate (mR/hr /pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
3	0.0028	3	1.39E-07		0
3	0.003	3	1.66E-08		0
21	0.021	21	3.01E-07		0
21	0.0212	21	5.74E-07		0
22	0.022	22	8.83E-09		0
22	0.0222	22	1.69E-08		0
24	0.0238	24	2.03E-07		0
25	0.0249	25	6.05E-09		0
30	0.0304	30	5.01E-13	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
				(Ei) 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 1 pCi/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
				(Ei) Total:	210

APPENDIX I

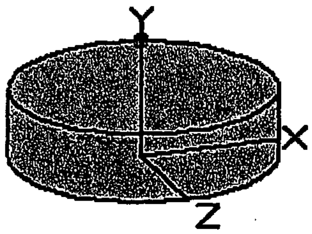
MicroShield v6.02 (6.02-00253)

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_i Calculation Sheet

[illegible]	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_i) Total:	**506**

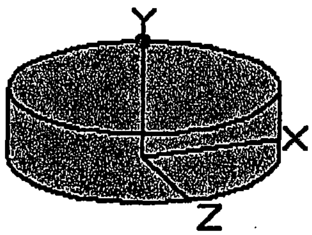
MicroShield v6.02 (6.02-00253)

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				
			Exposure Rate (mR/hr / 1 pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
	Energy MeV	Energy kev			
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
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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**

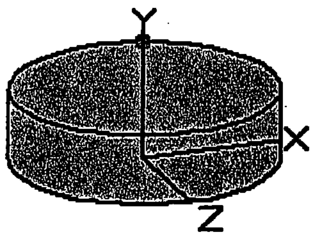
APPENDIX M

MicroShield v6.02 (6.02-00253)

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

File Ref	:
Date	:
By	:
Checked	:

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**

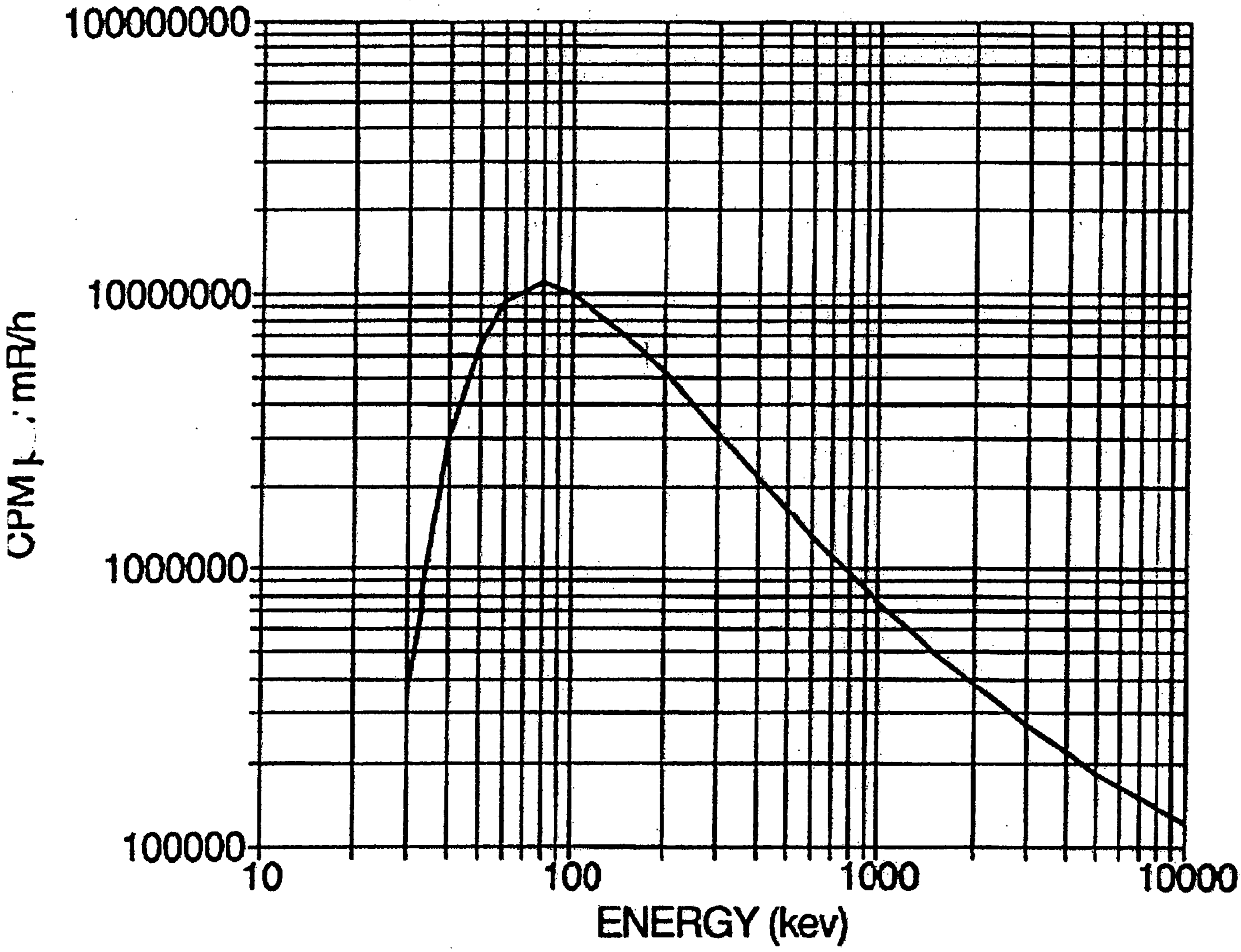
APPENDIX N

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



Generic ALARA Evaluation Comparison Worksheet

Survey Area: OOL-13 Survey Unit: 01

Reference Generic ALARA Evaluation No.: YA-REPT-00-003-05

Applicable Generic ALARA AL: 165

	Radionuclide	Average Concentration	DCGL	fraction DCGL
1.	Cs-137	0.0468 pCi/g	3.0 pCi/g	0.02
2.				
3.				
4.				
			Σ(fraction DCGL) =	0.02

If the Σ(fraction DCGL) < the generic ALARA AL, then the generic ALARA evaluation is applicable to the survey unit.

Check one:

✓ Generic ALARA AL **IS** satisfied.

____ Generic ALARA AL **IS NOT** satisfied.

Prepared by: [signature] Date: 7-14-06
FSS Radiological Engineer

Reviewed by: [signature] Date: 7/14/06
FSS Project Manager

1 of 19

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/	[signature]	Date: 10/10/05
Preparer: Gordon Madison, CHP/	[signature]	Date: 10/11/05
Reviewer: Jim Hummer, CHP/	[signature]	Date: 10/18/05
Approver (FSS Manager): Dann Smith, CHP/	[signature]	Date: 11/4/05

Rev. 0

γ

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

TABLE OF CONTENTS

3

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 <u>Detector Description</u>

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 m².

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 m²

	Soil $DCGL_W$ (pCi/g) (NOTE 1)	Soil $DCGL_W$ (pCi/g) (NOTE 2)	Area Factor for 1 m² (NOTE 3)	$DCGL_{EMC}$ for 1 m² (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 m² area

The $^{1m^2}DCGL_{EMC}$ values listed in Table 1 do not account for a source positioned at the edge of the field-of-view. Therefore, the $^{1m^2}DCGL_{EMC}$ 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 m² field-of-view. The second scenario assumes radioactivity localized over a 1 m² 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 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 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:

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

Where: $DCGL_{EMC}$ = ($DCGL_W$ 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 m^2 (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 m^2 field-of-view.
NOTE 2 – Efficiency calibration modeled for a 1 m^2 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 m^2.
NOTE 3 – Ratio = (12.6 m^2 MDC ÷ 1 m^2 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 m^2 (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 m^2 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 m^2

	Bldg $DCGL_W$ (dpm/100m^2) (NOTE 1)	Bldg $DCGL_W$ (dpm/100cm^2) (NOTE 2)	Area Factor For 1 m^2 (NOTE 3)	$DCGL_{EMC}$ For 1 m^2 (dpm/100cm^2) (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 m^2 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 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 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 m^2 MDC (dpm/100cm²) (NOTE 1)	1 m^2 MDC (dpm/100cm²) (NOTE 2)	RATIO (NOTE 3)	$DCGL_{EMC}$ For 1 m^2 (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		Deviation due to density increase (excess moisture)
	1.7 g/cc	2.08 g/cc	
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 References

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.

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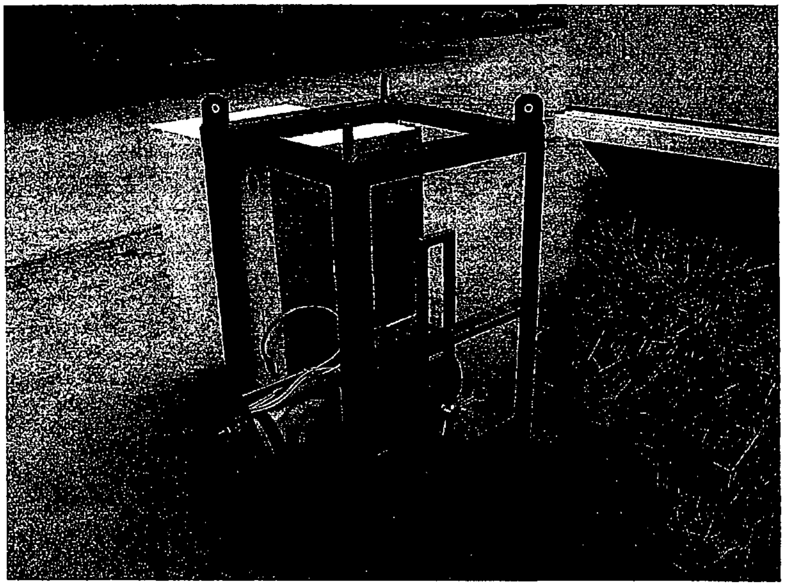
Attachment 1
Portable ISOCS® Detector System Photos



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

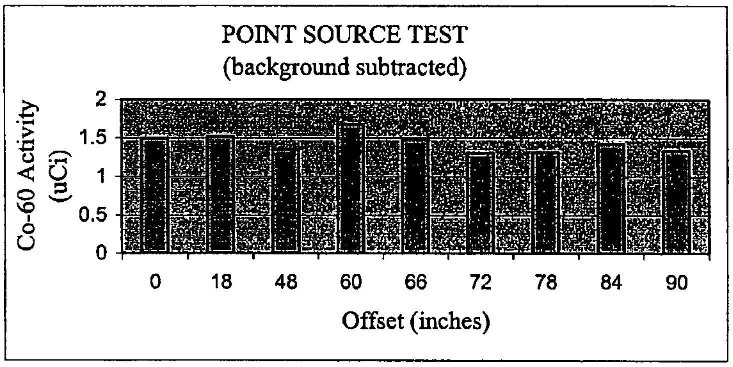
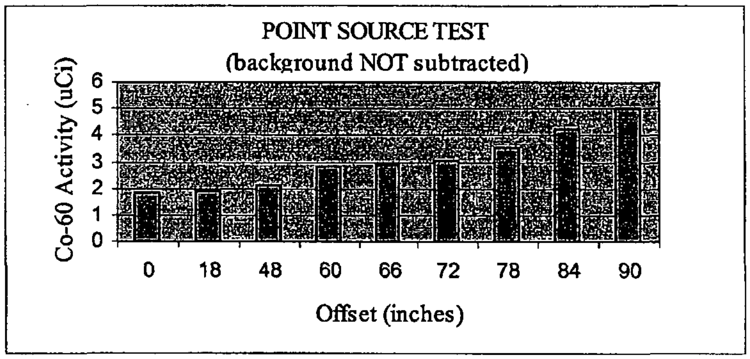
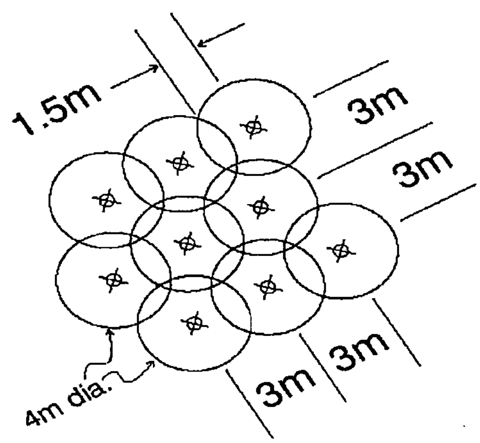


Figure 2 shows the effect of plant-derived materials present in the reference background, which indicates an increasing over-response the further the point source is moved off center. Detector response outside the assumed (i.e. 2-meter) field-of-view would yield conservative results. Normally, source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



Typical Scan Grid Pattern
(For 2m scan height using 90° collimator.)

=Scan Point Location   =Scan Area Footprint
(4m dia. for 2m scan height)

Attachment A – Maps and Posting Plots

List of Figures

Figure 1 OOL-13 Relative to Structures

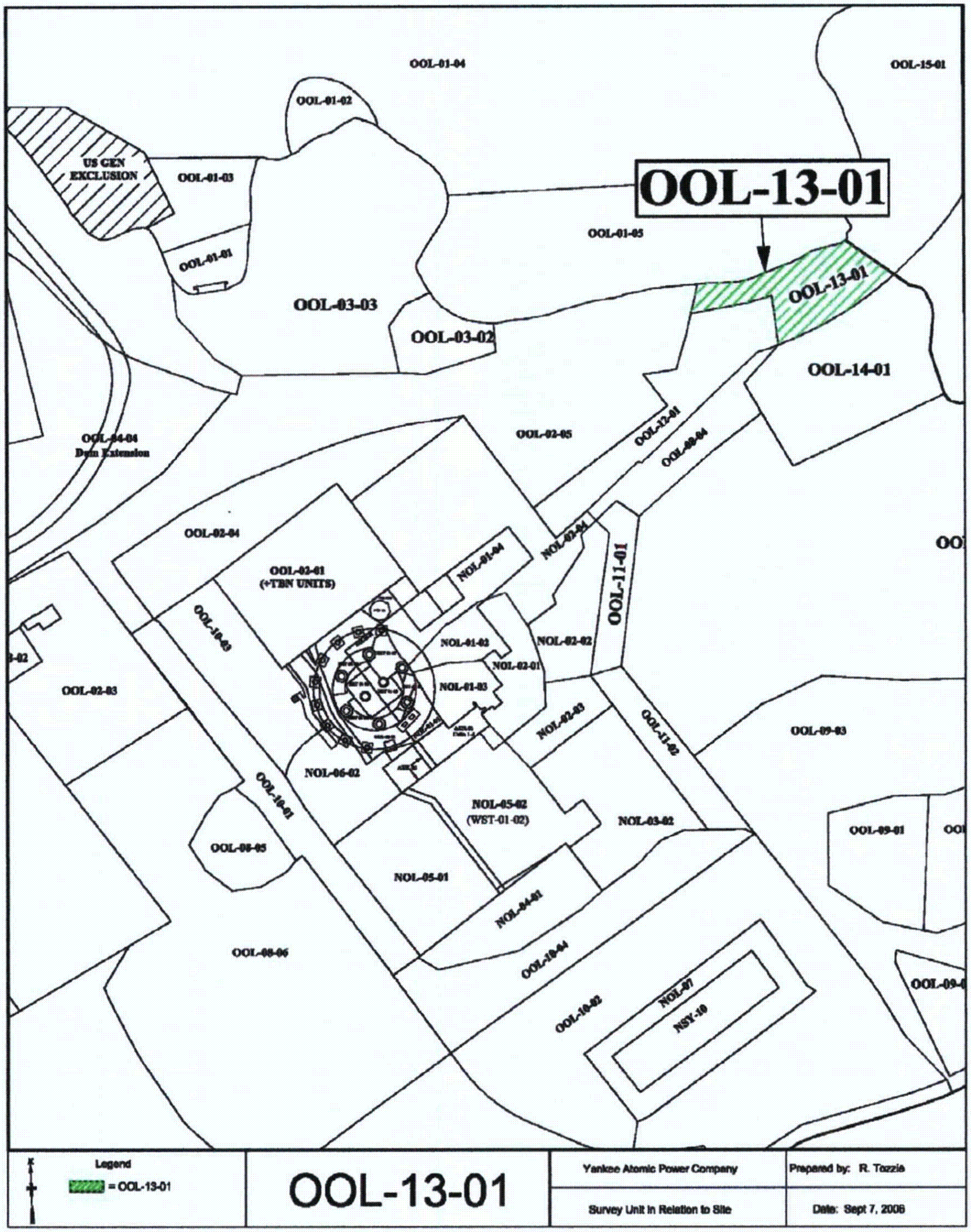
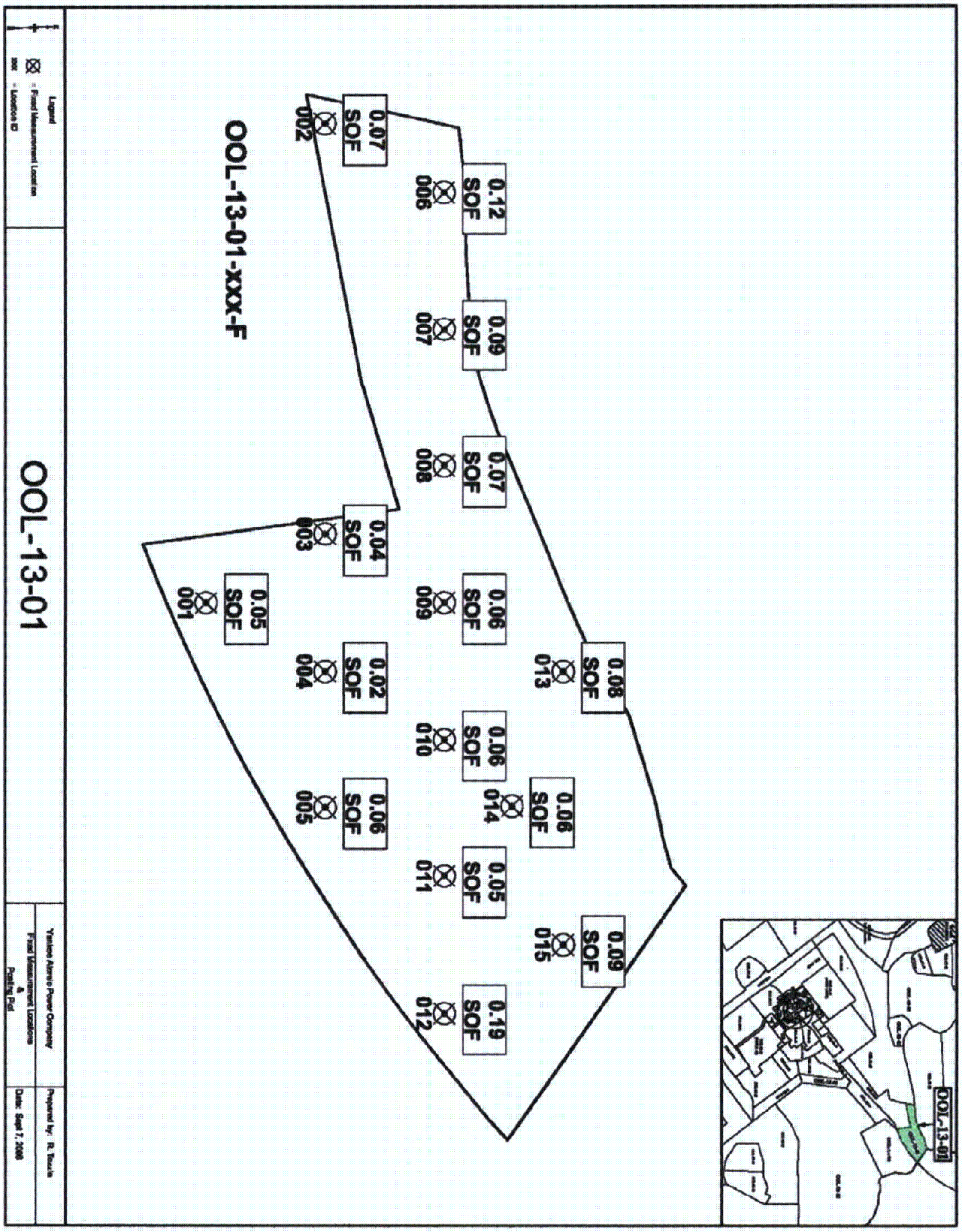


Figure 2 OOL-13-01 Posting Plot



Attachment B

Data Quality Assessment Plots and Curves

List of Figures

The LBGR on the Power Curves have been adjusted to demonstrate the actual power of the survey.

Figure 1 OOL-13-01 Prospective Power Curve

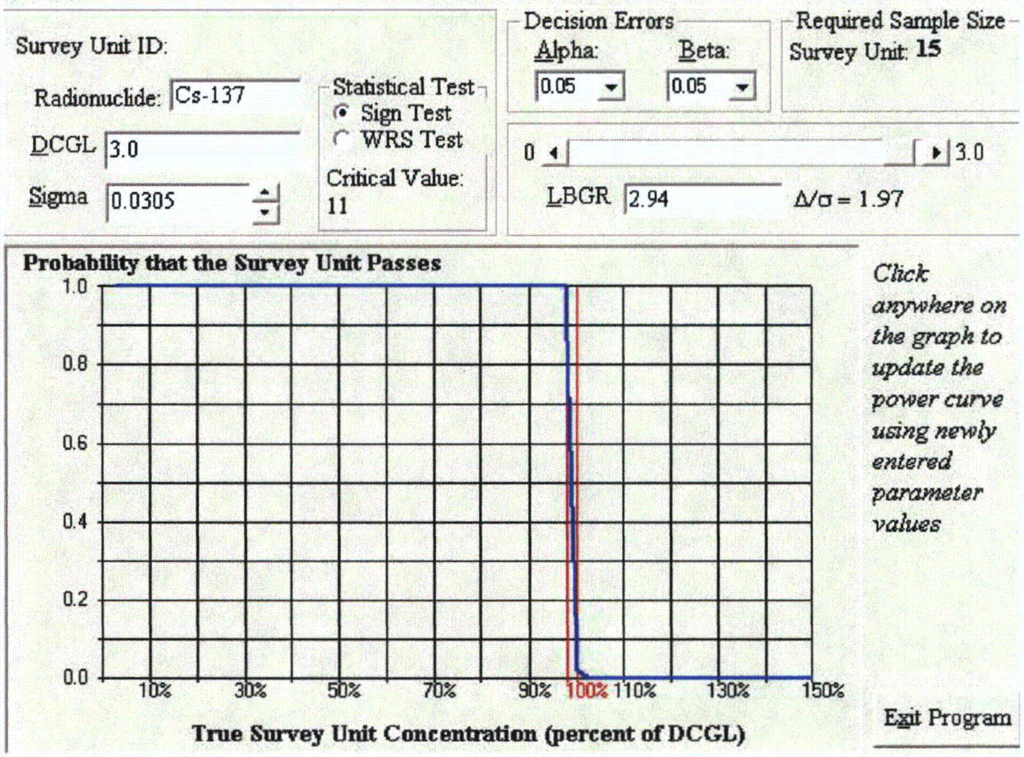


Figure 2 OOL-13-01 Retrospective Power Curve

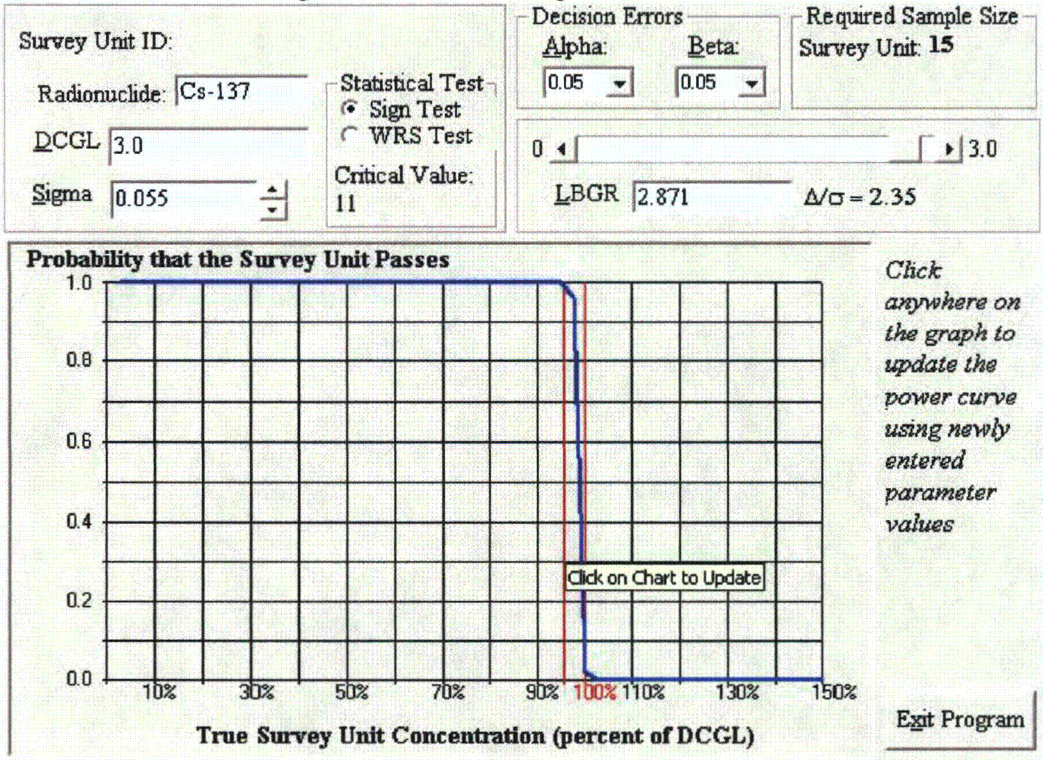


Figure 3 OOL-13-01Sum of Fractions Scatter Plot

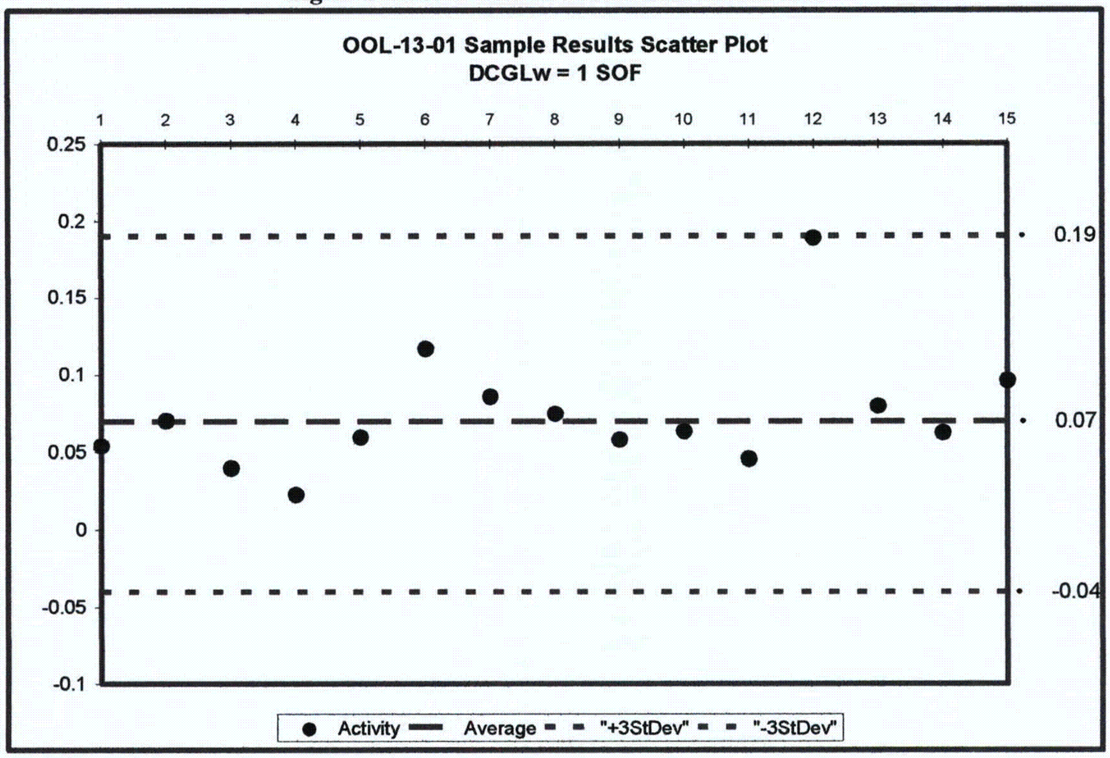


Figure 4 OOL-13-01 Sum of Fractions Quantile Plot

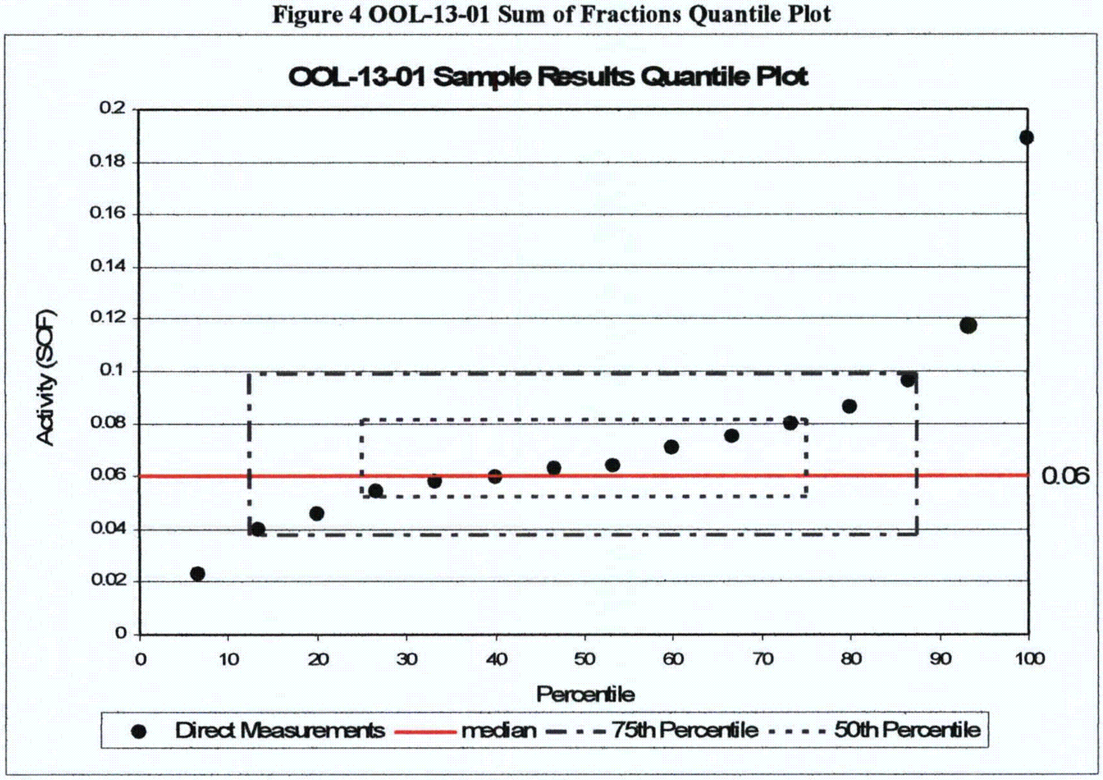
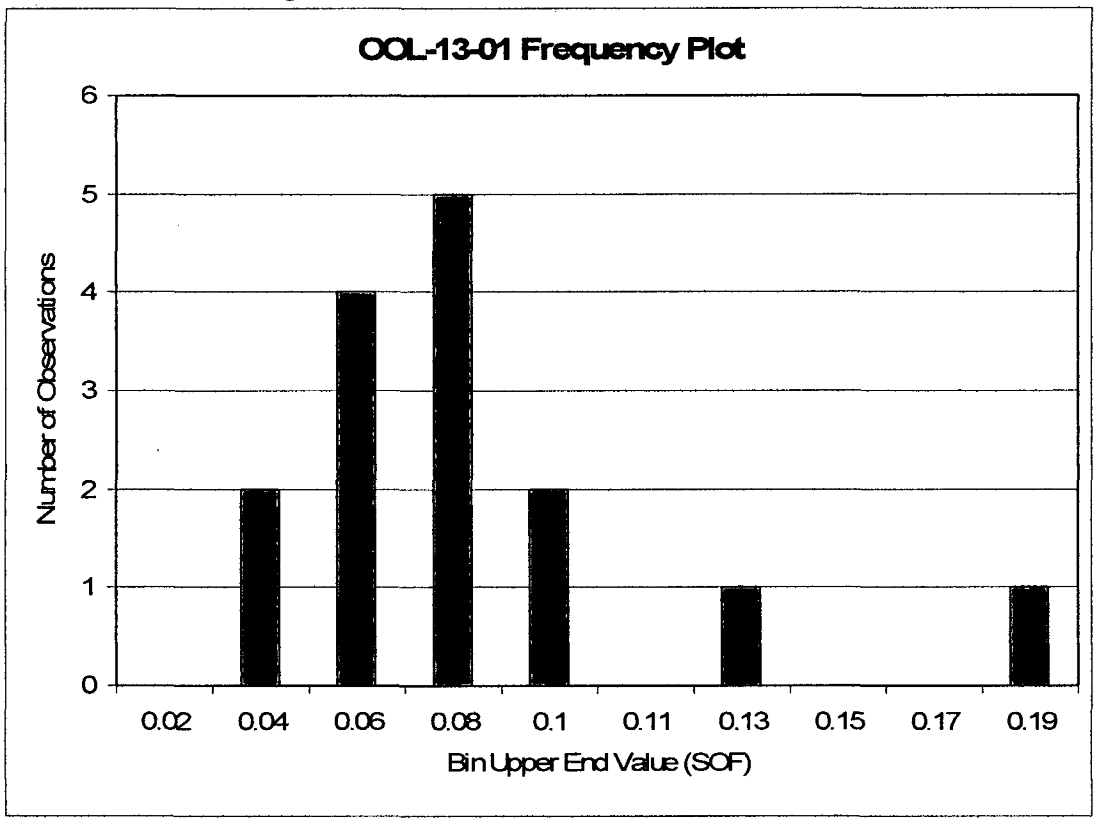
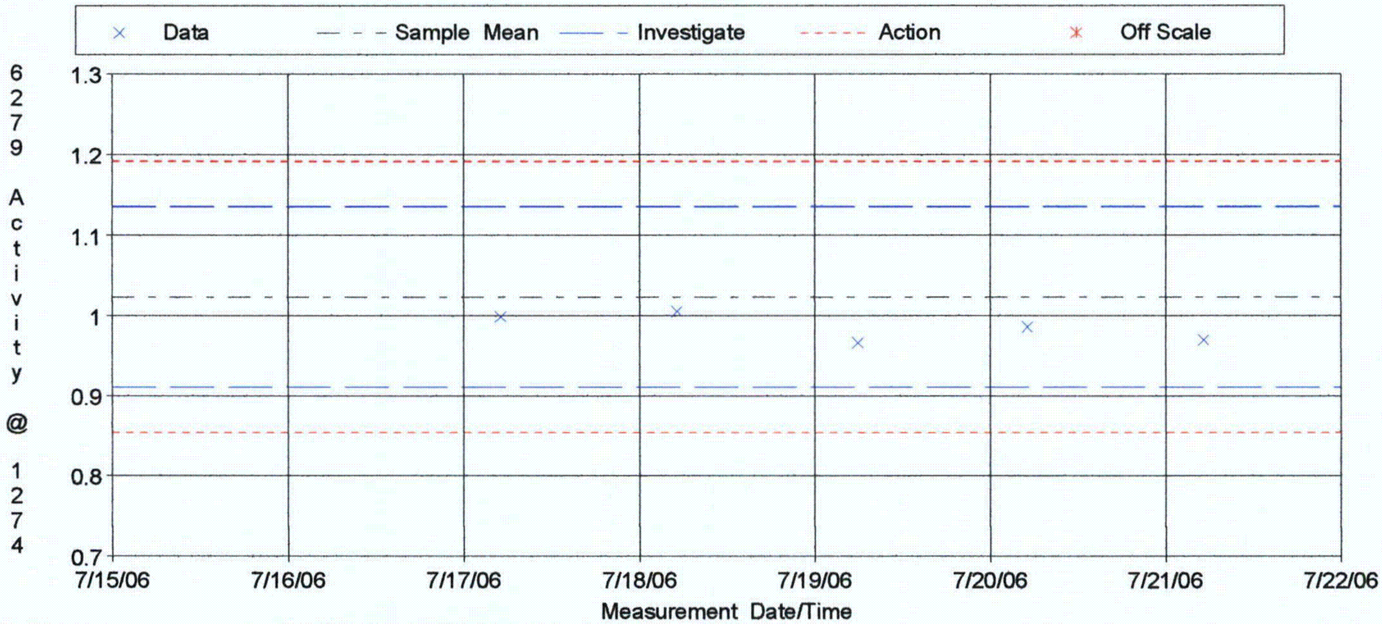


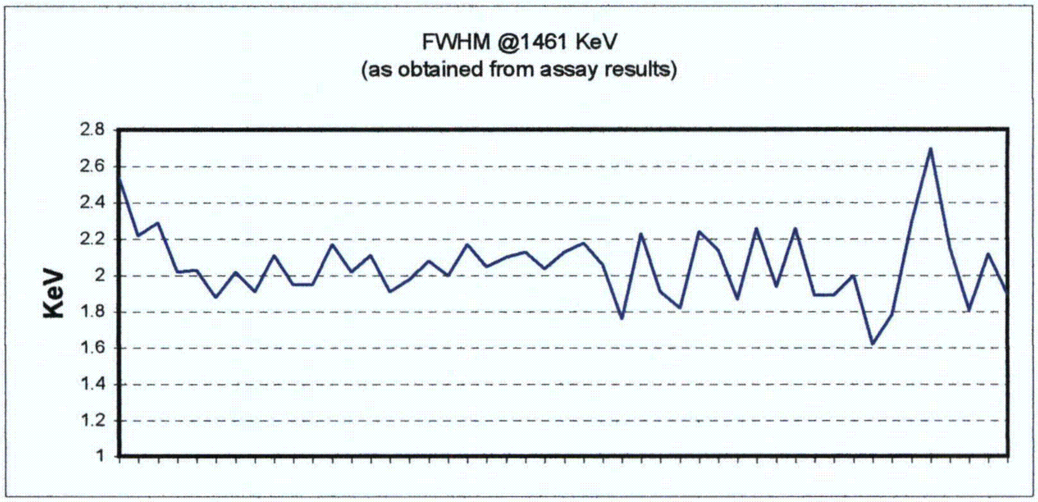
Figure 5 OOL-13-01 Sum of Fractions Frequency Plot

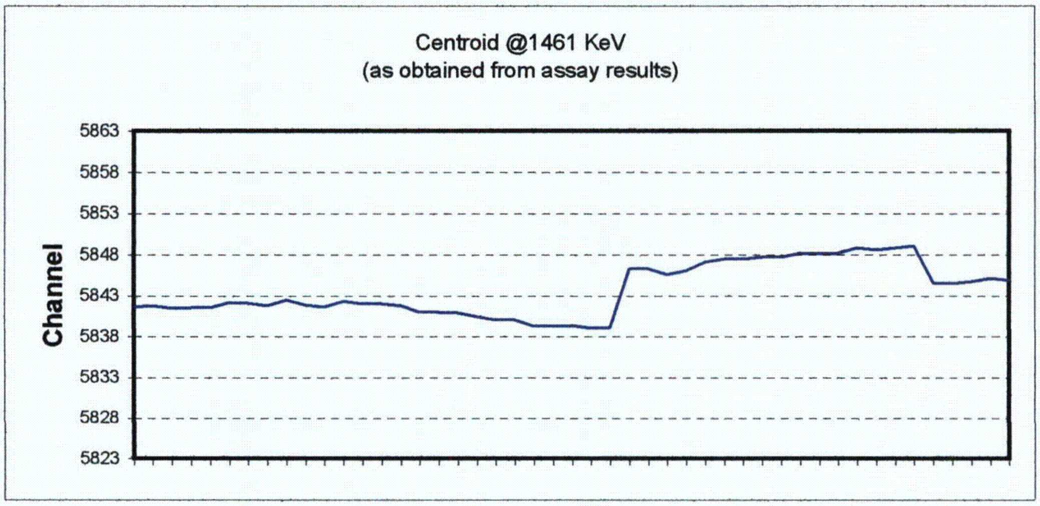


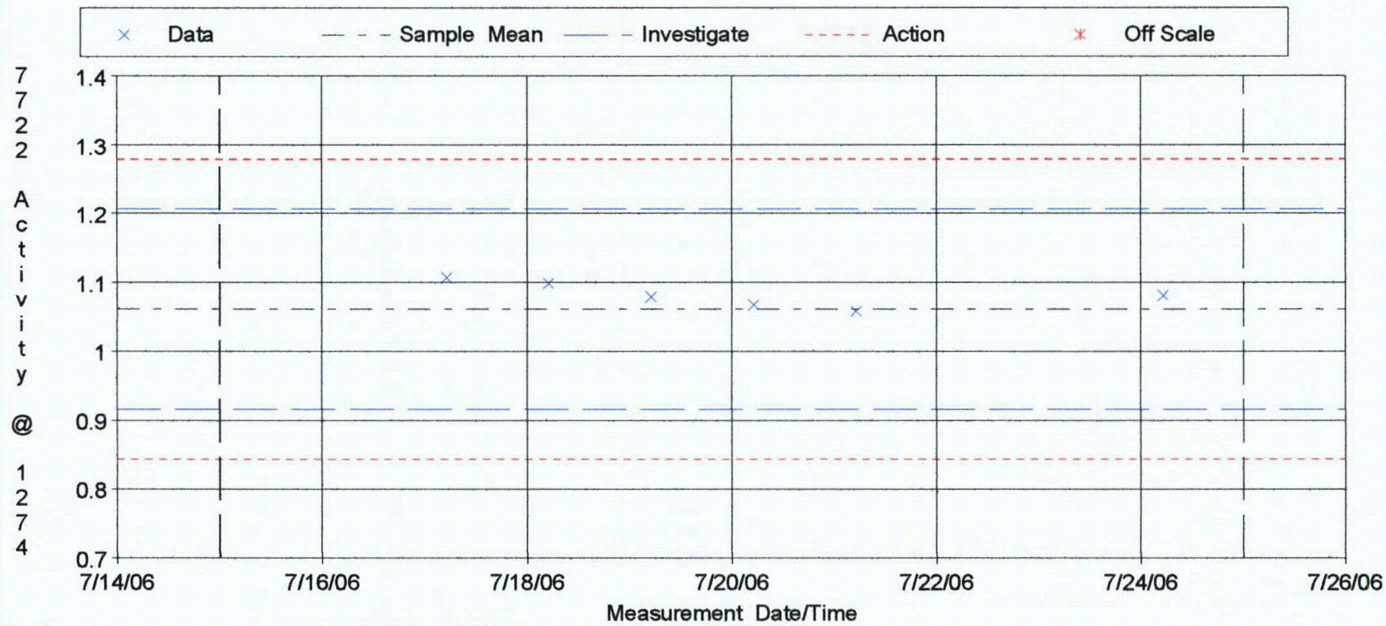


QA Filename : S:\1BlueRover (6279)\Archived QC Files\6279.QAF
Parameter Description : 6279 Activity @ 1274 keV (uCi)
Selection Dates : 7/15/06 12:00:00 AM - 7/22/06 12:00:00 AM
Sample Mean +/- Std Dev : 1.023 +/- 0.056

OOL-13
ISOCS DETECTOR 6279

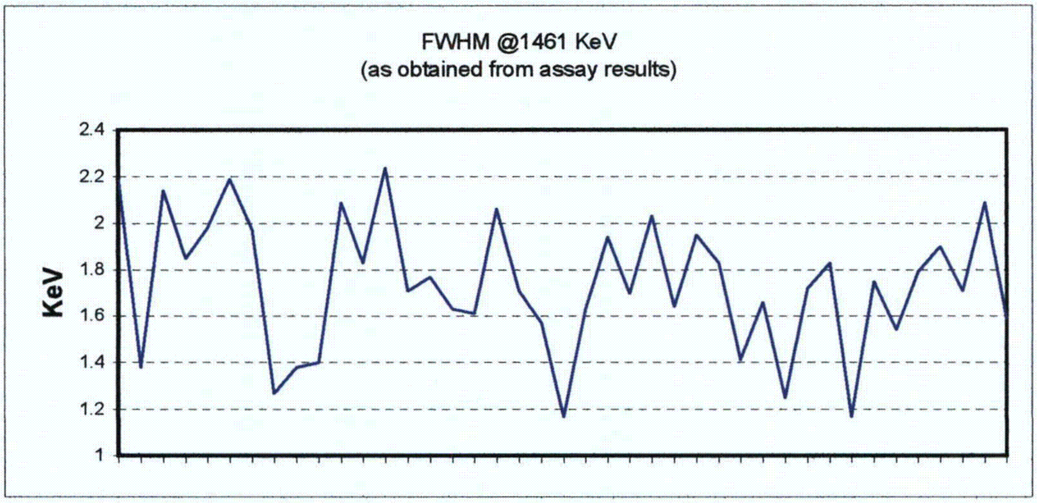


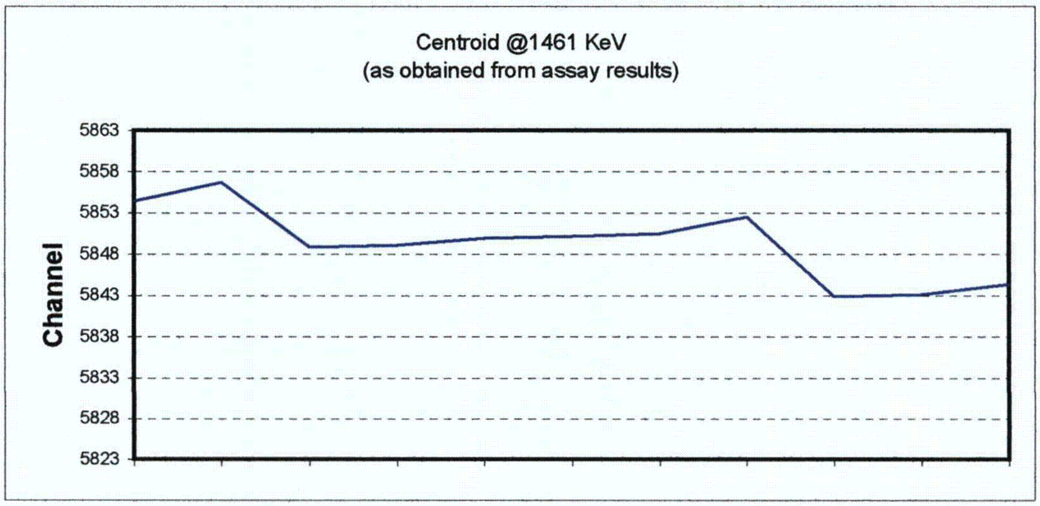


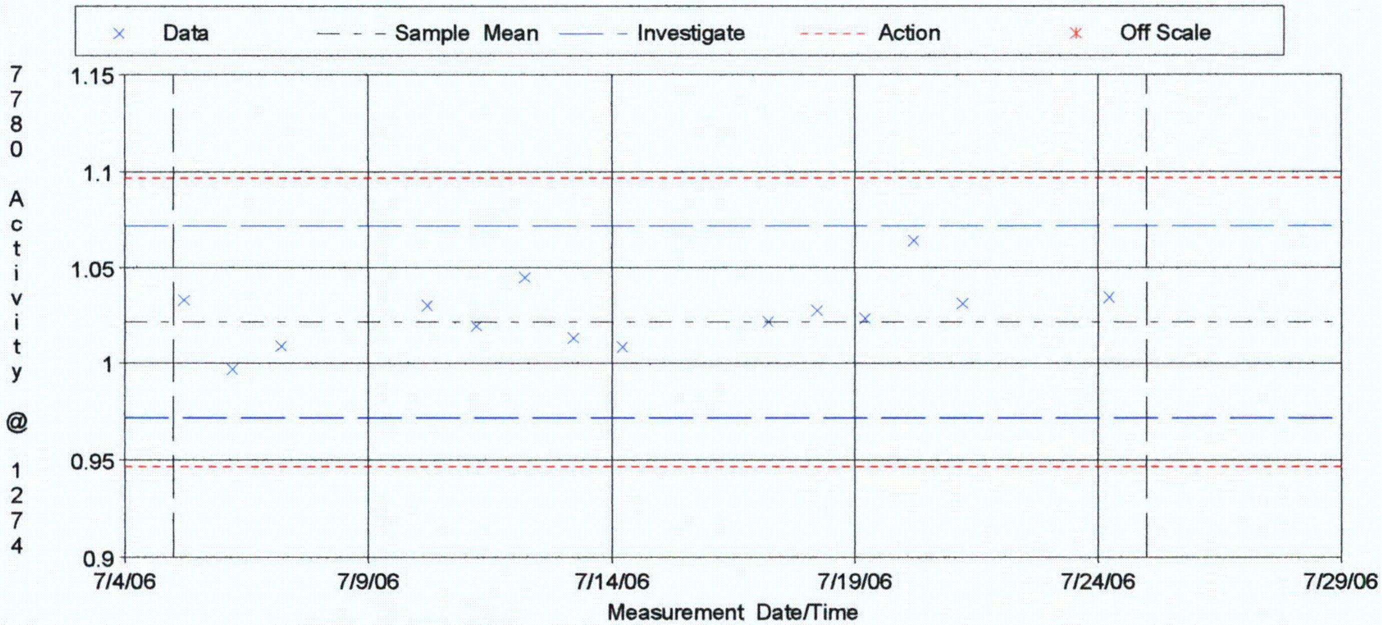


QA Filename : S:\3BrownRover (7722)\Archived QC Files\7722.QAF
Parameter Description : 7722 Activity @ 1274 keV (uCi)
Selection Dates : 7/15/06 12:00:00 AM - 7/25/06 12:00:00 AM
Sample Mean +/- Std Dev : 1.062 +/- 0.073

OOL-13
ISOCS DETECTOR 7722







QA Filename : S:\4GreenRover (7780)\Archived QC Files\7780.QAF
Parameter Description : 7780 Activity @ 1274 keV (uCi)
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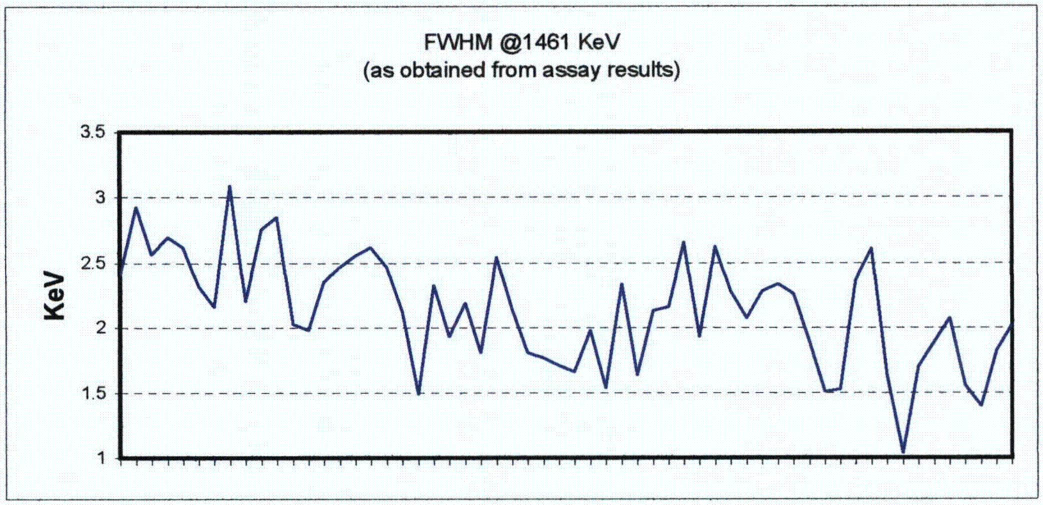
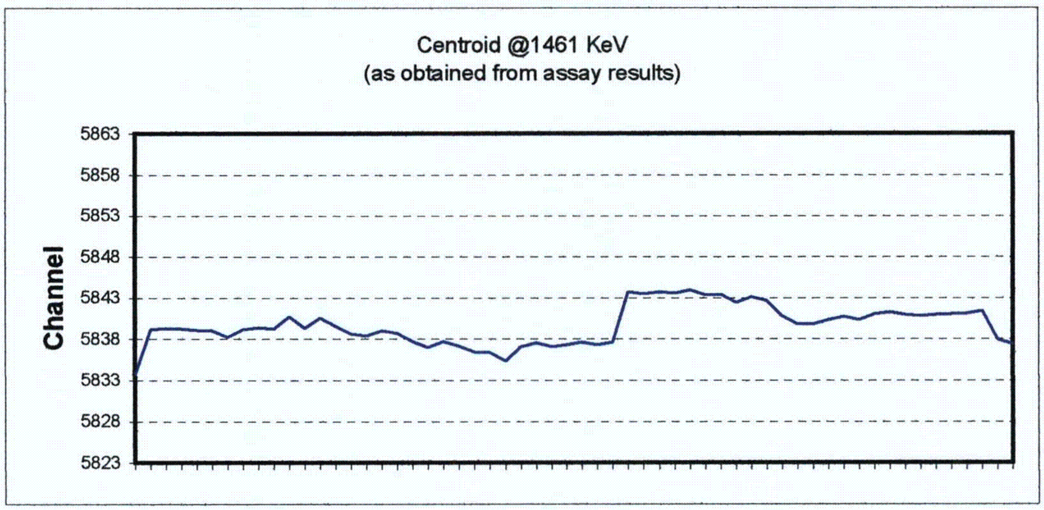
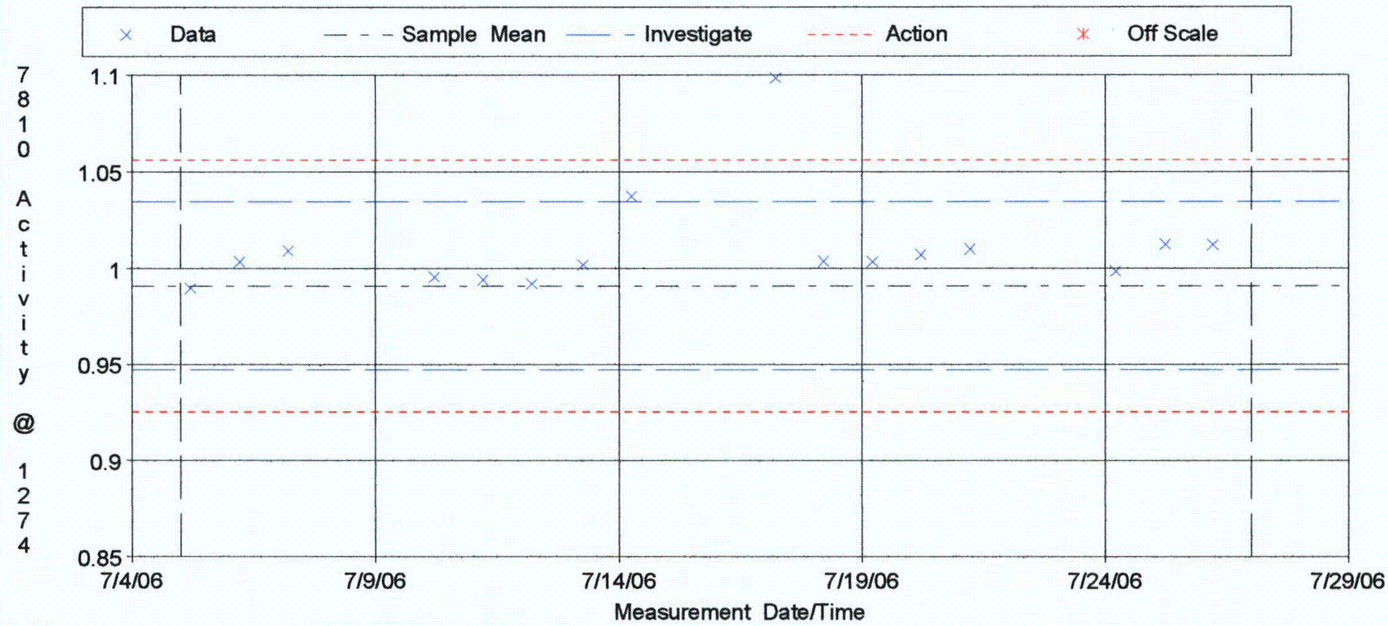
Sample Mean +/- Std Dev : 1.022 +/- 0.025

OOL-13
ISOCS DETECTOR 7780







QA Filename : S:\5YellowRover (7810)\Archived QC Files\7810.QAF
Parameter Description : 7810 Activity @ 1274 keV (uCi)
Selection Dates : 7/05/06 12:00:00 AM - 7/27/06 12:00:00 AM
Sample Mean +/- Std Dev : 0.991 +/- 0.022

OOL-13
ISOCS DETECTOR 7810