YANKEE ATOMIC ELECTRIC COMPANY Telephone (413) 424-5261

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September 18, 2006
BYR 2006-081

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-OOL16-00, the Final Status Survey Report for Survey Areas OOL-16

Dear Madam/Sir:

This letter submits YNPS-FSS-OOL16-00, Final Status Survey Report for OOL-16. 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-OOL16-00 (2 hard copies plus CDs)

cc (w/o encl):

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Yankee Nuclear Plant Station
Final Status Survey Report
For OOL-16

Yankee Atomic Electric Company

YANKEE NUCLEAR POWER STATION
FINAL STATUS SURVEY REPORT

REPORT NO.: YNPS-FSS-OOL-16-00

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

Reviewed by: _____ Date: 9/13/06
Robert Tozzie, FSS Radiological Engineer

Approved by: _____ Date: 9/13/06
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[1]	Easy-to-Detect
FSS	Final Status Survey
FSSP	Final Status Survey Plan
GPS	Global Positioning System
H_o	Null Hypothesis
HSA	Historical Site Assessment
HTD	Hard-to-Detect
ISOCS	*In-situ* Object Counting System®
LBGR	Lower Bound of the Grey Region
LTP	License Termination Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
PAB	Primary Auxiliary Building
QAPP	Quality Assurance Project Plan
QC	Quality Control
RCA	Radiological Controlled Area
RP	Radiation Protection
RSS	Reactor Support Structure
SFP	Spent Fuel Pool
VC	Vapor Container
VCC	Vertical Concrete Cask
VSP	Visual Sample Plan
YNPS	Yankee Nuclear Power Station

1.0 EXECUTIVE SUMMARY

A Final Status Survey (FSS) was performed of Survey Area OOL-16 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

Survey Unit OOL-16 consists of a single unit, OOL-16-01, known as the Furlon House Lot, approximately 2,342.4 m^2 of surface area. Survey Unit OOL-16-01 is entirely bounded by non-impacted YAEC-owned property. The only subsurface structure that traverses or connects within OOL-16-01 is the sanitary sewer system that services the Furlon House. Survey Unit OOL-16-01 contains soil that was excavated during the construction activities of the YNPS site. Because site excavated soils were deposited, low levels of radioactivity may minimally impact this area. OOL-16-01 was never part of the RCA, did not contain any radioactive systems and no decommissioning activities were performed in this area; therefore it meets the criteria for a Class 3 survey unit.

1.2 Dates(s) of Survey

Table 1 Date of Surveys

Survey Unit	Survey Start Date	Survey End Date	DQA Date
OOL-16-01	7/13/2006	7/25/2006	7/27/2006

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 20 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, hand-held survey instrument scans were performed over 80 m^2 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-16 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-16 consists of a single unit, OOL-16-01, known as the Furlon House Lot, approximately 2,342.4 m^2 of surface area. Survey Unit OOL-16-01 is entirely bounded by non-impacted YAEC-owned property. The only subsurface structure that traverses or connects within OOL-16-01 is the sanitary sewer system that services the Furlon House.

3.2 History of Survey Area

Survey Unit OOL-16-01 contains soil that was excavated during the construction activities of the YNPS site. Because site excavated soils were deposited, low levels of radioactivity may minimally impact this area. OOL-16-01 was never part of the RCA, did not contain any radioactive systems and no decommissioning activities were performed in this area, however some roll off containers were staged in this area.

3.3 Division of Survey Area into Survey Units

OOL-16 has a single Survey Unit, OOL-16-01 which is a Class 3 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

The final status survey of OOL-16-01 was performed between the dates of 7-13-06 and 7-25-06.

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 indicated no other LTP-specified radionuclides warrant consideration in the OOL-16 Survey Area, however, the soil samples for this Survey Area were evaluated for all LTP listed nuclides.

4.1.3 Scoping & Characterization

The characterization data in the HSA was not sufficient to support FSS planning. Two characterization soil samples were collected from this Survey Unit. The results were consistent with historical use information in that no plant-related radionuclide was identified in either sample. Survey Unit OOL-18-01, the Monroe Hill Lot, was utilized in the same manner as OOL-16-01, as a staging area for shipments. 13 additional characterization samples were collected from OOL-18-01 to support this FSS. All FSS soil samples collected in OOL-16 were analyzed for the LTP-listed gamma-emitting radionuclides, and 5% of the FSS soil samples were sent to an independent laboratory for complete analyses (HTD nuclides and TRUs).

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-16 is identified as a Class 3 Area.

4.3 Remedial Actions and Further Investigations

No remedial actions or investigations were performed.

4.4 Unique Features of Survey Area

Survey Area OOL-16 has no unique features; it is an open land area containing soils.

4.5 ALARA Practices and Evaluations

An ALARA evaluation was developed for OOL-16-01 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-16 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-16 Design Parameters

Survey Unit	Design Parameter	Value	Basis
OOL-16-01	Survey Unit Area	2342 m2	Class 3, Soil, no restrictions
	Number of Direct Measurements	15 (calculated) + 5 (added) Total: 20	α (Type I) = 0.05 β (Type II) = 0.05 σ: 0.0327 Relative Shift: 2 DCGLw: 3 LBGR: 2.9346
	Critical Value	14 for Sign test.	(20/2)+(1.645/2)*Square Root (20)
	Gridded Sample Area Size Factor	Class 3: N/A	No grid in Class 3 area
	Sample Grid Spacing:	No Grid	No grid in Class 3 area, random locations
	Direct Measurement Investigation Level	> 50% DCGLw	Class 3 Area: > 50% DCGLw
	Scanning Coverage Requirements	Judgmental	Class 3 Soil Area: Judgmental
	Scan Investigation Level	> Background	Class 3 Area: Detectable over background

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-16 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, 5 additional samples were added to the statistical measurements, no biased, 1 recount, and 2 split samples were also collected.

The direct measurement sampling locations were selected with a random pattern and 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 Survey Units in OOL-16.

Table 4 FSS Activity Summary for OOL-16 Survey Units

Survey Unit	Date	Activity
OOL-16-01	5-22-06	Performed walk-down of Survey Unit
	7-13-06	Established Isolation and Controls
	7-13-06	Performed Job Hazard Analysis
	7-13-06	Performed Unit Classification
	7-13-06	Performed Sample Quantity Calculations, established DQOs
	7-13-06	Generated FFS Sample Plans
	7-13-06 to 7-25-06	Initiated Scans, and Direct measurements.
	7-27-06	Performed DQA, FSS Complete

5.3 Surveillance Surveys

5.3.1 Periodic Surveillance Surveys

Upon completion of the FSS of Survey Area OOL-16, 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 resurvey was performed.

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-16-01 had no 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 Units exceeds the release criteria) is rejected.

Table 5 Direct Measurement Summary

Sample Description	Activity (SOF)
OOL-16-01-001-F	5.14E-02
OOL-16-01-002-F	6.74E-02
OOL-16-01-003-F	7.56E-02
OOL-16-01-004-F	5.84E-02
OOL-16-01-005-F	3.82E-02
OOL-16-01-006-F	3.67E-02
OOL-16-01-007-F	2.43E-02
OOL-16-01-008-F	3.07E-02
OOL-16-01-009-F	4.65E-02
OOL-16-01-010-F	2.81E-02
OOL-16-01-011-F	8.71E-02
OOL-16-01-012-F	1.67E-02
OOL-16-01-013-F	4.65E-02
OOL-16-01-014-F	4.01E-02
OOL-16-01-015-F	3.89E-02
OOL-16-01-016-F	1.15E-01
OOL-16-01-017-F	5.02E-02
OOL-16-01-018-F	4.17E-02
OOL-16-01-019-F	3.56E-02
OOL-16-01-020-F	5.02E-02

Maximum Sum of Fractions	1.15E-01
Standard Deviation	2.31E-02

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-16-01. 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 displayed some asymmetry in the lower quartile due to the number of lower values present. 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 E-600 w/SPA-3 was in accordance with DP-8535,"*Setup and Operation of the Eberline E-600 Digital Survey Instrument,*" with QC checks preformed in accordance with DP-8540, "*Operation and Source Checks of Portable Friskers.*" Instrument response checks were performed prior to and after use for the E-600 w/SPA-3. All instrumentation involved with the FSS of OOL-16 satisfied the above criteria for the survey. QC records are found in Attachment C.

6.2 Split Samples and Recounts

One recount and two split 'QC" samples were 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-16.

7.0 CONCLUSION

The FSS of OOL-16 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_o) is rejected.

OOL-16 meets the objectives of the Final Status Survey.

Based upon the evaluation of the data acquired for the FSS, OOL-16 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

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GENERAL SECTION	
Survey Area No.: OOL-16	Survey Unit No.: 01
Survey Unit Name: Furlon House Lot	
FSSP Number: YNPS-FSSP-OOL-16-01-01	

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. ☑ Refer to 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. ☐

1.7 Classification: CLASS 1 ☐ CLASS 2 ☐ CLASS 3 ☑

DATA QUALITY OBJECTIVES (DQO)

1.0 State the problem:

Survey Unit OOL-16-01 consists of the Furlon House Lot, approximately 2342.4 m^2 in surface area. Survey Unit OOL-16-01 is entirely bounded by non-impacted YAEC-owned property. The only subsurface structure that traverses or connects within OOL-16-01 is the sanitary sewer system that services the Furlon House. Survey Unit OOL-16-01 contains soil that was excavated during the construction activities of the YNPS site. Because site excavated soils were deposited, low levels of radioactivity may minimally impact this area. OOL-16-01 was never part of the RCA, did not contain any radioactive systems and no decommissioning activities were performed in this area; therefore it meets the criteria for a Class 3 survey unit. 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 the release criteria? Alternative actions may include no action, investigation, resurvey, remediation and reclassification.

3.0 Identify the inputs to the decision:

Sample media:	Soil
Types of measurements:	Soil samples and gamma scans
Radionuclides-of-concern:	Cs^{137}

The characterization data in the HSA is not sufficient to support FSS planning. Two characterization soil samples were collected from this relatively small survey unit. The results were consistent with historical use information in that no plant-related radionuclide was identified in either sample. The characterization samples were not analyzed for hard-to-detect (HTD) nuclides such as H^3, Sr^{90}, and TRUs. However, given that the gamma analysis did not identify any plant-related radioactivity, plant-related HTD nuclides are not expected to be present in absence of plant-related gamma-emitters, which were historical more abundant in all the plant waste streams. Survey Unit OOL-18-01 Monroe Hill Lot was utilized to store Low-level Rad Waste containers in the same manner as OOL-16-01; therefore 13 additional characterization samples from OOL-18 taken on 6/5/06 were used to support this plan. Nevertheless, all FSS soil samples will be analyzed for the LTP-listed gamma-emitting radionuclides, and at least 5% of the FSS soil samples will be sent to an independent laboratory for complete analyses (HTD nuclides and TRUs).

Applicable DCGL:		The DCGLs applied under this survey plan correspond to annual doses of 8.73 mrem/y (the 10-mrem/y DCGL adjusted for the dose contributions from sub-surface concrete structures and tritium in ground water).			
Nuclide	DCGL (pCi/g)	Nuclide	DCGL (pCi/g)	Nuclide	DCGL (pCi/g)
Co^{60}	1.4E+00	Eu^{152}	3.6E+00	Sr^{90}	6.0E-01
Nb^{94}	2.5E+00	Eu^{154}	3.3E+00	Tc^{99}	5.0E+00
Ag^{108m}	2.5E+00	Eu^{155}	1.4E+02	Pu^{238}	1.2E+01
Sb^{125}	1.1E+01	H^3	1.3E+02	$Pu^{239/240}$	1.1E+01
Cs^{134}	1.7E+00	C^{14}	1.9E+00	Pu^{241}	3.4E+02
Cs^{137}	3.0E+00	Fe^{55}	1.0E+04	Am^{241}	1.0E+01
		Ni^{63}	2.8E+02	$Cm^{243/244}$	1.1E+01

The presence of all LTP-listed radionuclides (gamma-emitters, HTD beta-emitters, and TRUs) in the soil will be evaluated under this survey plan. The YNPS Chemistry Dept. will analyze each FSS soil sample for all LTP-listed gamma-emitting nuclides, except $Cm^{243/244}$. In addition, 5% of FSS soil samples will be sent to an independent laboratory for analyses of gamma-emitters, HTD beta-emitting radionuclides, and alpha-emitting radionuclides, which will include $Cm^{243/244}$.

Survey Design / Release Criteria

Classification:	Class 3
Average Cs^{137} concentration:	0.0293 pCi/g
Standard deviation Cs^{137} (σ):	0.0327 pCi/g
DCGL:	3.0 pCi/g
Surrogate DCGL:	N/A (a surrogate DCGL will not be used)
LBGR:	2.9346 (Initial LBGR: 1.5)
Number of Samples	15 (calculated) + 5 (added), for a total of 20 samples. (+ 2 QC)
Survey Unit Area:	2342.4m^2

Grid Area (A/N):	No grid.
Investigation Level for soil samples:	• >$DCGL_W$ for any LTP listed nuclide. • Sum of DCGL fractions >1.0.
Scan Coverage:	≥10% of the surface area using SPA-3.
SPA-3 Gamma Scan Coverage:	SPA-3 scans will be performed over an approximate 1m by 1m area surrounding each soil sample. At least three judgmental SPA-3 scans will be performed in Survey Unit OOL-16-01, each of which will cover an area of approximately 10 m^2 (1m in width and 10m in length). These scans will be performed in the parking lot area in the approximate location shown on the attached map.
Investigation Level for SPA-3 Scans:	Reproducible indication above background using SPA-3 and audible discrimination. The expected background range for SPA-3 scans is between 4,000 cpm and 10,000 cpm.
Radionuclides for analysis:	All LTP nuclides with the focus on Cs^{137}.
MDCs for gamma analysis of soil samples:	Nuclide — 10% - 50% of DCGL (pCi/g) Co^{60} — 1.4E-01 - 7.0E-01 Nb^{94} — 2.5E-01 - 1.3E+00 Ag^{108m} — 2.5E-01 - 1.3E+00 Sb^{125} — 1.1E+00 - 5.6E+00 Cs^{134} — 1.7E-01 - 8.7E-01 Cs^{137} — 3.0E-01 - 1.5E+00 Eu^{152} — 3.6E-01 - 1.8E+00 Eu^{154} — 3.3E-01 - 1.7E+00 Eu^{155} — 1.4E+01 - 6.9E+01 The desired MDCs in the laboratory analyses of FSS soil samples will be the 10% DCGL values. If it is impractical to achieve those, the 50% DCGL values must be achieved in the laboratory analyses of the FSS soil samples.
MDCs for HTD nuclide:	Nuclide — 10% - 50% DCGL (pCi/g) H^3 — 1.3E+01 - 6.4E+01 C^{14} — 1.9E-01 - 9.7E-01 Fe^{55} — 1.0E+03 - 5.1E+03 Ni^{63} — 2.8E+01 - 1.4E+02 Sr^{90} — 6.0E-02 - 3.0E-01 Tc^{99} — 5.0E-01 - 2.5E+00 Pu^{238} — 1.2E+00 - 5.8E+00 Pu^{239} — 1.1E+00 - 5.3E+00 Pu^{241} — 3.4E+01 - 1.7E+02 Am^{241} — 1.0E+00 - 5.1E+00 Cm^{243} — 1.1E+00 - 5.6E+00 The MDC values for difficult to detect nuclides will be conveyed to the outside laboratory via the sample chain-of-custody form DPF-8823.1 which will accompany the soil samples.
MDCR for SPA-3:	The accompanying MCDR/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. Note: Any radiation levels detected above background in a Class 3 survey unit should be investigated. A Class 3 survey unit is expected to

have minimal contamination and not expected to have any hot spots. MARSSIM recommends scanning in a Class 3 survey unit be performed to verify proper classification. Scan MDC is not tied to the $DCGL_W$ in a Class 3 survey area and therefore scanning to levels above background is a measure of due-diligence on the appropriateness of the classification. (http://www.orau.gov/ddsc/expert/answers/marssim.htm question/answer dated 2/4/2003)

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.
- Two QC split sample will be collected (note: this exceeds the DP-8852 requirements).
- YNPS Chemistry Lab will perform a QC Recount on at least one soil sample in accordance with DP-8852 requirements.

4.0 Define the boundaries of the survey:

Boundaries of Survey Unit OOL-16-01 are as shown on the attached map. The Furlon House Parking Lot is bounded on the east side by Monroe Hill Road, Lord Brook to the west and a wooded area to the north. The Furlon House footprint occupies the southwestern corner of the survey unit.

The survey will be performed under appropriate weather conditions (as defined by instrumentation limitations and human tolerance). Surveys may be performed on any shift of work.

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 LTP-listed nuclides are below the 8.73 mrem/year DCGLs and the sum of fractions of LTP-listed nuclides are below unity, then reject the null hypothesis (i.e., Survey Unit OOL-16-01 meets the release criteria).

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

(c) If the average concentration of any LTP-listed nuclide exceeds its respective $DCGL_w$ or the average sum of fractions of LTP-listed nuclides exceeds unity, then accept the null hypothesis (i.e., Survey Unit OOL-16-01 fails to meet the release criteria).

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-16-01 exceeds the release criteria.
Probability of type I error:	0.05
Probability of type II error:	0.05
LBGR:	The applicable soil (8.73-mrem/y) DCGL ÷ 2 LBGR = 2.9346 (Initial LBGR: 1.5)

7.0 Optimize Design:

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

Number and Location of Samples: 20 soil samples will be collected in randomly selected locations (refer to accompanying DPF-8853.1).

GENERAL INSTRUCTIONS

1. Where possible, measurement locations will be identified using GPS in accordance with DP-8859. Each location will be marked to assist in identifying the location. Any locations that are not suitable for soil sampling will be relocated to the nearest suitable location and documented in the field log in accordance with DP-8856.
2. Soil samples will be collected in accordance with DP-8120.
3. Chain-of-Custody forms will be used in accordance with DP-8123 for all soil samples sent to an off-site laboratory. The required MDCs for the analyses performed by the off-site laboratory will be communicated to the Lab via an attachment to the Chain-of-Custody form.
4. All soil samples will be received and prepared in accordance with DP-8813. Note: Split samples to be sent to an off-site lab will not be dried prior to counting on site or shipping.
5. Survey instrument: Operation of the E-600 w/SPA-3 will be 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. All SPA-3 scans will be performed with the audible feature activated. FSS Technicians 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.
7. The job hazards associated with the survey described in this package are addressed in the accompanying Job Hazard Assessment (JHA) for OOL-16-01.
8. All personnel participating in this survey shall be trained in accordance with DP-8868.

SPECIFIC INSTRUCTIONS

1. All designated measurement locations will be identified by GPS per DP-8859 or by use of reference points 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. A detailed description of the alternate location will be recorded on form DPF-8856.2, the survey unit map will be annotated appropriately, and the alternate location will be conspicuously marked 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.
2. Sample Requirements:

   Collect 20 random 1-liter soil samples in accordance with DP-8120. Two of the 20 random soil samples will be analyzed as a QC split sample to fulfill the QC requirement of DP-8852. The same QC split samples 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:

FSS soil samples:	OOL-16-01-001-F through OOL-16-01-020-F corresponding to FSS sample locations 001 through 020.
Biased soil samples:	None.
QC split samples:	OOL-16-01-008-F-S and OOL-16-01-017-F-S to be designated as QC split samples.

	split samples.
Recount samples:	OOL-16-01-006-F-RC is to be counted twice on site. The results will be compared in accordance with DP-8864.

4. Sample Analysis:

   - Gamma analysis will be performed on all soil samples. 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.
   - YNPS Chemistry will analyze OOL-16-01-001-F through OOL-16-01-020-F for gamma-emitting nuclides.
   - YNPS Chemistry will analyze OOL-16-01-008-F-S and OOL-16-01-017-F-S for gamma-emitting nuclides prior to being sent to the off-site laboratory. These samples will be analyzed for gamma-emitting nuclides and HTDs as collected from the field (i.e. without drying) at the off-site laboratory. Ensure that the lid to the 1-liter Marinelli container is secured and sealed with electrical tape to prevent loss of moisture during shipping.
   - YNPS Chemistry will analyze OOL-16-01-006-F as a sample recount. The recounted sample will possess the naming convention OOL-16-01-006-F-RC.
   - On-site gamma analysis of the FSS samples shall achieve the MDC values stated in the DQO section of this plan. The MDCs will be communicated to the laboratory using an attachment to the Chain-of-Custody form.

5. If the results of any FSS sample (statistical points) analysis exceed 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).

   - Scan a 1-meter radius footprint around the sample location with a SPA-3 in rate-meter mode moving the detector at a speed of 0.25m or less per second, keeping the probe at a distance of approximately 3" from the surface and following a serpentine path that includes at least 3 passes across each square meter. 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 of the highest identified activity areas:
     - Perform and record a 1-minute scaler mode SPA-3 measurement. Designate the reading as "OOL-16-01-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-16-01-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.

6. If the results of an scan exceed 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).

- Scan the footprint with a SPA-3 in rate-meter mode moving the detector at a speed of 0.25m or less per second, keeping the probe at a distance of approximately 3" from the surface and following a serpentine path that includes at least 3 passes across each square meter.
- 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 areas:
  - Perform and record a 1-minute scaler mode SPA-3 measurement. Designate the reading as "OOL-16-01-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-16-01-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.

N. Tozzo

Prepared by _____ Date 7/13/06
FSS Radiological Engineer

Reviewed by _____ Date 7-13-2006
FSS Radiological Engineer

Approved by _____ Date 7/13/06
FSS Project Manager

SPA-3 Scan Tables

Max Background

BKG(cpm)	MDCR	MDC(fDCGL)
4,000	639	1.13E+00
5,000	715	1.27E+00
6,000	783	1.39E+00
7,000	845	1.50E+00
8,000	904	1.60E+00
9,000	959	1.70E+00
10,000	1,011	1.79E+00
11,000	1,060	1.88E+00
12,000	1,107	1.96E+00
13,000	1,152	2.04E+00
14,000	1,196	2.12E+00
15,000	1,238	2.19E+00
16,000	1,278	2.27E+00
17,000	1,318	2.34E+00
18,000	1,356	2.40E+00
19,000	1,393	2.47E+00
20,000	1,429	2.53E+00
21,000	1,464	2.60E+00
22,000	1,499	2.66E+00
23,000	1,533	2.72E+00
24,000	1,565	2.78E+00
25,000	1,598	2.83E+00
26,000	1,629	2.89E+00
27,000	1,660	2.94E+00
28,000	1,691	3.00E+00
30,000	1,750	3.10E+00
32,000	1,808	3.21E+00
34,000	1,863	3.30E+00
36,000	1,917	3.40E+00
38,000	1,970	3.49E+00
40,000	2,021	3.58E+00

YNPS-FSSP-OOL-16-01-00
Attachment 2

DCGL MDC Table

Nuclide	Soil DCGL (pCi/g)	[illegible] DCGL (pCi/g)	[illegible] DCGL (pCi/g)	[illegible]
Co-60	1.4E+00	1.4E-01	7.0E-01	ETD
Nb-94	2.5E+00	2.5E-01	1.3E+00	ETD
Ag-108m	2.5E+00	2.5E-01	1.3E+00	ETD
Sb-125	1.1E+01	1.1E+00	5.6E+00	ETD
Cs-134	1.7E+00	1.7E-01	8.7E-01	ETD
Cs-137	3.0E+00	3.0E-01	1.5E+00	ETD
Eu-152	3.6E+00	3.6E-01	1.8E+00	ETD
Eu-154	3.3E+00	3.3E-01	1.7E+00	ETD
Eu-155	1.4E+02	1.4E+01	6.9E+01	ETD
Am-241	1.0E+01	1.0E+00	5.1E+00	ETD
H-3	1.3E+02	1.3E+01	6.4E+01	HTD
C-14	1.9E+00	1.9E-01	9.7E-01	HTD
Fe-55	1.0E+04	1.0E+03	5.1E+03	HTD
Ni-63	2.8E+02	2.8E+01	1.4E+02	HTD
Sr-90	6.0E-01	6.0E-02	3.0E-01	HTD
Tc-99	5.0E+00	5.0E-01	2.5E+00	HTD
Pu-238	1.2E+01	1.2E+00	5.8E+00	HTD
Pu-239	1.1E+01	1.1E+00	5.3E+00	HTD
Pu-241	3.4E+02	3.4E+01	1.7E+02	HTD
Cm-243	1.1E+01	1.1E+00	5.6E+00	HTD

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:		Date: 10-7-04
Reviewer:	James R. Hummer	Date: 10/7/04
Approver (Cognizant Manager):		Date: 10/7/04

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Appendix

1.0 Executive Summary:

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

2.0 Introduction:

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

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

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

3.0 Calibration Sources:

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

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

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

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

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

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

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

4.0 Efficiency Determination:

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

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

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

4.1 Alpha and Beta Instrument Efficiency (ε_i):

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

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

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

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

Table 4.1
Instrument Efficiencies (ε_i)

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

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

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

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

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

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

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

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

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

Table 4.3
Source Efficiencies as listed in ISO 7503-1

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

APPENDIX A

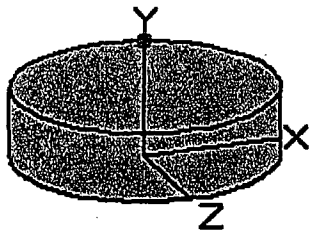
MicroShield v6.02 (6.02-00253)

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

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

Source Dimensions:

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



Dose Points

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

Shields

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

Source Input : Grouping Method - Actual Photon Energies

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

Buildup : The material reference is - Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

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

APPENDIX B

Co-60

Microsoft Excel Ei Calculation Sheet

	Energy MeV	Energy kev	Exposure Rate (mR/hr /pCi/g)	Energy Response (cpm/mR/h)	Ei (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
				(Ei) Total:	**379**

APPENDIX C

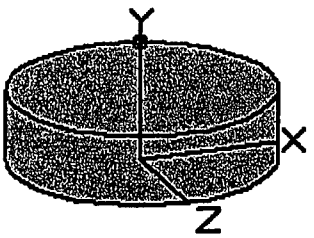
MicroShield v6.02 (6.02-00253)

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

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

Source Dimensions:

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



Dose Points

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

Shields

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

Source Input : Grouping Method - Actual Photon Energies

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

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

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

APPENDIX D

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

APPENDIX E

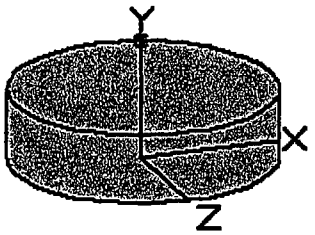
MicroShield v6.02 (6.02-00253)

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

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

Source Dimensions:

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



Dose Points

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

Shields

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

Source Input : Grouping Method - Actual Photon Energies

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

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

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

APPENDIX F

Ag-108m
Microsoft Excel E Calculation Sheet

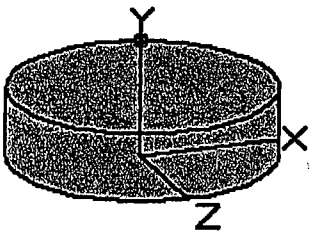
	Energy MeV	Energy keV	Exposure Rate (mR/hr / µCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
3	0.0028	3	1.39E-07		0
3	0.003	3	1.66E-08		0
21	0.021	21	3.01E-07		0
21	0.0212	21	5.74E-07		0
22	0.022	22	8.83E-09		0
22	0.0222	22	1.69E-08		0
24	0.0238	24	2.03E-07		0
25	0.0249	25	6.05E-09		0
30	0.0304	30	5.01E-13	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
0		0			0
				(Ei) Total:	637

APPENDIX G

MicroShield v6.02 (6.02-00253)

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

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**

Sb-125

Energy MeV	Energy keV	Exposure Rate (mR/h-1pCi/g)	Energy Response (cpm/mR/h)	E_i (cpm/pCi/g)
4	0.0036	4	1.43E-07	6618312	0
27	0.0272	27	2.69E-07	510290	0
28	0.0275	28	5.07E-07	554334	0
31	0.031	31	2.00E-07	1219281	0
36	0.0355	36	1.17E-07	2418948	0
117	0.117	117	5.78E-08	9167000	1
159	0.159	159	2.51E-08	8917000	0
173	0.1726	173	7.33E-08	6859000	1
176	0.1763	176	2.87E-06	6192600	18
204	0.2041	204	1.64E-07	6011300	1
208	0.2081	208	1.26E-07	4073050	1
228	0.2279	228	7.67E-08	3110500	0
321	0.321	321	3.63E-07	3000500	1
380	0.3804	380	0.000001564	2348000	4
408	0.408	408	2.047E-07	2155800	0
428	0.4279	428	0.0000347	2083165	72
444	0.4435	444	3.709E-07	2026225	1
463	0.4634	463	0.0000133	1953590	26
601	0.6006	601	0.0000293	1452810	43
607	0.6066	607	0.000008355	1430910	12
636	0.6359	636	0.00001967	1323965	26
671	0.6714	671	0.000003311	1194390	4
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E_i) Total:	**210**

APPENDIX I

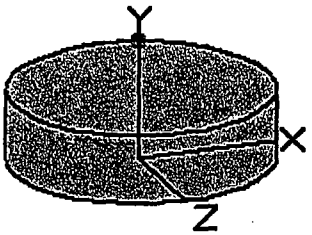
MicroShield v6.02 (6.02-00253)

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

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

Source Dimensions:

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



Dose Points

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

Shields

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

Source Input : Grouping Method - Actual Photon Energies

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

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

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

Cs-134
Microsoft Excel E Calculation Sheet

Energy MeV	Energy keV	Exposure Rate (mR/hr / pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
5	0.0045	5	2.58E-09	1,406,947	0
32	0.0318	32	5.32E-09	1,505,273	0
32	0.0322	32	3.94E-09	2,696,122	0
36	0.0364	36	4.16E-09	3,637,000	0
277	0.2769	277	2.61E-08	1,910,155	4
475	0.4753	475	1.92E-06	1,589,320	21
563	0.5632	563	1.30E-05	1,567,055	38
569	0.5693	569	2.42E-05	1,437,845	233
605	0.6047	605	1.62E-04	998,082	182
796	0.7958	796	1.82E-04	939,149	18
802	0.8019	802	1.87E-05	752,085	2
1039	1.0386	1,039	2.70E-06	664,161	4
1168	1.1679	1,168	5.35E-06	573,136	6
1365	1.3652	1,365	1.02E-05		
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
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:	506

APPENDIX K

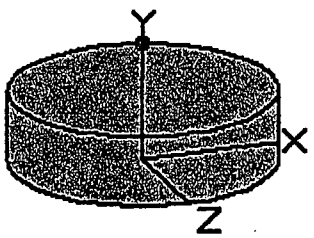
MicroShield v6.02 (6.02-00253)

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

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

Source Dimensions:

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



Dose Points

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

Shields

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

Source Input : Grouping Method - Actual Photon Energies

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

Buildup : The material reference is - Source

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

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

APPENDIX L

Cs-137
Microsoft Excel E_i Calculation Sheet

	Energy MeV	Energy kev	Exposure Rate (mR/hr / 1/pCi/g)	Energy Response (cpm/mR/h)	Ei (cpm/pCi/g)
5	0.0045	5	2.83E-08		0
32	0.0318	32	4.86E-08	1,406,947	0
32	0.0322	32	9.08E-08	1,505,273	0
36	0.0364	36	3.80E-08	2,696,122	0
662	0.6616	662	1.53E-04	1,228,700	188
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
0		0			0
				(E) Total:	**188**

APPENDIX M

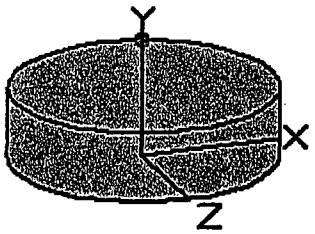
MicroShield v6.02 (6.02-00253)

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

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

Source Dimensions:

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



Dose Points

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

Shields

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

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

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

Buildup : The material reference is - Source
Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

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

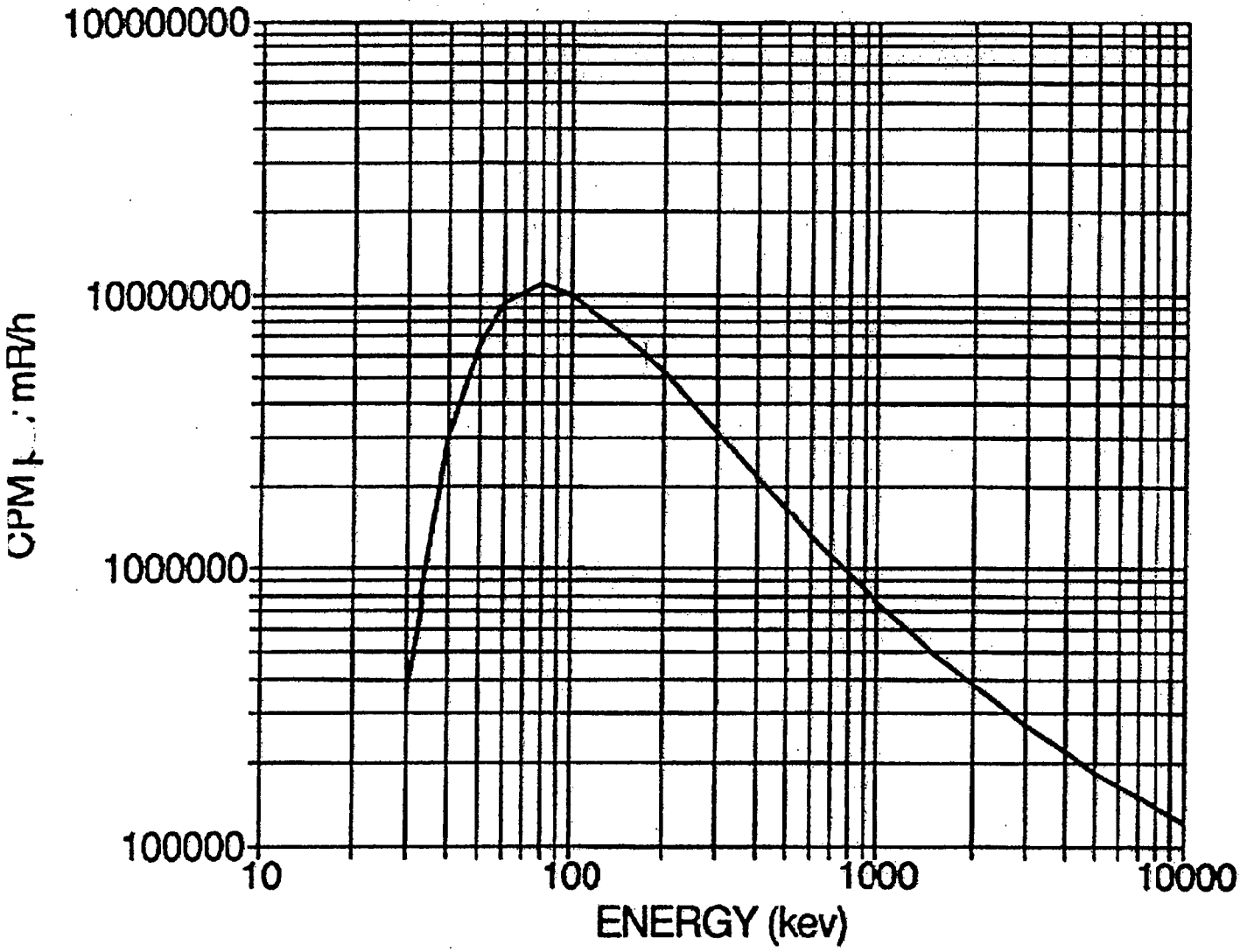
APPENDIX N

Eu-152

Y	Energy MeV	Energy keV	Exposure Rate (mR/h) (1 pCi/g)	Energy Response (cpm/mR/h)	E_i (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	1,465,000	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
0		0			0
0		0			0
				(E_i) Total:	**344**

APPENDIX O

Calculated Energy Response
(Eberline Instruments)
CPM/mR/h



Generic ALARA Evaluation Comparison Worksheet

Survey Area: OOL-16 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	0.0293	3	9.77E-03
2		0		
3				
4				
			Σ(fraction DCGL):	9.77E-03

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

Check one:

X Generic ALARA AL **IS** satisfied.

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

Prepared by: Nancy Tozzie Nancy Tozzie Date: 7/13/2006
FSS Radiological Engineer

Reviewed by: Matt C Bail Date: 7/13/06
FSS Project Manager/Radiation Protection Manager

Attachment A – Maps and Posting Plots

List of Figures

Figure 1 OOL-16 Relative to Structures

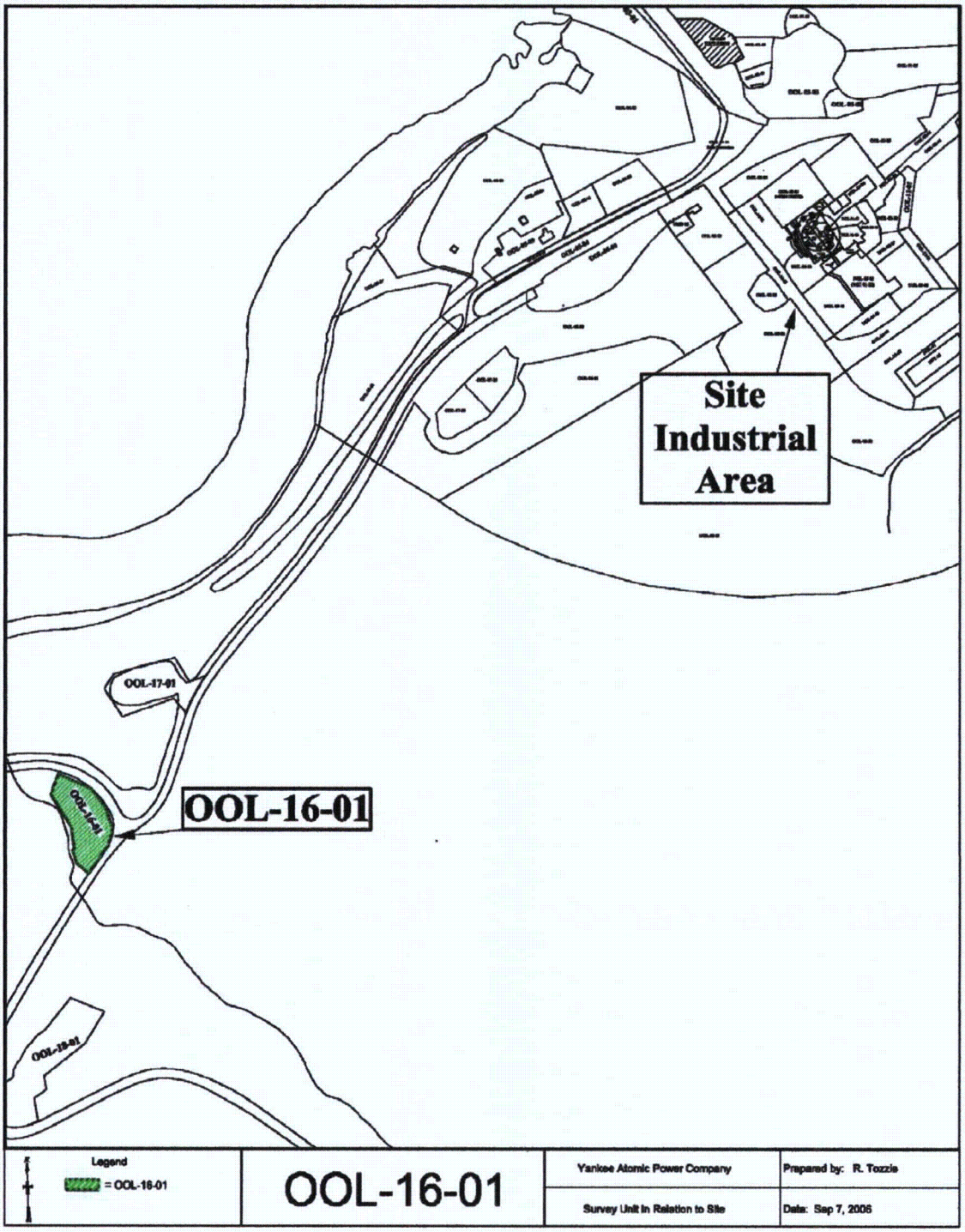
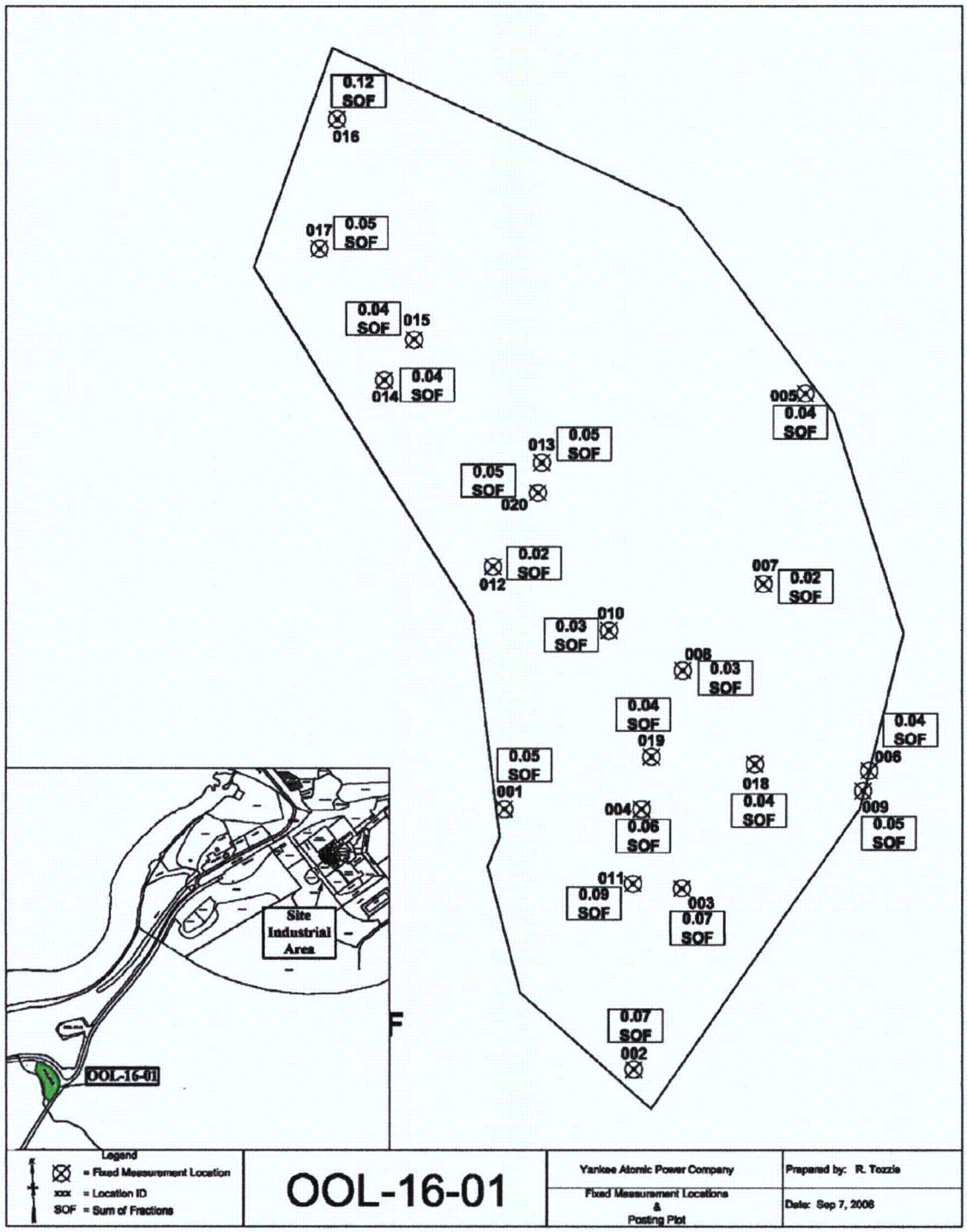


Figure 2 OOL-16-01 SOF Posting Plot



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-16-01 Prospective Power Curve

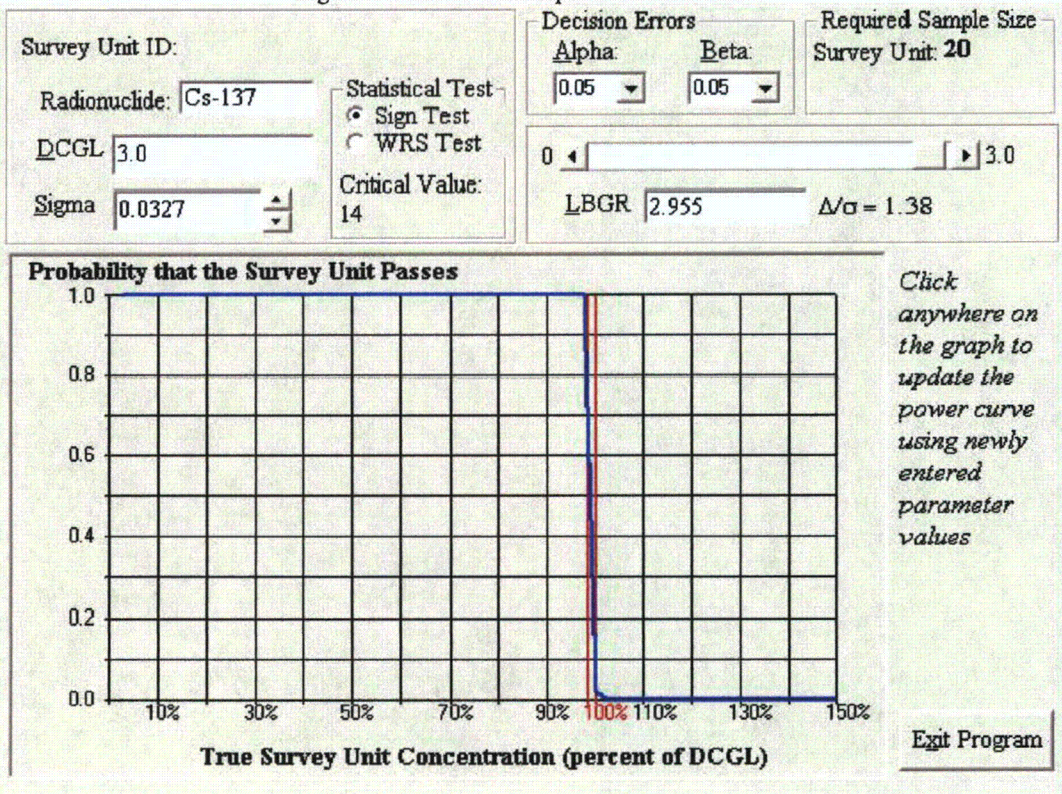


Figure 2 OOL-16-01 Retrospective Power Curve

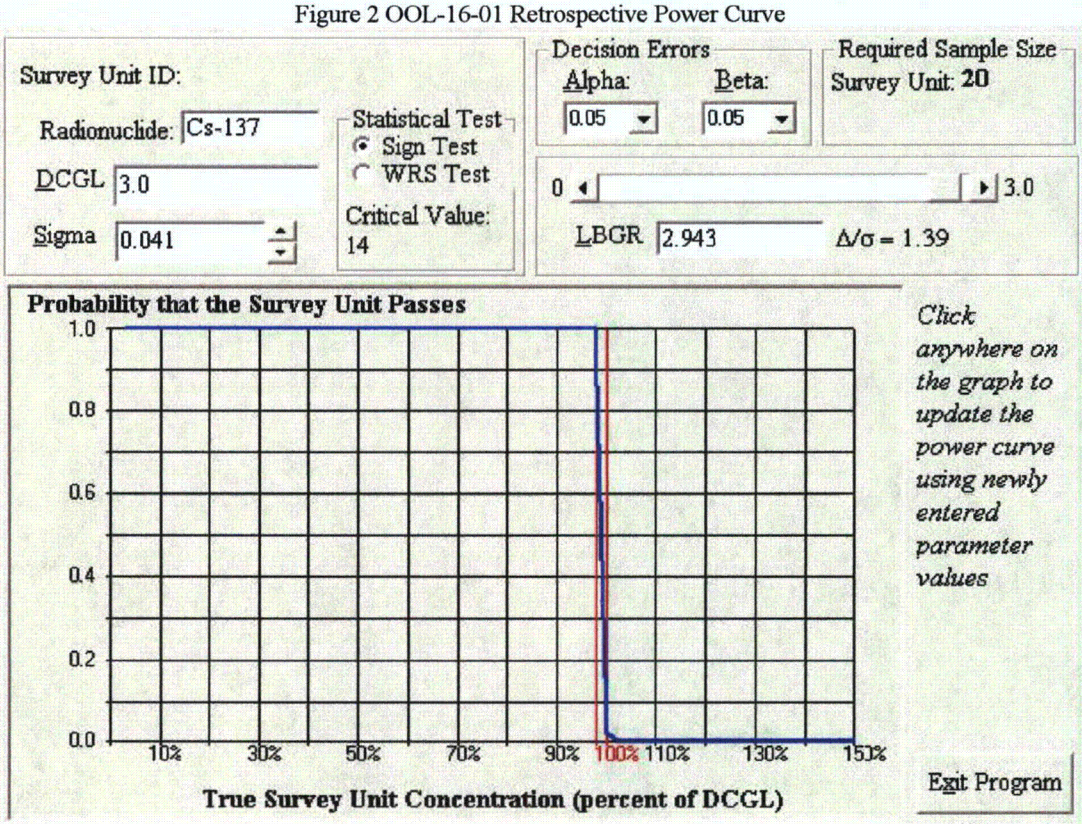


Figure 3 OOL-16-01Sum of Fractions Scatter Plot

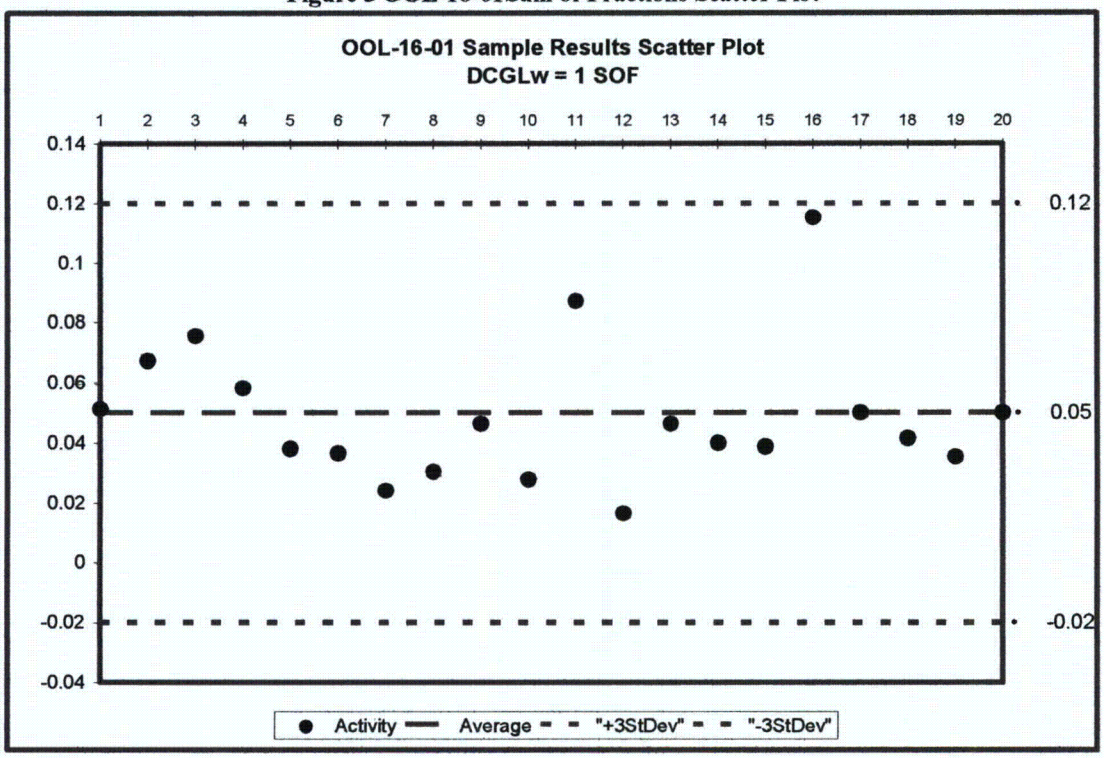


Figure 4 OOL-16-01 Sum of Fractions Quantile Plot

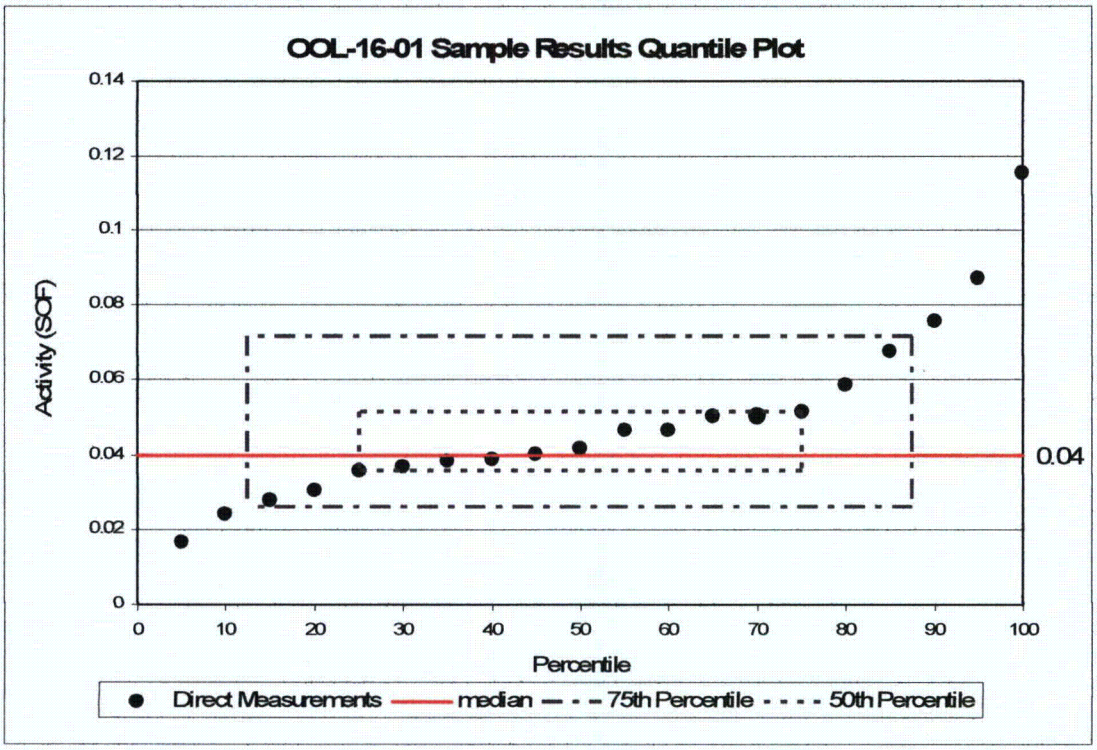
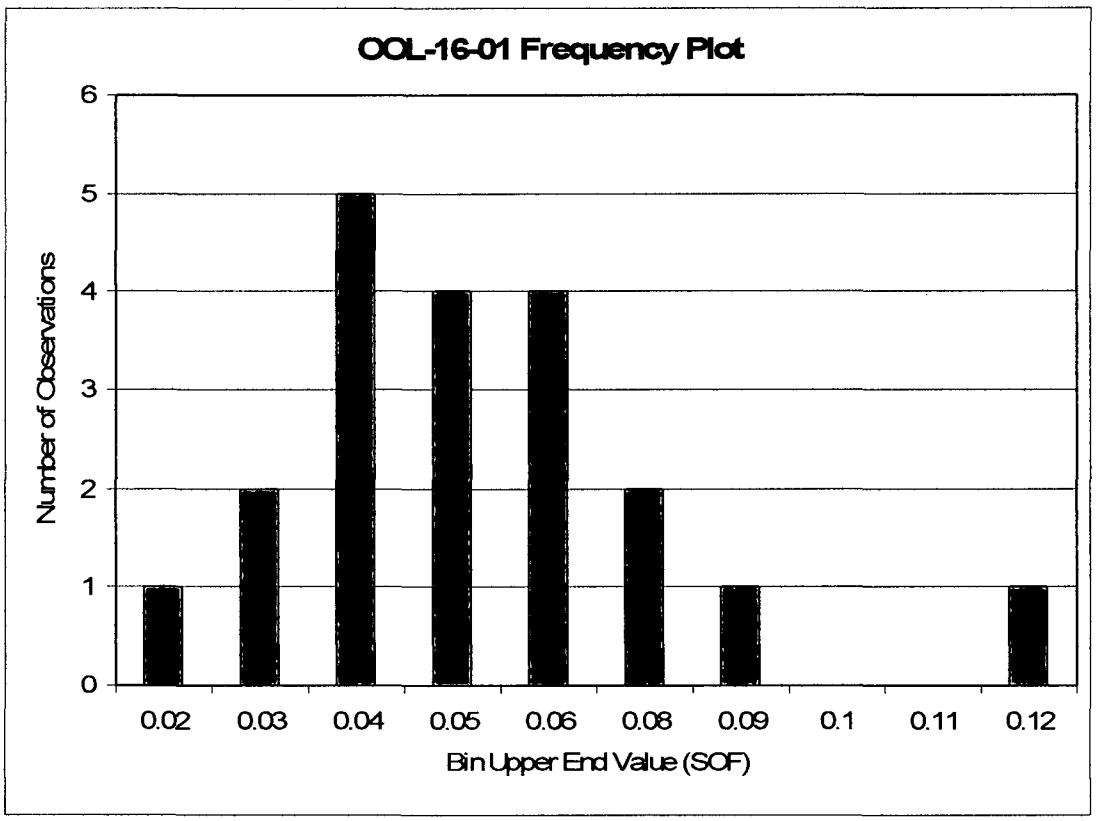


Figure 5 OOL-16-01 Sum of Fractions Frequency Plot



Daily Survey Journal

Page 1 of _

Survey Area Unit No.: OOL-16-01		Survey Date: JULY 13, 2006	
Survey Plan #: YNPS - FSS - OOL-16-01 - ~~00~~ 01 N 8/29/06			
Supervisor: L. Dockins	Crew: D. PAYEUR		
Instruments:			
Model:			
Serial #:			
Cal. Due.		N A	
Pre-op source ✓:	Sat.☐	Sat.☐	
Post-op source ✓:	Sat.☐ Date:	Sat.☐ Date:	Sat.☐ Date:

TIME	NOTES FOR SURVEY DATE
1710 -	CONDUCTED BRIEFING.
1720 -	GPS PRE-OP QC CHECK SAT.
1800 -	STAKED OUT & FLAGGED DIRECT SOIL SAMPLE
	LOCATION 004, 011 and 019.
2215 -	COLLECTED Samples 004, 011 and 019 and
	processed them into the prep. trailer.
2300 -	GPS POST-OP CHECK SAT.
	N A

Completed by [signature] Date July 13, 2006
FSS Field Supervisor

Reviewed by [signature] N. TOZZIE Date 7/26/06
FSS Radiological Engineer

Daily Survey Journal

Page 1 of 1

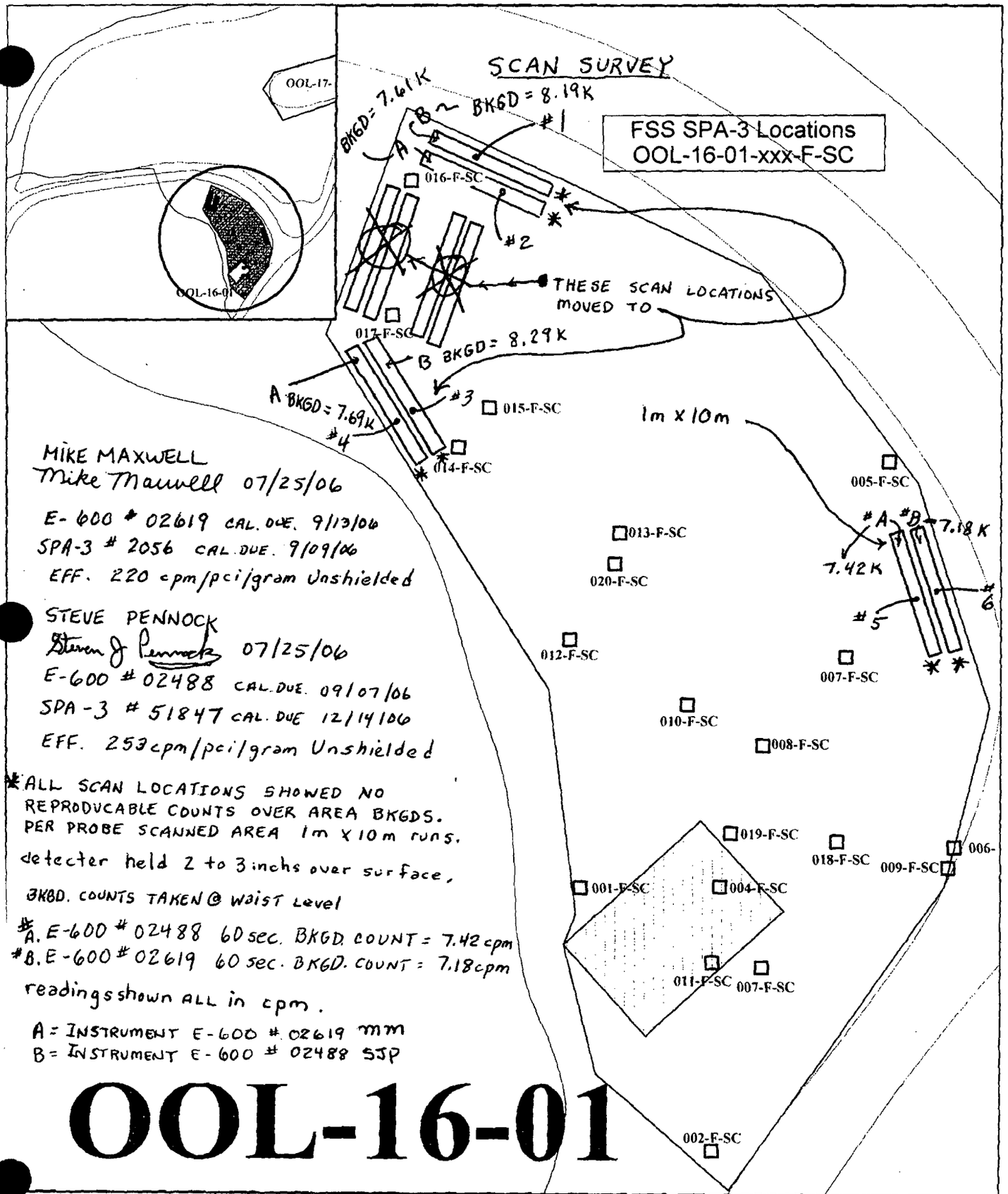
Survey Area No.: OOL-16	Survey Area Name: 01	Survey Date: 7/25/06
Survey Unit No. and Name: YNPS-FSS-OOL-16-01-~~00~~ 01 TK 8/29/06		
Supervisor: John McChesney	Crew: Steve Pennock, Mike Maxwell, Mike Sweet	
InstrumentsPre-op source Sat. ☒ Post-op source Sat. X☐	Pre-op source Sat. ☒ Post-op source Sat. ☐ Date	Pre-op source Sat. ☒ Post-op source Sat. ☐ Date

TIME	NOTES FOR SURVEY DATE
07:00	Briefed crew on area requirements.
07:30	Mike Sweet in the area to GPS soil sample locations. Excavator is being moved out of the area.
09:15	Mike Maxwell and Steve Pennock in the area to collect soil samples complete Scans.
13:00	Mike Maxwell called and part of the northern scan area is inexesssable, advised To scan in the general area to a point that we confident that we have done 2 meters by 20 meters.
14:10	OOL-16-01 is complete
	N
	A

Completed by _____ Date 7/26/06
FSS Field Supervisor

Reviewed by _____ N. Toccie Date 8/24/06
FSS Radiological Engineer

DPF-8856.2
Rev. 5
Page 2 of 2



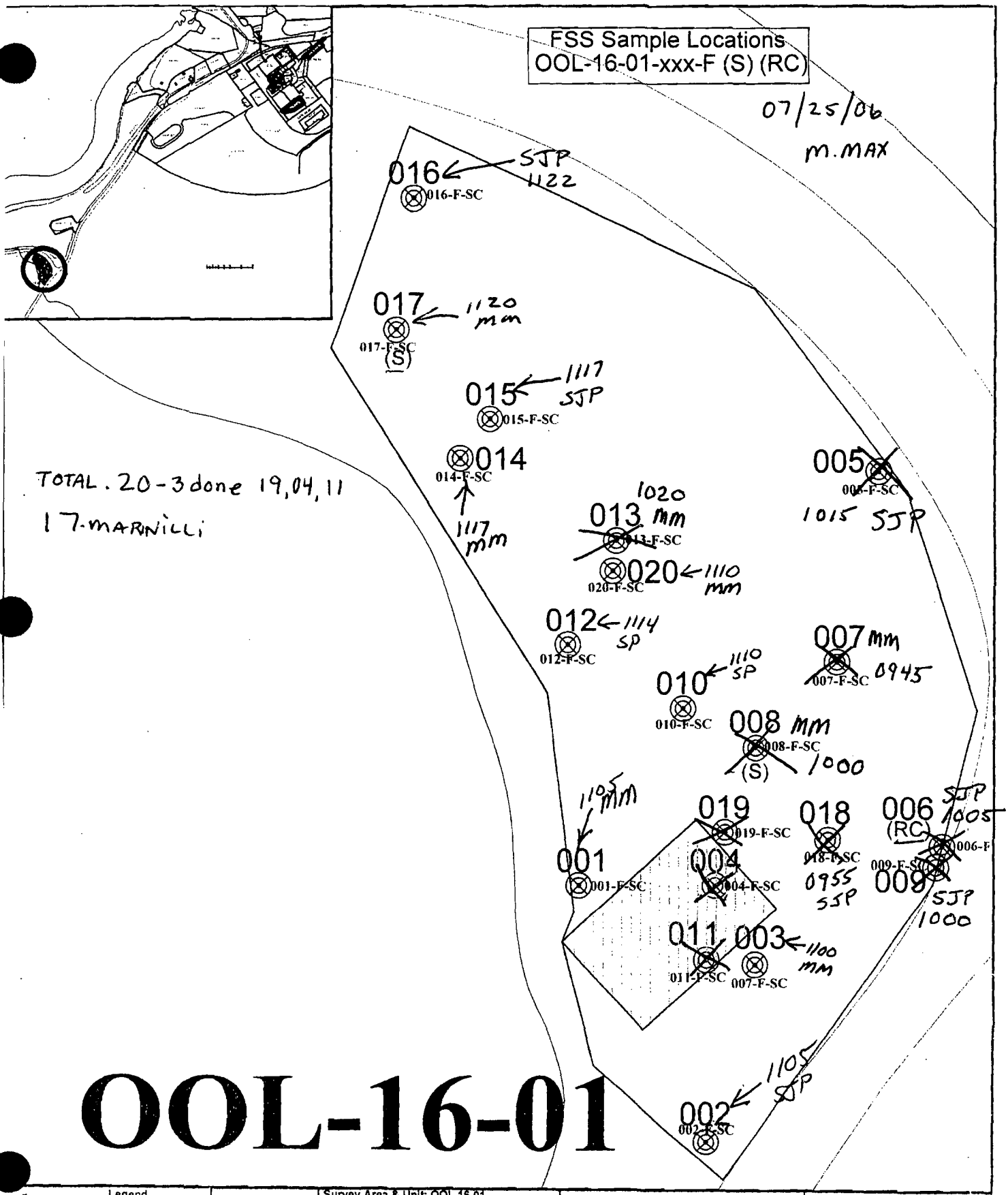
MIKE MAXWELL
Mike Maxwell 07/25/06
E-600 # 02619 CAL. DUE. 9/13/06
SPA-3 # 2056 CAL. DUE. 9/09/06
EFF. 220 cpm/pci/gram Unshielded

STEVE PENNOCK
Steven J Pennock 07/25/06
E-600 # 02488 CAL. DUE. 09/07/06
SPA-3 # 51847 CAL. DUE 12/14/06
EFF. 253 cpm/pci/gram Unshielded

*ALL SCAN LOCATIONS SHOWED NO REPRODUCABLE COUNTS OVER AREA BKGDS. PER PROBE SCANNED AREA 1m X 10m runs.
detecter held 2 to 3 inchs over surface.
BKGD. COUNTS TAKEN @ waist Level
#A. E-600 # 02488 60 sec. BKGD. COUNT = 7.42 cpm
#B. E-600 # 02619 60 sec. BKGD. COUNT = 7.18 cpm
readings shown ALL in cpm.
A = INSTRUMENT E-600 # 02619 mm
B = INSTRUMENT E-600 # 02488 SJP

OOL-16-01

Legend	Map current as of July 13, 2006	Survey Area & Unit: OOL-16-01	Yankee Atomic Power Company	Prepared by:
= Scan Location = Furlon House Footprint xxx = Scan Location ID	Map Revison #: 0	SPA-3 Scans Area size: 2342.4 m^2	FSS SPA-3 Scan Location Map	Date:



Legend				
⊗ = Sample Location ▭ = Furlon House Footprint xxx = Sample Location ID	Map current as of May 23, 2006 Map Revison #: 0	Survey Area & Unit: OOL-16-01 **FSS Sample Locations Based on Random Start 20 sample locations** **Area size: 2342.4 m^2**	Yankee Atomic Power Company FSS Sample Location Map	Reviewed by: Date:

CONTROL POINT

PORTABLE INSTRUMENT ACCOUNTABILITY FORM

Instrument Type & YAEC or DE&S #	Batt ✓	Cal Due ✓	Src ✓ Out	Location and/or Reason For Use	Date and Time Out	Tech Name	Date and Time In	Srce ✓ In
E-600 # 2620 SPA-3 # 726557	✓	✓	✓	Rad waste	7/25/06 1240	Sweet	7/25/06 1400	✓
E-600 # 02619 SPA-3 # 7056	✓	✓	✓	FSS SCAN FURLON	07-25-06 / 1230	MAXWELL	07/25/06 1413	✓
~~E-600 # 2620 SPA-3 # 726557~~	✓	✓	✓					
E-600 # 02488 SPA3 # 5847	✓	✓	✓	FSSCAN. Furlong	7/25/06 / 1250	Rennie &	7/25/06 / 14[illegible]	✓
E-600 # 5073 4537 # 60071	✓	✓	✓	South Road	7-25-6 1515	Arnold.	7-25-6 1635	✓
E-600 # 5138 43-37 # 60897	✓	✓	✓					NOT USED
E-600 # 5156 SHP100 # 57598	✓	✓	✓	RETAINING WALL	7-25-06 0720	ALLER	7/25/06 1545	✓
E-600 # 02491 SHP-100 # 55296	✓	✓	✓					NOT USED
~~E-600 MSM~~								
E600 # 01623 SPA 725328	✓	✓	✓	West road	7-25-06 1600	Meyers	7-25-6 1630	✓

RP Supervisor Review _____ (1)

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

COPY

PORTABLE/GAMMA FRISKER SOURCE CHECK FORM

E-600	SPA-3	2056	277	181748	272620
Meter Type	Detector Type	Detector Number	Source ID	Net Acceptance Criteria - 20%	Net Acceptance Criteria + 20%

PRE USE CHECKS								POST USE CHECKS							
Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int	Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int
6-9-06	0600	SAT	N/A	4930	224000	219070	WS	6-9-6	1650	SAT	NA	5320	237000	231680	CJC
6-10-6	0520	SAT	NA	4520	238000	233480	CJC	6-10-06	1700	SAT	N/A	4680	238000	233320	WS
6-12-06	0540	SAT	N/A	5140	236000	230860	WS	6-12-6	1705	SAT	NA	5130	238000	232870	CJC
6-13-06	0540	SAT	N/A	4890	238000	233110	WS								*
6-14-06	0600	SAT	N/A	5370	238000	232630	WS	6-14-6	1635	SAT	NA	4950	224000	219050	CJC
6-15-06	0530	SAT	N/A	5360	224000	218640	WS	6-15-6	1645	SAT	NA	4680	223000	218320	CJC
7-19-06	0530	SAT	N/A	4760	221000	216240	WS								*
7-20-06	0545	SAT	N/A	5160	223000	217840	WS	7-20-06	0550	SAT	N/A	5550	220000	214450	WS
7-21-06	0550	SAT	N/A	5550	220000	214450	WS								*
7-24-06	0610	SAT	N/A	5520	222000	216480	WS	7-24-6	15:35	SAT	NA	5130	216000	210870	CJC
7-25-06	0545	SAT	N/A	4910	221000	216090	WS	7-26-06	0600	SAT	N/A	5760	220000	214240	WS
7-26-06	0600	SAT	N/A	5760	220000	214240	WS								*
7-27-06	0650	SAT	N/A	4940	220000	215060	WS								*
7-28-06	0600	SAT	N/A	5880	220000	214120	WS	7-28-6	1605	SAT	NA	5420	220000	214580	CJC
7-31-06	0550	SAT	N/A	4580	220000	215420	WS								*

RP Supervisor Review: C Bishop (1)

* Not used

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

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PORTABLE/GAMMA PRE & SOURCE CHECK FORM

E 600	SPA-3	DE+S 51849	279	201077.6	301616.4
Meter Type	Detector Type	Detector Number	Source ID	Net Acceptance Criteria - 20%	Net Acceptance Criteria + 20%

PRE USE CHECKS								POST USE CHECKS							
Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int	Date	Time	Audible Check	Alarm Check	BKG Counts	SRC Counts	Net Counts	Int
7-7-06	0540	SAT	N/A	5380	252000	246620	WS								(1)
7-10-06	0545	SAT	N/A	5060	250000	244940	WS								(1)
7-11-6	06:45	SAT	NA	4950	253000	248350	cjc	7-11-6	12:45	SAT	NA	5290	252000	246710	cjc
7-12-06	0545	SAT	N/A	5280	251000	245720	WS	7-12-6	16:45	SAT	NA	7140	253000	245860	cjc
7-13-06	0545	SAT	N/A	5200	252000	246800	WS	7-13-06	1530	SAT	N/A	5300	250000	244700	WS
7-14-06	0540	SAT	N/A	4780	251000	246220	WS	7-14-6	1600	SAT	NA	5730	252000	246270	cjc
7-17-06	0545	SAT	N/A	5550	249000	243450	WS	7-17-6	1405	SAT	NA	4920	252000	247080	cjc
7-18-6	0610	SAT	NA	5090	251000	245910	cjc	7-18-6	1705	SAT	NA	4900	251000	246100	cjc
7-19-06	0550	SAT	N/A	4460	250000	245540	WS	7-19-6	1635	SAT	NA	4960	251000	246040	cjc
7-20-06	0545	SAT	N/A	4600	252000	247400	WS	7-21-06	0550	SAT	N/A	5080	251000	245920	WS
7-21-06	0550	SAT	N/A	5080	251000	245920	WS								(1)
7-24-06	0610	SAT	N/A	4860	251000	246140	WS								(1)
7-25-06	0545	SAT	N/A	4700	251000	246300	WS	7-25-6	1530	SAT	NA	5460	251000	245540	cjc
7-26-06	0600	SAT	N/A	5450	250000	244550	WS	7-26-6	1620	SAT	NA	4940	250000	245060	cjc
7-27-06	0600	SAT	N/A	5490	249000	243510	WS	7-27-6	1525	SAT	NA	5480	251000	245520	cjc

RP Supervisor Review: [signature] (1)

(1) NOT USED

(1) If any post-use source check failures occur, ensure that the condition is documented by a Condition Report.

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