OFFICE OF NUCLEAR MATERIAL SAFETY
AND SAFEGUARDS
SAFETY EVALUATION REPORT
REVIEW OF FINAL STATUS SURVEY REPORT
FOR THE HEMATITE SITE IN JEFFERSON COUNTY, MISSOURI

LICENSE NO. SNM-00033 DOCKET NO. 070-00036

WESTINGHOUSE ELECTRIC COMPANY, LLC.

JEFFERSON COUNTY, MISSOURI

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Enclosure 1

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List of Acronyms and Abbreviations

ADAMS	Agencywide Documents Access and Management System
AF	Area Factor
ALARA	As Low As Reasonably Achievable
Am	Americium
BSA	Building Survey Area
CFR	Code of Federal Regulations
cm	centimeter
cpm	counts per minute
CSM	Conceptual Site Model
DCGL	Derived Concentration Guideline Level
DP	Hematite Decommissioning Plan
dpm	disintegrations per minute
emc	elevated measurement criteria
EPA	U.S. Environmental Protection Agency
ft	foot
FSS	Final Status Survey
FSSFR	Final Status Survey Final Report
g	gram
GPS	Global Positioning System
HP	Health Physics
HSU	Hydrostratigraphic Unit
L	Liter
LSA	Land Survey Area
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
m	meter
MCL	Maximum Contaminant Level
mrem	milli Roentgen equivalent man (10^{-3} rem)
Np	Neptunium
NRC	U.S. Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
pCi	picoCurie (10^{-12} Ci)
pkg	package
PSA	Piping Survey Area
Pu	Plutonium
Ra	Radium
RAI	Request for Additional Information
ROC	Radionuclides of Concern
RSO	Radiation Safety Officer
SER	Safety Evaluation Report
SNM	Special Nuclear Material
SOF	Sum of Fractions
SU	Survey Unit
Tc	Technetium
Th	Thorium
U	Uranium
Westinghouse	Westinghouse Electric Company LLC
WRS	Wilcoxon Ranked Sum

1 Background

The Hematite Decommissioning Plan (DP) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML092330136 (pkg)) provides detailed descriptions of the facility, facility operating history, and location as well as the physical characteristics of the site including meteorology, climatology, geology, seismology, hydrology, and natural resources. An abbreviated summary of the more relevant topics is provided below.

The 228-acre Hematite facility is located in Jefferson County, Missouri. The Hematite facility is located approximately 0.75 miles northeast of the unincorporated town of Hematite and approximately 35 miles south of the City of St. Louis, Missouri. Licensed activities were restricted to a central tract of land of about 10 acres. Land near the Hematite facility is primarily forest, farms, and residences. Joachim Creek, located along the southeast site boundary, is a permanent flowing gaining stream, and therefore, a recipient of shallow groundwater discharge originating, in part, from the site. There are several other surface water features also present on or near the site.

Prior to beginning remediation, the Hematite site contained 16 buildings that were impacted by licensed activities, most of which have been demolished and removed. The site currently contains 3 primary buildings along with a variety of smaller structures, such as concrete pads, not considered to be habitable. Contaminated equipment and piping which exceeded the release criteria were removed from the buildings and grounds and disposed of as waste according to the site's radioactive waste management program as approved by the U.S. Nuclear Regulatory Commission (NRC) and described in Chapter 12 of the DP. Buried contaminated materials, previously disposed of on site, and contaminated soil exceeding the release criteria have been also removed and disposed of as waste according to the site's radioactive waste management program as approved by the NRC and described in Chapter 12 of the DP. Excavations were surveyed and backfilled. A network of monitoring wells was installed to monitor the impacts to ground water prior to, during and after remediation. All impacted remaining media on site were remediated and/or surveyed as described in the Westinghouse Electric Company LLC's (herein referred to as the licensee) Final Status Survey Final Report (FSSFR). The various volumes and chapters comprising the FSSFR are presented in Appendix A of this Safety Evaluation Report (SER).

The Hematite site was originally farmland before it was purchased for industrial purposes. The original special nuclear material license for the Hematite facility was issued on June 18, 1956, by the Atomic Energy Commission (AEC), the predecessor agency to the NRC. From 1956 through 1974, under various owners, the facility primarily produced highly enriched uranium fuel for the U.S. government under a number of contracts. Operations involved the conversion of uranium hexafluoride (UF_6), into a variety of solid compounds including nuclear fuel for the Navy's nuclear powered ships and the Army's power reactors. Feed material for the operations came from AEC regulated or DOE controlled facilities and included spent nuclear fuel that had been recycled through DOE facilities. All recycled fuel feed material used at the facility contained fission byproducts such as Technetium-99 and various transuranics such as Neptunium-237. From 1975 until 2001, the facility was licensed by the NRC to produce low enriched (< 5%) commercial nuclear fuel. In April of 2000, the site was purchased by British Nuclear Fuels Limited (BNFL). At the time of the purchase, BNFL was the parent corporation to Westinghouse and the Hematite operations were consolidated into the Westinghouse nuclear operations. Production operations at the Hematite facility were permanently ceased in June 2001. On April 11, 2002, the facility was placed in a standby mode prior to decommissioning.

On August 12, 2009, Westinghouse Electric Company LLC (the licensee) submitted a DP in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 70.38(g)(1), "Expiration and termination of licenses and decommissioning of sites and separate buildings or outdoor areas," for the former Hematite Fuel Cycle Facility located near Hematite, MO, in Jefferson County. On October 13, 2011, the NRC staff approved the DP and amended the Westinghouse Electric Company license (ADAMS Accession No. ML112101699) to incorporate the DP.

In accordance with 10 CFR 70.38(j)(2), the licensee performed site remediation and supporting surveys to demonstrate compliance with the approved release criteria in the DP. The NRC and the licensee interacted frequently during the decommissioning process. Frequent public teleconferences were held to discuss and resolve issues that arose during the decommissioning and surveying processes. The NRC inspected the remediation and surveys and requested independent confirmatory surveys consistent with NRC procedures and guidance. The licensee generated final status survey (FSS) reports on a volume/chapter basis to document the methods used, history, and survey results for each survey unit. The NRC received the chapters of the FSSFR as they were completed, as presented in Appendix A to this document. The last serially submitted chapter of the FSSFR was dated March 13, 2018. In accordance with 10 CFR 70.38(j)(1), the licensee submitted a completed NRC Form 314 on March 1, 2018 (Adams Accession No. ML18066A612) certifying the disposition of all licensed materials, including wastes.

This SER documents the NRC staff's review of the Hematite site's FSS and includes a review of the survey design, results, and assessment of the potential dose to future site users, as well as a summary of the NRC's inspections and confirmatory surveys made during the FSS process. This SER also summarizes elements of the FSS approach and design, as approved in the DP, and highlights changes or enhancements to the approved FSS design that occurred during the decommissioning process.

2 Final Status Survey Approach

Chapter 14 (ADAMS Accession No. ML092330132) of the "Hematite Decommissioning Plan," dated August 12, 2009, established the general approach for the FSS for the Hematite site. The approved approach used NRC guidance in NUREG-1575, Revision 1, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)," issued August 2000 (ADAMS Accession No. ML003761445), and related documents, when applicable.

2.1 Site Release Criteria

The NRC criteria for unrestricted release in 10 CFR 20.1402, "Radiological Criteria for Unrestricted Use," are that the cumulative dose from residual radioactivity distinguishable from background to an average member of the critical group is no more than 25 millirem per year (mrem/yr) and is as low as reasonably achievable (ALARA). As documented in "U.S. NRC Safety Evaluation Report on the Westinghouse Amendment Request for Approval of Hematite Decommissioning Plan and Associated Supporting Documents" (the DP SER), issued October 2011 (ADAMS Accession No. ML112101630), the NRC staff approved the site-specific derived concentration guideline level (DCGL) values for soil, building surfaces, and buried piping, each of which corresponds to a dose of 25 mrem/yr per radionuclide of concern (ROC). As documented in the DP SER, the NRC staff found the information on the source term, exposure scenario(s), conceptual model(s), numerical analyses, and uncertainty analysis used to derive the site-specific DCGLs to be appropriate. Also at that time, the NRC staff approved site-specific dose-to-source ratios (DSRs) for assessing ground water dose. As part of the FSS, the licensee applied a sum of fractions (SOF) approach to evaluate whether the total dose from all radionuclides will be less than 25 mrem/yr and thus meet the unrestricted release criterion.

2.1.1 Soil Derived Concentration Guideline Level and Area Factors

As part of the DP, the licensee defined two conceptual models for soil contamination: a uniform model and a three-layer model. The uniform model assumes uniform soil contamination from the ground surface to the bottom of the contaminated zone (a depth of 6.7 meters (m) or 22 feet (ft). The three-layer model assumes a contaminated zone comprising three strata with associated exposure pathways:

- surface—surface soil to a depth of 15 centimeters (cm) (6 inches) below the ground surface
- root—subsurface soil starting at 15 cm (6 inches) and extending to 1.5 meters (m) (4.9 feet (ft)) below the ground surface
- deep—subsurface soil located below 1.5 m (4.9 ft) (i.e., below the root stratum) and extending to the bottom of the contaminated zone, which was conservatively estimated to be 6.7 m (22 ft) below the ground surface

As specified in the DP, to demonstrate compliance with the uniform model, the average concentration of residual contamination is compared to the uniform DCGL regardless of the depth of the contamination. To demonstrate compliance with the three-layer model, the surface, root, and deep layers are compared to their respective DCGLs, depending on the depth of the contamination.

Because the DP did not contain details as to how the sum of fractions would be calculated when using the three-layer model, the licensee subsequently developed a weighted SOF as shown in Equation 1. Specifically, when using the three-layer model, the unity rule must also be used to demonstrate compliance if contamination is present in more than one soil layer by applying a weighted SOF where the weights are based on the fractional area of the survey unit that is contaminated at each layer. The licensee applied Equation 1 (reproduced from Equation 3-2 in FSSFR, Volume 3, Chapter 1, Revision 1) to calculate the average $SOF_{weighted}$ for survey units that used the three-layer model.

Equation 1

$$Average\ SOF_{Weighted} = f_{SZ}\sum_{i=1}^{n}\left(\frac{\bar{C}_{i,SZ}}{D_{i,SZ}}\right) + f_{RZ}\sum_{i=1}^{n}\left(\frac{\bar{C}_{i,RZ}}{D_{i,RZ}}\right) + f_{DZ}\sum_{i=1}^{n}\left(\frac{\bar{C}_{i,DZ}}{D_{i,DZ}}\right)$$

where:

n	= number of measured ROCs;
f_{SZ}	= fraction of survey unit area at the surface stratum depth;
$\bar{C}_{i,SZ}$	= average concentration of *ith* measured ROCs in the surface stratum layer;
$D_{i,SZ}$	= surface stratum DCGLw for the *ith* measured ROCs;
f_{RZ}	= fraction of survey unit area at the root stratum depth;
$\bar{C}_{i,RZ}$	= average concentration of *ith* measured ROCs in the root stratum layer;
$D_{i,RZ}$	= root stratum DCGLw for the *ith* measured ROCs;
f_{DZ}	= fraction of survey unit area at the deep stratum depth;
$\bar{C}_{i,DZ}$	= average concentration of *ith* measured ROCs in the deep stratum layer; and
$D_{i,DZ}$	= excavation DCGLw for the *ith* measured ROC.

The licensee also adjusted the DCGLW values to account for the dose contribution from insignificant radionuclides. Table 1 reproduces the approved DCGLs, adjusted for insignificant radionuclide dose contribution.

Table 1. Adjusted Site-Specific Soil DCGLs

Radionuclide	DCGL$_W$ (pCi/g)[a] by Conceptual Site Model			
	Shallow Stratum	Root Stratum	Deep Stratum (Based on Excavation Scenario)	Uniform Stratum
U-234	508.5	872.4	872.4	195.4
U-235 + D[b]	102.3	208.1	208.1	51.6
U-238 + D[b]	297.6	551.1	551.1	168.8
Tc-99	151.0	74.0	74.0	25.1
Th-232 + C[c]	4.7	5.2	5.2	2.0
Ra-226 + C[c]	5.0	5.4	5.4	1.9

[a] The reported soil limits are the activities for the parent radionuclide as specified and were calculated using DP Chapter 14, Equation 14-1, to account for the dose contribution from insignificant radionuclides (see DP Section 14.1.3.2).
[b] + D = plus short-lived decay products.
[c] + C = plus the entire decay chain (progeny) in secular equilibrium.

As documented in the DP SER, the licensee developed area factors, as reproduced in Table **2** and in Table 3, to be used with the uniform and three-layer models, respectively (FSSFR, Volume 3, Chapter 1, Revision 1, Tables 3-2a–c).

Table 2. Area Factors for the Uniform Approach

Uniform Stratum Elevated Measurement Area (m^2)										
Radionuclide	**153,375**	**10,000**	**3,000**	**1,000**	**300**	**100**	**30**	**10**	**3**	**1**
U-234	1.0	1.2	1.3	1.3	4.0	9.3	19.6	34.3	70.5	132.8
U-235	1.0	1.1	1.1	1.1	1.9	2.5	3.3	4.7	9.6	20.5
U-238	1.0	1.1	1.3	1.3	2.5	3.6	5.0	7.2	14.9	31.6
Tc-99	1.0	1.0	1.0	1.0	3.4	10.3	34.3	102.9	342.7	1,027
Th-232	1.0	1.0	1.0	1.0	2.1	3.0	4.2	6.1	12.9	28.9
Ra-226	1.0	1.1	1.1	1.1	2.5	4.1	6.1	9.1	19.3	43.4

Table 3. Area Factors for the Three-Layer Approach

Surface Stratum Elevated Measurement Area (m^2)										
Radionuclide	**153,375**	**10,000**	**3,000**	**1,000**	**300**	**100**	**30**	**10**	**3**	**1**
U-234	1.0	1.5	2.2	2.6	7.8	19.3	41.7	67.3	96.0	119.5
U-235	1.0	1.1	1.2	1.2	1.3	1.5	1.8	2.6	5.4	12.1
U-238	1.0	1.2	1.5	1.6	2.2	2.6	3.4	4.9	10.2	22.3
Tc-99	1.0	1.0	1.0	1.0	3.4	10.3	34.2	102.2	338.5	1,009
Th-232	1.0	1.0	1.1	1.1	1.4	1.7	2.3	3.5	7.3	16.9
Ra-226	1.0	1.1	1.2	1.2	1.8	2.2	3.0	4.5	9.6	22.4
Root Stratum Elevated Measurement Area (m^2)										
Radionuclide	**153,375**	**10,000**	**3,000**	**1,000**	**300**	**100**	**30**	**10**	**3**	**1**
U-234	1.0	1.2	1.3	1.4	4.1	9.4	19.2	33.0	67.9	130.4
U-235	1.0	1.0	1.1	1.1	1.9	2.3	2.9	4.1	8.3	17.9
U-238	1.0	1.1	1.3	1.3	2.5	3.6	5.0	7.2	14.8	31.5
Tc-99	1.0	1.0	1.0	1.0	3.4	10.3	34.3	103.0	343.3	1,029
Th-232	1.0	1.0	1.0	1.0	2.1	3.0	4.2	6.0	12.8	28.4
Ra-226	1.0	1.0	1.1	1.1	2.4	3.9	5.8	8.7	18.5	41.6
Deep/Excavation Stratum Elevated Measurement Area (m^2)										
Radionuclide					**148**	**100**	**30**	**10**	**3**	**1**
U-234					1.0	2.0	6.7	19	35	65
U-235					1.0	1.3	2	2	4	7
U-238					1.0	1.9	3	4	7	13
Tc-99					1.0	2.0	6.7	20	67	200
Th-232					1.0	1.9	3	4	7	14
Ra-226					1.0	2.0	4	5	10	20

2.1.2 Building Surface Derived Concentration Guidelines

As reviewed and approved in the DP SER, the licensee modeled two room sizes for the building surface DCGL calculations: a small office and an open warehouse. The Small Office Model resulted in the most limiting DCGLs. The licensee elected to use the DCGLs based on the Small Office Model for all building surfaces and piping. The licensee developed area factors for the Small Office Model by adjusting the area of the floor only and calculating a DCGL applicable to elevated measurements for each area. For potentially contaminated soil beneath the remaining structures, the licensee stated that it would apply the uniform soil DCGLs.

Table 4 reproduces the building and structural surface DCGLs based on the Small Office Model that were approved as part of the DP. The licensee also calculated a gross activity DCGL based on the average radioactivity fractions from drain and dust samples from Buildings 230 and 110 (Table 4-1 of the DP).

Table 4. Building and Structural Surfaces Gross Radioactivity $DCGL_w$ for Small Office

Radionuclide	$DCGL_w$ (dpm/100 cm^2)	Radioactivity Fractions Based on Characterization Data[a]
U-234	20,000	8.27E-01
U-235 + D	19,000	3.72E-02
U-238 + D	21,000	1.27E-01
Tc-99	13,000,000	2.83E-03
Th-232 + C	1,200	3.21E-03
Np-237 + D	2,700	5.57E-05
Pu-239/Pu-240	3,500	2.03E-06
Am-241	3,400	2.68E-03
Gross Activity $DCGL_w$ (dpm/100 cm^2)[b]:		**18,925**

[a] Values are taken from Table 4-1 of DP Chapter 4.
[b] Calculated using Equation 4-4 of MARSSIM and rounded down (truncated) to two significant figures.
+ D = plus short-lived decay products.
+ C = plus the entire decay chain (progeny) in secular equilibrium.

Table 5. Area Factors for Building Surfaces (Small Office)[a]

Radionuclide	Elevated Measurement Area (m^2)		
	6.5	4	1
U-234	1.0	1.6	6.5
U-235 + D	1.0	1.6	6.1
U-238 + D	1.0	1.6	6.4
Tc-99	1.0	1.6	6.4
Th-232 + C	1.0	1.6	6.1
Np-237 + D	1.0	1.6	6.4
Pu-239/Pu-240	1.0	1.6	6.5
Am-241	1.0	1.6	6.5

[a] Reproduced from Table 5-20 of the DP, Revision 1.
+ D = plus short-lived decay products.
+ C = plus the entire decay chain (progeny) in secular equilibrium.

As documented in the DP SER and in Volume 4, Chapter 1, Section 3.2, of the FSSFR, the licensee did not derive separate DCGLs for ventilation ducts in remaining structures. Instead, the licensee stated that, at the time of license termination, it would measure and compare the levels of surface contamination within ventilation components to the limits for surface contamination measurements specified for uranium, U-natural, U-235, U-238, and associated decay products, in Table 1 of "Acceptable Surface Contamination Levels" in the "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," issued April, 1993 (1993 Guidelines for Decontamination, ADAMS Accession No. ML103620647).

As documented in Section 5.1.9 of the DP SER, in addition to the measurements of surface contamination, the licensee stated that it would perform air sampling at outlets of ventilation ducting remaining on site to directly assess the dose contribution from ventilation ducting. Air sampling locations would be established at various ventilation ducting openings of the ventilation systems that will remain. As stated in the FSSFR reports for ventilation (FSSFRs for Building Survey Area (BSA) 01-05 and BSA 02-20), a composite sample was generated from the samples collected from each building and analyzed at an offsite laboratory. The calculated dose contributions from the air samples associated with the remaining ventilation systems were added to the dose associated with the surface contamination measurements within each surface and structure survey unit as a final compliance measure to ensure that the 25 mrem/yr criterion is met (FSSFR, Volume 4, Chapter 1).

2.1.3 Buried Piping Derived Concentration Guidelines

As documented in the staff's SER evaluating DP Section 5.3, in response to a request for additional information (RAI) on the use of potential buried piping DCGLs, the licensee stated that it would use the small office DCGLs for buried piping.

Because the small office DCGLs are radionuclide-specific release criteria, the values could not be compared to field measurements of gross activity. To account for this difference, gross activity limits were applied based on the radioactivity fractions from drain and dust samples from Buildings 230 and 110. Since these radioactivity fractions were not necessarily representative of the fractions that exist in piping, the NRC staff asked the licensee to verify the radioactivity fractions in piping during the FSS to ensure that the gross activity small office DCGL was appropriate. The licensee verified the fractions, as discussed in Section 9 of this SER.

2.1.4 Ground Water

The licensee calculated dose-to-source ratios (DSRs) for the ROCs in ground water, which were presented in DP Chapter 5, Table 5-14, and reproduced in the table below. The licensee explained that it would calculate ground water dose using the DSRs and the maximum sample value identified during the post-remediation monitoring period collected in the bedrock aquifers. The potential dose from ground water based on the maximum individual aquifer sample would ultimately be added to the dose from the land survey units. The NRC reviewed and approved this approach as part of its DP SER. Section 9.4 of this SER discusses the groundwater dose contribution and Appendix B shows the final values the licensee added to each of the land survey units. Staff note that while the licensee added doses associated with the average concentrations to the land survey units as shown in Appendix B, the NRC staff verified that the doses resulting from the maximum concentrations were also in compliance when added to the land survey units as discussed in Section 9.4.

Table 6. Ground Water Dose-to-Source Ratios*

Radionuclide	Well Water Concentration (pCi/L)	TEDE (mrem/yr)[a] for Water-Dependent Pathways	DSR (mrem/yr per pCi/L)
U-234	1.404E+01	2.151E+00	0.1532
U-235 + D	1.404E+01	2.032E+00	0.1447
U-238 + D	1.404E+01	2.042E+00	0.1454
Tc-99	9.415E+00	8.826E-03	9.374E-04

* Source: Westinghouse, "Hematite Decommissioning Plan," Revision 1, Chapter 5, Appendix H, and Table 5-14 (ADAMS Accession No. ML1135406310).

[a] At t = 0 years

2.2 Data Quality Assessment

As discussed in the DP SER, the DP required a measuring and test equipment (M&TE) program that is designed and implemented to meet the Project Quality Plan requirements. The M&TE program provided a list of measuring and test equipment, the associated measurement reference standards, and the assigned locations and custodians. The licensee established procedures for the control of M&TE to ensure, in part, that the right type of equipment is used to accomplish the specified requirement and that the equipment has the proper range of accuracy and tolerance to achieve the desired outcome. Qualified personnel using the M&TE were responsible for ensuring that the M&TE was properly calibrated before use. Calibration of the M&TE was a controlled process and was performed with controlled procedures. In addition, the system and related procedures were put in place to ensure that the M&TE was protected from adjustments or modifications that would invalidate the data collected and that there were requirements for tagging items as out of service or due for calibration, as well as a methodology for documenting and evaluating the validity of any data collected from previous measurements when the M&TE was found to be out of calibration. The licensee stated that the calibration and maintenance of M&TE is based on the guidelines provided in MARSSIM. Radioactive sources used for calibration of field instruments were traceable to the National Institute of Standards and Technology, as well as sources for other equipment such as high-purity germanium detectors.

For structural FSSs, the data quality assurance process used by the licensee included reviewing the data quality objectives and survey plan design, reviewing preliminary data, using appropriate statistical testing when applicable (statistical testing is not always required—for example, when all sample or measurement results are less than the $DCGL_w$), verifying the assumptions of the statistical tests, and drawing conclusions from the data. Once the FSS data were collected, the data for each survey unit were assessed and evaluated to ensure that they were adequate to support the release of the survey unit. Simple assessment methods, such as comparing the survey data mean result to the appropriate $DCGL_w$, were performed first. The specific nonparametric statistical test was then applied, as necessary, and the assumptions of the dataset verified. Once the assessment and evaluation were complete, the licensee concluded whether the survey unit actually met the site release criteria or whether additional actions were required. The licensee randomly selected about 5 percent of the BSA structural survey units and subjected these units to replicate surveys performed by different technicians using different instruments than were utilized for the original survey.

During the FSS of relevant media (such as soil), the licensee assessed field and laboratory duplicate analytical results to verify that the methods employed generate reproducible results. Field duplicate samples consisted of splitting a homogenized sample into two or more separate samples for analysis. Field duplicates were obtained from one location, homogenized, divided into separate containers, and treated as separate samples. Laboratory duplicate samples consisted of the reanalysis of the same sample at the laboratory. Both types of quality assurance samples were analyzed at a frequency of 1 sample per 20 FSS samples collected (5 percent). Field duplicate samples were evaluated according to the guidance in the “Multi-Agency Radiological Laboratory Analytical Protocols Manual,” issued July 2004. Laboratory duplicates were also evaluated internally by the laboratory as part of its quality assurance program. Samples collected by the licensee to support structural surveys and ground water monitoring were subject to quality assurance requirements similar to those for the soil samples collected to support open land survey units.

With the exception of the ground water monitoring reports, the FSSFRs all included a section on data quality assessment which addressed the applicable FSS data quality objectives and referenced the procedures that were followed. For example, this section normally included statements providing assurance that any instrumentation calibration and MDC achieved were acceptable, sampling or measurement requirements were achieved, stated that chain of custody procedures were followed (when applicable), that quality control results were acceptable, that the FSS data were acceptable based on the results obtained (as applicable), and that reasonable isolation and control steps were taken (when applicable). NRC staff found the data quality steps taken by the licensee to be adequate to demonstrate that the FSS followed reasonable processes to provide quality data and results consistent with the FSS objectives. The NRC staff also found the data quality assessment and other information contained in the FSSFRs, as well as NRC inspections and confirmatory surveys, to be adequate to satisfy the requirements of 10 CFR 72.38(j)(2)(ii) in that instrumentation was appropriately specified, calibrated and tested, and utilized.

2.3 Final Status Survey Plan Modifications

As previously stated, Section 14 of the DP initially described the FSS design. As stated in Section 14.4 of the SER approving the DP, the NRC staff found the survey design adequate to demonstrate compliance with 10 CFR 70.38(g)(4)(iv) and adequate to perform a FSS consistent with MARSSIM guidance. While inspecting the decommissioning and FSS activities, as well as the initial staff reviews of selected survey reports, the staff recognized several issues relating to the licensee's survey approach. These issues, which were either rectified with the licensee and corrected or found to comply with NRC requirements as a result of an alternative approach or a small change in consequences, included the following:

- modified soil scanning methods
- reestablishment of the soil reference dataset
- demonstration of 100-percent scanning of Land Survey Area (LSA) Class 1 survey units
- scanning and sampling of excavation sidewalls
- delineation of radiologically elevated areas in LSA survey units
- surveys surrounding the gas pipeline within LSA survey units
- isolation and control of LSA survey units after the FSS was conducted
- scanning of Piping Survey Area (PSA) survey units

Modifications from the methods in the DP involved staff RAIs and licensee responses, as well as interactions during publicly held teleconferences.

<u>Soil scanning method modification</u>

In June 2013, a fuel pellet fragment was found during confirmatory surveys of the LSA 05-02 survey unit, before backfilling. When backfill was initially added to LSA 05-02, an additional fuel pellet fragment was identified. This brought into question the scanning methods used during the FSS of the open land areas and for qualifying soil as being suitable for backfill.

As described in the DP, open area soil scanning involved use of a 2 inch x 2 inch sodium iodide (NaI) detector and utilized investigation action levels (IALs, as noted in Table 14-18 of the DP) to identify potential areas of elevated contamination. Technicians initially performed the scanning following guidance in MARSSIM and investigated elevations and exceedances of the IALs. They also used professional judgment to investigate select data points exceeding 3 sigma above the average based on the plotted data. For reuse soil, the radiation safety officer (RSO) determined a suitable reuse material screening action level (RMSAL) for scanning. Areas exceeding the RMSAL were identified and disposed of as waste according to the site's radioactive waste management program as approved by the NRC and described in Chapter 12 of the DP, while the areas meeting the RMSAL were "lifted" (instead of being removed by bulk excavation) in 1-foot lifts to be further evaluated. Corrective actions in response to discovering that scanning methods were insufficient to identify fuel pellet fragments included revising the scanning methods to make them more sensitive and reducing "lifts" to 3–6 inches. Scanning was performed between each lift.

The revised scanning methods for the ROCs (as established in the approved DP, radium (Ra)-226, thorium (Th)-232, technetium (Tc)-99, and uranium (U)) continued use of the 2-inch x 2-inch NaI detector and plotting of data but used a slower speed and closer scanning distance and credited the post-processing of the data. Specifically, the licensee performed open land scans at a 1 ft/s rate and a 2-inch average distance from the surface. This varies from the general guidance in MARSSIM (0.5 meters per second and 6-inch average distance). In addition, the licensee's post-processing of the data, performed to identify count elevations to be further investigated based on exceeding the average plus 3 times the standard deviation, resulted in using a surveyor efficiency of 0.75 (versus a surveyor efficiency of 0.5 in MARSSIM). These modified methods were able to achieve acceptably low scan minimum detectable concentrations (MDCs). Similar to previous efforts, the technician performing the scan had instructions to investigate further if the count rates were notably differentiated based on the audible signals or if the count rate exceeded the IAL set at the values in Table 14-18 of the DP. Section 8 of this SER discusses the NRC inspector's evaluation and reporting of these methods.

Tc-99 is a low-energy beta emitter and does not typically register with the field scanning instruments used for soil, which are photon (i.e., gamma and x-ray) detectors. Because Tc-99 is difficult to detect, the licensee, when planning the surveys, applied a surrogate relationship to U-235 (three different surrogate evaluation areas were identified), which reduced the applicable U-235 uniform $DCGL_w$ when accessing scanning capabilities. Tc-99 was analyzed separately in collected samples, so no adjustments to the DCGLs were needed for the final assessment of sample data. The modified scan MDCs were sufficiently low that adjustment of the sample placement or size was unnecessary. However, the modified methods were not in effect during some earlier LSA Class 1 survey unit FSSs, and the sample dataset size and density of samples in those survey units were modified so that the $DCGL_{emc}$ met or exceeded the scan MDC as determined by the methods described in the DP. Table 7 presents a comparison of the modified and DP-approved scan MDCs for the ROCs. The scan MDCs were determined for each survey unit based on the ambient count rates detected, the applicable surrogate evaluation area, and the average uranium enrichment in the Remedial Action Support Survey (RASS) samples (i.e., activity fractions of the uranium isotopes).

Table 7. Example Scan MDC Comparisons

Radionuclide	Modified Scan MDC (pCi/g)[a]	DP Scan MDC (pCi/g)[a]	Applicable Scan $DCGL_w$ (pCi/g)[b]
Ra-226	1.04	2.8	1.9
Th-232	0.75	1.8	2.0
Total U[c]	40.3	84.43	46.6
U-234	3659	7,383	195.4
U-235	2.32	4.9	2.5[d]
U-238	30.6	62.8	168.8

a Based on a 10,000 count per minute (cpm) background.
b Uniform $DCGL_w$ data set was used to develop the sampling plans.
c Total U scan MDC and $DCGL_w$ assume U isotope activity fractions for 2.9-percent enriched uranium.
d The U-235 $DCGL_w$ in this example is dropped from 51.6 picocuries per gram (pCi/g) to 2.5 pCi/g because it is considered a surrogate for Tc-99, a hard-to-detect radionuclide, in the plant soil surrogate evaluation area, for survey planning purposes.

The values for "Total U" are derived in the table above, where:

$$Total\ U\ DCGLw = \frac{1}{\left(\frac{f_{U-234}}{DCGLw_{U-234}} + \frac{f_{U-235}}{DCGLw_{U-235}} + \frac{f_{U-238}}{DCGLw_{U-238}}\right)}$$

$$Total\ U\ Scan\ MDC = \frac{1}{\left(\frac{f_{U-234}}{MDC_{U-234}} + \frac{f_{U-235}}{MDC_{U-235}} + \frac{f_{U-238}}{MDC_{U-238}}\right)}$$

The "f" in the equations above represents the fraction of uranium activity associated with the various isotopes of uranium.

<u>Reference dataset for soil</u>

The DP originally discussed reference soil areas in Section 14.4.2.5 and provided analytical results in Chapter 4. The licensee encountered some difficulties with the reference dataset when evaluating offsite borrow soil because of possible biases caused by changing laboratories for the FSS. The licensee discusses this issue in Volume 1, Chapter 1, Section 5.1.3, and in Volume 2, Chapter 8, Section 5.0, of the FSSFR. To address this issue, the licensee prepared a new reference dataset as described in the licensee memoranda HEM-15-MEMO-42, "Radium Ingrowth Background" (ADAMS Accession No. ML18052A567), and HEM-15-MEMO-44, "WRS Test Background Data Set" (ADAMS Accession No. ML18052A568) by obtaining new reference samples from the same areas specified for use as background in the DP. The licensee analyzed the samples twice by gamma spectroscopy to obtain analytical results based on both a short holding time and a longer holding time during which decay products were able to achieve near secular equilibrium conditions with the ROCs[i]. Samples were analyzed for uranium isotopes and Tc-99 separately (i.e., by methods other than gamma spectroscopy). The licensee used the applicable dataset that coincided with the turnaround time of samples being used to characterize soil (the LSA survey units typically used the longer hold time, while the reuse soil often used the shorter hold time). The primary difference in the two datasets was in the derived average Ra-226 value because the longer hold time resulted in a value that was about 0.17 pCi/g higher than the value used for the short hold time. These data were used for both survey planning and deriving the net concentrations in survey unit samples when determining the final SOF value for a sample or survey unit. For statistical tests, such as the Wilcoxon Rank Sum

(WRS) test, the full datasets of the samples were used with each sample's data being transformed into an SOF value based on the DCGLs applied to the survey unit data. The NRC staff found the updated reference dataset acceptable because the samples were obtained from locations previously approved for background and analyzed using the same laboratory and methods employed for the FSS.

Table 8 presents a summary of the reference dataset found in the memoranda cited above and in Table 5-1 of Volume 2, Chapter 8, of the FSSFR. As noted in the memoranda and in the DP, the licensee chose to consider background only for Ra-226 and Th-232 when determining a SOF value for demonstrating compliance with 10 CFR 20.1402. To maintain consistency with previous evaluations and the DP, the licensee used a value of 0.9 pCi/g for the "without ingrowth" dataset for Ra-226 and a value of 1.0 for Th-232 regardless of ingrowth. It should also be noted that the Tc-99 and the uranium isotope data were not generated by gamma spectroscopy, which explains why there is no change for those radionuclides based on the hold time.

Table 8. Average Reference Area ROC Concentrations

ID	Ra-226	Th-232	Tc-99	U-234	U-235	U-238	Total U
Without ingrowth[1]	0.985 (0.9)	0.978 (1.0)	0.044	0.707	0.035	0.738	1.48
Standard deviation	0.178	0.246	0.058	0.235	0.025	0.180	0.297
With Ingrowth	1.071	1.017 (1.0)	0.044	0.707	0.035	0.738	1.48
Standard deviation	0.168	0.219	0.058	0.235	0.025	0.180	0.297

Note: When more than one value is provided, the values in parentheses are those that the licensee conservatively used based on previous reference area characterizations. The values without parentheses are based on analytical results for the FSS characterization in the FSSFR.

Demonstration of 100-percent scanning of LSA Class 1 survey units

The demonstration of 100-percent scanning of Class 1 LSA survey units was raised as an issue when a NRC inspector noted that an LSA survey unit plot of the scanned data showed some small gaps. The plot of global positioning system (GPS)-logged data points was scaled to be a dot approximating 2 feet in diameter in the survey unit. While most of the area was covered by the dots, gaps between them were sometimes visible. The NRC staff found that the GPS data may provide only an approximate location of actual detector location and such plotting should not be relied on to definitively demonstrate compliance with 100-percent scan coverage. However, such data could show that there was sufficient coverage within a survey unit that the expectation of 100-percent coverage was reasonably attempted. The staff further notes that some gaps may occur because of inaccessibility during the scanning survey, such as would occur when standing or running water is present or a pipeline, rail line, or other object transects the survey unit, and that justification for not surveying those areas would be necessary in the FSSFR. Each LSA survey unit FSSFR provided plots of the gamma walkover survey (GWS). The staff reviewed these plots and found any

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[1] Ingrowth refers to the increasing activity of decay progeny that occurs over time. Full ingrowth would correspond to full equilibrium conditions which, for situations where the progeny has a much shorter half-life than the parent radionuclide, occurs after about 8 half-lives of the progeny. In some sample analysis methods, the analytical process often considers the emissions from progeny when determining the parent's activity level.

significant gaps to be adequately justified. In addition, surveying was observed during NRC inspection and verified by confirmatory surveys, as discussed in Section 8 of this SER.

Scanning and sampling of excavation sidewalls

Excavation sidewall scanning and sampling was another issue raised during inspections (see Section 8 of this SER). The NRC inspectors noted that the licensee was not meeting its commitment to perform a 100-percent scan of the exposed and accessible surfaces in the Class 1 land survey units. Specifically, the licensee was not scanning the sidewalls of the excavation because of safety concerns and improper equipment. As described in the FSSFR, Volume 3, Chapter 1, Section 5.2, the licensee performed discretionary sidewall sampling for Tc-99 if the sidewall areas of an excavation exceeded 5 percent of the total area of the survey unit and to evaluate any inaccessible surfaces by review of the scanning plot to determine whether count rates were trending up towards the inaccessible surface. This sampling was intended to address the inspector's concern about the failure to perform 100-percent scanning of the sidewalls. However, some areas were backfilled before sidewall scanning or sampling could be performed. No apparent foreign materials (e.g., discolored soil areas or non-soil materials) were present in these areas before backfilling excavations, and the sampling and scanning data obtained indicate that an exceedance of the $DCGL_W$ criteria is unlikely in the limited areas where scanning excavation sidewalls did not occur. The staff therefore finds the licensee's sidewall scanning and sampling methods adequate to demonstrate satisfaction of the FSS commitments even though it did not scan some difficult to access areas of some excavations.

Delineation of radiologically elevated areas in LSA survey units

Radiologically elevated areas were identified as a subject of concern during the staff's review of FSS reports for LSA survey units. Specifically, the staff noted that in LSA 08-01, the elevated area appeared to cross the survey unit boundary into survey unit 08-02. The staff requested and the licensee provided additional information about the elevated measurement comparison (EMC) areas (ADAMS Accession No. ML18052B085). In this particular case, the area was relatively small, the licensee conceptually "shifted" it to lie within just one survey unit, and the area bounded by sampling results was increased to conservatively encompass more area. The staff was concerned that an elevation that straddled or was adjacent to a survey unit boundary may be artificially limited if using the survey unit boundary as a boundary for the elevation and could be transferred from a survey unit without an adequate margin of allowance for the elevated area. In addition, the staff noted several LSA survey units (e.g., LSA 08-10 and LSA 08-12) that bounded the elevated area using the survey unit boundary. This issue was resolved to the staff's satisfaction because the one elevation would not exceed the applicable limit if it were in either survey unit, and the elevated sample in the other survey units was conservatively contained by the assumed area based on scanning results.

Surveys surrounding the gas pipeline within LSA survey units

The NRC staff identified the Laclede Gas Pipeline, a high-pressure natural gas pipeline running through some LSA survey units, as an issue because, while the pipeline is on Hematite property, it is in an easement, and the pipeline is not the licensee's property. The licensee was careful to not unduly disturb the pipeline during remediation, and the piping is considered not to be impacted by licensed activities, although surrounding soil may have been impacted. The presence of the pipeline resulted in less than 100 percent of the survey unit area being scanned and may also have required adjusting some sampling locations. Remediation and surveys were allowed to consider soil supporting the pipeline to be inaccessible and, unless scanning or sampling of soil close to the pipeline indicated that the soil likely was contaminated above the DCGL values, it could remain undisturbed. Laclede and the State of Missouri expressed concern to the NRC that future workers may receive exposure (chemical as well as radiological) if they need to access the pipeline for maintenance once the site is released. Laclede and the licensee arrived at a settlement, and the State of Missouri and Laclede withdrew their concerns after internal meetings between managers from the Missouri Department of Natural Resources, the Hematite Decommissioning Project (HDP), and Laclede.

Isolation and control of LSA survey units after the FSS was conducted

The staff identified isolation and control of LSA survey units post-FSS as a concern during inspection and confirmatory surveys (see Section 8 of this SER) after a localized flooding event carried some contaminated debris into an area that had previously been surveyed by the licensee. While the licensee subsequently removed the material and rescanned the survey unit, the survey unit was among several that were backfilled, at risk of potentially having to reaccess the area, before the closing of the inspection finding. Eventually, upon completion of site remediation, additional confirmatory sampling was performed to assess a cross section of open land areas that may have been affected by the flooding. This sampling was done to determine whether contamination was likely to have been redistributed into previously surveyed areas. The sampling found no evidence of cross-contamination exceeding the $DCGL_W$.

Scanning of PSA survey units

Methods for scanning PSA survey units had some unconventional aspects. In the case of scanning Class 1 piping, the licensee progressed the scanning instrument at a reasonable speed within the piping but logged 1-minute counts for subsequent review because the area was inaccessible to personnel (described in the FSSFR, Volume 5, Chapter 3, Section 6.1). The logged survey data were then reviewed to discern whether an elevation was present within the piping. This surveying method is an atypical approach because it measures average contamination over the distance traversed over the 1-minute period. A shorter timeframe for the logging function when scanning would have provided more localized results to use in identifying areas of potentially elevated activity. Regardless, contamination within the piping survey units was shown to be, on average, significantly below the $DCGL_{SO}$, and therefore, the staff finds the likelihood of significant elevations exceeding the $DCGL_{SO}$ to be low and the licensee's scanning approach to be adequate in this case.

Another issue with the PSA surveys was simply that the scanning and measurements in the Class 1 piping were taken along the bottom of the pipe, while the sidewalls and tops were not surveyed. While this is inconsistent with the 100-percent guidance for scanning Class 1 survey units, the staff considered that the liquids and particulates that may have been present were most likely to result in contamination along the bottom of the piping so that the licensee had measured and scanned portions of the piping most likely to be contaminated. For this reason, the staff considered the piping surveys to be bounding for residual radioactivity in the pipes, and therefore, the licensee's piping survey is adequate.

3 Land Survey Areas

This section of the SER addresses only the surveys of LSAs by considering the soil sampling and scanning of the open land area survey units upon removal of waste. It does not consider other media that may be present upon completion of decommissioning such as reuse soil used for backfill, ground water, piping, or structures. Subsequent sections discuss those media. Section 9 of this SER considers the dose from all site media and evaluates compliance with 10 CFR 20.1402 and 10 CFR 70.38(j)(2).

3.1 Final Status Survey Design

Survey and assessment of LSAs are discussed throughout Section 14 of the DP and in Volume 3 of the FSSFR as referenced in Appendix A. Upon removal of the various process buildings, the site was divided into 12 open land areas. Each land area was further divided into survey units of an approximate size consistent with their contamination potential according to the guidance in MARSSIM.

MARSSIM established classification of areas to determine the level of survey effort needed: Class 1 areas are considered impacted by licensed activity with a potential to exceed the release criterion and have small areas of elevated activity, Class 2 areas are considered impacted but with low potential to exceed the release criterion or have elevations, while Class 3 areas are impacted but with little or no potential to exceed the release criterion.

As discussed in the DP, the licensee can adjust the plan based on new information, such as reclassifying an area as Class 1 instead of a lower classification, or to better accommodate remediation efforts. The licensee did adjust some LSA survey unit classifications and borders based on survey data, consistent with the methodology described in the DP and MARSSIM. The changes made to the conceptual configuration of the land survey units can be seen by comparing Figure 14-14 of the DP, “Conceptual Open Land Area Survey Units,” to Appendix A of the FSSFR, Volume 3, Chapter 1, “Final Configuration of HDP Land Survey Areas.” Some survey units slightly exceeded the guidance for maximum area but by less than 10 percent, as allowed by the DP. Ultimately, 69 LSA survey units were identified.

The licensee performed Remedial Action Support Surveys (RASSs) during the site remediation that involved scanning and sampling. Once the licensee determined that a survey unit was sufficiently remediated, an FSS was designed that involved scanning of the land area and sample collection and analysis consistent with the survey unit being designated as Class 1, 2, or 3 according to MARSSIM. Section 2.1.1 of this SER presents the criteria to which a survey unit was being remediated. In most cases, the licensee determined it would utilize the “uniform” DCGLs; however, 9 of the 69 LSA survey units were evaluated based on the “layered” DCGLs.

For soil in open land areas, the licensee used RASS data to establish the approximate mean and standard deviation of the contaminant levels in a survey unit. Reference area mean and standard deviation data were reestablished during the FSS, as described in Section 2.3 of this SER. The number of statistically required sampling locations was determined from the RASS data and the reference area data using a Type 1 error rate of 0.05 (probability of incorrectly determining a site meets the release criteria when it is actually contaminated in excess of the criteria) and a Type 2 error rate of 0.10 (probability of incorrectly determining a site exceeds the release criteria when it is actually meeting the criteria) for the WRS statistical test. The licensee also performed a post-FSS evaluation of the WRS test sampling size using the data collected during the FSS and the reference area dataset. This secondary evaluation was performed to ensure that adequate samples were taken to satisfy the specified error rates of the test in the event that the RASS samples were not representative of the contamination in the survey unit.

Consistent with MARSSIM, adjustments to the sampling requirements were made if the a priori scanning MDC exceeded the derived $DCGL_{emc}$ for any Class 1 survey unit. The DP provided example scan MDC determinations consistent with methodologies in MARSSIM and NUREG-1507, "Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions," issued August 1995 (ADAMS Accession No. ML003676046). The licensee later modified these methods for determining open land area scan MDCs because of findings that the methods were not capable of identifying discrete sources of uranium (e.g., fuel pellet fragments) in soil. Section 2.3 of this SER discusses the modified methods of scanning soil.

The licensee performed a gamma walkover survey (GWS) of each LSA survey unit consistent with the guidance for coverage in MARSSIM and the DP. The licensee conducted 100-percent scans of the Class 1 survey unit accessible areas, at least 10-percent scans of the Class 2 units, and scanning as directed by the RSO in Class 3 survey units, consistent with MARSSIM and the DP. The GWS included GPS data logging and logging of each gamma flux measurement, which were subsequently plotted out and reviewed by the licensee to identify elevations that could be sampled to determine whether the data indicated exceedance of the $DCGL_w$'s. In some survey units, the scanning identified areas that likely exceeded the $DCGL_w$ and that were then remediated before being rescanned and sampled. The FSSFR of each LSA survey unit included plots of the scanning.

The licensee obtained samples from each strata existing after remediation in a survey unit following guidance in the DP. Samples were taken to correspond to the exposed surface or subsurface layers, depending on the remediation performed. "Surface" samples were to be taken from 0–6 inches below ground surface (bgs), "root" samples were to be taken from 6 to approximately 59 inches bgs, and "excavation" samples were to be taken from 59–65 inches bgs or until refusal or a sand gravel geological layer was encountered. The logic for sampling basically required at least one or two samples to be collected and analyzed from each location. If a surface layer was present, both a surface and root sample were collected and analyzed, and an excavation sample was collected but analyzed only if a root sample exceeded an SOF of 0.5. If remediation removed the surface layer, then a sample from both the root and excavation layers was collected and analyzed. If remediation removed both the surface and root overlying layers so that only the excavation strata remained, only an excavation sample was collected and analyzed. Because remediation may have removed portions of the strata within a survey unit, the licensee was careful to note the elevations across the survey unit and the strata each sample was pulled from in the data collection sheets. Samples were analyzed for all ROCs, including Tc-99, except for U-234, which was inferred from the U-235 and U-238 data by first determining the enrichment and then applying an implied U-234:U-235 ratio derived from the uranium enrichment in Table 14-5 of the DP.

The licensee then evaluated the collected data through several procedural steps. To evaluate the average contaminant level in a survey unit, the licensee generated an SOF for each sample using the most restrictive applicable $DCGL_w$ dataset in the survey unit and the gross analytical results. A similar dataset of reference area SOF data was obtained using the same $DCGL_w$ dataset. The WRS statistical test was performed to establish whether the average level of contamination based on the systematic samples (versus the biased samples) was less than the allowable $DCGL_w$'s.

The licensee performed additional evaluations to ultimately compare to the 10 CFR 20.1402 criteria. Another SOF dataset was established for each layer present in the survey unit using the net contaminant concentration (gross activity less the average reference dataset activity) of contaminants in each sample and the set of DCGLs applicable to the layer. The number of systematic samples from each layer was used to calculate a weighted SOF (SOF_{LSU}) by summing the weighted average SOF derived for each layer. The SOF_{LSU} calculation varied depending on whether the uniform DCGLs or the layered sets of DCGLs were applied. In the case of the uniform DCGLs, the weighting factor for each layer was determined by dividing the number of samples obtained in the layer by the total number of systematic *samples* obtained. For example, if only the root and excavation layers were present, and four samples were collected from the root layer and eight samples from the excavation layer, then the root average SOF was weighted by 0.33 (4/12) and the excavation average was weighted by 0.67 (8/12) before being summed to derive a total weighted average SOF based solely on the uniform set of DCGLs. When the layered DCGLs were applied (a separate set of DCGLs were applied to each layer), the weighting factor for each layer was calculated as the number of systematic samples collected in the layer divided by the total number of systematic *sampling locations* applicable in the survey unit strata. In an example similar to the previous one, if eight sample locations were identified for the survey unit, and four samples were collected from the root layer while eight were collected from the excavation layer, then the average root SOF was weighted by 0.5 (4/8), while the average excavation SOF was weighted at 1 (8/8). This provides a rough estimate of the proportion of a layer that was present in the survey unit at the time of the FSS.

If scanning or previous investigations identified a sample that exceeded the applicable $DCGL_w$'s (small areas may have been remediated), then the licensee evaluated the elevated area by first determining an appropriate area factor and multiplying by the applicable $DCGL_w$ to obtain a $DCGL_{emc}$. This was done separately for each ROC, as the area factors varied among the radionuclides and layers of a survey unit (see Section 2.1.1 of this SER). An SOF_{emc} was then calculated from the net average contaminant level of samples located in the elevated area. The net average of the elevation was calculated as the average of contaminants in samples taken within the elevated area less the average contaminant level for the survey unit based on systematic samples. The SOF_{LSU} for the land survey unit was then adjusted by summing the SOF based on the systematic samples with the SOF_{emc}'s.

For the purpose of demonstrating compliance with the 25 mrem/yr criterion, the various SOFs were totaled consistent with the equation below. This equation is a generalization because there is more than one contaminant of concern.

For LSAs using the uniform criteria:

$$SOF = \frac{f_{surface}\delta_{surface}}{DCGLw_{uniform}} + \frac{f_{root}\delta_{root}}{DCGLw_{uniform}} + \frac{f_{excavation}\delta_{excavation}}{DCGLw_{uniform}} + \frac{(ave.conc.hot\ spot\ 1-\ \delta)}{DCGLemc1} + \frac{(ave.conc.hot\ spot\ 2-\ \delta)}{DCGLemc2} + etc.$$

where:

f is the fraction of samples taken in the respective layer to all systematic samples obtained in the survey unit (surface, root, and excavation); and δ represents the net average concentration in the respective layer of the survey unit determined by unbiased measurements.

For LSAs using the layered criteria, the primary differences are that f is the fraction of samples obtained and analyzed in the respective layer to all systematic sampling *locations* in the survey unit and the DCGLw is that associated with the layer being evaluated. The f value, in this case, provides an estimate of how much of any specific layer remained in a survey unit. Because portions of a removed layer have been backfilled with reuse soil or offsite borrow material, the use of the f value accounts for the dilution that other materials would create in the layer. Reuse soil is accounted for separately when demonstrating compliance with 10 CFR 20.1402.

3.2 Final Status Survey Results

Volume 3 of the FSSFR describes and reports on the open land surveys that were performed. The licensee established 12 Land Survey Areas (LSAs) that are generally within natural boundaries and consistent with potential contamination of an area. The licensee generated an FSSFR, containing summary data, for each survey unit within each LSA as presented in Appendix A to this SER.

To determine the average contamination level based on randomized sampling locations, the licensee scanned and sampled each LSA survey unit. The accessible exposed surfaces in each Class 1 survey unit were scanned to provide confidence that any elevations above the applicable $DCGL_w$ were identified and evaluated. No exceedance of the $DCGL_w$ in the Class 2 and 3 survey units was expected (if an exceedance was identified, the survey unit was reclassified as Class 1) so a lower level of scanning was performed in those survey units consistent with the DP. Each FSSFR for each survey unit included plots of the scanning surveys, and the licensee used these plots not only to identify potential elevations for biased sampling but also to estimate the areal percentage of the survey unit that was scanned.

The soil in the area of identified elevations was subsequently sampled to quantify the average contaminant levels and help define the boundaries of the elevations. In at least two instances (LSA 10-03 and 10-04), the licensee elected to perform remediation of small areas of contaminated soil that the licensee determined were likely to exceed the applicable DCGLs. These areas were subsequently sampled to ensure that the soil met the $DCGL_w$. The SOF_{LSU} of each survey unit summed the average SOF values from the remaining strata with any elevated contribution identified in excess of the $DCGL_w$, according to the approved methods in the DP.

The table below summarizes the survey results from the LSA survey units. The SOF (Wtd Avg) is the weighted SOF value based only on the systematic samples that were obtained less any that may have been present in an elevated area. The elevated area SOF is provided when an elevated area was evaluated in a survey unit. ROCs in parentheses are those that primarily contributed to exceedance of the $DCGL_w$. These two SOF values would be summed to determine the SOF_{LSU} of a survey unit based only on the soil sampling performed. The SOF_{LSU} does not consider reuse soil, ground water, and any structures or piping that may be present in a LSA survey unit.

Table 9. Land Survey Unit Results Summary

Survey Unit	**Description**	**Layered or Uniform**	**Elevated Area Evaluation SOF**	**SOF (Wtd Avg)**
LSA-01 South Site Waterways				
LSA 01-01	Site Creek/Joachim Creek	Uni	N/A	0.01
LSA 01-02	South Section of Site Creek	Uni	N/A	0.03
LSA 01-03	North Section of Site Creek	Uni	N/A	0.08
LSA-02 Site Pond				
LSA 02-01	North Section of Site Pond	Uni	0.24 (U)	0.09
LSA 02-02	Central Section of Site Pond	Uni	0.25 (U)	0.17
LSA 02-03	South Section of Site Pond	Uni	0.19 (U)	0.11
LSA-03 West Open Land Area				
LSA 03-01	Area West of Site Pond	Uni	N/A	0.09
LSA 03-02	Area Southwest of Site Pond	Uni	N/A	0.20
LSA-04 Southwest Open Land Area				
LSA 04-01	Area between Buildings 230/231 and Site Pond	Uni	N/A	0.08
LSA 04-02	Area East of North Section of Site Pond (west soil laydown area)	Uni	N/A	0.11
LSA 04-03	Area East of Central Section of Site Pond (west soil laydown area)	Uni	N/A	0.09
LSA 04-04	Area South of Building 231	Uni	N/A	0.11
LSA 04-05	Wooded Area South of Building 231	Uni	N/A	0.06
LSA-05 Barns and Cistern Open Land Area				
LSA 05-01	Revised, Site Spring Area adjacent to State Road P	Uni	0.11 (Tc-99)	0.13
LSA 05-02	Revised, Tile Barn and Red Room Roof	Uni	N/A	0.34
LSA 05-03	Revised, Wood Barn	Uni	N/A	0.12
LSA 05-04	Revised, Site Spring and Cistern	Uni	N/A	0.11
LSA-06 North Open Land Area				
LSA 06-01	Main Parking Lot	Uni	N/A	0.06
LSA 06-02	West Parking Lot	Uni	N/A	0.08
LSA-07 North Central Open Land Area				
LSA 07-01	Truck Scale Area	Uni	N/A	0.11
LSA-08 Central Open Land Area				
LSA 08-01	Process Building Area Section 1	Layered	.22 (Tc-99)	0.05
LSA 08-02	Process Building Area Section 2	Layered	N/A	0.06
LSA 08-03	Process Building Area Section 3	Uni	N/A	0.05
LSA 08-04	Process Building Area Section 4	Uni	N/A	0.14

Survey Unit	**Description**	**Layered or Uniform**	**Elevated Area Evaluation SOF**	**SOF (Wtd Avg)**
LSA 08-05	Process Building Area Section 5	Uni	N/A	0.18
LSA 08-06	Process Building Area Section 6	Uni	N/A	0.19
LSA 08-07	Process Building Area Section 7	Uni	N/A	0.17
LSA 08-08	Process Building Area Section 8	Uni	N/A	0.25
LSA 08-09	Process Building Area Section 9	Layered	N/A	0.15
LSA 08-10	Process Building Area Section 10	Uni	.11 (Tc-99 and U)	0.22
LSA 08-11	Process Building Area Section 11	Layered	.21 (Tc-99)	0.17
LSA 08-12	Process Building Area Section 12	Layered	0.14 (Tc-99 and U)	0.30
LSA 08-13	Process Building Area Section 13	Layered	N/A	0.23
LSA 08-14	Process Building Area Section 14	Uni	N/A	0.23
LSA 08-15	Process Building Area Section 15	Uni	N/A	0.09
LSA 08-16	Process Building Area Section 16	Uni	N/A	0.13
LSA 08-17	Process Building Area Section 17	Uni	N/A	0.15
LSA-09 Rail Spur Open Land Area				
LSA 09-01	East Rail Spur Area	Uni	N/A	0.05
LSA 09-02	Central Rail Spur Area	Layered	N/A	0.11
LSA 09-03	West Rail Spur Area	Layered	N/A	0.11
LSA-10 Burial Pits Open Land Area				
LSA 10-01	Burial Pit Area Section 1	Uni	N/A	0.19
LSA 10-02	Burial Pit Area Section 2	Uni	N/A	0.07
LSA 10-03	Burial Pit Area Section 3	Uni	N/A	0.34
LSA 10-04	Burial Pit Area Section 4	Uni	0.14 (U)	0.14
LSA 10-05	Burial Pit Area Section 5	Uni	N/A	0.29
LSA 10-06	Burial Pit Area Section 6	Uni	N/A	0.11
LSA 10-07	Burial Pit Area Section 7	Uni	0.01 (U)	0.16
LSA 10-08	Burial Pit Area Section 8	Uni	N/A	0.05
LSA 10-09	Burial Pit Area Section 9	Uni	N/A	0.09
LSA 10-10	Burial Pit Area Section 10	Uni	N/A	0.14
LSA 10-11	Burial Pit Area Section 11	Uni	N/A	0.15
LSA 10-12	Burial Pit Area Section 12	Layered	N/A	0.23
LSA 10-13	Burial Pit Area Section 13	Uni	N/A	0.19
LSA 10-14	Burial Pit Area Section 14	Uni	N/A	0.13
LSA-11 East Open Land Area				
LSA 11-01	Northeast Site Creek	Uni	N/A	0.03

Survey Unit	Description	Layered or Uniform	Elevated Area Evaluation SOF	SOF (Wtd Avg)
LSA 11-02	Rail Road Line	Uni	N/A	0.07
LSA 11-03	East Site Wooded Area	Uni	N/A	0.18
LSA 11-04	Small East Site Wooded Area	Uni	N/A	0.17
LSA 11-05	Northeast Site Creek East Section	Uni	N/A	0.04
LSA 11-06	Rail Road Line Elevated Area	Uni	0.07 (Tc-99)	0.15
LSA-12 Laydown Area				
LSA 12-01	Reuse Soil Laydown Area Section 1	Uni	N/A	0.04
LSA 12-02	Reuse Soil Laydown Area Section 2	Uni	N/A	0.09
LSA 12-03	Reuse Soil Laydown Area Section 3	Uni	N/A	0.08
LSA 12-04	Reuse Soil Laydown Area Section 4	Uni	N/A	0.09
LSA 12-05	Reuse Soil Laydown Area Section 5	Uni	N/A	0.11
LSA 12-06	Reuse Soil Laydown Area Section 6	Uni	N/A	0.11
LSA 12-07	Reuse Soil Laydown Area Section 7	Uni	N/A	0.06
LSA 12-08	Reuse Soil Laydown Area Section 8	Uni	N/A	0.08
LSA 12-09	Reuse Soil Laydown Area Section 9	Uni	N/A	0.10

Notes: The SOF (Wtd. Avg) presented in this table is the weighted SOF value derived from the systematic sampling performed, less any samples collected from an area of elevation. These SOF values are not considering any reuse soil used as backfill, existing ground water contamination, or structure or piping that may be present.

The highest SOF value based only on the systematic average data occurred in LSA survey units 05-02 and 10-03, both of which had an SOF value of 0.34. The highest contribution from an elevated area occurred in LSA 02-02, which had an elevated contribution of 0.25. The LSA 08-12 survey unit had the highest combined SOF (sum of the average SOF and elevated area contribution) of 0.44.

3.3 NRC Evaluation

The NRC staff coordinated appropriately with the licensee during the decommissioning effort. This coordination included arranged publicly held teleconferences (usually held on a weekly basis) so that, when needed, issues could be discussed and resolved promptly. Because of the many survey units, large amount of data, and evolving methodologies for assessing layered survey units, the NRC staff reviewed some of the FSSFR chapters as they were initially generated to provide timely feedback to the licensee. This early review of the FSSFR chapters increased the likelihood that subsequent submittals included all appropriate information and were less likely to repeat any identified methodological errors. Once all chapters of the FSSFR were submitted, the NRC staff broadly reviewed the methods used and results obtained from all LSA survey units and chose to look in depth at the FSSFRs for seven LSA survey units (approximately 10 percent of the submitted LSA FSSFRs) to determine whether the methodologies being used were implemented correctly. The NRC staff selected these survey units (LSA 03-01, LSA 05-01, LSA 08-01, LSA 08-10, LSA 08-12, LSA 10-12, and LSA 11-01) to include all contamination potentials (Class 1, 2, and 3 designations) and both the layered and uniform approaches to evaluating the sampling data. Some were specifically selected because they were reported as having higher dose estimates. The staff's review of these FSSFRs involved the following:

- verification of the soil reference dataset
- verification that raw data were transcribed correctly
- verification that the U-234 concentrations were inferred correctly
- verification that the correct set of DCGLs was applied
- verification that the scan MDC was assessed correctly in the planning
- verification that the correct number of systematic sampling/measurements was planned
- review of the scanning survey results
- verification that any statistical testing was performed correctly
- verification that any elevated areas were evaluated properly (e.g., area factors and $DCGL_{emc}$ were calculated correctly)
- verification that the SOF for each survey unit was properly calculated and that the potential dose associated with each survey unit was less than the 25 mrem/yr criterion

The staff noted during its reviews that many of the FSSFRs contained typographical or transcription errors between text and tables. The staff pointed out these errors as they were identified, primarily through interactions with the licensee during the publicly held teleconferences. Errors affecting the technical evaluations and their resolutions were docketed. For example, when reviewing the spreadsheets developed for the first revision generated for LSA 08-12, the staff noted that the cell ranges in some formulas did not incorporate all of the reference and survey unit data when performing the WRS test. However, this excluded only one data point and did not impact the conclusion of the test. Similarly, when reviewing the report on LSA 08-01, the staff noted that the figure showing the elevated area was inconsistent with the area stated in the text and used for determining the $DCGL_{emc}$. The licensee acknowledged those identified errors (some were introduced when modifying the methods for performing the WRS test) and corrected the spreadsheets and survey reports. While many of these errors are still present in the current revisions of the FSSFR, the staff did not find that the errors significantly detracted from the FSSFR nor did they alter the conclusions presented by the licensee.

The licensee and its contractor replicated Excel spreadsheets as tools to assess each survey unit. These spreadsheets were provided to the NRC staff, who could verify formulas in the spreadsheets used to perform statistical tests, calculations, and similar manipulations of the data to eventually derive an SOF value for each survey unit. As most survey units showed only relatively minor variations, this approach was adequate to assess the methodologies used.

As previously discussed in Section 2.3 of this SER, the licensee did not always meet the 100-percent scan commitment, but the NRC staff found that the failures were reasonable in the situation (e.g., inaccessible areas) or were unlikely to have affected the survey findings (e.g., sidewalls of excavations). The plots of the scanning performed provide adequate confidence that 100-percent scanning of Class 1 areas was reasonably attempted to identify elevated areas of contamination in soil. The licensee's decision to sample within many of the identified elevations demonstrates that the elevations were appropriately investigated.

Several of the staff's evaluations involved simple comparisons (e.g., background data verification, data transcriptions, applicable DCGLs, and inferred U-234); however, the staff also reviewed the scanning MDC procedure developed by the licensee to verify scanning capabilities and used the Visual Sampling Plan software to assess the reference data and RASS data to verify the statistically required number of samples. If the scan MDC exceeded the $DCGL_w$ value for total uranium, the staff determined the applicable area factors to verify whether the sampling density was adjusted correctly. The statistical testing of each selected survey unit's data was independently performed to verify the results. Finally, the staff reviewed the licensee's data and analysis to determine if the SOF weighted fractions were accurately determined and that elevated areas were correctly assessed.

During the publicly held teleconferences, the staff expressed several concerns about the scanning methodology the licensee was using for open land area. First, there is no formal guidance or acknowledged precedence for determining the effectiveness of post-processed scanning survey data, as the licensee did for the Hematite site. Second, inspections documented that the scanning may not have been conducted consistently with the assumptions used to establish the a priori scan MDC, such as maintaining an average distance of 2 inches from the surface. Finally, the staff previously noted that it is unlikely that a scanning methodology is generally available for Tc-99 in soil, a low-energy beta emitter that likely would not register using a gamma detector. The staff asked the licensee to provide a posteriori assessment of the scanning methodology, which was subsequently submitted (ADAMS Accession No. ML18199A623). The staff found that the assessment demonstrated that the scanning methods (post-processing the data, along with professional judgment and the prescribed IALs) were adequate to identify total uranium at less than 40 pCi/g (an approximate total uranium $DCGL_W$ value applicable for survey planning and scanning), which, if it is collocated with Tc-99, would generally be sufficient to identify the contaminants at concentrations at or below the uniform $DCGL_w$.

The staff also considered the applicable area factor for total uranium that would normally bound an area of 250 square meters (m^2). A Class 1 survey unit is generally constrained to 2,000 m^2, and eight sample locations is the minimum number for any survey unit such that 2,000 $m^2/8$ = 250 m^2, the area represented by an individual sample. The staff noted that the total uranium area factor for a 250-m^2 area, for the surface, root, and uniform scenarios, is greater than 3 when assuming a 3-percent enrichment, such that the $DCGL_{emc}$ would exceed the scan MDC for total uranium, and no further sample size adjustment would be necessary. For the excavation scenario, the criteria were sufficiently high that the scan MDC would always be less than the $DCGL_w$, which complies with MARSSIM guidance for scanning capabilities.

The staff noted that the licensee considered whether Tc-99 had previously been identified in the survey unit at levels exceeding the $DCGL_w$. When this occurred, the licensee adjusted the sample size requirements to ensure detection of an area in which the Tc-99 $DCGL_{emc}$ would equal the highest concentration of Tc-99 observed. This approach provided confidence that the licensee took appropriate measures to resolve elevated Tc-99 considerations when designing the survey. Finally, the staff noted that only rarely did the retrospective sample size evaluation not confirm the actual number of samples collected. On those occasions, the minimum number of samples required fell within the 20-percent “cushion” that is part of the MARSSIM survey design and thus still provided a statistically sufficient number of samples.

The staff selectively verified the raw data transcriptions and U-234 inferred methods used by the licensee. The staff also verified the determinations of each selected survey unit’s $DCGL_w$ for total uranium, scanning MDC for total uranium, and scan $DCGL_w$. While the staff used average RASS sample concentrations for uranium as inputs to the Visual Sampling Plan software to determine the appropriate $DCGL_w$ and scan $DCGL_w$ for uranium, the licensee utilized the concentrations associated with the average enrichment determined from the RASS samples. The difference between the staff’s and licensee’s approach did not result in a significant change in the statistically required number of samples. The table below provides this comparison for the seven LSA survey units that the NRC staff evaluated in detail.

Table 10. FSS Planning Comparison of Licensee versus NRC Sampling Requirements

Survey Unit	Licensee-Determined Required Number of Samples	NRC-Determined Required Number of Samples
LSA 03-01	8	6 (8 when adding 20%)
LSA 05-01	8*	6 (8 when adding 20%)
LSA 08-01	8*	6 (8 when adding 20%)
LSA 08-10	8	6 (8 when adding 20%)
LSA 08-12	8	6 (8 when adding 20%)
LSA 10-12	8	6 (8 when adding 20%)
LSA 11-01	8	6 (8 when adding 20%)**

* Actual number of nonbiased sampling locations increased because the scan MDC exceeded the scan DCGLw for uranium or because Tc-99 was detected above the $DCGL_w$ during prior characterization.

** A transcription error is in the RASS summary table in the FSS planning document. The actual standard deviation for Th-232 is 0.028 as given in the RASS data table in the document.

Of the survey units containing elevations, no more than one elevated area was present in any survey unit. In total, 11 elevated areas in 11 separate survey units contributed to a survey unit SOF determination. Of some concern, 6 of the 11 elevations were primarily the result of Tc-99 concentrations, which caused the sample specific SOF based on the $DCGL_w$ to exceed unity. When evaluated as a hot spot, the licensee was able to show the identified elevated areas met the applicable $DCGL_{emc}$. Regardless, Tc-99 is considered a hard-to-detect radionuclide for which scanning may not be effective to identify elevated concentrations and it raises concern when found at concentrations exceeding the $DCGL_w$. In each situation, the licensee evaluated for Tc-99 hot spots by considering the maximum Tc-99 detected in the survey unit. The licensee determined what area or area factor would correspond to an elevation containing that average concentration. If the sampling density in the survey unit (m^2/sample) was at least as large as the corresponding area or area factor size (m^2), then sampling provided adequate confidence that any significant Tc-99 at the highest levels observed was likely to have been identified and appropriately considered in the FSS.

The staff identified a concern regarding LSA 11-06. This Class 1 survey unit was established after the survey of LSA 11-02, a Class 3 survey unit, randomly identified a Tc-99 hot spot exceeding the uniform $DCGL_w$. The licensee then established LSA 11-06 to consider this elevation as part of a Class 1 survey unit. LSA 11-06 is totally enclosed by LSA 11-02, even though it is relatively close to other Class 1 LSA survey units. While it may seem practical to extend the LSA 11-06 survey unit to border other Class 1 survey units, maintaining a limited size ensured adequate sampling to delineate the elevated area. There were no indications that the Tc-99 elevated area was symptomatic of a larger area extending outside the LSA 11-06 survey unit.

Inspections and confirmatory surveys were performed throughout the FSS process to verify compliance with the methods committed to in the DP and to verify the results that were generated. The NRC inspectors requested Oak Ridge Associated Universities (ORAU) to perform confirmatory surveys of select survey units when the licensee had completed its FSS of the unit. Section 8 of this SER discusses these inspections and confirmatory surveys.

The staff finds that the FSSs of the LSA survey units were adequate to provide reasonable assurance that contaminant concentrations in soil meet the applicable DCGLs for soil. The results of the surveys demonstrate that each LSA survey unit met the $DCGL_W$'s and $DCGL_{emc}$'s for soil, as applicable.

4 Reuse Soil

4.1 Final Status Survey Design

Section 14.3.2.3 of the DP and Volume 2 of the FSSFR discuss reuse soil and offsite borrow soil. The licensee stated that it would use scanning and sampling to determine the soil that was acceptable for reuse. The licensee identified three separate approaches to assessing the reuse soil as detailed in the DP and in FSSFR, Volume 2, Chapter 1. Sampling to determine contaminant concentrations would ultimately be used to assess the soil to be reused as backfill. Reuse soil differs from offsite borrow soil because offsite soil is considered not impacted and contributes no dose from residual radioactivity to potential land occupants when used as backfill. For that reason, this SER does not further discuss offsite soil. As stated in the DP, the licensee's decommissioning operations within open land areas included identifying and separating soil that could be reused from soil that exceeded the site cleanup criteria. The soil exceeding the site cleanup criteria was disposed of as waste according to the site's radioactive waste management program as approved by the NRC and described in Chapter 12 of the DP. Chapter 14 of the DP stated that "as soil is excavated, gamma scans will be used to guide the remediation and to support the segregation of soil for potential re-use as backfill."

The licensee performed gamma scan surveys during the excavation of soil potentially suitable for reuse as backfill (e.g., overburden in the burial pit area) with the objective of identifying discrete locations of elevated concentrations, as indicated by instrument count rate, for segregation from the balance of the soil. These surveys, using a 2 inch x 2 inch NaI detector, confirmed that the count rates associated with the remaining soil intended for reuse as backfill were relatively uniform and below count rates associated with soil containing concentrations in excess of the $DCGL_w$. Count rates were compared to the reuse material screening action level (RMSAL) and, if the level was not exceeded, a "lift" of the materials, as opposed to bulk excavation, was then loaded onto a dump truck and moved to a staging area for additional consideration. In most cases, each truck full of soil was assayed using a box counting system, rescanned using a 2 inch x 2 inch NaI detector after being transported, and composite sampled. Adjustments to the RMSAL occurred, as approved by the RSO, based on comparison of the detected count rates to the analytical results. If field scanning efforts were not deemed adequate, soil was transported to a laydown area, spread out, and scanned before being sampled and either added to a stockpile or disposed of as waste according to the site's radioactive waste management program as approved by the NRC and described in Chapter 12 of the DP. The approach taken for each stockpile is described in the FSSFR, Volume 2, Chapter 1.

As previously mentioned, in June 2013, confirmatory surveys of the LSA 05-02 survey unit found a fuel pellet fragment before backfill. When backfill was initially added, an additional fuel pellet fragment was identified. The presence of these fuel pellet fragments raised questions about the scanning methods that had been used during the FSS of the open land areas and to qualify soil as being suitable as backfill. One of the corrective actions was to reevaluate all of the soil in the seven reuse stockpiles generated to that date. To accomplish the reevaluation, the licensee engaged the services of the ISO-Pacific Nuclear Assay Systems S3 ("S3") soil sorting system. This operation began in November 2013 and continued through March 2014. Other adjustments to the methods used to assess potential reuse soil included reducing the depth of the "lifts" and, if scanning was not performed before excavation, spreading the soil out to a 6-inch depth and rescanning after transporting it to a laydown area.

As a result of processing these soils through the S3, certain stockpiles were consolidated: Reuse Stockpiles 1 and 2, Reuse Stockpiles 4 and 7, and Reuse Stockpiles 5 and 6. Because of contractual time constraints with the S3 soil sorting system, not all of the soil in each of the reuse stockpiles could be evaluated by processing it through the S3. The soil not evaluated by the S3 was combined to form Reuse Stockpile 9. Similar to Stockpile 9, Stockpiles 8a and 8b were generated after the S3 system had been returned by using modified methods for scanning and evaluating soil added to the stockpile.

A total of 10 isolated stockpiles of reuse soil were generated during the site remediation process (stockpiles numbered 1, 2, 3, 4, 5, 6, 7, 8a, 8b, and 9), with seven isolated reuse soil stockpiles (numbered 1–2, 3, 4–7, 5–6, 8a, 8b, and 9) identified upon completion of processing the soil to determine the acceptability for reuse. The soil in each stockpile was radiologically assessed and stored segregated from other site activities and each other until used for backfilling onsite excavated areas.

As described in the DP and in FSSFR, Volume 2, Chapter 1, there were three approaches to evaluating reuse soil. The most commonly used method involved evaluating the reuse soil on a truck-by-truck basis. The licensee began its evaluation by scanning the soil before it was loaded on a truck. If the soil did not exceed the action level, a "lift" of the scanned soil was loaded into a dump truck, which was weighed and analyzed using a box counter to provide an initial indication as to whether it would likely meet or exceed the uniform DCGLs being applied. A composite sample was generated from the soil once it was dumped. The licensee analyzed the sample using gamma spectroscopy and isotopic analysis for Tc-99. The U-234 data were inferred for the sample by assuming a U-234:U-235 activity ratio, which was based on the U-235:U-238 activity ratio (i.e., the enrichment) as determined by analytical results. Ratios of the various uranium isotopes by enrichment were listed in Table 14-5 of the DP, and these values were used to determine sample uranium enrichment and to infer U-234.

Once the full dataset of the soil concentration of ROCs was generated, a SOF value for each sample was derived using the net concentrations and the uniform soil DCGLs. Each SOF value associated with loads added to a stockpile was then weighted by a factor equal to the ratio of the net truck weight to the sum of all the net truck weights added to the stockpile. The weighted SOF values were multiplied by the number of truck loads added to the stockpile to get a sample weighted SOF value. The average of the sample weighted SOF values was assigned to the stockpile (SOF_{PILE}). The NRC staff requested, and the licensee provided, an unweighted average SOF value for the stockpiles that showed a negligible difference between the weighted and unweighted values. When two stockpiles were combined, the average of the two stockpiles' weighted SOF values was assigned to the combined stockpile. As the combined stockpiles were generated from very similarly contaminated individual stockpiles (with almost the same average SOF value), there was very little difference between the SOF for the combined stockpile and the individual stockpiles.

The licensee assessed Stockpiles 5, 6, and 9 using one of the other approaches, a FSS-style approach for open land areas. Soil for those stockpiles was spread out, scanned, and sampled to determine its acceptability for reuse. Soil deemed acceptable was "lifted," and the survey was re-performed for each subsequent layer. The licensee essentially performed an FSS of each layer of leftover soil added to the stockpile and scanned between each lift. A SOF value was obtained using the net concentrations in samples taken from all layers and the uniform DCGLs as described previously. The average SOF was then calculated for the entire stockpile.

In September 2015, during a review of combined Reuse Stockpiles 4–7, and as summarized in the FSSFR Volume 2, Chapter 1 (ML18052A565) the NRC staff determined that the previous approach to demonstrating the acceptability of reuse soil was not adequate to account for potential hot spots of Tc-99. The NRC conveyed the following:

> All radionuclides of concern, when assessed via composite sampling, should typically have an associated MIL to identify a DCGL hot spot of concern unless other surveys are used. It is understood that the gamma walkover surveys and ISO-Pacific Soil Screening are intended to identify locations that could present a DCGL hot spot concern for all radionuclides of concern except for Tc-99.

The modified investigation level (MIL) investigation was therefore confined to Tc-99. The licensee assessed its options and decided to place soil in a stratum where the MIL for Tc-99 is below the associated DCGL. The MIL was an action level derived for Tc-99 by dividing the $DCGL_w$ value by the number of individual aliquots used to generate the composite sample that was analyzed.

Subsequently, the licensee considered whether the Tc-99 MIL was exceeded or if the uniform $DCGL_w$ criteria were exceeded (SOF greater than 1) for any sample in a stockpile with regards to eventual placement in an LSA survey unit. If this occurred, soil from the stockpile would be dispositioned only in the strata of a survey unit for which the layer $DCGL_w$ exceeded the sample concentrations. The weighted average SOF for each stockpile (SOF_{PILE}) used as backfill in a survey unit was considered as an addition to the potential exposure in the survey unit.

4.2 Final Status Survey Results

As previously mentioned, the licensee generated seven reuse soil stockpiles before additional processing occurred as a result of corrective action in response to an inspection finding that cast doubt on the scanning methodologies used. The soil stockpiles were reevaluated using an S3 soil sorting device, and some were subsequently combined. Additional soil piles were generated after the S3 soil sorting equipment was demobilized so that a total of seven soil stockpiles were ultimately available as backfill in excavated LSA survey units. These stockpiles were designated 1–2, 3, 4–7, 5–6, 8a, 8b, and 9. Some stockpiles received additional attention because of slightly elevated Tc-99 in some samples which exceeded the MIL and also samples that exceeded the uniform $DCGL_W$ criteria. The licensee designated those stockpiles to be used only as backfill in the excavation or "deep" zone of applicable survey units.

The licensee calculated a weighted average SOF for each stockpile of reuse soil. If stockpiles were combined, the average of both original stockpiles was used to assess the combined stockpiles. Tables 7-1 and 7-2 of Volume 2, Chapter 1, of the FSSFR presents the final summary of evaluations and dispositions of reuse soil stockpiles (ADAMS Accession No. ML17009A154). The information in Table 7-1 of Volume 2, Chapter 1, of the FSSFR also appears in Section 9.1 of this SER and, for that reason, is not repeated here. Subsequent chapters of Volume 2 of the FSSFR, as referenced in Appendix A, discuss in detail each of the generated stockpiles. The SOF_{PILE} for all stockpiles was less than unity, with the highest SOF_{PILE} being 0.31 for combined Stockpile 5–6. The SOF_{PILE} is an addition to the SOF_{LSU} when used as backfill in a specific land survey unit for demonstrating compliance with 10 CFR 20.1402. Section 9 of this SER discusses that evaluation.

4.3 NRC Evaluation

The staff reviewed the reuse soil FSSFRs and verified specific determinations of the SOF values. The scanning, sampling, and use of the S3 soil sorting equipment provide confidence that soil exceeding the DCGLs was identified and segregated from the reuse soil. The significant amount of movement and mixing that the reuse soil underwent made it impractical to account for any elevations that may have been identified. For this reason, the licensee agreed to disposition reuse soil that had indications of an elevation exceeding the uniform DCGLs in the deeper layers of an excavation such that, if the layered DCGLs were applied, the soil would meet that set of criteria. Also, using the uniform DCGLs to assess the reuse soil would result in a conservative dose estimate based on these values. Finally, adding the average SOF of the reuse pile to any survey unit in which it was placed is also a conservative method of addressing the residual radioactivity contribution in the soil. The staff finds that the methods used to assess reuse soil were adequate to provide reasonable assurance that the soil meets the applied DCGLs and to conservatively account for its application as backfill in excavations in LSA survey units.

5 Building Survey Areas

5.1 Final Status Survey Design

Section 14 of the DP and Volume 4 of the FSSFR discuss the approach taken to building surveys. The Process Building, barns, and storage buildings, all their internal components and equipment, the concrete slab and foundation, and all related subterranean piping were removed and disposed of offsite during the decommissioning process. The remaining structures are primarily Building 110, Building 230, Building 231, and ancillary structures, such as the site pond dam, parking lots, various concrete slabs and walls, and other small structures. The full extent of the various remaining structures is described in Volume 4 of the FSSFR. Appendix A to this SER contains references to the FSSFRs generated for the various building survey areas (BSAs) and associated survey units, which summarize the survey design, results, and potential dose.

Five BSAs were associated with the structures left on site. BSA 01 had five survey units, all associated with Building 110, including subsurface soil and ventilation. BSA 02 had 27 survey units, all associated with Building 230 and also including subsurface soil and ventilation. BSA 03 had four survey units associated with Building 231, including subsurface soil, but no ventilation system was present in the structure. BSA 04 had 17 survey units associated with various small structures, concrete, asphalt, or rail lines that remained on site. Finally, BSA 05 had two survey units associated with LSA 05-01 and LSA 05-02 in which some ancillary structures were also present. The submittals for LSA 05-01 and LSA 05-02 included the FSSFRs for BSA 05.

The licensee performed structural BSA surveys for each applicable media in or under the structure. Specifically, the licensee sampled underlying soil; performed surveys for residual surface activity on the interior and exterior walls, floors, roof, and ceilings; and surveyed and sampled the contamination in ventilation. If accessible piping was present, it was also surveyed. The staff noted that the licensee removed floor drains and connected piping and disposed of it based on cost considerations rather than cleaning and surveying that material. Coring tools were used to provide access through slabs and foundations to facilitate the collection of sub-slab soil samples. In addition to obtaining adequate data to evaluate spatial distribution, the licensee performed biased sampling at locations having a high potential for the accumulation and migration of radioactive contamination to subsurface soil such as stress cracks, floor and wall interfaces, penetrations through walls and floors for piping, runoff from exterior walls, and leaks or spills in adjacent outside areas.

The areas and media were considered separate survey units within the BSA, consistent with MARSSIM guidance. Underlying soil sampling was similar to that of the LSA survey units and compared to the uniform $DCGL_w$ criteria to develop a SOF value for each sample. Again, similar to the method used for LSA survey units, the average of the systematic samples was determined for the BSA survey unit for underlying soil. Surface activity measurements (total alpha and beta) were obtained at a statistically determined number of locations based on RASS data and using a Type 1 error rate of 0.05 and a Type 2 error rate of 0.10 for the Sign Test. Surface contamination in ventilation was measured at accessible points and bends of the ductwork. Air samples of ventilation contamination were obtained from the supply vents of the operating heating, ventilation, and air conditioning (HVAC) units in Buildings 110 and 230. The sample filters were composited, analyzed by an offsite laboratory, and the results scaled from the 10 CFR Part 20, "Standards for Protection against Radiation," Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage," to generate a dose estimate. Measurements of removable activity (smear surveys) were obtained at each total surface activity measurement location.

The licensee performed scanning and obtained total surface activity measurements by using total alpha/beta detecting instruments and using a weighted instrument efficiency for the contaminants of concern based on the isotopic relative activity as described in the DP (over 95 percent of the activity was attributed to uranium isotopes and their short-lived decay products). Smear samples were also obtained from the direct measurement locations, analyzed for alpha and beta activity, and then the results were summed to obtain the total alpha/beta activity. If scanning identified an elevated area that was likely to exceed the $DCGL_w$'s for small office ($DCGL_{SO}$; see Section 2.1.2 of this SER), then the identified area was remediated until it was measured to be less than the $DCGL_{SO}$. Note that exceedance of the $DCGL_{SO}$ would mandate that a survey unit be considered a Class 1 designated area in which 100-percent scanning would be performed.

All high-efficiency particulate air (HEPA) ventilation associated with facility process equipment in Building 230 had been completely removed and shipped for offsite disposal before approval of the DP. Building 110 did not contain a HEPA ventilation system. The only remaining ventilation systems are the HVAC systems that service the administrative areas of Buildings 110 and 230. Radiological assessments of the HVAC systems were made by obtaining surface contamination measurements and smear samples for removable contamination. Measurements were obtained where residual radioactivity levels were representative of that on the interior surfaces (e.g., access points, filter housings, and probable collection areas). Exterior surfaces of such systems were also evaluated as part of the building or structure where the system was attached or was otherwise an integral component.

Once the FSS data were collected, the licensee assessed and evaluated the data for each survey unit to ensure that it was adequate to support the release of the survey unit. Simple assessment methods, such as comparing the survey data mean result to the appropriate $DCGL_w$, were performed first. All data were less than the applicable $DCGL_w$ so no additional assessment of the data was necessary, although comparisons using applicable statistical tests were performed for consistency. Details of the FSS design for each BSA survey unit are available, along with the data collected, in the various chapters of Volume 4 of the FSSFR as referenced in Appendix A to this SER.

5.2 Final Survey Status Results

The FSS evaluated five BSAs: BSA-01 (Building 110, 5 survey units), BSA-02 (Building 230, 27 survey units), BSA-03 (Building 231, 4 survey units), BSA-04 (ancillary structures, 17 survey units), and BSA-05 (foundations in LSA 05, 2 survey units). Subsurface soils were evaluated in all but BSA-04 and BSA-05. Ventilation was evaluated only in BSA-01 and BSA-02. The licensee established survey units of the structural interior and exterior walls, floors, ceilings, roof, and ventilation that were consistent with the guidance in MARSSIM, with allowable deviations as described in the DP.

The measurements in the BSA survey units were all significantly less than the applicable criteria being applied (i.e., $DCGL_{SO}$ = 18,925 disintegrations per minute (dpm)/100 cm^2, the uniform DCGL for soil, and the 1993 Guidelines for Decontamination), and the licensee usually needed only the minimum number of measurements tabulated in MARSSIM to fulfill the statistical requirements for the FSS. Scanning of some Class 1 survey units identified small areas that could exceed the $DCGL_{SO}$ criteria. The licensee chose to further remediate these areas instead of evaluating them as elevated areas within the survey unit. Subsequent measurements of the areas thus remediated met the $DCGL_{SO}$ criteria. No BSA survey unit measurement, either systematic or biased, exceeded the $DCGL_{SO}$. Similarly, no removable activity measurement, taken at the same location as the total activity measurement, exceeded 10 percent of the $DCGL_{SO}$, and most removable activity measurements were less than the instrument minimum detectable activity (MDA). All ventilation survey activity measurements were less than the criteria in the 1993 Guidelines for Decontamination. All underlying soil measurements met the uniform DCGLs. A SOF value was calculated for each survey unit based on the measured average and the applicable criteria. For the ventilation survey units, an annual dose estimate was made based on sampling results and divided by 25 mrem to obtain the SOF value.

The highest BSA survey unit had an average SOF of 0.19 (BSA 01-01, subsurface soils below Building 110). This SOF value is derived using the net concentrations of contaminants similar to those of the LSA survey units and comparison to the uniform DCGLs. Of the structural survey units, the highest SOF, based on the randomized (nonbiased) total alpha/beta activity measurement, was 0.06 (BSA 02-05, Rod Load Area—Sect 3 Floor and Lower Walls). The table below summarizes the BSA survey results for each survey unit.

Table 11. BSA Survey Unit Summary of FSS Results

BSA	Survey Unit	Description	Class	Average of Nonbiased Measurements (dpm/100 cm^2)	Average SOF ($DCGL_{SO}$ = 18,925 dpm/100 cm^2)
1	**1**	Subsurface Soil	2	sampled	0.19 ± 0.12
	2	Exterior	3	729	0.04 ± 0.04
	3	Interior Wall + Ceiling	3	218	0.01 ± 0.03
	4	Interior Floors	2	415	0.02 ± 0.03
	5	Ventilation Interiors	3	sampled	0.002
2	**1**	Subsurface Soils	2	sampled	0.05 ± 0.07
	2	Exterior walls + Roof	3	748	0.04 ± 0.04
	3	Rod Load Area—Section 1 Floor and Lower Walls	1	794	0.04 ± 0.01
	4	Rod Load Area—Section 2 Floor and Lower Walls	1	612	0.03 ± 0.02
	5	Rod Load Area—Section 3 Floor and Lower Walls	1	1152	0.06 ± 0.03
	6	Rod Load Area—Section 4 Floor and Lower Walls	1	751	0.04 ± 0.01
	7	Rod Load Area Kardex Walls	1	447	0.02 ± 0.01
	8	Upper Rod Load Area Upper Walls + Ceiling	2	347	0.02 ± 0.02
	9	Cushman Room Lower (N)	1	288	0.02 ± 0.01
	10	Cushman Room Upper	2	204	0.01 ± 0.01
	11	Gadolinium Room Lower (N)	1	433	0.02 ± 0.02
	12	Gadolinium Room Upper	2	53	0.003 ± 0.01
	13	U-Shaped Area (NW) Section 6 Floor + Walls	2	836	0.04 ± 0.01
	14	U-Shaped Area (SE) Section 7 Floor + Walls	2	321	0.02 ± 0.02
	15	U-Shaped Area Section 8 Trench	1	83	0.004 ± 0.006
	16	U-Shaped Area Section 9 Spill Area	1	302	0.02 ± 0.01
	17	U-Shaped Area All Upper Walls + Ceiling	3	82	0.004 ± 0.006
	18	Warehouse Area (W)	2	230	0.01 ± 0.01
	19	Mezzanine	3	58	0.003 ± 0.005
	20	Ventilation	3	sampled	0.004

BSA	Survey Unit	Description	Class	Average of Nonbiased Measurements (dpm/100 cm²)	Average SOF (DCGL$_{SO}$ = 18,925 dpm/100 cm²)
	21	U-Shaped Areas (SW) Storage Floor + Walls	2	783	0.04 ± 0.02
	22	Cushman Room Lower (S)	1	741	0.04 ± 0.02
	23	Gadolinium Room Lower (S)	1	518	0.03 ± 0.04
	24	Rod Load East and South Lower Walls	1	0	0
	25	Rod Load West and North Lower Walls	1	0	0
	26	Warehouse Area (E)	2	240	0.01 ± 0.01
	27	U-Shaped Area (NW) FSS Floor and Walls	2	380	0.02 ± 0.02
3	**1**	Subsurface Soils	2	sampled	0.05 ± 0.04
	2	Exterior Walls and Roof	3	442	0.02 ± 0.03
	3	Lower Interior Walls and Floor	2	602	0.03 ± 0.01
	4	Upper Interior Walls and Ceiling	2	265	0.01 ± 0.01
4	**1**	Site Pond Dam (LSA 02-03)	1	515	0.03 ± 0.02
	2	Septic Tank (LSA 08-17)	1	475	0.03 ± 0.05
	3	Parking Lot East (LSA 06-01)	3	163	0.01 ± 0.01
	4	Parking Lot West (LSA 06-02)	2	496	0.03 ± 0.01
	5	Vault Wall—Exterior wall Portion of Building 230	1	27	0.001 ± 0.004
	6	Building 115 (LSA 07-01)	2	534	0.03 ± 0.02
	7	Concrete (LSA 08-10)	1	338	0.02 ± 0.01
	8	Concrete (LSA 08-15)	2	160	0.01 ± 0.01
	9	Asphalt (LSA 04-01)	3	508	0.03 ± 0.01
	10	Slab (LSA 08-06)	1	474	0.03 ± 0.01
	11	Concrete (LSA 08-16)	1	229	0.02 ± 0.02
	12	Concrete (LSA 08-03)	1	25	0.001 ± 0.003
	13	Transformer Pad (LSA 08-04)	1	195	0.01 ± 0.01
	14	Truck Scale Foundation (LSA 07-01)	2	104	0.01 ± 0.01
	15	Rail Line (LSA 09-01)	2	366	0.02 ± 0.01
	16	Rail Line and Scale Foundations (LSA 09-02)	1	158	0.01 ± 0.02
	17	Rail Line (LSA 09-03)	1	293	0.02 ± 0.02
5	**1**	Springhouse Foundation (LSA 05-01)	1	273	0.01 ± 0.02
	2	Ancillary Structures (LSA 05-02)	1	488	0.03 ± 0.02

Note that when demonstrating compliance with 10 CFR 20.1402, the licensee summed the BSA average SOF of a survey unit with the encompassing LSA survey units when that situation exists, such as for the BSA 04 and 05 survey units. Similarly, the licensee summed applicable dose from multiple media, such as the SOF from ventilation and the SOF from individual structural survey units, to arrive at a bounding SOF for any particular BSA survey unit. For BSAs 1 through 3, the total SOF for any BSA, considering all contributing media, was less than 0.25. Section 9 of this SER presents the total dose assessment and discusses the summation of doses from multiple media.

5.3 NRC Evaluation

Similar to the review of the LSA survey units, the staff selected five BSA survey unit FSSFRs (approximately 10 percent) to review in detail while reviewing the remainder more broadly. Specifically, the staff reviewed in detail BSA 01-01, 02-01, 02-05, 02-20, and 04-07. The staff verified that the necessary number of measurements were obtained to meet the applicable statistical requirements and that the average SOF for the survey units was determined correctly. The BSA survey results were all less than the applied criteria, whether it be the uniform soil $DCGL_w$'s, the decontamination guidelines, or the $DCGL_w$ established for the small office. Thus, the surveys indicated that each survey unit met the criteria being applied.

The staff found methods for gathering measurements of surface activity and removable activity during the FSS to be generally adequate, although the review identified some issues. As discussed in more detail below, the first issue is that the surveys used an ambient instrument background that may not have been suitable for nonconcrete or tile, such as for the walls or ceilings of the structures. Second, the dose estimate based on results of the ventilation sampling was inaccurate. Third, the licensee used an improper calibration on one survey unit.

With regards to the use of an ambient instrument background to determine net measurement results, the staff noted that this often results in non-conservatively biased measurements of the walls and ceilings. Specifically, the staff found this to be readily apparent in the reported results for BSA survey units 02-23, 02-24, 02-25, and 02-26. Results for survey units 02-24 and 02-25 were almost entirely net negative measurements on walls, indicating that an improper material background was used. Similarly, survey units 02-23 and 02-26 had positive net results of the floor measurements but negative net results from wall measurements. After consultation with ORAU, the staff considered several options: (1) assume no instrument background for the structural surface activity measurements, (2) correct each measurement of non-floor materials in a survey by adding a positive value equal to the most negative net measurement, and (3) correct all surface activity results using judgment to select a conservative value for addition to the results.

Option 1 is the most conservative option but would add significant conservative bias to the results which would require additional data evaluations by the licensee. Option 2 would also likely result in conservative biases that would be difficult to define because each individual survey would have a different correction; also, this method may not be fully effective in Class 1 survey units where there is less possibility of the most negative value reflecting true background conditions. The staff chose Option 3 because of its simplicity and ease of assessing the impact. Thus, the staff considered the impacts of adding 1,000 dpm/100 cm^2 to each structural survey result (excluding sampling surveys conducted within the BSAs). This correction effectively forces all but two net negative measurements, obtained in BSA 01-02, to become positive, a consistent conservative correction of essentially all of the data because more than 99 percent of the negative measurements would become positive. The staff considers this conservative because net measurements of “at background” materials would generally expect to fluctuate around zero with some negative measurements. Because this correction makes almost every measurement positive, the staff has confidence that this conservatively corrects the oversight. The impact of such a correction is also easily considered as 1,000 dpm/100 cm^2 is about 5 percent of the $DCGL_{SO}$ criteria being applied to the structural surveys (equating to 1.32 mrem/yr). The staff notes that such a correction does not cause any of the biased measurements to exceed the $DCGL_{SO}$, which would require evaluation as an elevated area, nor does it cause any of the ventilation measurements to exceed the guidelines for decontamination criteria. As such, the staff finds this option effective in addressing the non-conservative bias present in non-floor measurements created from the use of ambient backgrounds, and no BSAs exceed the applicable criteria.

For the determination of dose resulting from ventilation contamination, the staff found that the method used by the licensee differs slightly from that approved in DP Section 14.4.4.1.5.4 and discussed in Volume 4, Chapter 1, Section 3.2, of the FSSFR. The licensee elected to directly compare the analytical results (or MDA values if results did not exceed the MDA) for uranium to the ALI for uranium in Appendix B to 10 CFR Part 20 (0.04 microcuries). The ALI corresponds to an exposure of 5 rem for an industrial worker, and the analytical values were used to scale an exposure estimate based on that relationship. This method could be acceptable if the volume of air sampled equates to the volume of air presumed to be breathed by an industrial worker during a 1-year period. However, the total volume of air sampled in Buildings 110 and 230 did not equate to the volume of air presumed to be breathed in a year. The staff estimates that a correction of less than a factor of 2 would be needed to accurately estimate this exposure. However, in this case, the estimated exposure from contamination in ventilation was much less than 1 millirem and, even when a factor of 2 is applied, the potential exposure remained significantly less than 1 millirem. The staff finds that correcting the dose estimate would be inconsequential in this case.

During the review of the ventilation surveys (BSA 01-05 and BSA 02-20), the staff noted that the instrument efficiencies for surface activity measurements varied significantly between the surveys conducted of the two buildings’ ventilation systems. The staff questioned the licensee and was informed in an email dated July 12, 2018 (ADAMS Accession No. ML18194A605), that the subcontractor had used an offsite instrument calibration efficiency instead of the proper onsite determined efficiency for the Building 110 survey. This resulted in a nonconservative bias in the Building 110 ventilation survey data. A correction of the data would, at most, increase the surface activity measurements taken during the Building 110 ventilation survey by 38 percent. This level of correction would not cause any surface activity measurement taken during the survey to exceed the decontamination guideline criteria (see Section 2.1.2 of this SER) being applied. The licensee also clarified that no other surface activity survey replicated this error.

The staff finds that the FSS of the BSA survey units was adequate to provide reasonable assurance that contaminant concentrations in underlying soil, ventilation, and structural surface activity meet the applicable DCGLs, or other criteria, for the various media. Even with an applied correction for use of a nonmaterial specific ambient background when taking surface activity measurements, the data demonstrate satisfaction of the DCGLs.

6 Piping Survey Areas

6.1 Final Status Survey Design

Sections 14.2.8 and 14.4.4.1.5.3 of the DP and Volume 5 of the FSSFR briefly discuss the general approach taken to surveying the piping remaining on site. Piping was considered a structure for the purposes of the FSS plan, and structures are discussed throughout Chapter 14 of the DP. The piping remaining on site and subject to an FSS includes the storm drain system, sanitary/grey wastewater discharge piping, raw water piping, public water supply piping, and rainwater drainage piping on buildings. A high-pressure natural gas pipeline also ran through a portion of the site; however, the interior of that piping was considered nonimpacted by site operations. Most of the potentially contaminated piping (including all process piping and drains) on the site was removed and disposed of as waste according to the site's radioactive waste management program as approved by the NRC and described in Chapter 12 of the DP. The remaining storm water and sanitary water treatment plant piping was visually inspected and cleaned before the surveys. Generally, the cleaning was effective in removing any sediments or scale from the surface of the piping so that little problem was encountered in meeting the release criteria (discussed in Section 2.1.3 of this SER). The other piping assessed was considered to have little likelihood of being contaminated in excess of the $DCGL_w$ (i.e., Class 3).

In total, the FSSFR identified three PSAs. PSA 01 included nine Class 1 survey units associated with the remaining storm drains. PSA 02 included one Class 1 survey unit associated with the remaining sanitary water treatment piping. PSA 03 included two Class 3 survey units associated with water supply lines and building downspouts. The piping was considered either Class 1 or Class 3, depending on the potential for contamination, consistent with guidance in MARSSIM. Volume 5 of the FSSFR gives details of the PSAs, survey design, and results.

PSA surveys of each designated piping survey unit were conducted. Piping surveys of Class 1 piping involved interior scanning of the bottom portion of the subject piping and systematic measurements of the bottom of the piping for comparison to the small office DCGLs and performance of the Sign Test, if needed. Table 4 in Section 2.1.2 of this SER presents fractional activity of the ROCs which were used to determine a total alpha/beta surface activity criteria ($DCGL_{SO}$ = 18,925 dpm/100 cm^2; see Section 2.1.3 of this SER) and weighted efficiencies of the instruments. For the Class 3 PSA survey units, measurements were typically taken at the accessible portions of each downspout or water pipe. Removable activity measurements were obtained from accessible total surface activity measurement locations.

The licensee used alpha/beta detecting instruments to obtain total alpha/beta activity measurements and to perform scanning. The initially estimated scan MDC for structural surfaces (piping was considered a structural surface) was calculated to be 1,299 dpm/100 cm^2 as shown below. An index of sensitivity (d') of 1.38 was used for surface scanning, based on a true positive proportion of 0.95 and a false positive proportion of 0.60. A survey efficiency of 0.5 was used, consistent with guidance in MARSSIM. A nominal background of 300 cpm was assumed for concrete, along with a general efficiency of 0.16 (combined instrument efficiency and source geometry efficiency). For scanning, the detector was pulled or pushed through the piping at speeds sufficient to remain below the small office $DCGL_w$'s ($DCGL_{SO}$), typically 1 to 2 inches per second, and the data were logged in the instrument for subsequent review. Actual efficiencies and background varied, affecting the scan

MDC. For example, the survey of PSA 02-01 used a much lower weighted efficiency of 0.01795 and a background of 460 cpm to achieve a scan MDC of 14,454 dpm/100 cm^2. The NRC staff noted that this value remains less than the $DCGL_{SO}$ of 18,925 dpm/100 cm^2. Scanning measurements of Class 1 piping were logged into the instrument at 1-minute intervals and reviewed after the survey to ascertain whether any significant elevations were present in the piping.

$$scan\ MDC = \frac{1.38\ x\ \sqrt{300\ x\ \frac{1}{60}}\ x\ \frac{60}{1}}{\sqrt{0.5}\ x\ 0.16\ x\ \frac{126}{100}} = 1{,}299\ dpm/100\ cm^2$$

Static measurements were obtained at the appropriate positions for 1 minute, consistent with the calculated static MDC. Class 1 piping was evaluated throughout its length, while Class 3 piping was evaluated only at accessible points. Smear samples were collected from accessible points of all piping. Similar to the scan MDC determinations, the static MDC varied depending on the applied efficiencies and background. However, the static MDC was consistently less than the scan MDC and the $DCGL_{SO}$. An example static MDC calculation is shown below with assumptions similar to those used for the scan MDC derivation above.

$$static\ MDC = \frac{3 + 4.65\ x\ \ \sqrt{300}}{0.16\ x\ \frac{126}{100}} = 415\ dpm/100\ cm^2$$

The number of systematic measurements for all Class 1 piping was calculated to be a minimum of 11 or 12 systematic locations based on RASS data. This number was based on use of the Sign Test and a Type 1 error rate of 0.05 and a Type 2 error rate of 0.10. For conservatism, the RSO directed that a minimum of 15 systematic locations be specified for each survey unit. Measurements were taken on a reference grid established on a straight line down the Class 1 piping. Because of the size of piping left in place, a Ludlum Model 43-68 (126-cm^2 flat gas flow proportional detector) was primarily used to conduct the FSS. The detector was either pushed or pulled through the Class 1 piping. The instrument was mounted on a sled in areas that could not be reached by the handheld instrument. In addition, a small, remotely operated cart was used with a camera to conduct visual inspections inside the piping. Biased measurements were commonly performed at the junctions of piping sections or at identified cracks in the piping. A Ludlum 43-89 (125-cm^2 alpha/beta scintillator) detector, or equivalent, was used for measurements of some accessible portions of Class 1 or Class 3 piping.

Each detector used to perform the FSS was calibrated with sources traceable to the National Institute of Standards and Technology and representative of the type and energy of the radiations emitted by the ROC for an 8-inch diameter pipe. The detectors were calibrated in a similar geometry, with a similar cable length, and with the source presented at a distance that approximates the distance to the surface of the piping that was used during the survey. This calibration applies to all piping remaining, with the exception of the sanitary waste treatment plant (SWTP) piping. Because the SWTP piping is 6.75 inches in diameter, a weighted detection efficiency was calculated for that piping.

6.2 Final Status Survey Results

Three PSA designations were surveyed: the storm drains (PSA-01, nine survey units, Class 1); the sanitary treatment piping (PSA-02, one survey unit, Class 1); and the water supply lines and Building 110 and 230 downspouts in the west open land area (PSA-03, two survey units, Class 3). As previously mentioned, the storm drains and sanitary treatment piping were cleaned before being surveyed.

The licensee took static measurements at the predetermined systematic and biased points. A minimum of 15 total alpha/beta measurements were obtained for the Class 1 survey unit piping along the length of the pipe. The ambient count rates of the instrument were subtracted, and the net results were compared to the $DCGL_{SO}$ (18,925 dpm/100 cm^2; see Section 2.1.2 of this SER) and no measurement exceeded the $DCGL_{SO}$. This was true of all measurements obtained in all of the various piping survey units, and no statistical testing was necessary to evaluate the data. While use of ambient background (generally obtained by simply holding the instrument in air away from any surface) was an issue identified by the NRC staff for the building and structural surveys, the staff believe this would be conservative for piping because the piping materials are likely to have a background higher than ambient. The measured smearable contamination was most often less than the MDA for the instrument being used, and when the MDA was exceeded, results were significantly less than 10 percent of the criterion (i.e., less than 1,893 dpm/100 cm^2).

The average net SOF of the systematic static measurements for the piping (SOF_{PIPE}) was calculated and added to the SOF determined for the encompassing LSA or BSA survey unit(s) when demonstrating compliance with 10 CFR 20.1402. Section 9.2 of this SER summarizes the average SOF for each survey unit, which is not repeated here. The highest SOF value (0.26) was obtained in PSA 02-01, the sanitary treatment piping.

6.3 NRC Evaluation

The NRC staff verified the scan MDC and static count MDC for the instruments used for the piping surveys and the number of required measurements for the survey based on RASS data. The staff found that some atypical aspects of the piping FSS, discussed in Section 2.3 of this SER, were still adequate in this case. No total activity measurement in the piping was greater than the $DCGL_{SO}$ criterion that were applied, and no removable activity measurement exceeded 10 percent of the $DCGL_{SO}$ criterion. Because all total activity measurements were obtained from the bottom of the piping, which was most likely impacted by operations and is expected to bound residual radioactivity on other portions of the piping, the staff considers the surveys adequate to characterize the residual radioactivity in the piping. The staff finds the methods used during the FSS of the piping to be adequate and to have demonstrated reasonable assurance of meeting the applicable DCGLs.

7 Ground Water

7.1 Final Status Survey Design

Volume 6 of the FSSFR reviews the ground water monitoring program that was conducted for the HDP. Section 14.5 of the DP (ADAMS Accession No. ML092330136) and a number of responses to NRC staff RAIs by the licensee (ADAMS Accession Nos. ML103490102, ML103560708, ML110730270, and ML111880290), describe specific actions that the licensee committed to take to protect the ground water at the site. As planned, the licensee (1) abandoned selected hybrid monitoring wells with well screens installed across both the silty clay and the sand/gravel unit below as an interim measure to prevent any radionuclides in the silt/silty clay from migrating to the underlying sand/gravel and bedrock aquifers, (2) removed and treated the impacted “leachate” from the overburden that accumulated in the excavation during removal of buried wastes and contaminated soil (ADAMS Accession Nos. ML18052A565), and (3) conducted ground water monitoring as described in the DP to assess any residual radioactivity in ground water at the site after the completion of site remediation (decommissioning activities such as excavation of burial pits, demolition and dismantling of structures, etc.).

The post-remediation monitoring network consisted of wells installed in both the shallow overburden sand/gravel aquifer and the Jefferson City-Cotter and Roubidoux bedrock aquifers at the site. These ground water monitoring wells were intentionally located immediately downgradient of the areas of excavated contaminant sources in order to better be able to detect if excavation activities were causing contamination to be released into the ground water. The post-remediation sampling and analysis focused on monitoring the migration of radionuclides that may have vertically moved from the silty/clayey overburden in the underlying sandy/gravelly unit and the bedrock aquifers. The approach was based on the site-specific hydrogeology, the pre-remediation ground water contaminant distribution, and potential radionuclide transport pathway data. The objective of the post-remediation ground water monitoring was to monitor and assess any deleterious effects of the soil excavation and remediation on the ground water and to demonstrate that the sum of the annual dose for all the residual radionuclides from ground water at the time of license termination, when added to all other sources at the site, does not exceed the total compliance limit in 10 CFR 20.1402 of 25 mrem/yr. For planning purposes, the licensee assumed that a maximum of 4 mrem/yr for the sum of all contaminants from groundwater would be allowed, as this level corresponds to the U.S. Environmental Protection Agency (EPA) maximum contaminant level (MCL) of 4 mrem/yr for unrestricted use of groundwater.

During site characterization, Tc-99 and the uranium isotopes were the most widely detected radioisotopes in ground water and were identified as the radionuclides of concern (ROCs) in the ground water underlying the facility. These ROCs were predominantly found near the evaporation ponds/leach field, one area on the northeast side of the former Process Building, and in the limestone storage/Deul’s Mountain area. Most radionuclide activity was identified in the leachate, ground water sampled from the wells screened in the silty clay aquitard hydrostratigraphic unit (HSU) near facility areas. Tc-99 and uranium measurements in leachate from overburden wells screened in the silty clay HSU indicated activity centered at the northeastern corner of the evaporation pond area and extending toward the eastern side of the Process Building. Very limited contamination was identified in the ground water from wells monitoring the sand and gravel aquifer. Tc-99 measurements in ground water from overburden wells monitoring the sand/gravel aquifer indicated only isolated, low-level detections in the aquifer. The NRC staff found that the levels of uranium activity in the sand/gravel aquifer were not significantly elevated above background and still well within the 10 CFR 20.1402 compliance limits.

The post-remediation monitoring network comprised a total of 31 wells, 18 in the Sand/Gravel HSU, 8 in the Jefferson City-Cotter HSU, and 5 in the Roubidoux HSU, with all located downgradient of respectively, the former burial pits, the former Process Building, and the evaporation ponds and leach field. In addition, a background well (WS-04), located off site at the Hematite Post Office, monitors the Roubidoux aquifer. Located in each of these HSUs, 23 monitoring wells were initially designed as the primary post-remediation well network, while the rest of the wells were secondary wells. The monitoring strategy was that the secondary wells would be sampled only if results from the primary wells indicated contamination. In response to the NRC's RAIs (ADAMS Accession Nos. ML102810455 and ML110210533), the licensee revised this sampling strategy to include the primary and secondary wells in each round of quarterly sampling.

As indicated in the DP, post-remediation ground water monitoring was initiated quarterly following completion of buried waste removal, contaminated soil removal, and site remediation activities. As there were no previous sample analysis results indicating radionuclide contamination in the ground water within the Sand/Gravel, Jefferson City-Cotter, or Roubidoux HSU that exceeded the MCLs or a dose limit of 4 mrem/yr (which was being applied as a hypothetical threshold by the licensee to help guide soil remediation so the entire site would meet the 10 CFR 20.1402 25 mrem/yr limit), the purpose of post-remediation sampling was to verify that any disturbances associated with the remediation of the source areas had not contributed radionuclide contamination to the ground water at the site. Therefore, the licensee terminated the post-remediation ground water monitoring in 2017 after six quarters of sampling (the DP committed to only four quarters) when sample data indicated that site remediation activities had caused no deleterious effect to ground water. Appendix A to this SER references the FSSFR submittals for post-remediation ground water overview and summary, as well as quarterly sampling reports.

7.2 Final Status Survey Results

The post-remediation ground water monitoring began in March 2016 and ended in September 2017. As described in the DP, ground water monitoring was performed quarterly. Samples were collected from the monitoring wells in the monitoring network and analyzed for gross alpha, gross beta, uranium isotopes, and Tc-99. Chapters 2–9 in Volume 6 of the FSSFR presents the results of the post-remediation ground water monitoring. Chapter 7 of the FSSFR includes a complete tabulation of analytical results of ROCs for up to six quarters, with the original laboratory data packages by Test America as appendices. A trend analysis using the Mann-Kendall method was included to identify trends of ROCs. The tables below summarize the monitoring results of radionuclides of concern in the Sand/Gravel HSU, Jefferson City-Cotter HSU, and Roubidoux HSU, including the detected maximum concentrations of each ROC and its range of averages.

Table 12. Summary of Radionuclides of Concern in Sand/Gravel HSU

Radionuclides	Unit	Maximum concentration	Monitoring well	MCL	Range of averages
Technetium-99	**pCi/L**	80.3 ± 8.24	GW-X	900	0–72.1
Uranium-234	**pCi/L**	4.5 ± 0.518	GW-HH	20*	0.0115–1.585
Uranium-235/236	**pCi/L**	0.121 ± 0.0655	GW-HH	20*	0.0005–0.0389
Uranium-238	**pCi/L**	3.86 ± 1.28	PZ-02	20*	0.0126–0.981

Table 13. Summary of Radionuclides of Concern in Jefferson City-Cotter HSU

Radionuclides	Unit	Maximum concentration	Monitoring well	MCL	Range of averages
Technetium-99	**pCi/L**	1.19 ± 1.02	BR-14-JC	900	0–0.2975
Uranium-234	**pCi/L**	11.7 ± 1.39	BR-17-JC	20*	1.30–6.80
Uranium-235/236	**pCi/L**	0.149 ± 2.8	BR-19-JC	20*	0.022–0.0917
Uranium-238	**pCi/L**	2.04 ± 0.44	BR-17-JC	20*	0.252–1.032

Table 14. Summary of Radionuclides of Concern in Roubidoux HSU

Radionuclides	Unit	Maximum concentration	Monitoring well	MCL	Range of averages
Technetium-99	**pCi/L**	0.969 ± 0.97	BR-10-RB	900	0–0.242
Uranium-234	**pCi/L**	6.2 ± 0.732	BR-08-RB	20*	1.089–5.878
Uranium-235/236	**pCi/L**	0.0757 ± 0.737	BR-08-RB	20*	0.0127–0.0429
Uranium-238	**pCi/L**	0.717 ± 0.152	WS-04	20*	0.132–0.593

* The EPA MCL for uranium is 30 micrograms per liter (µg/L). Natural uranium has a specific activity of 0.67 µCi/g which, when used to convert the EPA MCL, equates to 20 picocuries per liter (pCi/L).

The monitoring results show that all ROCs were significantly below the U.S. EPA MCLs (which were being applied by the licensee as hypothetical thresholds to help guide remediation so the entire site would meet the 10 CFR 20.1402 25 mrem/yr limit) in each of the HSUs at the site during the post-remediation ground water monitoring period. The maximum Tc-99 concentration was detected at 80.3 ± 8.24 pCi/L in the Sand/Gravel HSU, 1.19 ± 1.02 pCi/L in the Jefferson City-Cotter HSU, and 0.969 ± 0.97 pCi/L in the Roubidoux HSU, varying between 1 and 2 orders of magnitudes less than the MCL. The maximum concentrations of total uranium (the sum of all uranium isotopes) varied from 13.89 ± 4.63 pCi/L in the Jefferson City-Cotter HSU, 8.48 ± 1.86 pCi/L in the Sand/Gravel HSU, to 6.99 ± 1.47 pCi/L in the Roubidoux HSU. The likely reason that the maximum total uranium concentration was found in the Jefferson City-Cotter HSU is because of a high background in the aquifer. As expected, higher concentrations of the ROCs (Tc-99 in particular) in the Sand/Gravel HSU were found near the former Process Building (Monitoring Wells GW-JJ and GW-X) and evaporation pond (Monitoring Well GW-CC). Higher concentrations of uranium were found around the Red Room Roof Burial Area (Monitoring Well GW-HH) and near the evaporation pond (Monitoring Well PZ-02) as well.

7.3 NRC Evaluation

The NRC staff verified the monitoring results presented in the FSSFR with those values in the result summary spreadsheets reported by the analytical laboratory in Appendices A through D to the FSSFR, Volume 6, Chapter 7. The NRC staff also reviewed the results of blanks and duplicates analysis to verify the accuracy of the analytical results.

The licensee conducted a trend analysis of the ROCs using the Mann-Kendall method. The figures in Attachment 2 in FSSFR Volume 6, Chapter 7, present the analysis results. Although a discussion of the Mann-Kendall method and assumptions was not included and labeling in the figures provided in FSSFR, Volume 6, was in error, this did not impact the staff's evaluation. The concentrations of ROCs monitored in the aquifers are significantly less than the applicable EPA MCL standards for drinking water (which were being applied by the licensee as hypothetical thresholds to help guide remediation so the entire site would meet the 25 mrem/yr compliance limit of 10 CFR 20.1402), with either a downward or no apparent trend. Based on the concentrations of ROCs in each of the HSUs, Section 9.4 of this report calculates an annual dose contribution from potential use of site ground water. As described in Section 9.4 of this report, the total dose from the site, including ground water, remains below the 25 mrem/yr compliance limit of 10 CFR 20.1402. The staff finds the methods used to assess ground water concentrations to be adequate for demonstrating compliance with the applied radiological criteria.

8 NRC Inspections and Confirmatory Survey Assessments

During the periods of decommissioning activity conducted by the licensee at the Hematite site, and throughout the entire FSS, NRC inspection staff performed inspections during significant evolutions and were present at the site to ensure that the licensee conducted its activities in accordance with the approved DP. Licensee activities included characterization, remediation, packaging and shipping of waste, and segregation of excavated soils to maintain accountability of the materials awaiting analysis to identify contaminant levels and prevent cross-contamination.

In addition to observation of licensed activities, the NRC obtained the services of an independent contractor, Oak Ridge Associated Universities (ORAU), to perform independent confirmatory assessments that were used to verify radiological measurements and samples taken by the licensee. Radiological confirmatory surveys performed by ORAU were also used to address NRC staff concerns about contamination controls and the completeness of the licensee's DP activities and FSSs, based on NRC inspection findings.

During its inspections, the NRC identified several deviations from the licensee's DP and deviations from the licensee's planned FSSFRs that could have allowed cross-contamination to occur or contamination to not be properly identified and managed.

- At the NRC's request, ORAU completed confirmatory surveys of two FSS survey units and performed gamma scans of two additional units at the Hematite site from May 4–7, 2015. The survey activities included document reviews, GWSs, soil sampling activities, and laboratory analysis of confirmatory soil samples. All final confirmatory survey ROC concentrations from the LSA 10-03 and LSA 10-04 soil samples were below the individual uniform stratum $DCGL_w$ limits and also satisfied the SOF $DCGL_w$ criteria. The average SOF concentrations between the ORAU and the licensee sample populations for both survey units were in statistical agreement. Based on the findings of the confirmatory survey, ORAU found that the licensee has adequately demonstrated that survey units LSA 10-03 and 10-04 met the release criteria. Though ORAU was unable to fully assess the residual radiological status of LSA 10-01 and 10-02 because the walls of the excavation had been backfilled and made inaccessible, the walkover survey data showed that gamma surface activity levels were within the background variance for the site. ORAU Report 5184-SR-06-0, dated March 15, 2016 (ADAMS Accession No. ML16082A071), documented confirmatory survey activities for LSA 02-01, 02-02, and 02-03. Based on the findings of the confirmatory survey and the ORAU followup walkover survey, the licensee has remediated all contaminated roofing material from LSA 02-01, and the NRC finds that the licensee has adequately demonstrated that survey units LSA 02-01, 02-02, and 02-03 meet the approved DCGLs.

- At the NRC's request, ORAU completed confirmatory surveys of three FSS survey units from September 1–3, 2015, and submitted its report on March 15, 2016 (ADAMS Accession

No. ML16078A258). The survey activities included document reviews, beta scans, GWSs, soil sampling, and laboratory analysis of confirmatory soil samples. All confirmatory survey ROC concentrations from the LSA 02-01, 02-02, and 02-03 soil samples (except sample 5184S0122, which was remediated by removal of the sample) were below the individual uniform stratum $DCGL_W$ limits and also satisfied the SOF $DCGL_W$ criteria. Overall, ORAU did not find any issues with the methodology used for the calculation that would lead it to dispute the licensee's determination. Confirmatory scans identified six discrete locations above the gamma investigation level within the survey unit, which were evaluated consistent with the DP and FSS plan. Thus, the NRC concludes that the overall radiological condition of each survey unit adequately demonstrated that LSA 08-17 satisfied the NRC-approved soil and surface activity DCGLs.

- During weekly scheduled public teleconferences with the licensee in the fall of 2015, the licensee reported that it would be unable to complete its planned survey of the area directly adjacent to Joachim Creek because of frequent flooding and concern for surveyor safety. To ensure that contamination in the area of Joachim Creek was surveyed to the greatest extent possible, the NRC asked ORAU to perform an independent survey of that area. Based on the information provided by ORAU (ADAMS Accession No. ML17089A429), the NRC concludes that there was no contamination identified above the applicable DCGLs in the area of Joachim Creek.

- During the inspection on December 15, 2015, the inspectors observed that during FSSs being conducted in LSA 08-01, the technician performing a GWS was traversing an area with a survey meter and the height of the probe did not appear to be 3 inches or less from the soil. The inspectors took a photo of the survey technique and immediately notified licensee management, which agreed that the survey distance was not 3 inches or less from the soil. In Inspection Report (IR) 070-00036/2015-003, dated November 27, 2015 (ADAMS Accession No. ML15334A404), the NRC identified several instances in which the licensee performed GWSs that were not consistent with the planned distance between the detector and the surface. As part of the corrective actions taken that same day, the licensee issued a stop-work order for the FSS process until a preliminary root cause and corrective actions could be identified and taken. The licensee continued the stop-work order until individuals were appropriately trained and other corrective actions could be taken to retrain the individuals and audit their survey techniques. The licensee responded to the potential violation and documented the corrective actions in a letter dated December 23, 2015 (ADAMS Accession No. ML15357A074). Corrective actions included resurvey of the affected areas of LSA 08-01.

- Also in IR070-00036/2015-003, the NRC reported that 15 pieces of radiologically contaminated asphalt were in an area that had previously been surveyed and was going to be released by the licensee for unrestricted use. The licensee determined that these items were moved into the area by water from a heavy rainstorm from an adjacent radiologically contaminated area. As a result of the specific evidence that water had moved contaminated items and sediment significant distances and recontaminated areas previously designated for unrestricted release, the NRC evaluated aboveground water transport of radiological contamination, as discussed below.

The NRC identified instances where flooding had taken place between the time the excavation pit was surveyed and the pits were filled. The NRC observed that there was an opportunity for soil from segregated piles awaiting dispositioning or disposal off site to migrate to the open excavations. The licensee provided historical meteorological data, including aerial photographs to verify that most of the site was unlikely to have been potentially impacted; however, for a few of the filled pits, photographs and meteorological data could not eliminate the possibility of cross-contamination. To sample and ascertain the radiological status of the soil layer at the previous bottom of the pits, the NRC asked ORAU to drill a number of boreholes to the recorded depth of the pits. In the report on its analysis of the soil samples, dated January 24, 2018 (ADAMS Accession No. ML18024A876), ORAU indicated that there was no detectable contamination above the DCGL in the soil layer of the pit; therefore, the concern with respect to this migration was resolved.

8.1 NRC Inspections

As noted above, NRC inspection staff scheduled inspections during significant evolutions of the decommissioning activites conducted by the licensee at the Hematite Site, including: characterization; remediation; packaging and shipping of waste; segregation of excavated soils to maintain accountability of the materials awaiting analysis to identify contaminant levels and prevent cross-contamination; and throughout the entire Final Status Survey. NRC inspectors were present at the site to ensure that the licensee conducted its activities in accordance with the approved DP and regulations. During its inspections, the NRC identified several deviations from the licensee's DP and deviations from the licensee's planned FSSFRs that could have allowed cross-contamination to occur or contamination to not be properly identified and managed. The inspections and findings were documented in inspection reports and notices of violation.

Table 15. NRC Inspection Reports for Hematite Decommissioning Project

Inspection Reports/by Year	ADAMS Accession No.	Date of Report	Selected Violations/Findings
IR070-00036/2017-001	ML18099A019	04/6/2018	• NRC independent contractor conducted independent radiological surveys.
IR070-00036/2016-004 IR070-00036/2016-002 IR070-00036/2016-001	ML17101A640 ML16250A618 ML16190A360	04/11/2017 08/24/2016 06/27/2017	• NRC independent contractor conducted numerous independent surveys including of Joachim Creek and core bores in two LSA burial pits.
IR070-00036/2015-004 IR070-00036/2015-003 IR070-00036/2015-002 IR070-00036/2015-001	ML16172A285 ML15334A404 ML15218A328 ML15118A946	06/20/2016 11/27/2015 08/05/2015 04/28/2015	• Two violations of license for failing to perform GWS at the required distance; thereby unable to confirm that LSA could be released for unrestricted use. • Violation for licensee failure to prevent licensed material from entering nonradiological areas.

Inspection Reports/by Year	ADAMS Accession No.	Date of Report	Selected Violations/Findings
			• Violation for licensee failure to perform adequate surveys when potentially contaminated water left the site. • Finding: Licensee did not perform adequate surveys near and under a high-pressure natural gasline. • NRC independent contractor conducted independent radiological surveys.
IR070-00036/2014-005 IR070-00036/2014-004 IR070-00036/2014-003 IR070-00036/2014-002 IR070-00036/2014-001	ML15054A418 ML14192B070 ML14254A119 ML14160B134 ML14084A566	02/20/2015 07/11/2014 09/10/2014 06/06/2014 03/24/2014	• Violation for failing to perform adequate soil surveys. • Violation for failing to analyze water and sediment in storage tanks for fissile material. • Finding: Licensee could not fully evaluate significant rain events because of inadequate radiological controls. • NRC independent contractor conducted independent radiological surveys.
IR070-00036/2013-004 IR070-00036/2013-003 IR070-00036/2013-002 IR070-00036/2013-001	ML13305B012 ML13336A408 ML13241A252 ML13154A125	10/31/2013 11/27/2013 08/29/2013 05/31/2013	• Violation: Failure to use a radiological detection system to identify radionuclides and concentrations necessary for compliance with criticality controls, transportation, and waste disposal. • Violation: Failure to perform FSS as required. • Violation: Failure to identify “nonconforming items” that could contain significant quantities of licensed material, including fissile material. • Violation: Failure to perform radiological surveys on reuse soil.

Inspection Reports/by Year	ADAMS Accession No.	Date of Report	Selected Violations/Findings
			• Finding: Licensee lost criticality controls on 21 grams and 25.7 grams of fissile material. • Finding: Failure of the licensee to identify fissile material and other radiological contaminants during an FSS. • NRC independent contractor conducted independent radiological surveys.
IR070-00036/2012-004 IR070-00036/2012-003 IR070-00036/2012-002 IR070-00036/2012-001	ML13014A325 ML12244A427 ML12220A215 ML12157A407	01/11/2013 08/30/2012 08/02/2012 06/01/2012	• Violation: Failure to control licensed material that could have exceeded criticality control limits. • Finding: Licensee unable to identify that radiological surveys could not detect all radioactive or fissile material for the purposes of transportation, criticality controls, and waste disposal. • Finding: Licensee unable to adequately address potential radiological release off site during and after a significant rain event. • NRC independent contractor conducted independent radiological surveys.
IR070-00036/2011-002 IR070-00036/2011-001	ML12024A029 ML11304A099	01/20/2012 10/28/2011	• Finding: Licensee damaged ground water monitoring well during remediation causing Tc-99 to enter ground water. • NRC independent contractor conducted independent radiological surveys.

8.2 Oak Ridge Associated Universities Confirmatory Surveys

The NRC obtained the services of an independent contractor, Oak Ridge Associated Universities (ORAU), to perform independent confirmatory assessments that were used to verify radiological measurements and sample results obtained by the licensee. Radiological confirmatory surveys performed by ORAU were also used to address NRC staff concerns about contamination controls and the completeness of the licensee's DP activities and FSSs, based on NRC inspection findings. These confirmatory surveys were provided to the NRC in the form of letter reports and survey summaries as presented in the Table below.

Table 16. Independent Confirmatory Surveys Performed by ORAU To Support the NRC's Oversight of the Hematite Decommissioning Project

Report	Date	ADAMS Accession No.	Title
5184-SR-01-0	09/21/2012	ML12279A200	Independent Confirmation Survey Summary and Results for the Hematite Decommissioning Project
5221-LR-02-0	10/30/2013	ML13309A832	Letter, Report for two soil samples from Westinghouse Hematite
5184-SR-02-0	01/14/2014	ML14036A282	Independent Confirmatory Survey Summary and Results of Reuse Stockpiles 1, 2, and 3 for the Hematite Decommissioning Project
5184-SR-03-0	01/14/2014	ML14036A284	Independent Confirmatory Survey Summary and Results for Survey Units LSA 05-01, LSA 05-02, and LSA 05-03 for the Hematite Decommissioning Project
5184-SR-04-0	02/20/2014	ML14080A138	Independent Confirmatory Survey Summary and Results for Survey Units LSA 10-06 and LSA 10-07 for the Hematite Decommissioning Project
5221-LR-03-0	02/20/2014	ML14058A411	Letter Report for Analytical Results for Six Soil Samples Associated with the Westinghouse Hematite Decommissioning Project
5221-LR-05-0	10/22/2014	ML14308A342	ORAU Letter, Report for NRC Inspection Report 07000036/2014005(DNMS)—Westinghouse Electric Company (Hematite)
5221-LR-04-0	10/02/2014	ML14283A576	ORAU-Oak Ridge Associated Universities, Westinghouse-Hematite ORISE Sample Results
5184-DR-03-0	4/28/2015	ML15120A627	RAIs of TBDs and FSS Procedures
5221-LR-06-0	06/04/2015	ML15159A565	Letter Report for Analytical Results for Five Sediment and Twenty Nine Soil Samples Associated with the Westinghouse Hematite Decommissioning Project
5279-LR-01-0	11/12/2015	ML16034A089	ORAU Report 5279-LR-01-0 for IR 07000036/2016-001 (Hematite)

Report	Date	ADAMS Accession No.	Title
5184-SR-06-0	03/15/2016	ML16078A258	Independent Confirmatory Survey Summary and Results for Survey Units LSAs 02-01, 02-02, and 02-03 for the Hematite Decommissioning Project
5184-SR-05-0	04/15/2016	ML16111B050	Independent Confirmatory Survey Summary and Results for Survey Units LSA 10-03 and LSA 10-04 and Scan Survey Results for LSA 10-01 and LSA 10-02 for the Hematite Decommissioning Project
5184-SR-07-0	05/20/2016	ML16144A018	Independent Confirmatory Survey Summary and Results for Survey Units LSAs 08-06, 08-11, and 08-17 for the Hematite Decommissioning Project
5184-SR-08-1	03/16/2017	ML17089A429 ML17076A212	ORAU Survey Data from Joachim Creek for Westinghouse Hematite FSSR Independent Confirmatory Survey Summary and Results for Survey Units LSA 01-01, LSA 01-02, and LSA 01-03 at the Hematite Decommissioning Project
5184-PL-04-0	10/12/2017	ML17304A715	Project-Specific Plan for Confirmatory Subsurface Investigations and Sampling for the Hematite Decommissioning Project
5184-SR-09-0	01/24/2018	ML18024A876	Hematite Subsurface Sampling Final Report (012418)

9 NRC Evaluation of Dose Assessment

As described in the DP SER (ADAMS Accession No. ML112101640) associated with License SNM-33, Amendment 57, the projected dose from residual radioactivity at the Hematite site is received through the direct radiation, soil ingestion, and inhalation of dust pathways, as well as water-dependent pathways (i.e., ground water or surface water pathways). The licensee derived site-specific DCGL values for soil, building surfaces, and buried piping, which each correspond to a dose of 25 mrem/yr per ROC, based on a residential farmer scenario, which is the limiting scenario. The licensee also derived dose-to-source ratios (DSRs) for assessing ground water dose.

As part of the FSS, the licensee calculated a dose for each survey unit by comparing the average concentration in the survey unit to the DCGLs (or by multiplying the DSRs for ground water) and incorporating the dose from any elevated areas using area factors. The doses from reuse soil, buried piping, remaining structures (BSAs), and ground water were added to the dose from the LSA, where applicable, to find the total dose of each LSA compared to the license termination criteria of 25 mrem/yr and ALARA.

9.1 NRC Evaluation of Reuse Soil Dose

The DP did not contain detailed information on how the dose from reuse soil would be determined. Instead, FSSFR, Volume 3, Chapter 1, discusses in detail the methodology used to incorporate the dose impact from reuse soil. The dose contribution from all reuse stockpiles was determined by comparing the concentration of each stockpile to the uniform DCGLs, regardless of whether restrictions were placed on the layer where the stockpile was placed. (Section 4 of this SER discusses the details of how the licensee used sample data to determine the weighted average SOF of each stockpile.) For example, in LSA 08-01 and LSA 08-02, reuse soil from Combined Stockpile 4–7 was restricted to placement only in the deep stratum because there was one truckload of soil in the stockpile that exceeded an SOF of 1 when using the uniform DCGLs. Because the stockpile was restricted to the deep stratum, the licensee could have compared the average concentration to the excavation DCGLs in determining dose. However, for purposes of simplicity and to be conservative, the licensee used the uniform DCGLs to evaluate the dose impact of using reuse soil placed in the deep stratum. The Combined Reuse Stockpile 4–7 was calculated to contribute 6.25 mrem/yr to the total dose of a survey unit when evaluated against the uniform release criteria (an SOF of 0.25).

Also, as a conservative measure and to simplify the approach, the licensee did not use weighting factors for onsite reuse soil when only a portion of the stockpile was used in a given survey unit. When an onsite reuse soil stockpile was used in a survey unit, the entire dose for that stockpile was added to that survey unit, even if the entire stockpile was not used in that particular survey unit. For example, the total dose of 6.25 mrem/yr was added to the total dose calculation for survey units LSA 08-01, LSA 08-02, and LSA 08-08 even though only portions of Combined Reuse Stockpile 4–7 were used as backfill.

Table 1717 summarizes the dose impact from the reuse stockpiles and their placement in land survey areas.

Table 17. Reuse Stockpile Dose Contribution

Reuse Stockpile	Dose (mrem/yr)	SOF	Reuse Soil Placement Survey Unit Location	Survey Unit Stratum
Combined 1–2	2.5	0.1	LSA 10-14 and LSA 05-02	Deep
3	3.5	0.14	LSA 10-13	Deep
Combined 4–7	6.25	0.25	LSA 08-01, 08-02, and 08-08	Deep
Combined 5–6	7.75	0.31	LSA 11-01	Any
8a	5.5	0.22	LSA 08-06	Deep
8b	4.25	0.17	LSA 02-03, 03-01, 03-02, and 05-04	Any
9	3	0.12	LSA 08-04 and 08-05	Any

The NRC staff finds the methodology used to incorporate dose from reuse soil adequate because the uniform DCGLs were applied regardless of which strata the soil was placed into, and the entire dose was added to any survey unit that received soil, even if only a portion of the stockpile was used in a particular survey unit. The results provide reasonable assurance that the land survey units, when incorporating the potential exposure from backfilled soil, meet the unrestricted release criteria of 10 CFR 20.1402.

9.2 NRC Evaluation of Buried Piping Dose

The buried piping that remains at the Hematite site consists of sections of storm water piping (MARSSIM Class 1), the former sanitary wastewater treatment plant (SWTP) discharge line (MARSSIM Class 1), and the public/raw water system (MARSSIM Class 3). Table 188 summarizes the dose contribution from the buried piping survey areas (PSAs) and shows to which LSA the buried piping dose was added.

Table 18. Buried Piping Dose Contribution

PSA-SU	Class	DP Description	Avg. SU Residual Radioactivity (Fraction of $DCGL_{so}$)	Avg. SU Residual Radioactivity (mrem/yr)	PSA Dose Added to:
01-01	1	STM-1	0.00	0.0	LSA 07-01, LSA 06-01
01-02	1	STM-2	0.002	0.1	LSA 06-01, LSA 08-03, LSA 08-04, LSA 08-16
01-03	1	STM-3	0.013	0.3	LSA 06-01, LSA 06-02, LSA 08-16
01-04	1	STM-4	0.00	0.0	LSA 06-02
01-05	1	STM-5	0.00	0.0	LSA 06-02
01-06	1	STM-6	0.02	0.5	LSA 06-02, LSA 05-04, LSA 02-01
01-07	1	STM-7	0.00	0.0	LSA 05-04
01-08	1	STM-8	0.00	0.0	LSA 04-01, LSA 06-02, LSA 08-15
01-09	1	STM-9	0.00	0.0	LSA 08-06, LSA 08-10, LSA 08-15
02-01	1	SAN-1	0.26	6.5	LSA 08-10, LSA 08-15, LSA 04-04
03-01	3	WAT-1-8	0.02	0.5	LSA 08-03, LSA 08-16, LSA 08-17, BSA 01-01, BSA 02-01
03-02	3	DRN-X	0.007	0.2	BSA 01-02, BSA 02-02, BSA 03-02, BSA 04-06

As described in the DP, the dose from buried piping is determined by comparing the average residual radioactivity concentration based on the systematically collected measurements to the gross activity DCGL for small office.

The piping survey area with the highest dose contribution was PSA 02-01. FSSFR, Volume 5, Chapter 2, Revision 1, dated March 21, 2017 (ADAMS Accession No. ML17081A455), summarizes the final release record for PSA 02-01, the midsection of the SWTP piping, designated as SAN-1 in the DP. At the time the former SWTP was abandoned, decontaminated, and eventually demolished, the licensee collected a characterization sludge sample from the materials recovered from the discharge line during decontamination. The licensee verified that the radionuclide fractions in the SWTP sample result are consistent with the DP assumptions regarding the initial fractions (see Table 4 of this SER) that were used to determine the gross activity value that is equivalent to 18,925 dpm/100 cm^2. Therefore, the licensee did not need to calculate an alternative gross activity DCGL for the SWTP piping using different activity fractions.

The average radioactivity for the SAN-1 piping in PSA 02-01 was 26 percent of the gross $DCGL_{SO}$ of 18,925 dpm/100 cm^2, equating to a residual dose contribution of 6.5 mrem/yr. The remaining portion of the SWTP discharge piping designated as PSA 02-01 is present in LSA 08-10, 08-15, and 04-04. Therefore, the 6.5-mrem/yr dose contribution determined for PSA 02-01 was added to the total dose contribution for each of those LSAs.

If the remaining buried piping had exceeded the small office DCGL and could not be practically decontaminated or removed, the licensee committed in the DP to determining the specific dose from buried piping and adding it to the dose from the land survey unit in accordance with Policy HDP-PO-FSS-800, "Final Status Survey Plan for Piping," Section 12.4, issued July 3, 2012 (ADAMS Accession No. ML12187A121 and ML13031A452). However, this was not necessary in any case for piping because the levels did not exceed the small office gross activity DCGL.

FSSFR, Volume 5, Chapter 3, summarizes PSA 01-01 through PSA 01-09 (storm drain piping and manholes). FSSFR, Volume 5, Chapter 4, summarizes PSA 03-01 and 03-02 (water supply lines and Building 110/230 downspouts). These piping units intersect LSAs as shown in Table 18.

The NRC staff finds the methodology used to incorporate dose from piping adequate because the licensee verified that the initial distributions used to determine the gross activity value (18,925 dpm/100 cm^2) were reflected in sample results from the SWTP piping, and therefore, the gross activity DCGL value was appropriate. The NRC staff also verified that the appropriate doses related to this piping were added to the BSAs or LSAs where piping remains.

9.3 NRC Evaluation of Building Survey Area Dose

As described in the DP, the licensee determined the dose from residual surface contamination on building structures in each building survey unit by comparing the average of the systematic measurement samples to the small office gross activity DCGL. For subsurface soils beneath the building floors, the licensee compared the average concentration of systematic measurements to the uniform DCGLs.

FSSFR, Volume 4, describes the BSAs. The building structures that remain on site to be released for unrestricted use at license termination are Building 110 (Office and Security), Building 115 (Fire Pump House), Building 230 (Rod Loading), and Building 231 (Warehouse). Except for Building 115, each building was considered a separate BSA. Building 115 was folded into BSA 04 (Ancillary Structures) because of its relative size.

The BSA with the highest dose was BSA 01, which included subsurface soil beneath the Building 110 concrete slab. BSA 01-01 is the survey unit that specifically addressed this soil, and the results of the FSS for BSA 01-01 are compared to the uniform DCGLs for soil. The estimated dose contribution for BSA 01-01 is 5.25 mrem/yr (FSSFR, Volume 4, Chapter 6, dated September 6, 2017 (ADAMS Accession No. ML17257A187)).

The licensee assessed dose from ventilation systems in Building 110 (BSA 01-05) and Building 230 (BSA 02-20), as described in FSSFR, Volume 4, Chapter 16, dated September 6, 2017 (ADAMS Accession No. ML17311A684), and compared the dose to criteria, as summarized in Sections 2.1.2 and 2.2.3 of this report. The licensee found the dose from the ventilation system to be 0.05 mrem/yr for BSA 01-05 and 0.09 mrem/yr for BSA 02-20. The dose from the BSA 01-05 ventilation system was added to the interior walls and ceilings, as well as the interior floor survey units in Building 110 (BSA 01-03 and BSA 01-04). The dose from the BSA 02-20 ventilation system was added to all the survey units in Building 230, with the exception of the subsurface soils (BSA 02-01) and the exterior walls and roof (BSA 02-02). The NRC staff finds the doses attributed to the ventilation systems acceptable, based on the discussion in Section 5 of this SER.

In Appendix B to this SER, Table B-2 shows the total doses for each BSA associated with Buildings 110, 230, and 231. As noted in Section 5.3 of this SER, the NRC staff decided it would be appropriate to add approximately 1,000 dpm to each structural survey unit (except those associated with ventilation or underlying soil). This value equates to roughly 5 percent of the $DCGL_{so}$ or 1.25 mrem. The staff notes that even if 1.25 mrem/yr were added to each BSA, the total dose would still be within the criterion of 25 mrem/yr.

Table B-3 in Appendix B to this SER shows the doses for the ancillary structure BSAs and the associated LSAs that encompass these ancillary structures. The doses for the ancillary structures are listed in the “Remaining Structures” column in Table B-1, showing the total dose for the LSAs.

The NRC staff finds that the dose contribution from BSA survey units meets the 10 CFR 20.1402 criteria for unrestricted release because the average concentrations on building surfaces meet the small office DCGLs, and the licensee directly assessed the dose contribution from ventilation ducting through air sampling and added it to the appropriate BSA or where applicable. Also, in cases where a BSA represented a remaining structure encompassed within an LSA, the NRC staff verified that the appropriate BSA doses were added to the appropriate LSAs to demonstrate satisfaction of the applicable limits. In cases where subsurface soil beneath the building floors was a separate survey unit, the staff added the dose from subsurface soils to each survey unit within each respective building to conservatively assess potential exposure against applicable limits. The dose an occupant of the remaining buildings may receive when outside on the grounds is conservatively bounded by the results of the land surveys, and the doses remain below the 25 mrem/yr limit required by 10 CFR 20.1402. The results provide reasonable assurance that the BSAs meet the unrestricted release criteria of 10 CFR 20.1402.

9.4 NRC Evaluation of Ground Water Dose Contribution

As part of the DP, the licensee committed to assuming a SOF for ground water of 0.16 in the survey area release records for each LSA to support the NRC review of LSA survey area release records before the completion of the post-remediation ground water monitoring. This value is based on the ground water not exceeding the EPA drinking water standard of 4 mrem/yr (FSSFR, Volume 3, Chapter 1; the licensee applied the 4 mrem/yr as a hypothetical threshold to help guide soil remediation so the entire site would meet the 25 mrem/yr limit of 10 CFR 20.1402). This value was assigned before the completion of post-remediation ground water monitoring because at that point in time the monitoring had not yet been completed, so the licensee had to estimate an upper bound for groundwater contribution to the applicable standard in 10 CFR 20.1402. After the groundwater sampling was completed, the licensee used the actual sampling data to more accurately estimate groundwater dose contribution.

While the ROCs for the soil and unconsolidated sediments included uranium isotopes, Tc-99, Ra-226, Th-232, neptunium (Np)-237, americium (Am)-241, and plutonium (Pu)-239, the ROCs for ground water in the aquifer were Tc-99 and the uranium isotopes. As summarized in the NRC's SER for the DP, "the chemical analyses of groundwater samples collected from the monitoring wells completed in various hydrostratigraphic units (HSUs) confirmed that only Uranium-234, Uranium-235, Uranium-238 and Technetium-99 are the primary radionuclides of concern in ground water" (ADAMS Accession No. ML112101630).

During its review of the FSSFR, the NRC staff examined the technical basis for the primary radionuclides of concern for ground water. Neptunium-237, Am-241, and Pu-239 were determined to be insignificant contributor radionuclides for soil and unconsolidated sediments. Given that these insignificant radionuclides are potentially present in the soil and unconsolidated sediments, they were also potentially present in the ground water. However, during the site characterization for the DP, it was shown that these insignificant radionuclides were not ROCs in the ground water.[2] The licensee submitted summaries of the technical basis explaining why uranium isotopes and Tc-99 are the primary radionuclides of concern in ground water in e-mails dated March 13, 2018 (ADAMS Accession No. ML18124A231), and May 22, 2018 (ADAMS Accession No. ML18159A143).

The licensee sampled post-remediation monitoring wells quarterly after the completion of remediation until September 2017. The data collected were used to confirm that the sum of the annual dose from ground water for all the radionuclides did not exceed the EPA MCL of 4 mrem/yr (Volume 1, Chapter 1 of the FSSFR (ADAMS Accession No. ML17009A152)). Using the DSRs for Tc-99 and the uranium isotopes (U-234, U-235, and U-238) and the average concentrations over the monitoring period, the licensee calculated the dose contribution for each of the three HSUs for the site. The highest dose of the three HSUs associated with the average concentrations was 0.68 mrem/yr in the Jefferson City-Cotter HSU as noted in Volume 6, Chapter 2, "Ground Water Monitoring Results During Remediation," dated October 10, 2016 (ADAMS Accession No. ML16287A537). Therefore, the licensee added the value of 0.68 mrem/yr as the ground water contribution dose to all LSAs as shown in Table B-1 in Appendix B to this SER.

The licensee also calculated the dose assuming the maximum concentration in each of the HSUs. The doses associated with the maximum concentrations for the three HSUs are 2.11 mrem/yr for the Jefferson City-Cotter HSU, 1.3 mrem/yr for the Sand/Gravel HSU, and 0.56 mrem/yr for the Roubidoux HSU as noted in Volume 6, Chapter 2, "Ground Water Monitoring Results During Remediation," dated October 10, 2016 (ADAMS Accession No. ML16287A537). The NRC staff verified that even if the dose based on the maximum concentration of 2.11 mrem/yr was added to the LSAs instead of the dose based on the average concentration of 0.68 mrem/yr, all LSAs would still meet the 25-mrem/yr release criterion.

The NRC staff finds the approach used to determine dose contribution from ground water to be adequate because, even if assuming the maximum concentrations over the monitoring period, the

2 See Table 4-28 in the DP summarizing the ground water activity samples taken during characterization, indicating no detection of Np-237, Am-241, and Pu-239 in the bedrock aquifer. Table 4-29 of the DP provides the characterization values gross alpha and total uranium. The mean activity for gross alpha in the bedrock aquifer is 12.2 pCi/L. The mean activity for total uranium in the bedrock aquifer as shown in Table 4-29 is 3.2 pCi/L. The background values for Ra-226 range from 2.0 to 12.5 pCi/L (ADAMS Accession No. ML18211A553).

ground water doses are still within the amount the licensee initially allocated to groundwater of 4 mrem/yr. Furthermore, even if 4 mrem/yr, instead of the dose based on measured concentrations, were added to the LSAs, the total dose from all sources would still be below the 25 mrem/yr compliance limit of 10 CFR 20.1402.

9.5 NRC Evaluation of Land Survey Areas and Total Compliance Dose

The total dose for each LSA survey unit was calculated by adding the average survey unit dose, using the systematic measurements to the dose for each elevated area in the survey unit, as well as accounting for buried piping, ground water, and reuse soil, as appropriate. The average survey unit dose was determined for each survey unit by multiplying the SOF calculated based on the individual radionuclide $DCGL_w$ values by 25 mrem/yr, because the $DCGL_w$ values correspond to a dose of 25 mrem/yr for residual radioactivity. The $DCGL_w$ values were those either associated with the uniform approach or the three-layer approach.

In the three-layer approach, the sum of the weighted SOFs from each layer was calculated since the DCGLs in each individual layer represent 25 mrem/yr. The weighted average SOF is calculated using Equation 3-2 in Volume 3, Chapter 1, of the FSSFR (also reproduced above as Equation 1). Equation 1 weights the SOF of each stratum by the fraction of the survey unit area with contamination at the particular stratum depth. The number of sample stations at a particular stratum depth over the total number of stations is used as a proxy for the contaminated area within each stratum. This is appropriate since the sample stations are located on a grid, with each station representing the same area within the survey unit.

The licensee applied the uniform DCGLs in 60 of the 69 LSA survey units and applied the three-layer DCGLs in 9 of the 69 survey units. Five of those nine survey units (LSAs 10-12, 08-09, 08-11, 08-12, and 08-13) received clean offsite soil as backfill. As a result, the surface stratum does not have a dose contribution in those five survey units. In two of the remaining four survey units that applied the three-layer approach (08-01 and 08-02), reuse soil from Stockpile 4–7 was placed only in the deep stratum (FSSFR, Volume 3, Chapter 1). No backfill soil was applied in the remaining two survey units using the three-layer approach (09-02 and 09-03), which encompassed the rail line.

During the review, the NRC staff found that the licensee was using a weighted sum of fractions equation to calculate the SOF for the survey units that used the uniform approach, as well as for the survey units applying the three-layer approach. However, the licensee was using a different definition for the fractions. For the uniform approach, the licensee was using the fraction of the number of samples collected at a certain layer (instead of the sample locations). Therefore, the fractions would always add up to 1, whereas the fractions using the three-layer approach added up to 1 or greater. The NRC staff asked the licensee to explain why this approach would not potentially introduce error. The licensee explained in an e-mail dated January 9, 2008 (ADAMS Accession No. ML18038B548) that it decided to structure the FSS data evaluation spreadsheets to reflect the way the samples were physically collected, which also allowed it to structure the spreadsheets similarly for both uniform and three-layer survey units. The licensee explained that as the fractions used to weight each layer in the survey units always equal 1 for uniform survey units, the weighted average SOF will always equal the average SOF for all systematic samples collected in the survey unit. The NRC staff finds this approach adequate based on its verification of the LSA SOF calculations for the survey units using the uniform approach.

Table B-1 in Appendix B to this SER shows the total dose for each LSA, including contributions from elevated areas, buried piping, remaining structures, reuse soil, and ground water. The NRC staff notes that the dose in all LSA survey units is below the 10 CFR 20.1402 release criterion of 25 mrem/yr.

In summary, the NRC staff finds the total compliance dose estimates adequate based on review of the data submitted, verification that selected summary spreadsheets used the appropriate DCGLs and area factors, as well as verification that the licensee added doses from buried piping, reuse soil, remaining structures, and ground water, where necessary. The results provide reasonable assurance that the site land survey units meet the unrestricted release criteria of 10 CFR 20.1402.

9.6 ALARA Assessment

The NRC's regulations at 10 CFR 20.1402 provide, among other things, that before a site may be considered acceptable for unrestricted use, the residual radioactivity must be reduced to levels that are ALARA. The staff used the guidance in NUREG-1757, Volume 2, Rev. 1 "Consolidated Decommissioning Guidance," (ADAMS Accession No. ML063000252) specifically Section 6 and Appendix N, to assess whether the licensee met this regulatory requirement as documented in Section 7 of the DP SER.

The licensee considered the ALARA requirement for three actions: soil removal, washing of building surfaces, and scabbling of building surfaces. The licensee's analysis, which the staff previously found adequate in the SER supporting approval of the DP, determined that the planned actions for soil removal were ALARA, that the licensee appropriately evaluated potential ALARA actions associated with washing building surfaces and that further washing actions were unnecessary under ALARA, and that scabbling is unnecessary with respect to ALARA requirements. The NRC staff notes that the assumptions and data used for the evaluations were consistent with the FSS data in that the average contamination level in remaining structures was less than 21 percent of the DCGLs (i.e., a SOF of <0.21). While the highest PSA survey unit had an SOF of 0.26, this was determined by a conservative comparison to the small office DCGLs, which is not appropriate for assessing dose from residual radioactivity in the sanitary waste piping (also, the piping was cleaned before the FSS, which could be considered an ALARA action). The staff confirmed that the findings in the DP ALARA analysis remain applicable upon completion of the FSS: the ALARA evaluations performed by the licensee were appropriate for the decommissioning option, nature of existing contamination, and exposure scenarios assumed. In addition, the licensee's actions provided reasonable assurance that the ALARA requirement of the dose criterion in 10 CFR 20.1402 was met.

10 Conclusions

The licensee has completed the decommissioning of its Hematite Fuel Facility site located in Festus, MO. Based on observations during NRC inspections and the findings in this SER, decommissioning activities have been carried out in accordance with the DP, except as otherwise documented and approved in this SER. The NRC staff has reviewed the FSS data and results for the Hematite Fuel Facility, license number SNM-00033 according to the "Consolidated Decommissioning Guidance" (NUREG-1757) and guidance in MARSSIM (NUREG-1575). For the reasons described above, the staff has concluded that the FSS design and data collected were adequate to characterize the residual radioactivity. The staff also concluded that the data analysis and dose assessments performed are appropriate and that the projected dose from residual radioactivity in these areas is less than 25 mrem/yr. As documented in the NRC's SER for the Phase II DP, the staff concluded that the DCGL values are ALARA. Additionally, the NRC staff concluded in its approval that the ALARA requirement in 10 CFR 20.1402 is met for the dose assessment approach because of the extent of remediation performed by the licensee. For these reasons, the NRC staff has determined that the licensee has demonstrated that the site meets the radiological criteria for license termination described in 10 CFR 20.1402 and that there is reasonable assurance that the dose to the average member of the critical group is not likely to exceed the 25 mrem/yr dose criterion. In addition, the licensee submitted a completed Form 314 on March 1, 2018 certifying the disposition of licensed materials from the site. As such, staff has determined that the criteria in 10 CFR 70.38(k)(1) through (4) have been met and written notice of the termination of license SNM-000033 can occur.

11 References

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12 Appendix A. Tables of the Primary Submitted Final Status Survey Final Report Volumes and Chapters

The following tables list the volumes and chapters of the final status survey final report (FSSFR) submitted by the licensee, along with the date of submission and the Agencywide Documents Access and Management System (ADAMS) accession numbers. In some cases, the ADAMS accession number refers to a single document (for example, an attachment to a submission), while in other cases, the accession number refers to a package of documents, indicated with “(pkg).” When the accession number refers to a single document, the various appendices and attachments associated with the specific chapter usually may be accessed by locating the package associated with the cover letter listed in the properties of the ADAMS document.

Table A-1. FSSFR Overview

Description	FSSFR Volume 1, Chapter Number	ADAMS Accession Number and Document Date
Final Status Survey Final Report Overview	1 Revision 2	01/03/2017 ML17009A152

Table A-2. Primary FSSFRs Pertaining to Reuse Soil and Offsite Borrow Soil

Stockpile Number	Description	FSS Complete Date	FSSFR Volume 2 Chapter Number	ADAMS Accession Number and Document Date
Overview				
	Reuse and Offsite Soil Overview	N/A	1 Revision 2	02/12/2018 ML18052A565
Reuse and Offsite Soil				
1–2	Reuse Soil + Errata Page. Sample identification number 2426-RU-120404-02-04 the Sample Uniform SOF (sum of fractions) corrected.	03/2014	2 Revision 1	12/16/2014 ML14350A230 01/09/2017 (errata) ML17010A284
3	Reuse Soil	03/2014	3 Revision 0	09/13/2016 ML16285A379 (pkg)
	Reuse Soil Submit Errata Page. Sample identification number 2426-RU-120404-02-04 corrected single cell calculation.	03/2014	3 Revision 1	01/09/2017 ML17010A284
4–7	Reuse Soil	03/2014	4	09/13/2016 ML16285A379 (pkg)
5–6	Reuse Soil	03/2014	5 Revision 1	09/13/2016 ML16285A379 (pkg)
8a–8b	Reuse Soil, Revision to correct a typographical error that indicated an	10/2015	6 Revision 1	01/03/2017 ML17009A157

Stockpile Number	Description	FSS Complete Date	FSSFR Volume 2 Chapter Number	ADAMS Accession Number and Document Date
	incorrect Ra-226 background value for the soil sample data.			
9	Reuse Soil	05/2015	7	09/13/2016 ML16285A379 (pkg)
Offsite Borrow	Offsite Soil	09/2015	8	09/13/2016 ML16285A379 (pkg)

Table A-3. Primary FSSFRs Pertaining to the Land Surveys

Survey Unit	Description	FSS Complete Date	FSSFR Volume 3 Chapter Number	Accession Number and Document Date
Overview				
	Vol 3, Ch 1, LSA Overview, Revised to address NRC review comments	N/A	1 Revision 3	02/13/2017 ML17046A005
LSA-01 South Site Waterways				
LSA 01-01	Site Creek/Joachim Creek	12/16/2015	20	04/13/2017 ML17110A447
LSA 01-02	South Section of Site Creek	01/14/2016	20	04/13/2017 ML17110A447
LSA 01-03	North Section of Site Creek	01/14/2016	20	04/13/2017 ML17110A447
LSA-02 Site Pond				
LSA 02-01	North Section of Site Pond	09/29/2015	22	08/15/2017 ML17250A538
LSA 02-02	Central Section of Site Pond	09/29/2015	22	08/15/2017 ML17250A538
LSA 02-03	South Section of Site Pond	09/29/2015	22	08/15/2017 ML17250A538
LSA-03 West Open Land Area				
LSA 03-01	Area West of Site Pond	11/06/2015	23	05/15/2017 ML18199A623
LSA 03-02	Area Southwest of Site Pond	11/12/2015	23	05/15/2017 ML18199A623
LSA-04 Southwest Open Land Area				
LSA 04-01	Area between Buildings 230/231 and Site Pond	04/5/2016	15	07/24/2017 ML17230A161
LSA 04-02	Area East of North Section of Site Pond (west soil laydown area)	04/22/2016	15	07/24/2017 ML17230A161
LSA 04-03	Area East of Central Section of Site Pond (west soil laydown area)	04/21/2016	15	07/24/2017 ML17230A161
LSA 04-04	Area South of Building 231	04/12/2016	15	07/24/2017 ML17230A161
LSA 04-05	Wooded Area South of Building 231	06/21/2016	15	07/24/2017 ML17230A161
LSA-05 Barns and Cistern Open Land Area				
LSA 05-01	Site Spring Area Adjacent to State Road P	03/09/2014	16 Revision 1	01/09/2018 ML18019A541
LSA 05-02	Tile Barn and Red Room Roof	09/13/2013	16 Revision 1	01/09/2018 ML18019A541
LSA 05-03	Wood Barn	11/07/2013	16 Revision 1	01/09/2018 ML18019A541
LSA 05-04	Site Spring and Cistern	04/27/2016	16 Revision 1	01/09/2018 ML18019A541
LSA-06 North Open Land Area				
LSA 06-01	Main Parking Lot	06/24/2016	17	08/02/2017 ML17240A134
LSA 06-02	West Parking Lot	06/17/2016	17	08/02/2017

Survey Unit	Description	FSS Complete Date	FSSFR Volume 3 Chapter Number	Accession Number and Document Date
				ML17240A134
LSA-07 North Central Open Land Area				
LSA 07-01	Truck Scale Area	05/03/2016	17	08/02/2017 ML17240A134
LSA-08 Central Open Land Area				
LSA 08-01	Process Building Area Section 1	03/15/2016	12	04/03/2017 ML17117A312
	Errata pages, corrections per NRC comments		12	05/12/2018 ML18124A056
LSA 08-02	Process Building Area Section 2	02/04/2016	12	04/03/2017 ML17117A312
LSA 08-03	Process Building Area Section 3	03/18/2016	11	07/06/2017 ML17209A048
LSA 08-04	Process Building Area Section 4	04/07/2016	10	06/05/2017 ML17173A250
LSA 08-05	Process Building Area Section 5	04/12/2016	10	06/05/2017 ML17173A250
LSA 08-06	Process Building Area Section 6	01/06/2016	11	07/06/2017 ML17209A048
LSA 08-07	Process Building Area Section 7	01/07/2016	11	07/06/2017 ML17209A048
LSA 08-08	Process Building Area Section 8	04/07/2016	10	06/05/2017 ML17173A250
LSA 08-09	Process Building Area Section 9	04/28/2016	21 Revision 2	02/28/2018 ML18079A180
LSA 08-10	Process Building Area Section 10	07/13/2016	14 Revision 1	10/31/2017 ML17311A613
LSA 08-11	Process Building Area Section 11	12/16/2015	13	06/27/2017 ML17192A382
LSA 08-12	Process Building Area Section 12	04/22/2016	21 Revision 2	02/28/2018 ML18079A180
LSA 08-13	Process Building Area Section 13	04/21/2016	21 Revision 2	02/28/2018 ML18079A180
LSA 08-14	Process Building Area Section 14	05/24/2016	10	06/05/2017 ML17173A250
LSA 08-15	Process Building Area Section 15	07/18/2016	14 Revision 1	10/31/2017 ML17311A613
LSA 08-16	Process Building Area Section 16	03/17/2016	11	07/06/2017 ML17209A048
LSA 08-17	Process Building Area Section 17	01/19/2016	11	07/06/2017 ML17209A048
LSA-09 Rail Spur Open Land Area				
LSA 09-01	East Rail Spur Area	05/24/2016	18	05/11/2017 ML17159A672
LSA 09-02	Central Rail Spur Area	07/05/2016	18	05/11/2017 ML17159A672
LSA 09-03	West Rail Spur Area	05/24/2016	18	05/11/2017 ML17159A672
LSA-10 Burial Pits Open Land Area				
LSA 10-01	Burial Pit Area Section 1	06/17/2015	2 Revision 1	12/05/2017 ML17363A338

Survey Unit	**Description**	**FSS Complete Date**	**FSSFR Volume 3 Chapter Number**	**Accession Number and Document Date**
LSA 10-02	Burial Pit Area Section 2	06/17/2015	2 Revision 1	12/05/2017 ML17363A338
LSA 10-03	Burial Pit Area Section 3	06/17/2015	3 Revision 1	11/20/2017 ML17341A128
LSA 10-04	Burial Pit Area Section 4	06/17/2015	3 Revision 1	11/20/2017 ML17341A128
LSA 10-05	Burial Pit Area Section 5	02/13/2014	6	12/13/2017 ML18010A249
LSA 10-06	Burial Pit Area Section 6	01/10/2014	6	12/13/2017 ML18010A249
LSA 10-07	Burial Pit Area Section 7	01/10/2014	6	12/13/2017 ML18010A249
LSA 10-08	Burial Pit Area Section 8	09/02/2013	6	12/13/2017 ML18010A249
LSA 10-09	Burial Pit Area Section 9	10/21/2013	6	12/13/2017 ML18010A249
LSA 10-10	Burial Pit Area Section 10	02/20/2014	6	12/13/2017 ML18010A249
LSA 10-11	Burial Pit Area Section 11	05/21/2015	7 Revision 1	11/02/2017 ML17313A003
LSA 10-12	Burial Pit Area Section 12	06/17/2015	4 Revision 2	02/08/2018 ML18074A283
LSA 10-13	Burial Pit Area Section 13	06/10/2015	5 Revision 1	11/29/2017 ML17363A356
LSA 10-14	Burial Pit Area Section 14	06/10/2015	5 Revision 1	11/29/2017 ML17363A356
LSA-11 East Open Land Area				
LSA 11-01	Northeast Site Creek	10/29/2015	7 Revision 1	11/02/2017 ML17313A003
	Vol 3 Ch 7, Errata Spreadsheet	N/A	7 Errata	01/05/2018 ML18010A132
LSA 11-02	Rail Road Line	07/05/2016	19	03/06/2017 ML17076A222
LSA 11-03	East Site Wooded Area	06/24/2015	19	03/06/2017 ML17076A222
LSA 11-04	Small East Site Wooded Area	04/24/2015	19	03/06/2017 ML17076A222
LSA 11-05	Northeast Site Creek East Section	06/03/2015	19	03/06/2017 ML17076A222
LSA 11-06	Rail Road Line Elevated Area	07/05/2016	19	03/06/2017 ML17076A222
LSA-12 Laydown Area				
LSA 12-01	Reuse Soil Laydown Area Section 1	07/13/2016	8 Revision 1	02/27/2017 ML17066A057
LSA 12-02	Reuse Soil Laydown Area Section 2	07/13/2016	8 Revision 1	02/27/2017 ML17066A057
LSA 12-03	Reuse Soil Laydown Area Section 3	07/12/2016	9 Revision 1	03-01-2017 ML17074A598
LSA 12-04	Reuse Soil Laydown Area Section 4	07/12/2016	9 Revision 1	03-01-2017 ML17074A598

Survey Unit	**Description**	**FSS Complete Date**	**FSSFR Volume 3 Chapter Number**	**Accession Number and Document Date**
LSA 12-05	Reuse Soil Laydown Area Section 5	07/12/2016	9 Revision 1	03-01-2017 ML17074A598
LSA 12-06	Reuse Soil Laydown Area Section 6	07/12/2016	9 Revision 1	03-01-2017 ML17074A598
LSA 12-07	Reuse Soil Laydown Area Section 7	07/12/2016	9 Revision 1	03-01-2017 ML17074A598
LSA 12-08	Reuse Soil Laydown Area Section 8	07/12/2016	9 Revision 1	03-01-2017 ML17074A598
LSA 12-09	Reuse Soil Laydown Area Section 9	07/12/2016	9 Revision 1	03-01-2017 ML17074A598

Table A-4. Primary FSSFRs Pertaining to Building/Structural Surveys

Survey Unit	Description	FSS Complete Date	FSSFR Volume 4 Chapter Number	Accession Number and Document Date
Overview				
Vol 4 Ch 1	BSA Overview, Revise to address NRC review comments	N/A	1 Revision 1	04/04/2017 ML17095A951
BSA-01 Building 110				
BSA 01-01	Subsurface Soil	05/22/2015	6	09/06/2017 ML17257A187
BSA 01-02	Exterior	06/25/2015	7	09/27/2017 ML17279A281
BSA 01-03	Interior Walls and Ceiling	06/25/2015	7	09/27/2017 ML17279A281
BSA 01-04	Interior Floors	05/04/2015	6	09/06/2017 ML17257A187
BSA 01-05	Ventilation Interiors	07/18/2016	16	10/24/2017 ML17311A684
BSA-02 Building 230				
BSA 02-01	Subsurface Soils	09/04/2015	5	09/27/2017 ML17279A280
BSA 02-02	Exterior Walls and Roof	04/27/2016	5	09/27/2017 ML17279A280
BSA 02-03	Rod Load Area—Section 1 Floor and Lower Walls	07/21/2015	2	08/23/2017 ML17249A017
BSA 02-04	Rod Load Area—Section 2 Floor and Lower Walls	08/12/2015	2	08/23/2017 ML17249A017
BSA 02-05	Rod Load Area—Section 3 Floor and Lower Walls	07/14/2015	2	08/23/2017 ML17249A017
BSA 02-06	Rod Load Area—Section 4 Floor and Lower Walls	08/07/2015	2	08/23/2017 ML17249A017
BSA 02-07	Rod Load Area Kardex Walls	08/19/2015	2	08/23/2017 ML17249A017
BSA 02-08	Upper Rod Load Area Upper Walls and Ceiling	08/22/2015	2	08/23/2017 ML17249A017
BSA 02-09	Cushman Room Lower (N)	09/01/2015	4	10/12/2017 ML17299A319
BSA 02-10	Cushman Room Upper	07/09/2015	4	10/12/2017 ML17299A319
BSA 02-11	Gadolinium Room Lower (N)	06/29/2015	4	10/12/2017 ML17299A319
BSA 02-12	Gadolinium Room Upper	07/06/2015	4	10/12/2017 ML17299A319
BSA 02-13	U-Shaped Area (NW) Section 6 Floor and Walls	11/05/2015	3	10/03/2017 ML17286A082
BSA 02-14	U-Shaped Area (SE) Section 7 Floor and Walls	10/25/2015	3	10/03/2017 ML17286A082
BSA 02-15	U-Shaped Area Section 8 Trench	06/15/2015	3	10/03/2017 ML17286A082
BSA 02-16	U-Shaped Area Section 9 Spill Area	09/10/2015	3	10/03/2017 ML17286A082
BSA 02-17	U-Shaped Area All Upper Walls Ceiling	06/16/2016	3	10/03/2017 ML17286A082
BSA 02-18	Warehouse Area (W)	06/17/2016	3	10/03/2017

Survey Unit	Description	FSS Complete Date	FSSFR Volume 4 Chapter Number	Accession Number and Document Date
				ML17286A082
BSA 02-19	Mezzanine	03/15/2016	3	10/03/2017 ML17286A082
BSA 02-20	Ventilation	06/27/2016	16	10/24/2017 ML17311A684
BSA 02-21	U-Shaped Area (SW) Storage Floor and Walls	11/04/2015	3	10/03/2017 ML17286A082
BSA 02-22	Cushman Room Lower (S)	08/31/2015	4	10/12/2017 ML17299A319
BSA 02-23	Gadolinium Room Lower (S)	06/29/2015	4	10/12/2017 ML17299A319
BSA 02-24	Rod Load East and South Lower Walls	07/23/2015	2	08/23/2017 ML17249A017
BSA 02-25	Rod Load West and North Lower Walls	07/16/2015	2	08/23/2017 ML17249A017
BSA 02-26	Warehouse Area (E)	06/16/2016	3	10/03/2017 ML17286A082
BSA 02-27	U-Shaped Area (NW) FSS Floor and Walls	09/11/2015	3	10/03/2017 ML17286A082
BSA-03 Building 231				
BSA 03-01	Subsurface Soils	03/04/2016	8	10/17/2017 ML17299A521
BSA 03-02	Exterior Walls and Roof	03/28/2016	8	10/17/2017 ML17299A521
BSA 03-03	Lower Interior Walls and Floor	03/16/2016	8	10/17/2017 ML17299A521
BSA 03-04	Upper Interior Walls and Ceiling	03/16/2016	8	10/17/2017 ML17299A521

Survey Unit	Description	FSS Complete Date	FSSFR Volume 4 Chapter Number	Accession Number and Document Date
BSA-04 Ancillary Structures				
BSA 04-01	Site Pond Dam (LSA 02-03)	08/21/2015	9	08/15/2017 ML17250A539
BSA 04-02	Septic Tank (LSA 08-17)	10/13/2015	10	07/06/2017 ML17209A049
BSA 04-03	Parking Lot East (LSA 06-01)	05/21/2016	11	08/02/2017 ML17240A163
BSA 04-04	Parking Lot West (LSA 06-02)	05/22/2016	11	08/02/2017 ML17240A163
BSA 04-05	Vault Wall—Exterior Wall Portion of Building 230	11/11/2015	5	09/27/2017 ML17279A280
BSA 04-06	Building 115 (LSA 07-01)	03/02/2016	11	08/02/2017 ML17240A163
BSA 04-07	Concrete (LSA 08-10)	06/17/2016	12	07/12/2017 ML17205A374
BSA 04-08	Concrete (LSA 08-15)	05/29/2016	12	07/12/2017 ML17205A374
BSA 04-09	Asphalt in LSA 04-01	02/26/2016	13	07/24/2017 ML17230A207
BSA 04-10	Slab in LSA 08-06	08/08/2016	10	07/06/2017 ML17209A049
BSA 04-11	Concrete LSA 08-16	02/26/2016	10	07/06/2017 ML17209A049
BSA 04-12	Concrete LSA 08-03	04/15/2016	10	07/06/2017 ML17209A049
BSA 04-13	Transformer Pad outside 110 (LSA 08-04)	04/15/2016	14	06/05/2017 ML17173A251
BSA 04-14	Truck Scale Foundation (LSA 07-01)	06/16/2016	11	08/02/2017 ML17240A163
BSA 04-15	Rail Line in LSA 09-01	06/16/2016	15	05/11/2017 ML17159A672
BSA 04-16	Rail Line and Rail Scale Foundations LSA 09-02	05/13/2016	15	05/11/2017 ML17159A672
BSA 04-17	Rail Line in LSA 09-03	05/12/2016	15	05/11/2017 ML17159A672
BSA-05 Ancillary Structure in LSA 05				
BSA 05-01	Springhouse Foundation (LSA 05-01)	08/29/2013	Vol 3, Ch 16	01/09/2018 ML18019A541
BSA 05-02	Barn Foundation, Drain Basin, Drain Piping (LSA 05-02)	08/29/2013	Vol 3, Ch 16	01/09/2018 ML18019A541

Table A-5. Primary FSSFRs Pertaining to Piping Surveys

Survey Unit	Description	FSS Complete Date	FSSFR Volume 5 Chapter Number	Accession Number and Document Date
Overview				
	Vol 5, Ch 1, PSA Overview, Revised to address NRC review comments	N/A	1 Revision 1	06/06/2016 ML16158A445
PSA-01 Storm Drains				
PSA 01-01	Building 110 Storm Drain (STM-1)	11/24/2015	3	05/08/2017 ML17206A347
PSA 01-02	Building 110 to Building 230 Storm Drain (STM-2)	02/11/2016	3	05/08/2017 ML17206A347
PSA 01-03	Building 230 North Storm Drain (STM-3)	01/29/2016	3	05/08/2017 ML17206A347
PSA 01-04	Building 230 North Storm Drain (STM-4)	06/07/2016	3	05/08/2017 ML17206A347
PSA 01-05	Building 230 North Storm Drain (STM-5)	06/08/2016	3	05/08/2017 ML17206A347
PSA 01-06	Building 230 North Storm Drain (STM-6)	06/08/2016	3	05/08/2017 ML17206A347
PSA 01-07	Building 230 North Storm Drain (STM-7)	06/07/2016	3	05/08/2017 ML17206A347
PSA 01-08	Building 230 West Storm Drain (STM-8)	02/17/2016	3	05/08/2017 ML17206A347
PSA 01-09	Building 230 South Storm Drain (STM-9)	12/03/2015	3	05/08/2017 ML17206A347
PSA-02 Sanitary Treatment Piping				
PSA 02-01	Former SWTP Discharge Line (SAN-1), Revised for NRC Comments	11/15/2015	2 Revision 1	03/21/2017 ML17081A455
PSA-03 West Open Land Area				
PSA 03-01	Water Supply Lines (WAT 1-8)	03/22/16	4	02/27/2017 ML17066A031
PSA 03-02	Building 110/230 Downspouts (DRN-X)	01/25/16	4	02/27/2017 ML17066A031

Table A-6. Primary FSSFRs Pertaining to Ground Water Monitoring

Monitoring Period	Report Complete Date	FSSFR Volume 6 Chapter Number	Accession Number and Document Date
Ground Water Overview,	10/05/2016	1 Revision 1	10/5/2016 ML16287A531
Ground Water Monitoring Results During Remediation	10/10/2016	2	10/10/2016 ML16287A537 (pkg)
Postremediation Ground Water Monitoring 1st Quarter Results	10/05/2016	3	10/5/2016 ML16287A534
Postremediation Ground Water Monitoring 2nd Quarter Results	11/16/2016	4	11/16/2016 ML16342B552
Postremediation Ground Water Monitoring 3rd Quarter Results	01/16/2017	5	01/16/2017 ML17018A105

Monitoring Period	Report Complete Date	FSSFR Volume 6 Chapter Number	Accession Number and Document Date
Postremediation Ground Water Monitoring 4th Quarter Results	05/17/2017	6	05/17/2017 ML17142A356
Postremediation Ground Water Monitoring Summary	03/13/2018	7 Revision 1	03/13/2018 ML18078A327
Postremediation Ground Water Monitoring 5th Quarter Results	08/24/2017	8	08/24/2017 ML17240A168
Postremediation Ground Water Monitoring 6th Quarter Results	11/08/2017	9	11/08/2017 ML17317A473

Table A-7. FSSFR Summary

Description	FSSFR Volume 7, Chapter Number	ADAMS Accession Number and Document Date
Final Status Survey Final Report Summary	1	12/19/2017 ML17356A169

13 Appendix B. Compilation of Sum of Fractions Values Used To Determine Dose

Table B-1. Total Dose Determination for Land Survey Areas

LSA-SU	Description	Class	DCGL	Avg. SU Soil (SOF)	Avg. SU Soil (mrem)	EMC (SOF)	EMC (mrem)	Remaining Structure (SOF)	Remaining Structure (mrem)	Buried Piping (SOF)	Buried Piping (mrem)	Reuse Soil (SOF)	Reuse Soil (mrem)	Ground Water (SOF)	Ground Water (mrem)	Total SU SOF	Total SU Dose (mrem)
LSA-01 South Site Waterways																	
01-01	Site Creek/Joachim Creek	3	Uniform	0.01	0.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.04	**0.93**
01-02	South Section of Site Creek	2	Uniform	0.03	0.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.06	**1.43**
01-03	North Section of Site Creek	1	Uniform	0.08	2.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.11	**2.68**
LSA-02 Site Pond																	
02-01	North Section of Site Pond	1	Uniform	0.09	2.25	0.24	6.00	N/A	N/A	0.02	0.50	N/A	N/A	0.03	0.68	0.38	**9.43**
02-02	Central Section of Site Pond	1	Uniform	0.17	4.25	0.25	6.25	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.45	**11.18**
02-03	South Section of Site Pond	1	Uniform	0.11	2.75	0.19	4.75	0.03	0.75	N/A	N/A	0.17	4.25	0.03	0.68	0.53	**13.18**
LSA-03 West Open Land Area																	
03-01	Area West of Site Pond	3	Uniform	0.09	2.25	N/A	N/A	N/A	N/A	N/A	N/A	0.17	4.25	0.03	0.68	0.29	**7.18**
03-02	Area Southwest of Site Pond	2	Uniform	0.20	5.00	N/A	N/A	N/A	N/A	N/A	N/A	0.17	4.25	0.03	0.68	0.40	**9.93**
LSA-04 Southwest Open Land Area																	
04-01	Area between Buildings 230/231 and Site Pond	3	Uniform	0.08	2.00	N/A	N/A	0.03	0.75	0.00	0.00	N/A	N/A	0.03	0.68	0.14	**3.43**
04-02	Area East of North Section of Site Pond (west soil laydown area)	1	Uniform	0.11	2.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.14	**3.43**
04-03	Area East of Central Section of Site	1	Uniform	0.09	2.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.12	**2.93**

LSA-SU	Description	Class	DCGL	Avg. SU Soil (SOF)	Avg. SU Soil (mrem)	EMC (SOF)	EMC (mrem)	Remaining Structure (SOF)	Remaining Structure (mrem)	Buried Piping (SOF)	Buried Piping (mrem)	Reuse Soil (SOF)	Reuse Soil (mrem)	Ground Water (SOF)	Ground Water (mrem)	Total SU SOF	Total SU Dose (mrem)
	Pond (west soil laydown area)																
04-04	Area South of Building 231	1	Uniform	0.11	2.75	N/A	N/A	N/A	N/A	0.26	6.50	N/A	N/A	0.03	0.68	0.40	**9.93**
04-05	Wooded Area South of Building 231	2	Uniform	0.06	1.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.09	**2.18**
LSA-05 Barns and Cistern Open Land Area																	
05-01	Site Spring Area Adjacent to State Road P	1	Uniform	0.13	3.25	0.11	8.75	0.01	0.25	N/A	N/A	N/A	N/A	0.03	0.68	0.28	**12.93**
05-02	Tile Barn and Red Room Roof	1	Uniform	0.34	8.50	N/A	N/A	0.03	0.75	N/A	N/A	0.10	2.50	0.03	0.68	0.50	**12.43**
05-03	Wood Barn	1	Uniform	0.12	3.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.15	**3.68**
05-04	Site Spring and Cistern	1	Uniform	0.11	2.75	N/A	N/A	N/A	N/A	0.02	0.50	0.17	4.25	0.03	0.68	0.33	**8.18**
LSA-06 North Open Land Area																	
06-01	Main Parking Lot	3	Uniform	0.06	1.50	N/A	N/A	0.01	0.25	0.015	0.40	N/A	N/A	0.03	0.68	0.11	**2.83**
06-02	West Parking Lot	2	Uniform	0.08	2.00	N/A	N/A	0.03	0.75	0.03	0.80	N/A	N/A	0.03	0.68	0.17	**4.23**
LSA-07 North Central Open Land Area																	
07-01	Truck Scale Area	2	Uniform	0.11	2.75	N/A	N/A	0.04	1.00	0.01	0.02	N/A	N/A	0.03	0.68	0.18	**4.45**
LSA-08 Central Open Land Area																	
08-01	Process Building Area Section 1	1	3 Layer	0.05	1.25	0.22	5.50	N/A	N/A	N/A	N/A	0.25	6.25	0.03	0.68	0.55	**13.68**
08-02	Process Building Area Section 2	1	3 Layer	0.06	1.50	N/A	N/A	N/A	N/A	N/A	N/A	0.25	6.25	0.03	0.68	0.34	**8.43**
08-03	Process Building Area Section 3	1	Uniform	0.05	1.25	N/A	N/A	0.001	0.10	0.022	0.60	N/A	N/A	0.03	0.68	0.10	**2.63**

LSA-SU	Description	Class	DCGL	Avg. SU Soil (SOF)	Avg. SU Soil (mrem)	EMC (SOF)	EMC (mrem)	Remaining Structure (SOF)	Remaining Structure (mrem)	Buried Piping (SOF)	Buried Piping (mrem)	Reuse Soil (SOF)	Reuse Soil (mrem)	Ground Water (SOF)	Ground Water (mrem)	Total SU SOF	Total SU Dose (mrem)
08-04	Process Building Area Section 4	1	Uniform	0.14	3.50	N/A	N/A	0.01	0.25	0.002	0.10	0.12	3.00	0.03	0.68	0.30	**7.53**
08-05	Process Building Area Section 5	1	Uniform	0.18	4.50	N/A	N/A	N/A	N/A	N/A	N/A	0.12	3.00	0.03	0.68	0.33	**8.18**
08-06	Process Building Area Section 6	1	Uniform	0.19	4.75	N/A	N/A	0.03	0.75	N/A	N/A	0.22	5.50	0.03	0.68	0.47	**11.68**
08-07	Process Building Area Section 7	1	Uniform	0.17	4.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.20	**4.93**
08-08	Process Building Area Section 8	1	Uniform	0.25	6.25	N/A	N/A	N/A	N/A	N/A	N/A	0.25	6.25	0.03	0.68	0.53	**13.18**
08-09	Process Building Area Section 9	1	3 Layer	0.15	3.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.18	**4.43**
08-10	Process Building Area Section 10	1	Uniform	0.22	5.50	0.11	2.75	0.02	0.50	0.26	6.50	N/A	N/A	0.03	0.68	0.64	**15.93**
08-11	Process Building Area Section 11	1	3 Layer	0.17	4.25	0.21	5.25	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.41	**10.18**
08-12	Process Building Area Section 12	1	3 Layer	0.30	7.50	0.14	1.25	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.47	**9.43**
08-13	Process Building Area Section 13	1	3 Layer	0.23	5.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.26	**6.43**
08-14	Process Building Area Section 14	1	Uniform	0.23	5.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.26	**6.43**
08-15	Process Building Area Section 15	2	Uniform	0.09	2.25	N/A	N/A	0.01	0.25	0.26	6.50	N/A	N/A	0.03	0.68	0.39	**9.68**
08-16	Process Building Area Section 16	1	Uniform	0.13	3.25	N/A	N/A	0.02	0.50	0.032	0.90	N/A	N/A	0.03	0.68	0.21	**5.33**
08-17	Process Building Area Section 17	1	Uniform	0.15	3.75	N/A	N/A	0.03	0.75	0.02	0.50	N/A	N/A	0.03	0.68	0.23	**5.68**

LSA-SU	Description	Class	DCGL	Avg. SU Soil (SOF)	Avg. SU Soil (mrem)	EMC (SOF)	EMC (mrem)	Remaining Structure (SOF)	Remaining Structure (mrem)	Buried Piping (SOF)	Buried Piping (mrem)	Reuse Soil (SOF)	Reuse Soil (mrem)	Ground Water (SOF)	Ground Water (mrem)	Total SU SOF	Total SU Dose (mrem)
LSA-09 Rail Spur Open Land Area																	
09-01	East Rail Spur Area	3	Uniform	0.05	1.25	N/A	N/A	0.02	0.50	N/A	N/A	N/A	N/A	0.03	0.68	0.10	**2.43**
09-02	Central Rail Spur Area	1	3 Layer	0.11	2.75	N/A	N/A	0.01	0.25	N/A	N/A	N/A	N/A	0.03	0.68	0.15	**3.68**
09-03	West Rail Spur Area	1	3 Layer	0.11	2.75	N/A	N/A	0.02	0.50	N/A	N/A	N/A	N/A	0.03	0.68	0.16	**3.93**
LSA-10 Burial Pits Open Land Area																	
10-01	Burial Pit Area Section 1	1	Uniform	0.19	4.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.22	**5.43**
10-02	Burial Pit Area Section 2	1	Uniform	0.07	1.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.10	**2.43**
10-03	Burial Pit Area Section 3	1	Uniform	0.34	8.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.37	**9.18**
10-04	Burial Pit Area Section 4	1	Uniform	0.14	3.50	0.14	3.50	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.31	**7.68**
10-05	Burial Pit Area Section 5	1	Uniform	0.29	7.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.32	**7.93**
10-06	Burial Pit Area Section 6	1	Uniform	0.11	2.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.14	**3.43**
10-07	Burial Pit Area Section 7	1	Uniform	0.16	4.00	0.01	0.25	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.20	**4.93**
10-08	Burial Pit Area Section 8	1	Uniform	0.05	1.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.08	**1.93**
10-09	Burial Pit Area Section 9	1	Uniform	0.09	2.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.12	**2.93**
10-10	Burial Pit Area Section 10	1	Uniform	0.14	3.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.17	**4.18**
10-11	Burial Pit Area Section 11	1	Uniform	0.15	4.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.18	**5.43**
10-12	Vol 3, Ch 7, Errata Spreadsheet	1	3 Layer	0.23	5.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.26	**6.43**
10-13	Burial Pit Area Section 12	1	Uniform	0.19	4.75	N/A	N/A	N/A	N/A	N/A	N/A	0.14	3.50	0.03	0.68	0.36	**8.93**
10-14	Burial Pit Area Section 13	1	Uniform	0.13	3.25	N/A	N/A	N/A	N/A	N/A	N/A	0.10	2.50	0.03	0.68	0.26	**6.43**
LSA-11 East Open Land Area																	
11-01	Northeast Site Creek	2	Uniform	0.03	0.75	N/A	N/A	N/A	N/A	N/A	N/A	0.31	7.75	0.03	0.68	0.37	**9.18**

LSA-SU	Description	Class	DCGL	Avg. SU Soil (SOF)	Avg. SU Soil (mrem)	EMC (SOF)	EMC (mrem)	Remaining Structure (SOF)	Remaining Structure (mrem)	Buried Piping (SOF)	Buried Piping (mrem)	Reuse Soil (SOF)	Reuse Soil (mrem)	Ground Water (SOF)	Ground Water (mrem)	Total SU SOF	Total SU Dose (mrem)
11-02	Rail Road Line	3	Uniform	0.07	1.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.10	**2.43**
11-03	East Site Wooded Area	3	Uniform	0.18	4.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.21	**5.18**
11-04	Small East Site Wooded Area	3	Uniform	0.17	4.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.20	**4.93**
11-05	Northeast Site Creek East Section	3	Uniform	0.04	1.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.07	**1.68**
11-06	Rail Road Line Elevated Area	1	Uniform	0.15	3.75	0.07	1.75	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.25	**6.18**
LSA-12 Laydown Area																	
12-01	Reuse Soil Laydown Area Section 1	2	Uniform	0.04	1.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.07	**1.68**
12-02	Reuse Soil Laydown Area Section 2	2	Uniform	0.09	2.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.12	**2.93**
12-03	Reuse Soil Laydown Area Section 3	1	Uniform	0.08	2.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.11	**2.68**
12-04	Reuse Soil Laydown Area Section 4	1	Uniform	0.09	2.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.12	**2.93**
12-05	Reuse Soil Laydown Area Section 5	1	Uniform	0.11	2.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.14	**3.43**
12-06	Reuse Soil Laydown Area Section 6	1	Uniform	0.11	2.75	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.14	**3.43**
12-07	Reuse Soil Laydown Area Section 7	1	Uniform	0.06	1.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.09	**2.18**
12-08	Reuse Soil Laydown Area Section 8	1	Uniform	0.08	2.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.11	**2.68**
12-09	Reuse Soil Laydown Area Section 9	1	Uniform	0.10	2.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.03	0.68	0.13	**3.18**

Table B-2. Total Dose Determination for Building Survey Areas within Buildings 110, 230, and 231

BSA-SU	Description	Class	Avg. SU Residual Radioactivity (Fraction of $DCGL_{so}$)	Avg. SU Residual Radioactivity (mrem)	Buried Piping Contribution (Fraction of $DCGL_{so}$)	Buried Piping Contribution (mrem)	Remaining Ventilation Contribution (Fraction of $DCGL_{so}$)	Remaining Ventilation Contribution (mrem)	Total SU Fraction of $DCGL_{so}$	Total SU Dose (mrem)
BSA-01 Building 110										
01-01	Subsurface Soil	2	0.19	4.75	0.02	0.50	N/A	N/A	0.21	**5.25**
01-02	Exterior	3	0.05	1.20	0.007	0.20	N/A	N/A	0.06	**1.40**
01-03	Interior Walls and Ceiling	3	0.01	0.25	N/A	N/A	0.002	0.05	0.01	**0.30**
01-04	Interior Floors	2	0.02	0.50	N/A	N/A	0.002	0.05	0.02	**0.55**
01-05	Ventilation Interiors	3	0.002	0.05	N/A	N/A	N/A	N/A	(Ventilation)	
BSA-02 Building 230										
02-01	Subsurface Soils	2	0.05	1.25	0.02	0.05	N/A	N/A	0.07	**1.75**
02-02	Exterior Walls and Roof	3	0.05	1.20	0.007	0.20	N/A	N/A	0.06	**1.40**
02-03	Rod Load Area—Section 1 Floor and Lower Walls	1	0.04	1.00	N/A	N/A	0.004	0.09	0.04	**1.09**
02-04	Rod Load Area—Section 2 Floor and Lower Walls	1	0.03	0.75	N/A	N/A	0.004	0.09	0.03	**0.84**
02-05	Rod Load Area—Section 3 Floor and Lower Walls	1	0.06	1.50	N/A	N/A	0.004	0.09	0.06	**1.59**
02-06	Rod Load Area—Section 4 Floor and Lower Walls	1	0.04	1.00	N/A	N/A	0.004	0.09	0.04	**1.09**
02-07	Rod Load Area Kardex Walls	1	0.02	0.50	N/A	N/A	0.004	0.09	0.02	**0.59**
02-08	Upper Rod Load Area Upper Walls and Ceiling	2	0.02	0.50	N/A	N/A	0.004	0.09	0.02	**0.59**
02-09	Cushman Room Lower (N)	1	0.02	0.50	N/A	N/A	0.004	0.09	0.02	**0.59**
02-10	Cushman Room Upper	2	0.01	0.25	N/A	N/A	0.004	0.09	0.01	**0.34**
02-11	Gadolinium Room Lower (N)	1	0.02	0.50	N/A	N/A	0.004	0.09	0.02	**0.59**

02-12	Gadolinium Room Upper	2	0.003	0.10	N/A	N/A	0.004	0.09	0.01	**0.19**
02-13	U-Shaped Area (NW) Section 6 Floor and Walls	2	0.04	1.00	N/A	N/A	0.004	0.09	0.04	**1.09**
02-14	U-Shaped Area (SE) Section 7 Floor and Walls	2	0.02	0.50	N/A	N/A	0.004	0.09	0.02	**0.59**
02-15	U-Shaped Area Section 8 Trench	1	0.004	0.10	N/A	N/A	0.004	0.09	0.04	**0.19**
02-16	U-Shaped Area Section 9 Spill Area	1	0.02	0.50	N/A	N/A	0.004	0.09	0.02	**0.59**
02-17	U-Shaped Area All Upper Walls Ceiling	3	0.004	0.10	N/A	N/A	0.004	0.09	0.01	**0.19**
02-18	Warehouse Area (W)	2	0.01	0.25	N/A	N/A	0.004	0.09	0.01	**0.34**
02-19	Mezzanine	3	0.003	0.08	N/A	N/A	0.004	0.09	0.01	**0.17**
02-20	Ventilation	2	0.004	0.09	N/A	N/A	N/A	N/A	(Ventilation)	
02-21	U-Shaped Area (SW) Storage Floor and Walls	2	0.04	1.00	N/A	N/A	0.004	0.09	0.04	**1.09**
02-22	Cushman Room Lower (S)	1	0.04	1.00	N/A	N/A	0.004	0.09	0.04	**1.09**
02-23	Gadolinium Room Lower (S)	1	0.03	0.75	N/A	N/A	0.004	0.09	0.03	**0.84**
02-24	Rod Load East and South Lower Walls	1	0.00	0.00	N/A	N/A	0.004	0.09	0.00	**0.09**
02-25	Rod Load West and North Lower Walls	1	0.00	0.00	N/A	N/A	0.004	0.09	0.00	**0.09**
02-26	Warehouse Area (E)	2	0.01	0.25	N/A	N/A	0.004	0.09	0.01	**0.34**
02-27	U-Shaped Area (NW) FSS Floor and Walls	2	0.02	0.50	N/A	N/A	0.004	0.09	0.02	**0.59**
BSA-03 Building 231										
03-01	Subsurface Soils	2	0.05	1.25	N/A	N/A	N/A	N/A	0.05	**1.25**
03-02	Exterior Walls and Roof	3	0.03	0.70	0.007	0.20	N/A	N/A	0.04	**0.90**
03-03	Lower Interior Walls and Floor	2	0.03	0.75	N/A	N/A	N/A	N/A	0.03	**0.75**
03-04	Upper Interior Walls and Ceiling	2	0.01	0.25	N/A	N/A	N/A	N/A	1.00	**0.25**

Table B-3. Dose Contribution for Ancillary Structure Building Survey Areas

BSA Survey Unit	Class	Avg. SU Residual Radioactivity (Fraction of $DCGL_{so}$)	Avg. SU Residual Radioactivity (mrem)	BSA Dose Added to:
BSA-04 Ancillary Structures				
04-01	1	0.03	0.75	LSA 02-03
04-02	1	0.03	0.75	LSA 08-17
04-03	3	0.01	0.25	LSA 06-01
04-04	2	0.03	0.75	LSA 06-02
04-05	1	0.001	0.10	(Bldg 230 Exterior)
04-06[a]	2	0.04	0.95	LSA 07-01
04-07	1	0.02	0.50	LSA 08-10
04-08	2	0.01	0.25	LSA 08-15
04-09	3	0.03	0.75	LSA 04-01
04-10	1	0.03	0.75	LSA 08-06
04-11	1	0.02	0.50	LSA 08-16
04-12	1	0.001	0.10	LSA 08-03
04-13	1	0.01	0.25	LSA 08-04
04-14	2	0.01	0.25	LSA 07-01
04-15	2	0.02	0.50	LSA 09-01
04-16	1	0.01	0.25	LSA 09-02
04-17	1	0.02	0.50	LSA 09-03
BSA-05 Ancillary Structures in LSA 05				
05-01	1	0.01	0.25	LSA 05-01
05-02	1	0.03	0.75	LSA 05-02

[a] The fraction for Building Survey Area (BSA) 04-06 of 0.04 includes contribution from Piping Survey Area 03-02 of a sum of fractions (SOF) of 0.007, which was also present on the exterior of BSA 04-06 (Building 115)