

Phase II Final Status Survey Report Mallinckrodt Columbium-Tantalum Plant

St. Louis, Missouri

Chapter 15

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ABBREVIATIONS AND ACRONYMS

%	percent
σ	sigma; standard deviation
AECOM	AECOM Technical Services
bgs	below grade surface
C-T	columbium-tantalum
CFR	Code of Federal Regulations
DCGL	derived concentration guideline level
DP	decommissioning plan
DQO	data quality objectives
EMC	elevated measurement comparison
FSS	Final Status Survey
FSSR	Final Status Survey Report
ft	feet
GWS	gamma walk-over survey
m ²	square meters
MARSSIM	Multi-Agency Radiation and Site Investigation Manual (NUREG-1575)
MDC	minimum detectable concentration
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
pCi/g	picoCuries per gram
Ra	radium
SOF	sum of fractions
Th	thorium
U	uranium
VCP	vitriified clay pipe
WRS	Wilcoxon Rank Sum

15.0 RESULTS SUMMARY FOR PLANT 5 SUBSURFACE SU09

This chapter of the Final Status Survey Report (FSSR) presents the results of the final status survey (FSS) and data assessment for Plant 5 subsurface survey unit SU09 in accordance with Columbium-Tantalum (C-T) Phase II Decommissioning Plan (DP) Section 14.5. The FSS for this Class 1 survey unit was completed by AECOM Technical Services (AECOM) in December 2011. The SU09 data assessment was performed based on the assumptions, methods, and performance criteria established to satisfy the data quality objectives (DQOs) in accordance with the C-T Phase II DP Section 14.4.3.8. The summary statistics provide numerical values for measures of central tendency (i.e., mean, median), variation (i.e., standard deviation), and spread (i.e., minimum, maximum). Data evaluation and statistical analyses were performed and a separate decision was made for each survey unit of the C-T Plant as to its suitability for release for unrestricted use based upon the industrial use scenario release criterion as established in C-T Phase II DP Chapter 5.

15.1 OVERVIEW

SU09 is a Class 1 survey unit located in the central portion of C-T Plant 5. The survey unit is approximately 269 square meters (m²) in size, which is less than the size limit of 3,000 m² for Class 1 survey units for subsurface material (per C-T Phase II DP, Table 14-4). Class 1 was the appropriate classification because the survey unit contained residual radioactivity that exceeded the DCGL_w prior to remediation. Figure 15-1 shows the location of SU09 within the Plant 5 area.

Figure 15-2 is a photograph of SU09 that was taken during the FSS, following remediation. The northern edge was a vertical wall¹, and the eastern edge was formed by a soil ramp that encompasses an overhead pipe rack column with an exit to the 7th Street roadway. Soil and related debris were removed from the area to an excavated depth range of approximately 15.5 to 19 feet (ft) below grade surface (bgs). A vitrified clay pipe (VCP) containing contaminated material was discovered running east to west through AECOM grid D4 to a manhole/collection basin, which was removed prior to remediation, in the northwest corner of AECOM grid E5. AECOM grid locations are illustrated on Figure 15-3. The VCP was removed during remediation, which left a deeper trenched area where the pipe formally ran. In addition, a 20 ft by 8 ft concrete pipe chase remains in the west side of AECOM grid D3.

There is a sloped area of material covered with fabric that can be seen in the lower left of the afore-mentioned picture, which was subtracted from the survey unit. This area was removed from the survey unit because no further remediation could be performed in this area due to structural stability concerns of the overhead pipe bridge at that time. The pipe bridge supports plant utilities for all the manufacturing buildings located within Plant 5.

¹ Remnant of historical development of the site. Not related to the Mallinckrodt C-T manufacturing buildings.



Figure 15-1 Location of Subsurface SU09 in C-T Plant 5



Figure 15-2 Photograph of SU09 Looking West toward East Side of Building 250

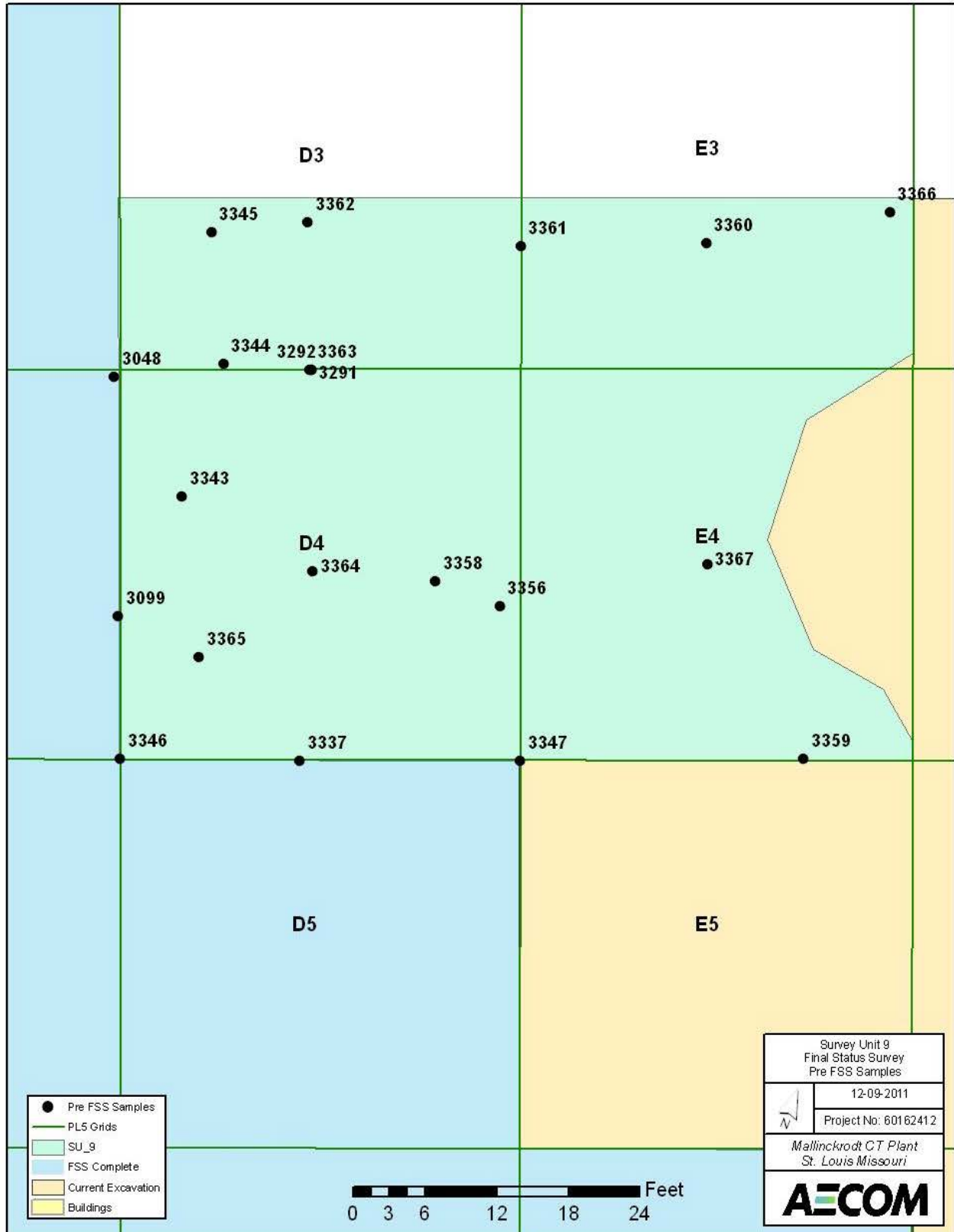


Figure 15-3 AECOM Grids and Post-Remediation Soil Sampling Locations

15.2 REMEDIAL ACTION AND RADIOLOGICAL SAMPLING SUMMARY

Extensive post-remediation soil sampling, shown in Figure 15-3 above, was performed by AECOM after GWS indicated successful remediation. In addition, three soil samples were collected beneath the concrete pipe chase to verify suitable levels of residual radioactivity remained. The soil sampling demonstrated that the survey unit was ready for FSS. Table 15-1 provides the results for 21 post-remediation samples.

Table 15-1 Post-Remediation Sampling Analytical Results

Sample ID	Collection Date	On-Site Results			Gross SOF
		Concentration (pCi/g)			
		²³² Th	²²⁶ Ra	²³⁸ U	
3048	8/4/2011	1.11	3.82	9.39	0.19
3099	8/16/2011	4.00	5.27	25.88	0.39
3291	10/17/2011	0.28	0.54	1.08	0.03
3292		1.38	2.23	5.12	0.14
3337	11/15/2011	0.94	1.26	0.86	0.08
3343	11/19/2011	-0.22	0.82	1.21	0.03
3344		1.07	2.60	4.00	0.14
3345		1.34	1.10	1.56	0.10
3346	11/22/2011	1.27	1.61	5.14	0.12
3347		0.86	2.78	10.90	0.15
3356	11/29/2011	0.97	1.61	0.83	0.10
3358		1.03	1.83	1.14	0.11
3359	12/7/2011	1.36	1.65	8.67	0.13
3360	12/8/2011	1.26	2.31	13.88	0.15
3361		0.73	11.03	0.75	0.41
3362		0.94	0.93	1.09	0.07
3363		1.25	1.78	1.26	0.12
3364		1.17	1.81	1.84	0.12
3365		1.20	1.40	1.67	0.10
3366		0.97	1.50	1.81	0.10
3367		1.06	1.27	1.33	0.09

15.3 DATA COLLECTION

Data collection was performed based on the assumptions, methods, and performance criteria established to satisfy the DQOs in accordance with the C-T Phase II DP, Sections 14.4.1 and 14.4.3. Details regarding FSS design and quality assurance and quality control applicable to all survey units were discussed in Chapters 4 and 5, respectively, of this FSSR.

15.3.1 Gamma Scans

A gamma walk-over survey (GWS) was performed over 100% of the excavated area to locate radiation anomalies that might indicate areas with elevated residual radioactivity where further data collection (i.e., biased soil sampling) was warranted.

15.3.2 Soil Sampling

Soil samples to be used for the statistical test were collected at a frequency and at representative locations throughout SU09 such that a statistically sound conclusion regarding the radiological condition of the survey unit could be developed. Additional biased soil samples were also collected at locations of elevated residual radioactivity identified by GWS. Figure 15-4 provides the GWS results and soil sampling locations. A total of 18 (15 systematic and 3 GWS biased) soil samples were collected over the areal footprint SU09.

All soil samples were analyzed on site via gamma spectroscopy analysis. Table 15-2 provides the sample results and summary statistics for the 15 systematic samples. Table 15-3 provides the sample results for the 3 GWS biased samples.

Any remaining sieved material from each sample was analyzed separately to verify residual radioactivity was consistent with sample results. The radiological screening process did not identify any significant levels of radioactivity in the sieved materials removed from samples.

The C-T Phase II DP, Table 4-17, provided mean background activity levels of 1.3, 2.5, and 4.4 picoCuries per gram (pCi/g) for thorium-232 (^{232}Th), radium-226 (^{226}Ra), and uranium-238 (^{238}U), respectively. These values were used to calculate net sum of fractions (SOF) values—note that when measured activity concentration levels were less than the background mean resulting in a negative value, the net activity concentration was set equal to zero for the net SOF calculation.

To mitigate the risk of backfilling, the on-site laboratory analytical results were reviewed to determine the likelihood of the survey unit failing to meet the criteria for radiological release. The on-site laboratory, by design, reported conservative sample results.

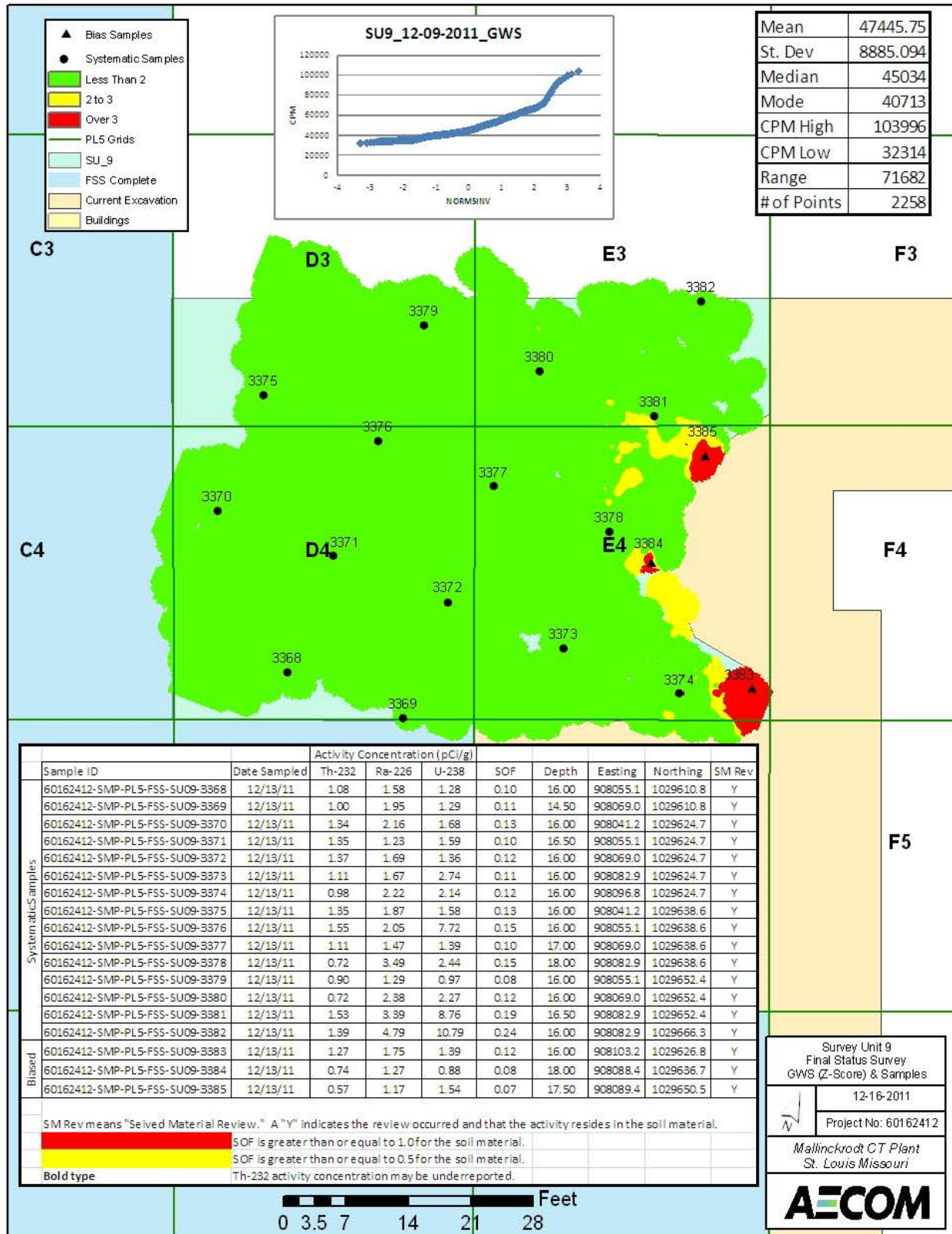


Figure 15-4 GWS and Soil Sampling Locations

Table 15-2 Gamma Spectroscopy Systematic Sample Analytical Results

Sample ID	Depth (ft bgs)	On-Site Results											Off-Site Results ^a											On-Site/ Off-Site Gross SOF Ratio
		Concentration (pCi/g)									SOF		Concentration (pCi/g)									SOF		
		²³² Th			²²⁶ Ra			²³⁸ U					²³² Th			²²⁶ Ra			²³⁸ U					
		Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net ^b	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net ^b	
3368	16	1.08	0.24	0.08	1.58	0.69	0.48	1.28	0.88	0.57	0.10	0.00	1.48	0.33	0.22	1.36	0.20	0.06	1.63	0.22	0.06	0.11	0.01	0.91
3369	14.5	1.00	0.20	0.07	1.95	0.68	0.45	1.29	0.83	0.55	0.11	0.00	1.03	0.25	0.18	0.96	0.14	0.05	1.04	0.15	0.05	0.08	0.00	1.42
3370	16	1.34	0.25	0.07	2.16	0.80	0.52	1.68	0.83	0.54	0.13	0.00	2.00	0.35	0.23	1.40	0.20	0.07	1.60	0.22	0.07	0.13	0.03	0.99
3371	16.5	1.35	0.29	0.08	1.23	0.86	0.65	1.59	0.91	0.63	0.10	0.00	1.29	0.31	0.22	1.27	0.18	0.06	1.38	0.19	0.06	0.10	0.00	1.01
3372	16	1.37	0.30	0.06	1.69	0.73	0.48	1.36	1.07	0.69	0.12	0.00	1.14	0.25	0.21	1.26	0.18	0.06	1.41	0.20	0.06	0.09	0.00	1.26
3373	16	1.11	0.30	0.11	1.67	1.08	0.82	2.74	1.21	0.78	0.11	0.00	1.18	0.27	0.21	1.68	0.23	0.06	1.98	0.26	0.06	0.11	0.00	0.98
3374	16	0.98	0.19	0.07	2.22	0.86	0.59	2.14	0.97	0.61	0.12	0.00	1.32	0.30	0.20	1.64	0.23	0.06	1.70	0.23	0.06	0.11	0.00	1.05
3375	16	1.35	0.31	0.09	1.87	0.90	0.65	1.58	1.00	0.68	0.12	0.00	1.71	0.34	0.21	1.46	0.21	0.06	1.55	0.21	0.06	0.12	0.02	0.99
3376	16	1.55	0.29	0.03	2.05	1.40	1.08	7.72	1.60	0.87	0.15	0.02	1.43	0.32	0.21	1.29	0.19	0.06	1.49	0.21	0.06	0.11	0.01	1.38
3377	17	1.11	0.24	0.10	1.47	0.81	0.59	1.39	0.98	0.68	0.10	0.00	1.46	0.38	0.31	1.27	0.21	0.09	1.45	0.23	0.09	0.11	0.01	0.93
3378	18	0.72	0.24	0.31	3.49	1.19	0.80	2.44	1.37	0.88	0.15	0.03	1.81	0.43	0.26	2.32	0.32	0.07	2.69	0.35	0.07	0.16	0.02	0.96
3379	16	0.90	0.18	0.05	1.29	0.66	0.48	0.97	0.69	0.49	0.08	0.00	1.11	0.30	0.29	1.16	0.19	0.08	1.23	0.20	0.08	0.09	0.00	0.94
3380	16	0.72	0.22	0.10	2.38	0.96	0.65	2.27	0.91	0.57	0.11	0.00	0.66	0.39	0.29	1.73	0.27	0.09	1.82	0.26	0.09	0.09	0.00	1.29
3381	16.5	1.53	0.24	0.09	3.39	1.55	1.26	8.76	1.58	0.88	0.19	0.05	1.40	0.28	0.21	1.16	0.18	0.06	1.42	0.20	0.06	0.10	0.00	1.91
3382	16	1.39	0.28	0.07	4.79	1.43	1.02	10.79	1.57	0.83	0.24	0.09	2.33	0.49	0.38	1.92	0.30	0.10	2.22	0.32	0.11	0.17	0.04	1.42
Summary Statistics																								
Count:	15				15						15	15	15			15			15			15	15	15
Average:	1.17				2.21						0.13	0.01	1.42			1.46			1.64			0.11	0.01	1.16
Median:	1.11				1.95						0.12	0.00	1.40			1.36			1.55			0.11	0.00	1.01
Standard Dev.:	0.27				0.97						0.04	0.03	0.41			0.35			0.41			0.03	0.01	0.28
Minimum:	0.72				1.23						0.08	0.00	0.66			0.96			1.04			0.08	0.00	0.91
Maximum:	1.55				4.79						0.24	0.09	2.33			2.32			2.69			0.17	0.04	1.91
Range:	0.83				3.56						0.15	0.09	1.67			1.36			1.65			0.09	0.04	1.00

^a Off-site laboratory results as reported by TestAmerica after sufficient in-growth time to reach ²²⁶Ra progeny equilibrium.

^b Calculated as discussed in Section 15.3.2.

Table 15-3 Gamma Spectroscopy Biased Sample Analytical Results

Sample ID	Depth (ft bgs)	On-Site Results											Off-Site Results ^a											On-Site/ Off-Site Gross SOF Ratio
		Concentration (pCi/g)									SOF		Concentration (pCi/g)									SOF		
		²³² Th			²²⁶ Ra			²³⁸ U			Gross	Net ^b	²³² Th			²²⁶ Ra			²³⁸ U			Gross	Net ^b	
Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net ^b	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net ^b			
GWS Biased Samples																								
3383	16	1.27	0.18	0.05	1.75	0.83	0.61	1.39	0.83	0.57	0.11	0.00	1.41	0.28	0.21	1.39	0.20	0.06	1.61	0.22	0.06	0.11	0.00	1.05
3384	18	0.74	0.16	0.07	1.27	0.72	0.53	0.88	0.69	0.48	0.08	0.00	0.88	0.30	0.28	1.15	0.19	0.08	1.23	0.19	0.08	0.08	0.00	0.97
3385	17.5	0.57	0.15	0.04	1.17	0.74	0.56	1.54	0.86	0.53	0.07	0.00	0.60	0.24	0.23	0.94	0.15	0.06	1.03	0.16	0.06	0.06	0.00	1.13

^a Off-site laboratory results as reported by TestAmerica after sufficient in-growth time to reach ²²⁶Ra progeny equilibrium.

^b Calculated as discussed in Section 15.3.2.

15.3.3 Core Boring

The C-T Phase II DP, Table 4-7, provided characterization borehole results. Of the locations provided in the table, one was collected within the extent of SU09: BH-031. Table 15-4 provides the data for this location. The results indicate that beyond the excavation extent, additional subsurface contamination is not reasonably expected. Therefore, in accordance with Page 14-22 of the C-T Phase II DP, FSS core sampling or measurements were not performed.

Table 15-4 Characterization Borehole Results

Location ID	Sample Depth (ft)	Activity Concentration (pCi/g) ^a			SOF ^b	
		²³² Th	²²⁶ Ra	²³⁸ U	Gross	Net ^c
BH-031	0.75 - 2	1.11	2.72	5.06	0.15	0.01
	4 - 6	1.74	1.68	4.69	0.14	0.02
	6 - 8	1.63	3.04	4.08	0.18	0.03
	8 - 10	6.86	22.70	6.29	1.07	0.92
	10 - 12	2.70	26.50	4.20	1.02	0.87
	12 - 14	0.67	1.70	1.40	0.09	0.00
	16 - 18	1.10	1.50	1.50	0.10	0.00

^a Italicized results indicate <MDC.

^b **Bolded orange** SOF values indicate a result >0.5 but ≤1 and **bolded red** SOF values indicate a result >1.

^c Calculated as discussed in Section 15.3.2.

15.4 DATA ANALYSIS

The data analysis was performed based on the assumptions, methods, and performance criteria established to satisfy the DQOs in accordance with the C-T Phase II DP, Sections 14.4.1 and 14.4.3. Details regarding FSS design and quality assurance and quality control applicable to all survey units were discussed in Chapters 4 and 5, respectively, of this FSSR.

15.4.1 Elevated Area Evaluation

There were no elevated areas identified in SU09.

15.4.2 Data Set Screening Analysis

Table 15-5 summarizes the results of the screening tests performed in accordance with Pages 14-27 through 14-29 of the C-T Phase II DP. All applicable tests demonstrating compliance passed.

Table 15-5 Screening Tests Results

Screening Test	Test Value	Conclusion
Min/Max	0.15	PASS
Low Level	N/A	Not applicable; Class 1 survey unit
DCGL _w	N/A	Not applicable; Min/Max < 1
EMC Limit	N/A	Not applicable; No elevated areas

15.4.2.1 Min/Max

In accordance with Page 14-27 of the C-T Phase II DP, the Min/Max screening test value was calculated by subtracting the minimum reference area result from the maximum survey unit systematic result. Sample 3382 with a gross SOF of 0.17 (from Table 15-2) was the maximum survey unit systematic result. Sample BH-Z-08 with a calculated gross SOF of 0.02 (from C-T Phase II DP Table B-1) was the minimum reference area result. The Min/Max screening test value was calculated to be 0.15. Because the test value was less than one, no further computations are required, i.e., $DCGL_W$ screening and Wilcoxon Rank Sum (WRS) tests.

15.4.2.2 Low Level

In accordance with Page 14-27 of the C-T Phase II DP, the Low Level screening test is not applicable to Class 1 survey units.

15.4.2.3 $DCGL_W$

In accordance with Page 14-28 of the C-T Phase II DP and because the Min/Max test value was less than one, the $DCGL_W$ screening test was not applicable to this survey unit.

15.4.2.4 EMC Limit

In accordance with Page 14-28 of the C-T Phase II DP, the elevated measurement comparison (EMC) Limit screening test was not applicable to this survey unit because no elevated areas were identified.

15.4.3 WRS Test

In accordance with Page 14-29 of the C-T Phase II DP and because the Min/Max test value was less than one, the WRS Test was not required to demonstrate compliance.

15.4.4 Retrospective Analysis

A retrospective analysis was performed of the FSS results to determine whether the results met the survey design objectives, in accordance with Page 14-30 of the C-T Phase II DP. Table 15-6 provides the results of the retrospective analysis. Because the actual sample size exceeded the retrospective value sample size, the conclusion is that the survey design objectives were met.

Table 15-6 Retrospective Analysis

Parameter	<i>A Priori</i> Value	Retrospective Value Based on FSS Results (Gross SOF)
Upper Bound of Gray Region	DCGL = 1	1
Lower Bound of Gray Region	0.5 x DCGL = 0.5	0.11
Spatial Variability (standard deviation)	1/6 x DCGL = 0.17	0.025
Type I Error (false positive)	0.05	0.05
Type II Error (false negative)	0.05	0.05
Relative Shift	3	35.6
Calculated N/2 Sample Size	15 ^a	9
Actual N/2 Sample Size	--	15

^aThe *a priori* value of 15 for the N/2 sample size was determined to be a conservative value that would allow application of either the Sign or WRS test. The *a priori* value for N/2 is 10 based on MARSSIM Table 5.3.

15.5 DEVIATIONS

In accordance with the second bullet in Section 14.5 of the C-T Phase II DP, the FSSR is required to list changes made in the FSS from what was proposed in the DP. Only one deviation was noted. Page 14-27 of the C-T Phase II DP indicated that the “data set for the survey unit will be processed within a database using screening software developed and verified for the project.” This database was not developed; instead, a combination of Microsoft® Excel® spreadsheets and hand calculations was utilized. This deviation is not significant and does not affect the data collection or assessment.

15.6 NRC INSPECTIONS

A summary of NRC inspections applicable to the FSS are provided in Section 5.8 of this FSSR. The scope of the inspections included, but was not limited to: review of project plans, interviewing of project personnel, evaluation of the on-site laboratory, and independent confirmatory surveys conducted by the NRC prior to and after backfilling. No violations were identified. No findings of significance were identified.

15.7 CONCLUSION

FSS data were verified to be reliable, appropriately documented, and technically defensible. Specifically, the following conclusions are made:

- The instruments used to collect the data were capable of detecting the radiation type (i.e., gamma) at or below the release criteria (described in Sections 4.4 and 4.5 of this FSSR).
- The calibration of the instruments used to collect the data was current and radioactive sources used for calibration were National Institute of Standards and Technology (NIST) traceable (described in Section 5.4 of this FSSR). Specific records available upon request.
- Instrument response was checked before instrument use each day, at minimum (described in Section 5.4 of this FSSR). Specific records available upon request.

- The survey methods used to collect the data were appropriate for the media and type of radiation being measured (described in Sections 4.4, 4.5, and 4.6 of this FSSR).
- The custody of samples collected for laboratory analysis was tracked from the point of collection until final results were obtained (described in Section 5.5.2 of this FSSR). Specific records available upon request.
- The survey data consist of qualified measurement results that are representative of the area of interest.
- Areas identified with elevated residual radioactivity (i.e. SOF > 1.0) were appropriately investigated and the DCGL_{EMC} properly applied.

All the applicable screening tests passed, the retrospective analysis found that the survey design objectives were met, and additional subsurface contamination was not reasonably suspected. SU09 meets the industrial use scenario release criterion as established in the C-T Phase II DP Chapter 5; and therefore, satisfies the unrestricted release provisions of Title 10, Code of Federal Regulations (CFR), Part 20, Subpart E.

15.8 REFERENCES

Mallinckrodt, *Mallinckrodt Columbium-Tantalum Phase II Decommissioning Plan*, Revision 2, August 2008.