Phase II Final Status Survey Report
Mallinckrodt Columbium-Tantalum Plant

St. Louis, Missouri

Chapter 7

Project No. 137131 **Revision 0**

Prepared by:
Energy*Solutions*, LLC
Commercial Projects
1009 Commerce Park Drive, Suite 100
Oak Ridge, TN 37830

Authored By:	Timothy J. Bauer, Health Physicist	8/22/2013 Date
Reviewed By:	Michael A. Carr, CHP, Radiological Engineer/Radiation Safety Officer	8-22-2013 Date
Reviewed By:	Mark Cambra, P.E., Project Manager	08-22-13 Date
Approved By:	Arthur J. Palmer, CHP, PMP, Director, Health Physics & Radiological Engineering	8/22/13 Date

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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
cm	centimeters
DCGL	derived concentration guideline level
DP	decommissioning plan
DQO	data quality objectives
EMC	elevated measurement comparison
Energy*Solutions*	Energy*Solutions*, LLC
F	exposure-weighted fraction of the $DCGL_W$
FSS	Final Status Survey
FSSR	Final Status Survey Report
ft	feet
GWS	gamma walk-over survey
HVAC	heating, ventilation, and air conditioning
m	meters
m^2	square meters
MARSSIM	Multi-Agency Radiation and Site Investigation Manual (NUREG-1575)
mm	milli-meters
MDC	minimum detectable concentration
NE	northeast
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
NW	northwest
ORISE	Oak Ridge Institute for Science and Education
pCi/g	picoCuries per gram
Ra	radium
SOF	sum of fractions
Th	thorium
U	uranium
WRS	Wilcoxon Rank Sum

7.0 RESULTS SUMMARY FOR PLANT 5 SUBSURFACE SU01

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 SU01 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 May and June of 2011. The SU01 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.

7.1 OVERVIEW

SU01 is a Class 1 survey unit located in the northwest portion of C-T Plant 5. The survey unit is approximately 353 square meters (m^2) in size, which is less than the size limit of 3,000 m^2 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 derived concentration guideline value ($DCGL_W$) prior to remediation. Figure 7-1 shows the location of SU01 within the Plant 5 area.

Figure 7-2 and Figure 7-3 are photographs of SU01 that were taken during the FSS, following remediation. In Figure 7-2, as viewed from the northeast corner of the survey unit looking west, shows the east wall at the north end of Building 250 in the background. SU02 (partially backfilled) appears next to Building 250 in the upper left of the figure. Evident are the large remnants of legacy concrete[1] that extend along the entire length of the north and south sides of the survey unit. Present near the center of Figure 7-2 is a concrete monolith poured during remediation to plug water flow from legacy sewer lines. Portions of brick foundations also remain on the west side of the survey unit adjacent to Building 250. Excavated depths ranged from 4 to 11 feet (ft).

There is a small area in the northwest corner of SU01 next to Building 250 (see Figure 7-2 upper right) beneath a mezzanine which supports heating, ventilation, and air conditioning (HVAC) equipment that was not excavated because of its proximity to Building 250 and the necessity to keep the HVAC systems operational.

[1] Based on historical research, Mallinckrodt Inc. concluded that the legacy concrete was a foundation for the Sheet Mills from the National Enameling and Rolling Mills Company that occupied the site in the late 1800's.

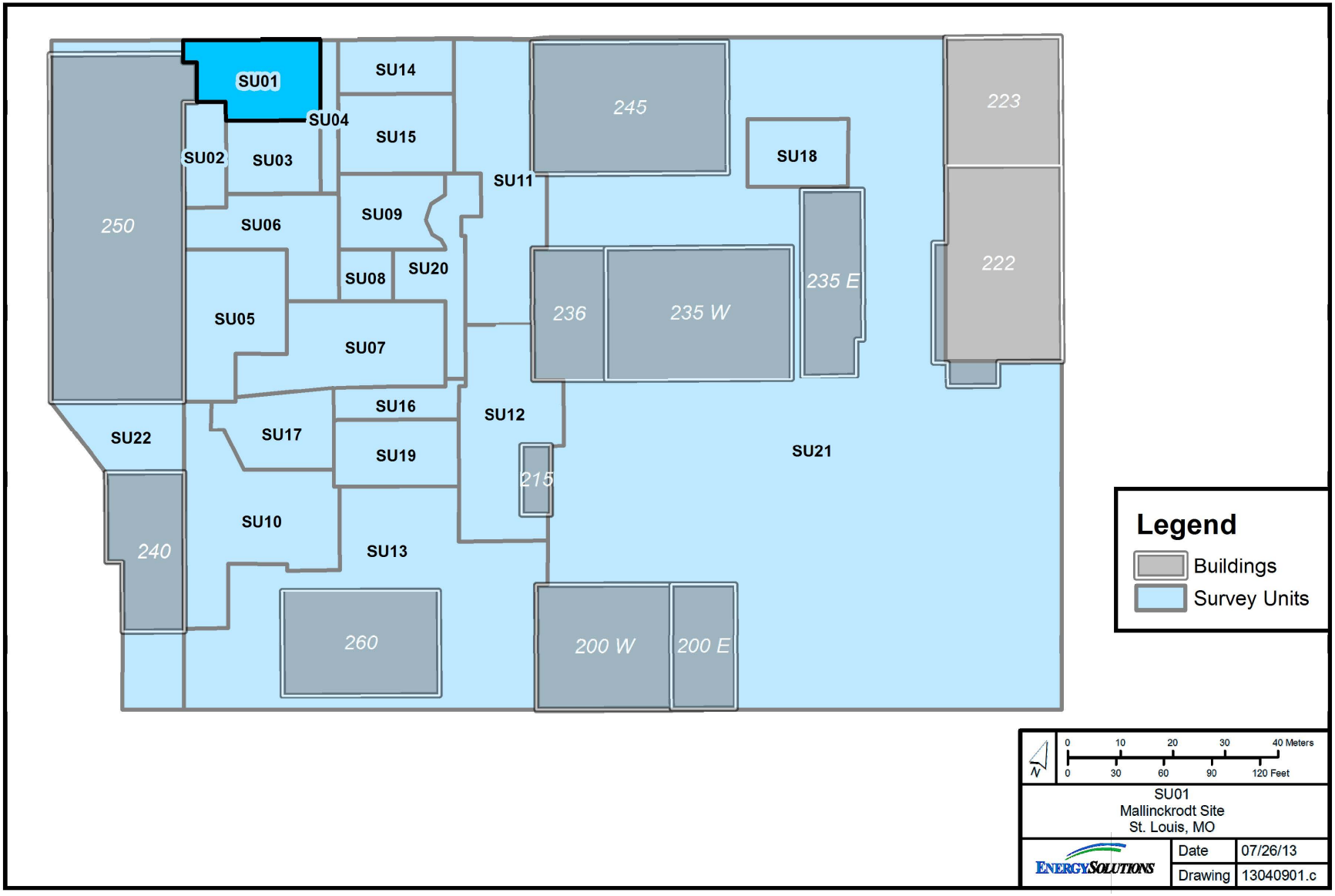


Figure 7-1 Location of Subsurface SU01 in C-T Plant 5

Figure 7-2 Photograph from NE Corner Looking West

Figure 7-3 Photograph from NW Corner Looking East

7.2 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 are discussed in Chapters 4 and 5, respectively, of this FSSR.

7.2.1 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. Due to the relatively large amount of non-soil surface area in SU01, a GWS of non-soil surfaces was performed and evaluated separately so as not to bias the soil GWS results as well as to ensure no non-soil anomalies were left undetected.

7.2.2 Soil Sampling

Soil samples to be used for the statistical test were collected at a frequency and at representative locations throughout SU01 such that a statistically sound conclusion regarding the radiological condition of the survey unit could be developed. Where sample locations were positioned on concrete/brick surfaces, the sample was collected from the nearest suitable location. Additional biased soil samples were also collected at locations of elevated residual radioactivity identified by GWS. Figure 7-4 provides the GWS results and soil sampling locations. A total of 28 soil samples were collected throughout SU01, 19 over the areal footprint of SU01 (15 systematic and 4 GWS biased) and 9 along the excavated west wall along the Building 250 HVAC support.

All soil samples were analyzed on site via gamma spectroscopy analysis. Table 7-1 provides the sample results and summary statistics for the 15 systematic samples. Table 7-2 provides the sample results for the 9 west wall samples and 4 GWS biased samples.

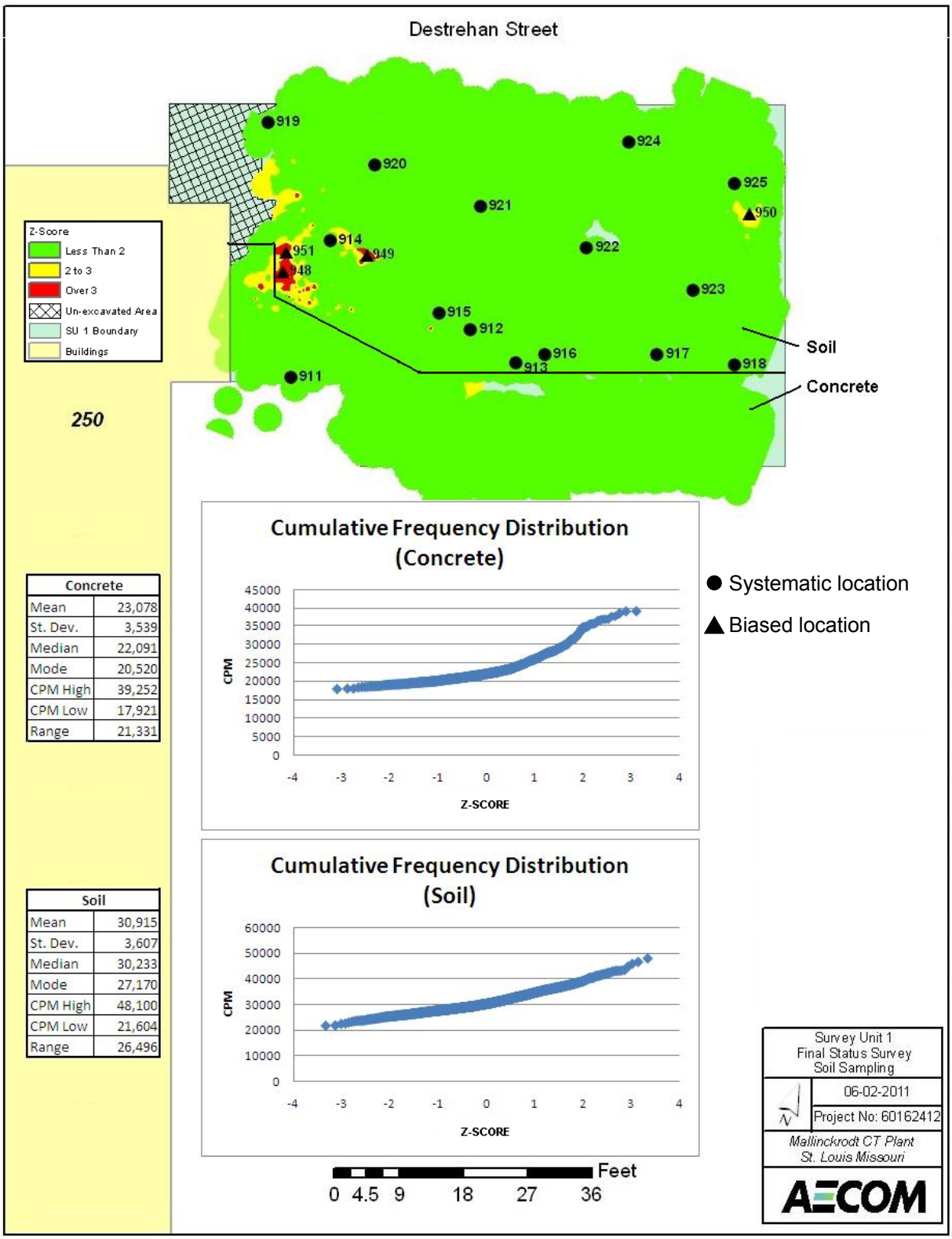
Any remaining sieved material from each sample was analyzed separately to verify residual radioactivity was consistent with sample results. The radiological screening process did not identify any significant levels of radioactivity in the sieved materials removed from samples.

The unexcavated area in the northwest corner of SU01 was identified during remediation as containing elevated levels of residual radioactivity (i.e., sum of fractions [SOF] > 1.0). The nine biased soil samples (0831 through 0839) were taken from the exposed face of the area. The locations of the samples are shown in Figure 7-5.

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 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.

AECOM did not send all biased samples to the off-site laboratory for analysis. Specifically, the biased samples collected from the unexcavated area in the northwest corner of SU01 were not sent. After Energy*Solutions*, LLC (Energy*Solutions*) arrived on site, the remaining samples were sent off site with the exception of sample 0834 because it could not be located. Based on the conservative reporting of the on-site laboratory, the results for sample 0834 were considered to be usable for FSS purposes.



Concrete	
Mean	23,078
St. Dev.	3,539
Median	22,091
Mode	20,520
CPM High	39,252
CPM Low	17,921
Range	21,331

Soil	
Mean	30,915
St. Dev.	3,607
Median	30,233
Mode	27,170
CPM High	48,100
CPM Low	21,604
Range	26,496

Figure 7-4 GWS and Soil Sampling Locations

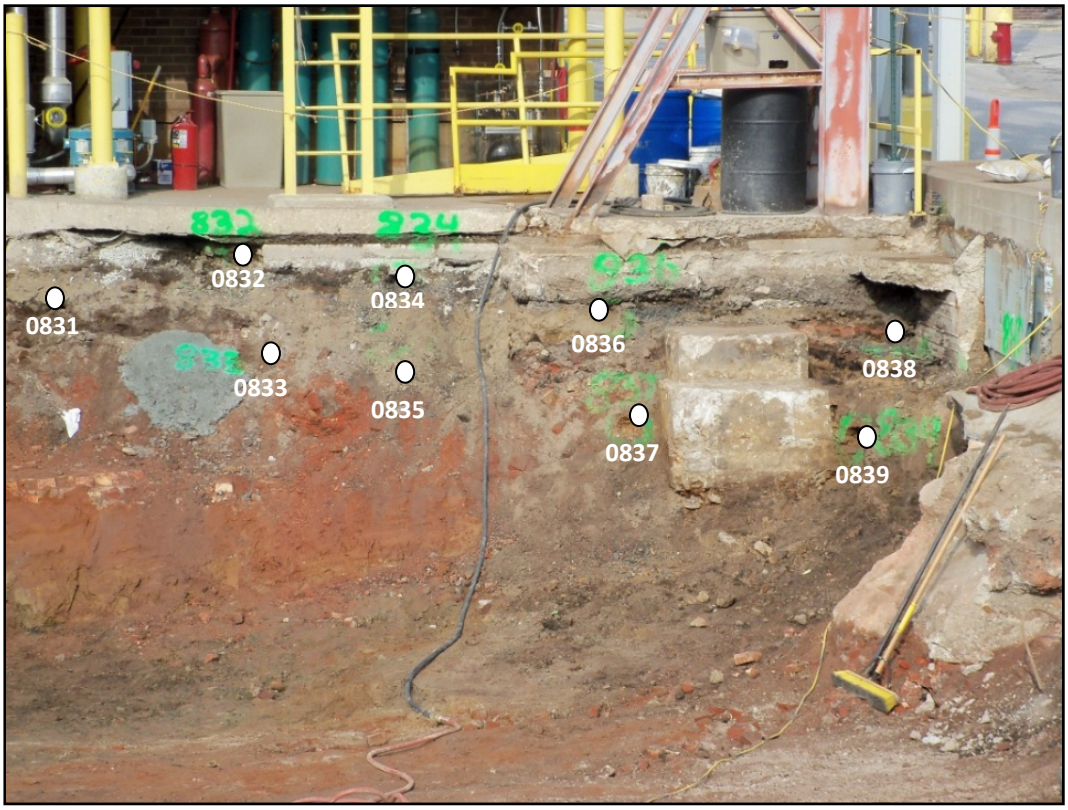


Figure 7-5 Sampling Locations in Elevated Area

Table 7-1 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
		Activity Concentration (pCi/g) [b]									SOF		Activity Concentration (pCi/g) [b]									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 [c]	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net [c]	
0911	3.5	1.42	0.23	0.07	3.53	0.99	0.74	9.32	1.11	0.56	0.19	0.05	1.38	0.36	0.37	2.30	0.33	0.11	2.71	0.37	0.10	0.14	0.00	1.38
0912	10	0.54	0.11	0.06	2.24	0.63	0.47	5.25	0.73	0.39	0.11	0.00	1.09	0.40	0.33	2.31	0.33	0.10	2.46	0.34	0.10	0.13	0.00	0.83
0913	10	0.82	0.11	0.05	3.15	0.72	0.53	6.47	0.61	0.33	0.15	0.02	1.27	0.44	0.37	2.90	0.42	0.10	3.08	0.41	0.11	0.16	0.01	0.96
0914	10	0.96	0.15	0.05	1.39	0.45	0.33	1.94	0.52	0.31	0.09	0.00	1.01	0.23	0.19	1.30	0.18	0.05	1.40	0.19	0.05	0.09	0.00	1.02
0915	10	0.89	0.13	0.07	5.06	0.81	0.55	7.35	0.98	0.51	0.22	0.09	1.05	0.37	0.34	3.83	0.54	0.10	3.94	0.52	0.11	0.18	0.05	1.22
0916	10	1.00	0.12	0.08	3.82	0.82	0.59	6.46	0.80	0.44	0.18	0.05	1.74	0.38	0.33	3.93	0.53	0.09	4.53	0.58	0.10	0.21	0.07	0.85
0917	10	1.06	0.12	0.05	3.71	0.75	0.54	6.96	0.68	0.38	0.18	0.04	1.49	0.37	0.34	2.68	0.36	0.08	2.91	0.37	0.10	0.16	0.01	1.14
0918	10	*0.00*	902.22	0.18	3.63	0.90	0.67	7.61	0.89	0.47	0.13	0.04	1.69	0.39	0.36	2.89	0.40	0.10	3.11	0.42	0.11	0.17	0.03	0.77
0919	2.5	0.82	0.14	0.05	1.01	0.39	0.29	1.34	0.43	0.28	0.07	0.00	1.22	0.36	0.29	0.96	0.17	0.08	1.04	0.17	0.09	0.09	0.00	0.83
0920	10	1.15	0.18	0.06	1.76	0.51	0.37	1.67	0.44	0.31	0.11	0.00	1.31	0.31	0.20	1.38	0.20	0.06	1.70	0.23	0.06	0.10	0.00	1.06
0921	10	0.42	0.01	0.14	2.07	0.56	0.41	3.32	0.59	0.36	0.09	0.00	1.01	0.37	0.26	1.67	0.25	0.07	1.86	0.26	0.07	0.10	0.00	0.91
0922	10.5	0.79	0.13	0.06	2.44	0.64	0.47	5.44	0.58	0.32	0.12	0.00	1.39	0.37	0.25	1.21	0.19	0.08	1.39	0.21	0.08	0.10	0.00	1.22
0923	10	1.13	0.21	0.08	4.00	0.91	0.67	9.64	1.03	0.53	0.20	0.06	1.22	0.38	0.37	3.39	0.45	0.10	3.92	0.50	0.10	0.17	0.03	1.15
0924	10	0.72	0.13	0.06	2.71	0.62	0.45	5.59	0.68	0.37	0.13	0.01	1.04	0.30	0.29	1.88	0.28	0.08	2.13	0.30	0.09	0.11	0.00	1.18
0925	10.5	1.57	0.23	0.08	5.83	1.34	0.99	14.44	1.54	0.77	0.28	0.14	1.77	0.54	0.48	4.02	0.54	0.13	4.42	0.63	0.14	0.22	0.07	1.31
Summary Statistics																								
Count:		15			15			15			15	15	15			15			15			15	15	15
Average:		0.89			3.09			6.19			0.15	0.03	1.31			2.44			2.71			0.14	0.02	1.06
Median:		0.89			3.15			6.46			0.13	0.02	1.27			2.31			2.71			0.14	0.00	1.06
Standard Dev.:		0.39			1.33			3.44			0.06	0.04	0.26			1.04			1.13			0.04	0.02	0.19
Minimum:		0.00			1.01			1.34			0.07	0.00	1.01			0.96			1.04			0.09	0.00	0.77
Maximum:		1.57			5.83			14.44			0.28	0.14	1.77			4.02			4.53			0.22	0.07	1.38
Range:		1.57			4.82			13.10			0.21	0.14	0.76			3.06			3.49			0.13	0.07	0.60

[a] Off-site laboratory results as reported by TestAmerica after sufficient in-growth time to reach ^{226}Ra progeny equilibrium.
[b] Italicized results indicate <MDC.
[c] Calculated as discussed in Section 7.2.2.

Table 7-2 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
		Activity Concentration (pCi/g) [b]									SOF [c]		Activity Concentration (pCi/g) [b]									SOF [c]	
		^{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 [d]	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Gross	Net [d]	
West Wall Samples																							
0831	5.5	1.77	0.40	0.16	14.89	2.08	1.38	15.32	1.90	1.06	**0.60**	0.46	1.72	0.47	0.59	11.70	1.42	0.40	14.20	4.88	5.61	0.49	0.34	1.23
0832	1	0.89	0.21	0.14	26.54	2.43	1.67	51.16	2.98	1.32	**1.01**	**0.88**	1.39	0.59	0.56	21.10	2.37	0.45	67.30	10.20	8.40	**0.87**	**0.72**	1.16
0833	3	0.92	0.15	0.05	1.84	0.56	0.41	3.42	0.57	0.33	0.11	0.00	1.14	0.29	0.14	1.57	0.27	0.14	3.35	1.31	1.76	0.11	0.00	1.00
0834	1	1.05	0.23	0.15	38.90	3.81	2.71	165.18	7.25	1.76	**1.60**	**1.46**	Sample Lost											
0835	3	0.51	0.11	0.05	1.50	0.60	0.47	6.85	0.74	0.38	0.08	0.00	0.45	0.19	0.24	0.96	0.21	0.14	8.00	2.36	2.34	0.06	0.00	1.31
0836	1	0.38	0.09	0.03	1.45	0.43	0.32	3.10	0.50	0.28	0.07	0.00	0.32	0.17	0.24	1.02	0.21	0.15	5.67	1.86	2.01	0.06	0.00	1.24
0837	4	1.04	0.11	0.04	1.86	0.51	0.37	2.91	0.60	0.36	0.11	0.00	1.33	0.28	0.18	1.23	0.25	0.19	6.05	2.21	2.55	0.11	0.00	1.04
0838	1	1.25	0.16	0.09	9.60	1.76	1.34	38.79	2.04	0.76	0.43	0.29	1.86	0.43	0.37	8.89	1.07	0.28	53.40	7.23	5.10	0.45	0.31	0.95
0839	4	0.92	0.13	0.06	1.25	0.39	0.28	1.50	0.48	0.31	0.08	0.00	0.83	0.31	0.50	1.30	0.30	0.21	*2.08*	0.98	3.16	0.08	0.00	1.02
GWS Biased Samples																							
0948	10	1.23	0.18	0.06	4.27	0.60	0.38	3.45	0.53	0.35	0.20	0.06	1.58	0.32	0.22	2.52	0.33	0.06	2.92	0.37	0.06	0.16	0.01	1.29
0949	4	0.87	0.15	0.07	2.87	0.63	0.44	2.63	0.68	0.41	0.14	0.01	0.98	0.31	0.30	2.50	0.36	0.08	2.72	0.37	0.09	0.13	0.00	1.06
0950	10	1.41	0.17	0.07	5.15	0.78	0.53	4.72	0.84	0.49	0.24	0.10	1.53	0.44	0.33	4.56	0.59	0.09	4.94	0.78	0.10	0.23	0.08	1.07
0951	4	0.34	0.01	0.11	2.16	0.39	0.25	1.49	0.42	0.25	0.09	0.00	0.43	0.23	0.24	1.18	0.18	0.07	1.30	0.19	0.07	0.06	0.00	1.50

[a] Off-site laboratory results as reported by TestAmerica after sufficient in-growth time to reach ^{226}Ra progeny equilibrium.
[b] Italicized results indicate <MDC.
[c] **Bolded orange** SOF values indicate a result >0.5 but ≤1 and **bolded red** SOF values indicate a result >1.
[d] Calculated as discussed in Section 7.2.2.

7.2.3 Core Boring

The C-T Phase II DP, Table 4-7, provided characterization borehole results. Of the locations provided in the table, three were collected within the extent of SU01: BH-022, BH-023, and BH-045. Table 7-3 provides the data for these three locations. 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 7-3 Characterization Borehole Results

Location ID	Sample Depth (ft)	Activity Concentration (pCi/g) [a]			SOF	
		^{232}Th	^{226}Ra	^{238}U	Gross	Net [b]
BH-022	0.75 - 2	1.60	*0.43*	10.30	0.10	0.02
	5 - 6	1.40	9.30	34.80	0.42	0.28
	6 - 7	0.07	4.86	31.00	0.21	0.12
	7 - 8	0.29	4.22	17.00	0.18	0.08
	9 - 10	1.60	4.70	13.00	0.24	0.10
BH-023	9 - 10	0.61	0.13	6.60	0.04	0.00
	14 - 15	1.10	*0.24*	2.50	0.06	0.00
BH-045	1.5 - 2	0.89	1.80	3.10	0.10	0.00
	9 - 10	0.81	1.10	1.50	0.07	0.00
	13 - 14	0.71	1.20	2.10	0.07	0.00

[a] Italicized results indicate <MDC.
[b] Calculated as discussed in Section 7.2.2.

7.3 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 are discussed in Chapters 4 and 5, respectively, of this FSSR.

7.3.1 Elevated Area Evaluation

Equation 9 from the C-T Phase II DP, Section 5.8.7 provides for the calculation of an *Index* value that represents the fraction or multiple of the $DCGL_{EMC}$. If the *Index* value is greater than one, then the $DCGL_{EMC}$ is exceeded. Parameters necessary to calculate the *Index* value for the unexcavated area in the northwest corner were:

- The levels of elevated area activity, represented conservatively by sample 0834, were 1.05, 38.90, and 165.18 pCi/g for ^{232}Th, ^{226}Ra, and ^{238}U, respectively (refer to Table 7-2);
- Mean background activity levels were 1.3, 2.5, and 4.4 pCi/g for ^{232}Th, ^{226}Ra, and ^{238}U, respectively (as provided in C-T Phase II DP Table 4-17);
- The size of the elevated area was determined to be approximately 21 m^2 (3 meters [m] by 7 m) with the elevated radioactivity extending to a depth less than 1 m; and,

- The area factors from C-T Phase II DP Figure 5-3 for the elevated area were 1.8, 1.9, and 2.7 for ^{232}Th, ^{226}Ra, and ^{238}U, respectively.

The calculation of the *Index* value is shown below. Because the ^{232}Th elevated area activity concentration was less than the background mean, the thorium series term was set equal to zero. Because the *Index* value as calculated in accordance with the DP was less than one, this elevated area is compliant with the C-T Phase II DP for elevated measurements in soil.

$$Index = (0)_{Th\ series} + \frac{(38.90 - 2.5)\ pCi/g}{(1.9 \times 29.4\ pCi/g)_{Ra226}} + \frac{(165.18 - 4.4)\ pCi/g}{(2.7 \times 721\ pCi/g)_{U}} = 0.73$$

7.3.2 Data Set Screening Analysis

Table 7-4 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 7-4 Screening Tests Results

Screening Test	Test Value	Conclusion
Min/Max	0.20	PASS
Low Level	N/A	Not applicable; Class 1 survey unit
$DCGL_W$	N/A	Not applicable; Min/Max < 1
EMC Limit	0.18	PASS

7.3.2.1 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 0925 with a gross SOF of 0.22 (from Table 7-1) 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 0.20. Because the test value was less than one, no further computations are required, i.e., $DCGL_W$ screening and Wilcoxon Rank Sum (WRS) tests.

7.3.2.2 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.

7.3.2.3 $DCGL_W$

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.

7.3.2.4 EMC Limit

In accordance with Page 14-28 of the C-T Phase II DP, the EMC limit screening test was applied due to the elevated area in the northwest corner (samples 0831 through 0839). Parameters necessary to calculate the exposure-weighted fraction of the $DCGL_W$, F, were:

- The size of the elevated area was determined to be approximately 21 m^2 (3 m by 7 m) with the elevated radioactivity extending to a depth less than 1 m,
- The area factor from C-T Phase II DP Figure 5-3 for the elevated area was conservatively set to 1.8 (based on thorium series only),
- The elevated area activity level was conservatively represented by sample 0834 with a gross SOF = 1.60, and
- The survey unit average was a gross SOF = 0.14 (refer to Table 7-1).

The calculation of the EMC screening test result is shown below, using C-T Phase II DP Equation 14-7.

$$F = \left[\frac{20\ m^2}{353\ m^2} \times \frac{1.60}{1.8 \times 1}\right] + \left[\frac{(353 - 20)\ m^2}{353\ m^2} \times \frac{0.14}{1}\right] = 0.18$$

In accordance with the C-T Phase II DP and because the result was less than one, the total radioactivity concentration in the survey unit is within the release criterion.

7.3.3 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.

7.3.4 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 7-5 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 7-5 Retrospective Analysis

Parameter	*A Priori* 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	0.14
Spatial Variability (standard deviation)	1/6 x DCGL = 0.17	0.043
Type I Error (false positive)	0.05	0.05
Type II Error (false negative)	0.05	0.05
Relative Shift	3	19.7
Calculated N/2 Sample Size	15 [a]	9
Actual N/2 Sample Size	--	15

[a] The *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.

7.4 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.

7.5 ORISE CONFIRMATORY SURVEY

The Oak Ridge Institute for Science and Education (ORISE), by NRC request, performed an independent evaluation of AECOM's FSS methods and results. It made two site visits - on April 28, 2011, and on June 1-2, 2011. During these visits, ORISE observed FSS activities and conducted confirmatory surveys of SU01 and SU03 (ORISE 2011).

Two specific issues were identified by ORISE:

1. The contractor (AECOM) sieved the soil samples resulting in the removal of contaminated slag material (greater than the sieve size) and the excess material/slag (potentially containing significant residual radioactivity) was left behind in the surveyed area.
2. The contractor (AECOM) technicians were not relying on the audible output of the instrument to pinpoint judgmental locations real time. Instead their process was to post-process the data and go back and investigate the suspect locations.

In response to the issues identified by ORISE, AECOM performed an assessment of its GWS and soil sampling methodology. The assessment is found in Appendix H of AECOM's Preliminary FSSR (AECOM 2012), and is summarized below.

Regarding ORISE's second issue, the GWS process was not modified to rely on the surveyor responding to an audible output of the instrument to pinpoint judgmental locations in real time. There are several reasons. A GWS data set collected uniformly over the surface of a survey unit, based on the rate at which data are logged (at 1-second intervals), is believed to more likely capture indications of an anomalous or subtle trending count rate than a surveyor responding to an audible indication. In addition, an evaluation of the GWS data set using both statistical and graphical methods (see Section 4.4.1.4 of this FSSR) is believed to provide superior information than a subjective response by a surveyor to an audible indication. For example, a cumulative frequency distribution provides information on the general shape of the data distribution, whether the population is normally or non-normally distributed, whether there are multiple populations present or individual outliers that may represent locations for further investigation. Another example is the z-score contouring process, which tends to smooth over single data points with slightly elevated values while accentuating clustered areas or single locations with significantly elevated values. This is the desired effect which aids in the data analysis by focusing attention on those areas most likely to have elevated residual radioactivity. These advantages are among those lost in a data set that is subjectively collected.

Table 7-6 lists the changes implemented by AECOM to improve the FSS survey and sampling methods.

Table 7-6 Changes to AECOM Survey and Sampling Methods

FSS Method	Change to Method	Rationale for Change
Perform single pass GWS	Perform double pass GWS with 2nd pass performed perpendicular to 1st pass.	A double pass increases data density and improves likelihood of detecting presence of small areas of elevated residual radioactivity.
Collect soil samples to a depth of 15 cm.	Collect soil samples to a depth of 30 cm.	External exposure is primary exposure pathway. The depth of contamination continues to affect external exposure up to 30 cm, beyond which impact is negligible.
Field screen soil samples using a ¼ inch sieve; discard plus ¼ inch material.	Collect all sample material. Do not field screen sample.	Radioactive material larger than 1/4 inch soil may exist.
Prepare soil samples by drying, screening using a No. 4 sieve, and mixing; discard plus No.4 (4.75 mm) material.	Prepare soil samples by drying, screening using No. 4 sieve, and mixing; retain plus No. 4 material.	Sample preparation preserves counting assumptions (uniformity, density, geometry) and comparability of onsite and offsite results.
Perform gamma spec count of prepared soil sample.	Perform gamma spec count of prepared soil sample; perform screening count of plus No. 4 material; investigate if above 0.5 x DCGL.	Radioactive material larger than No. 4 soil will be monitored with minimal impact on sampling process.

7.6 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, observation of FSS field activities, and independent confirmatory surveys conducted by the NRC prior to and after backfilling. No violations were identified. No findings of significance were identified.

7.7 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 are available upon request.
- Instrument response was checked before instrument use each day, at minimum (described in Section 5.4 of this FSSR). Specific records are 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 are 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. SU01 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.

7.8 REFERENCES

AECOM, *Phase II Decommissioning Mallinckrodt C-T Plant, St. Louis, Missouri, Preliminary Final Status Survey Report: Plant 5 Survey Units 01, 02, and 03*, March 2012.

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

Oak Ridge Institute for Science and Education (ORISE), *Final Report – Independent Confirmatory Survey Results for Survey Units 1 and 3 within the Plant 5 Footprint at the Mallinckrodt Inc. Site, St. Louis, Missouri*, September 2011.