

Phase II Final Status Survey Report Mallinckrodt Columbium-Tantalum Plant

St. Louis, Missouri

Chapter 8

Project No. 137131

Revision 0

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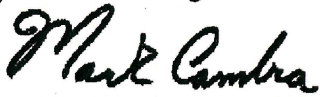
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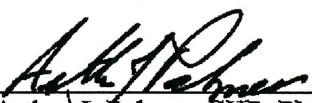
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- Non-Proprietary
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ABBREVIATIONS AND ACRONYMS

%	percent
σ	sigma; standard deviation
AECOM	AECOM Technical Services
bgs	below grade surface
C-T	columbium-tantalum
CFR	Code of Federal Regulations
cpm	counts per minute
DCGL	derived concentration guideline level
DP	decommissioning plan
DQO	data quality objectives
EMC	elevated measurement comparison
F	exposure-weighted fraction of the DCGL _w
FSS	Final Status Survey
FSSR	Final Status Survey Report
ft	feet
GWS	gamma walk-over survey
m	meters
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
WRS	Wilcoxon Rank Sum

8.0 RESULTS SUMMARY FOR PLANT 5 SUBSURFACE SU02

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 SU02 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 SU02 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.

8.1 OVERVIEW

SU02 is a Class 1 survey unit in the northwest portion of C-T Plant 5. The survey unit is approximately 161 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 8-1 shows the location of SU02 within the Plant 5 area.

Figure 8-2 is a photograph of SU02 that was taken during the FSS, following remediation. In Figure 8-2, as viewed from the southeast corner of the survey unit looking northwest, shows the east wall of Building 250 in the background. Evident in the figure is the sloped area next to Building 250, the red valve capping the fire suppression line, and several large remnants of concrete. The soil adjacent to Building 250 was removed down to the Building 250 grade beam and then along a 1-to-1 slope down to the final remedial depth. Additional excavation threatened to undermine the building foundation and was not performed. Excavated depth ranges from 4 to 8 feet (ft). The sloped area adjacent to Building 250 was addressed as part of the FSS.

The original southern boundary of SU02 extended to the north side of the manhole, which appears as the concrete structure on the far left in Figure 8-2. Following FSS completion, water problems were experienced in and around the manhole which led to soil erosion and required response actions which impacted the final radiological status of the area. As a result, the southern boundary of SU02 was relocated approximately 11 ft to the north. FSS data collected from the area no longer in SU02 were removed from the SU02 FSS data set.

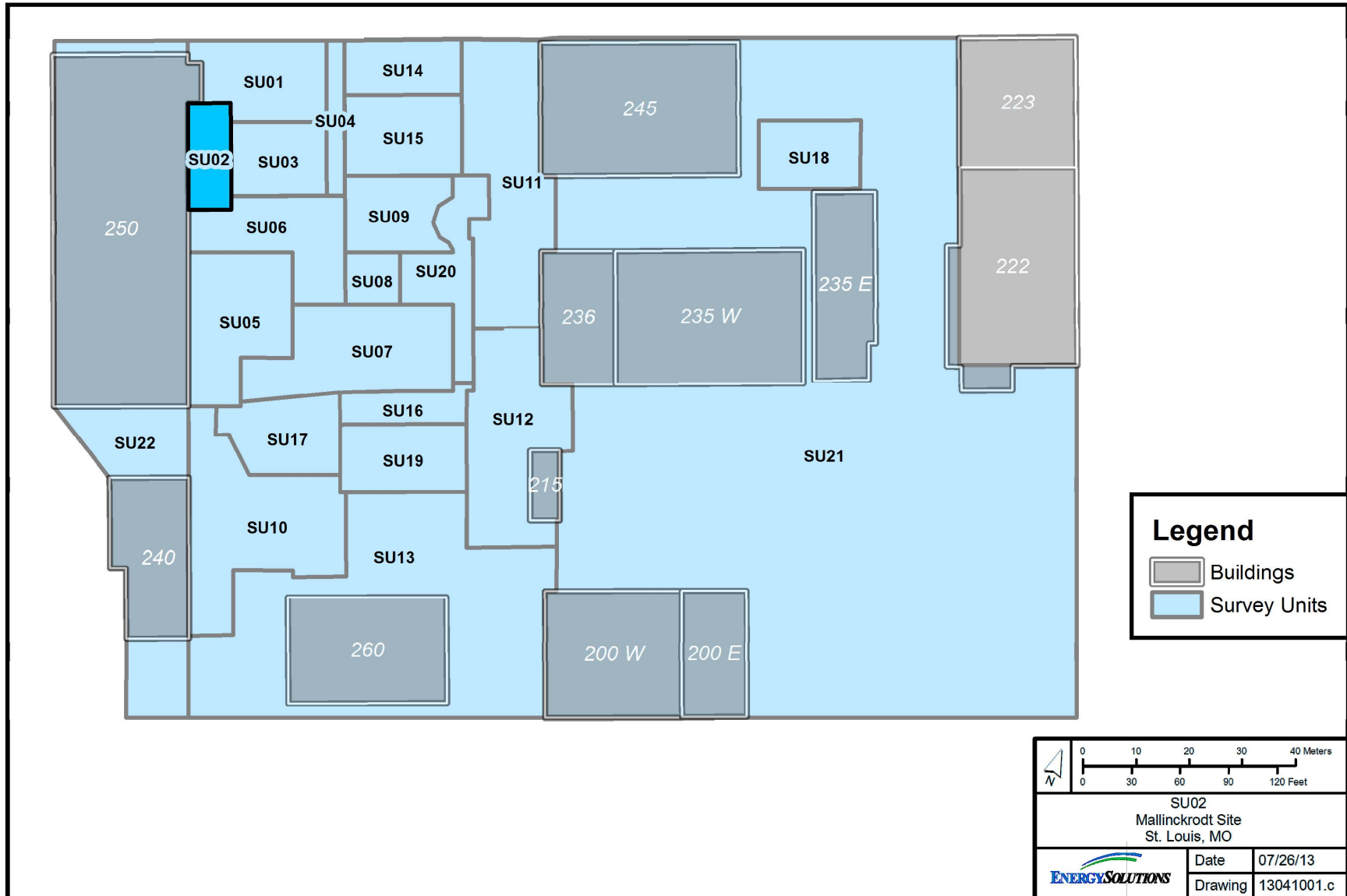


Figure 8-1 Location of SU02 in C-T Plant 5



Figure 8-2 Photograph of SU02 at Time of FSS

8.2 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 were discussed in Chapters 4 and 5, respectively, of this FSSR.

8.2.1 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. In locations where GWS coverage was inadequate due to low or no GPS signal, the surveyor-noted gross gamma activity ranges in 10 foot by 10 foot grids. The recorded scan measurements ranged from 29,000 to 75,000 counts per minute (cpm), which corresponded well to the GPS-captured data range of 23,000 to 69,000 cpm.

8.2.2 Soil Sampling

Soil samples to be used for the statistical test were collected at a frequency and at representative locations throughout SU02 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 8-3 provides

the GWS results and soil sampling locations. A total of 16 soil samples were collected throughout SU02, 14 over the areal footprint of SU02 (12 systematic and 2 GWS biased) and 2 around the fire suppression line.

All soil samples were analyzed on site via gamma spectroscopy analysis. Table 8-1 provides the sample results and summary statistics for the 12 systematic samples—3 systematic samples were not collected due to falling out of SU02 after adjusting the southern boundary. Table 8-2 provides the sample results for the 2 fire suppression line samples and 2 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.

Prior to the FSS, the area around the fire suppression line was excavated down to the Building 250 footer. Additional excavation to remove elevated levels of residual radioactivity (i.e., sum of fractions [SOF] > 1.0) threatened to undermine the building foundation. A set of two biased soil samples (0789 and 0790) was taken from the exposed face of the area. The locations of the samples are shown in Figure 8-3.

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.

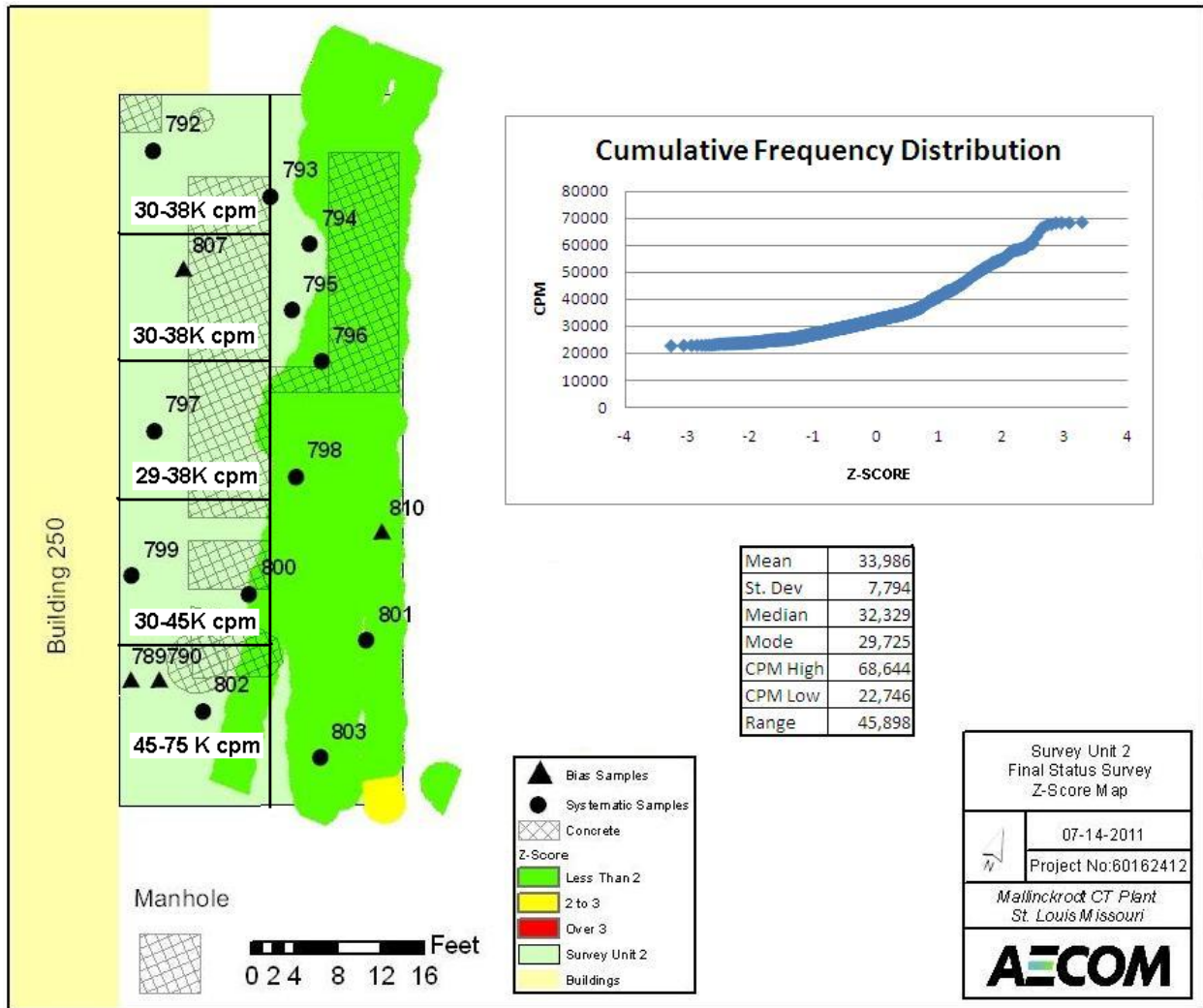


Figure 8-3 GWS and Soil Sampling Locations

Table 8-1 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			Gross	Net ^c	²³² Th			²²⁶ Ra			²³⁸ U			Gross	Net ^c					
Result	Uncert. (2σ)	MDC	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	Result	Uncert. (2σ)	MDC	Gross	Net ^c	
0792	3.5	1.52	0.24	0.09	6.47	1.16	0.81	0.09	9.76	1.28	0.68	0.30	0.15	1.52	0.52	0.42	4.14	0.58	0.11	4.31	0.57	0.12	0.21	0.06	1.41			
0793	3.5	1.29	0.25	0.10	5.92	1.00	0.66	0.10	5.90	1.01	0.59	0.26	0.12	1.82	0.42	0.32	4.78	0.63	0.09	5.36	0.69	0.09	0.25	0.10	1.07			
0794	3.5	1.15	0.19	0.07	5.11	0.99	0.72	0.07	9.97	1.18	0.61	0.24	0.10	1.65	0.45	0.33	3.44	0.47	0.09	4.11	0.53	0.10	0.19	0.05	1.23			
0795	5	1.39	0.23	0.09	7.31	1.07	0.70	0.09	7.09	1.07	0.61	0.32	0.17	1.41	0.55	0.48	4.48	0.60	0.13	4.91	0.69	0.14	0.22	0.07	1.45			
0796	5	1.04	0.18	0.08	5.13	0.82	0.55	0.08	6.95	0.74	0.42	0.23	0.09	1.45	0.44	0.36	3.19	0.44	0.10	3.79	0.50	0.11	0.17	0.03	1.31			
0797	7	1.24	0.23	0.08	4.72	0.91	0.61	0.08	4.92	1.05	0.59	0.22	0.08	1.84	0.41	0.34	3.19	0.45	0.10	3.64	0.48	0.10	0.19	0.05	1.15			
0798	8	1.18	0.23	0.09	3.93	0.92	0.67	0.09	6.70	0.77	0.45	0.19	0.05	1.26	0.37	0.35	3.15	0.45	0.09	3.50	0.46	0.10	0.16	0.02	1.17			
0799	7	<i>0.00</i>	425.43	0.18	5.37	1.19	0.88	0.18	12.54	1.23	0.61	0.20	0.11	1.07	0.37	0.41	3.79	0.53	0.11	3.95	0.52	0.12	0.18	0.04	1.12			
0800	4.5	1.03	0.15	0.08	6.67	1.33	0.98	0.08	19.87	1.61	0.72	0.30	0.16	1.26	0.31	0.27	4.77	0.61	0.07	5.29	0.66	0.08	0.22	0.08	1.34			
0801	8	0.85	0.19	0.08	4.59	1.04	0.76	0.08	10.44	0.93	0.48	0.21	0.08	1.06	0.39	0.34	3.10	0.43	0.10	3.27	0.44	0.11	0.15	0.02	1.34			
0802	7	1.15	0.17	0.06	1.71	0.48	0.34	0.06	1.61	0.43	0.31	0.11	0.00	1.28	0.34	0.31	1.53	0.22	0.08	1.69	0.23	0.09	0.11	0.00	1.01			
0803	8	0.48	0.11	0.05	2.30	0.59	0.43	0.05	3.74	0.48	0.28	0.10	0.00	0.30	0.21	0.22	1.47	0.22	0.06	1.61	0.23	0.07	0.06	0.00	1.60			
Summary Statistics																												
Count:	12				12				12			12	12	12			12			12			12	12	12			
Average:	1.03				4.94				8.29			0.22	0.09	1.33			3.42			3.79			0.18	0.04	1.27			
Median:	1.15				5.12				7.02			0.22	0.09	1.35			3.32			3.87			0.18	0.04	1.27			
Standard Dev.:	0.42				1.67				4.77			0.07	0.06	0.41			1.09			1.20			0.05	0.03	0.17			
Minimum:	0.00				1.71				1.61			0.10	0.00	0.30			1.47			1.61			0.06	0.00	1.01			
Maximum:	1.52				7.31				19.87			0.32	0.17	1.84			4.78			5.36			0.25	0.10	1.60			
Range:	1.52				5.60				18.26			0.21	0.17	1.54			3.31			3.75			0.18	0.10	0.59			

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

^b Italicized results indicate <MDC.

^c Calculated as discussed in Section 8.2.2.

Table 8-2 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)									SOF ^b		Activity Concentration (pCi/g)									SOF ^b		
		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			
Fire Suppression Line Samples																								
0789	5	2.20	0.29	0.18	58.63	3.43	1.70	40.72	2.91	1.45	2.14	2.00	3.71	0.95	1.07	40.30	5.20	0.25	43.50	5.30	0.30	1.59	1.44	1.35
0790	7	0.88	0.13	0.09	8.57	1.14	0.75	9.72	1.25	0.65	0.34	0.21	1.15	0.36	0.33	8.47	1.10	0.09	9.80	1.20	0.10	0.35	0.21	0.98
GWS Biased Samples																								
0807	6	0.84	0.16	0.05	3.16	0.67	0.46	3.37	0.70	0.41	0.15	0.02	1.02	0.35	0.31	1.94	0.29	0.09	2.08	0.28	0.09	0.11	0.00	1.32
0810	7	1.31	0.18	0.08	6.20	1.37	1.03	15.60	1.22	0.63	0.29	0.14	1.59	0.36	0.26	3.96	0.51	0.07	4.75	0.59	0.08	0.21	0.06	1.38

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

^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 8.2.2.

8.2.3 Core Boring

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 SU02: BH-029. Table 8-3 provides the data for the 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 8-3 Characterization Borehole Results

Location ID	Sample Depth (ft)	Activity Concentration (pCi/g)			SOF	
		²³² Th	²²⁶ Ra	²³⁸ U	Gross	Net ^a
BH-029	2 - 3	1.60	4.50	53.40	0.29	0.15
	3 - 4	0.93	1.84	5.59	0.11	0.00
	10 - 12	1.90	4.00	5.50	0.22	0.08
	15 - 16	0.90	1.40	1.60	0.09	0.00

^a Calculated as discussed in Section 8.2.2.

8.3 DATA ANALYSIS

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.

8.3.1 Elevated Area Evaluation

Equation 9 from 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 area around the fire suppression line were:

- The elevated area activity levels, represented conservatively by sample 0789, were 3.71, 40.30, and 43.50 pCi/g for ²³²Th, ²²⁶Ra, and ²³⁸U, respectively (from Table 8-2);
- Mean background activity levels were 1.3, 2.5, and 4.4 pCi/g for ²³²Th, ²²⁶Ra, and ²³⁸U, respectively (from C-T Phase II DP Table 4-17);
- The size of the elevated area was determined to be approximately 9 m² (1.5 meters [m] by 6 m); and,
- The area factors from C-T Phase II DP Figure 5-3 for the elevated area were 2.2, 2.4, and 3.3 for ²³²Th, ²²⁶Ra, and ²³⁸U, respectively.

The calculation of the *Index* value is shown below. 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.

$$Index = \frac{(3.71 - 1.3) \text{ pCi/g}}{(2.2 \times 23.9 \text{ pCi/g})_{Th \text{ series}}} + \frac{(40.30 - 2.5) \text{ pCi/g}}{(2.4 \times 29.4 \text{ pCi/g})_{Ra226}} + \frac{(43.50 - 4.4) \text{ pCi/g}}{(3.3 \times 721 \text{ pCi/g})_U} = 0.60$$

8.3.2 Data Set Screening Analysis

Table 8-4 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 8-4 Screening Tests Results

Screening Test	Test Value	Conclusion
Min/Max	0.23	PASS
Low Level	N/A	Not applicable; Class 1 survey unit
DCGL	N/A	Not applicable; Min/Max < 1
EMC Limit	0.21	PASS

8.3.2.1 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 0793 with a gross SOF of 0.25 (from Table 8-1) 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 0.23. Because the test value was less than one, no further computations are required, i.e., DCGL_W screening and Wilcoxon Rank Sum (WRS) tests.

8.3.2.2 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.

8.3.2.3 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.

8.3.2.4 EMC Limit

In accordance with Page 14-28 of the C-T Phase II DP, the EMC limit screening test was applied to the elevated area around the fire suppression line (samples 0789 and 0790). 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 9 m² (1.5 m by 6 m),
- The area factor from C-T Phase II DP Figure 5-3 for the elevated area was conservatively set to 2.2 (based on thorium series only),

- The elevated area activity level was conservatively represented by sample 0789 with a gross SOF = 1.59, and
- The survey unit average was a gross SOF = 0.18 (from Table 8-1).

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

$$F = \left[\frac{9 \text{ m}^2}{161 \text{ m}^2} \times \frac{1.59}{2.2 \times 1} \right] + \left[\frac{(161 - 9) \text{ m}^2}{161 \text{ m}^2} \times \frac{0.18}{1} \right] = 0.21$$

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.

8.3.3 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.

8.3.4 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 8-5 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 8-5 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	0.18
Spatial Variability (standard deviation)	1/6 x DCGL = 0.17	0.05
Type I Error (false positive)	0.05	0.05
Type II Error (false negative)	0.05	0.05
Relative Shift	3	16.2
Calculated N/2 Sample Size	15 ^a	9
Actual N/2 Sample Size	--	12

^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.

8.4 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.

8.5 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.

8.6 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 Section 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. SU02 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.

8.7 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.