Phase II Final Status Survey Report
Mallinckrodt Columbium-Tantalum Plant

St. Louis, Missouri

Chapter 25

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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	centimeter
cpm	counts per minute
DCGL	derived concentration guideline level
DP	decommissioning plan
DQO	data quality objectives
EMC	elevated measurement comparison
Energy*Solutions*, LLC	Energy*Solutions*
F	exposure-weighted fraction of the $DCGL_W$
FSS	Final Status Survey
FSSR	Final Status Survey Report
ft	feet
GPS	global positioning system
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

25.0 RESULTS SUMMARY FOR PLANT 5 SUBSURFACE SU19

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 SU19 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 Energy*Solutions*, LLC (Energy*Solutions*) in November and December of 2012. The SU19 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.

25.1 OVERVIEW

SU19 is a Class 1 survey unit in the south central portion of C-T Plant 5. The survey unit is approximately 303 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 25-1 shows the location of SU19 within the Plant 5 area.

Figure 25-2 is a photograph of SU19 that was taken during the FSS, following remediation. In Figure 25-2, as viewed from the southwest corner of the survey unit looking northeast, shows the west wall of Building 236 and 215 in the background along with the initial excavation of SU12 (slope in the background). The soil was fully excavated over the entire survey unit footprint to a depth between 16 to 18 feet (ft) below grade surface (bgs) to the indigenous clay leaving vertical walls to the east, south and west. The vertical walls of the excavation to the east, south and west were addressed as part of the FSS and surveyed by hanging a detector over the edge of the excavation at 1 meter (m) intervals performing a grid survey.

During FSS completion, water problems were experienced from infiltration from the perched water on top of the clay. As a result, a sump was placed in the northeast corner using stone to control the water. Upon completion of the bulk excavation, a layer of slurry-like material remained at the bottom of the excavation which could not be removed using the excavator. An industrial vacuum truck was then used to remove as much slurry as possible to prepare the bottom of the excavation for gamma walkover surveys and FSS sampling.

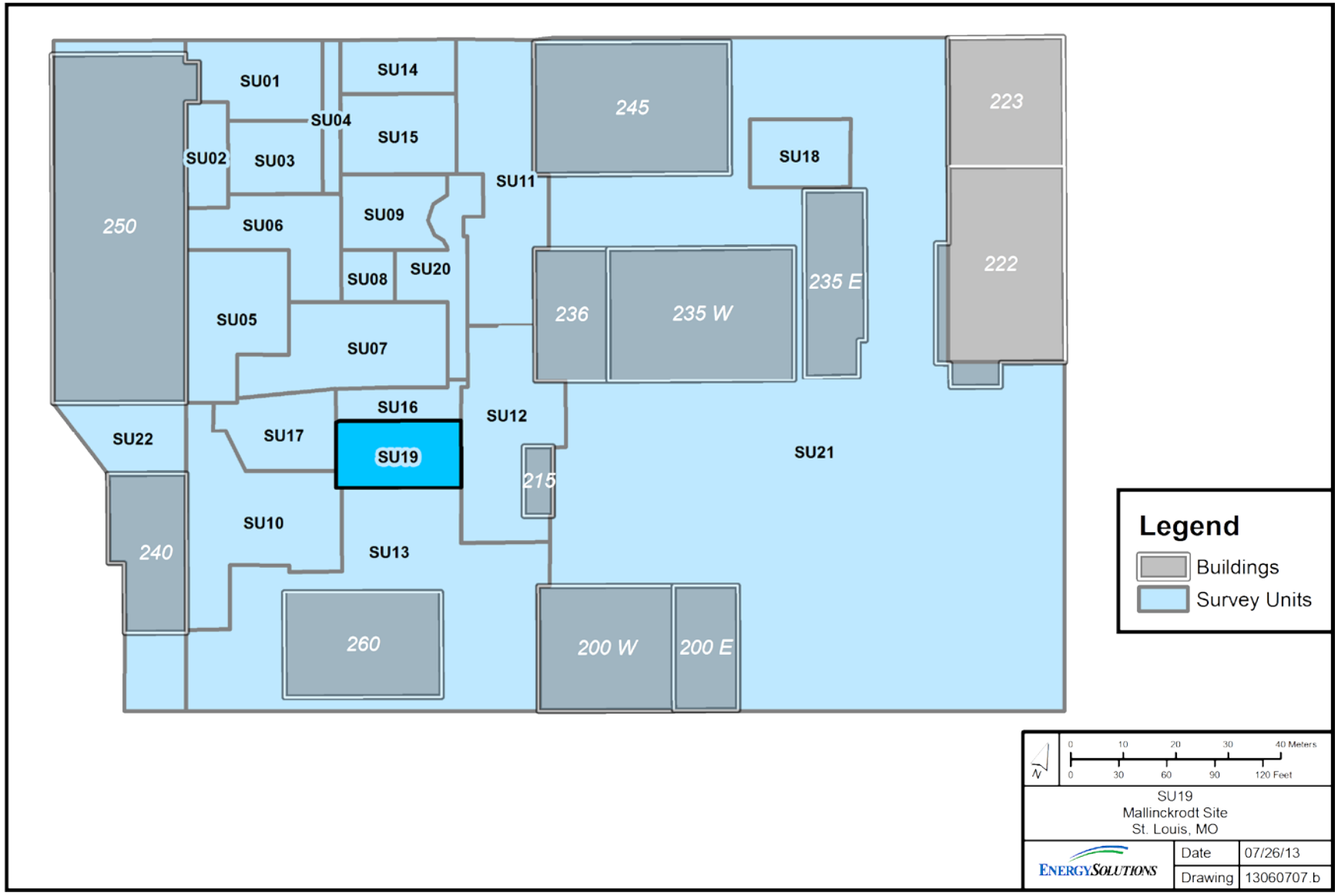

Figure 25-1 Location of SU19 in C-T Plant 5

Figure 25-2 Photograph of SU19 at Time of FSS

25.2 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.

25.2.1 Gamma Scans

A gamma walk-over survey (GWS) was performed over the majority 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. The GWS was not performed along the south and west edges of the excavation due to safety concerns associated with the proximity of the vertical walls. The eastern edge of SU19 was scanned and the results were consistent with the rest of the GWS; however, the GPS reception was poor and was not recorded during the GWS as shown in Figure 25-3.

The vertical walls along the east, south and west sides of the excavation were not scanned; however, they were surveyed from the top of the excavation by hanging the detector over the edge of the excavation at 1 m increments and 1 m intervals along the walls with one minute scalar counts recorded for each grid, see Figure 25-4. Each grid of the gamma survey was color coded to highlight the elevated readings. The darkest blue represents the minimum value and brightest orange represents the maximum value. The actual hue of the color varied based on the recorded value, with green representing the median value in the color scaling. The recorded measurements along the wall ranged from 10,000 to 78,000 counts per minute (cpm) with the higher measurements near the bottom of the walls. The higher readings near the bottom of the vertical walls were a result of geometry and the proximity to the bottom of the excavation and they corresponded well with the GPS-captured data from the bottom of the excavation which ranged from 16,000 to 70,000 cpm.

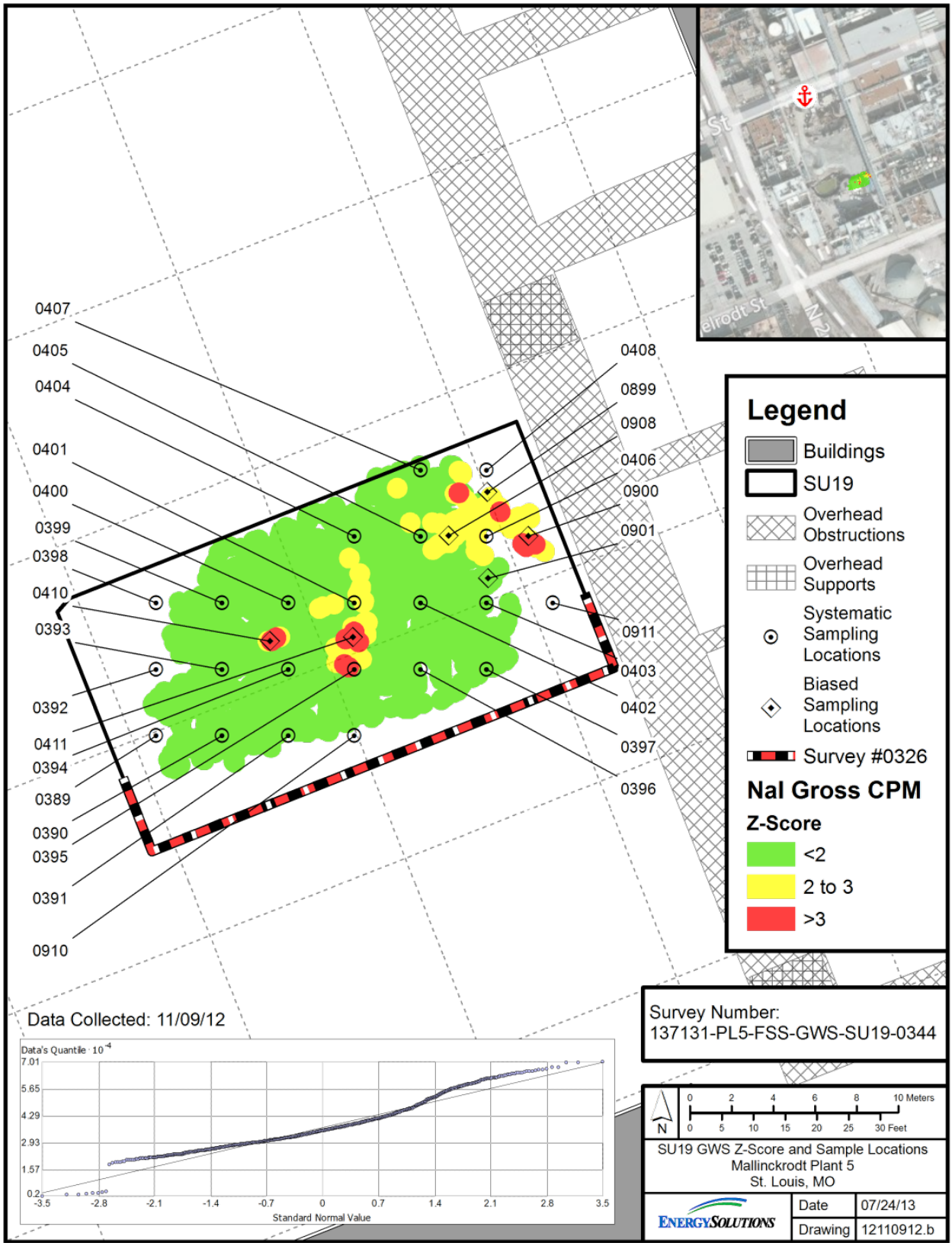

Figure 25-3 GWS and Soil Sampling Locations

bgs (m)																									
0 - 1	12,150	13,952	12,862	10,191	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	23,622	23,503	20,768	21,935
1 - 2	16,741	15,395	14,867	14,423	22,130	23,694	27,125	27,615	28,146	27,173	26,604	25,066	25,577	24,257	25,724	23,312	25,539	22,170	24,422	19,591	20,383	20,903	19,284	21,034	24,792	21,690	21,402	21,495
2 - 3	18,974	17,337	14,423	12,917	17,984	22,088	24,945	26,579	26,723	27,079	22,450	24,726	22,201	16,343	20,019	24,181	29,251	29,379	27,553	23,394	24,279	23,697	25,320	25,421	28,393	30,028	19,390	15,943
3 - 4	17,491	15,726	15,132	13,596	18,282	19,012	24,041	30,413	33,922	43,815	28,751	34,133	26,849	28,910	31,667	31,733	32,896	30,409	30,525	30,457	31,644	28,307	22,655	31,388	33,398	35,569	30,420	27,921
4 - 5	47,525	35,347	17,166	15,348	X	24,885	29,978	29,106	38,259	70,046	59,712	78,576	56,618	71,737	66,523	44,405	41,055	38,031	41,203	35,679	46,034	48,945	31,957	63,796	60,079	65,226	48,413	50,879
	EAST WALL				SOUTH WALL																				WEST WALL			

Represents approximately a 1 m by 1 m grid

X — Measurement not collected

Figure 25-4 Gamma Survey (#0326) of SU19 Walls

(results provided in counts per minute)

25.2.2 Soil Sampling

An increased sampling density was performed within SU19 due to the poor global positioning system (GPS) satellite reception within the excavation during GWS and because of safety reasons around the vertical edges of the excavation to ensure enough data were collected. Some of the sampling locations near the vertical walls were collected following backfill using a drill rig and split spoon sampling. Boreholes were drilled at several locations along the edges of the survey unit and the top 1-foot of sample media collected once the backfill was segregated from the borehole and the top of the excavated surface reached.

Soil samples to be used for the statistical test were collected at a frequency and at representative locations throughout SU19 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 and systematic sample 0406. Figure 25-3 provides the GWS results and soil sampling locations. A total of 28 soil samples were collected throughout SU19, 24 over the areal footprint of SU19 (22 systematic and 2 GWS biased) and 4 around systematic sample 0406 (one sample each to the north, south, east, and west of sample 0406 to bound the elevated area). No sampling of the vertical walls were performed for safety reasons; however, borehole samples along the edges of the excavation for SU10 and SU13 were used in lieu of wall sampling for informational purposes to ensure the excavation was complete.

All soil samples were analyzed on site via gamma spectroscopy analysis. Table 25-1 provides the sample results and summary statistics for the 22 systematic samples. Table 25-2 provides the sample results for the 6 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 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.

Table 25-1 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 [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]	
0389	16	0.93	0.21	0.10	1.69	0.86	0.62	1.25	0.47	0.40	0.10	0.00	1.66	0.41	0.16	1.37	0.32	0.23	*1.44*	0.85	2.75	0.12	0.02	0.83
0390	16	1.39	0.25	0.08	1.93	0.93	0.68	2.03	0.51	0.45	0.13	0.00	1.39	0.37	0.21	1.89	0.38	0.26	*1.11*	0.80	2.37	0.12	0.00	1.02
0391	16	1.35	0.25	0.08	2.42	0.77	0.50	1.60	0.41	0.44	0.14	0.00	*0.69*	0.46	0.79	1.45	0.37	0.23	*3.12*	1.41	3.80	0.08	0.00	1.71
0910	16	1.31	0.24	0.10	2.25	0.83	0.58	1.41	0.45	0.37	0.13	0.00	1.43	0.29	0.24	1.15	0.24	0.15	*0.88*	0.75	2.18	0.10	0.01	1.33
0392	16	1.47	0.28	0.06	2.52	0.84	0.57	1.69	0.85	0.41	0.15	0.01	0.63	0.30	0.57	2.51	0.49	0.30	4.30	2.37	2.99	0.12	0.00	1.27
0393	16	1.31	0.23	0.13	2.27	0.86	0.61	1.76	0.50	0.46	0.13	0.00	1.48	0.32	0.25	2.19	0.37	0.12	3.49	2.10	2.61	0.14	0.01	0.95
0394	16	1.31	0.28	0.07	3.52	1.07	0.74	2.90	0.49	0.53	0.18	0.04	1.79	0.42	0.18	2.94	0.48	0.17	4.36	2.72	3.53	0.18	0.04	0.99
0395	16	1.45	0.27	0.10	4.40	1.02	0.66	2.22	0.51	0.52	0.21	0.07	1.61	0.43	0.33	3.31	0.50	0.24	3.77	2.63	3.40	0.19	0.04	1.15
0396	16	1.09	0.26	0.10	1.85	0.81	0.57	1.34	0.37	0.40	0.11	0.00	1.09	0.32	0.15	1.55	0.30	0.17	2.87	2.14	2.76	0.10	0.00	1.08
0397	16	1.39	0.27	0.04	2.44	0.95	0.68	2.69	0.51	0.56	0.14	0.00	0.61	0.35	0.48	1.90	0.39	0.22	5.75	2.55	3.00	0.10	0.00	1.47
0398	16	1.33	0.23	0.05	1.44	0.71	0.51	1.44	0.49	0.46	0.11	0.00	1.31	0.35	0.22	1.42	0.30	0.21	*2.52*	2.08	2.81	0.11	0.00	1.00
0399	16	1.32	0.26	0.08	2.13	0.89	0.64	1.54	0.62	0.45	0.13	0.00	1.66	0.39	0.13	1.56	0.33	0.24	*2.38*	1.60	2.44	0.13	0.02	1.03
0400	16	1.22	0.22	0.09	5.26	1.30	0.90	7.58	0.81	0.71	0.24	0.10	1.15	0.33	0.18	2.36	0.39	0.22	12.10	3.54	3.75	0.15	0.01	1.66
0401	16	2.81	0.36	0.17	21.29	2.19	1.26	11.23	1.03	0.92	**0.86**	**0.71**	3.54	0.68	0.52	17.90	2.04	0.38	19.50	5.60	6.07	**0.78**	**0.64**	1.09
0402	16	2.54	0.35	0.12	16.46	1.88	1.08	8.20	0.93	0.85	**0.68**	**0.53**	3.09	0.57	0.41	12.40	1.45	0.40	12.90	3.94	4.61	**0.57**	0.42	1.19
0403	16	1.53	0.32	0.12	4.20	1.07	0.71	3.69	0.61	0.59	0.21	0.07	1.38	0.43	0.31	3.28	0.50	0.21	5.18	2.65	3.50	0.18	0.03	1.20
0905 [e]	16	2.20	0.38	0.24	26.13	2.85	1.69	13.28	2.11	1.18	**1.00**	**0.85**	2.17	0.72	0.64	20.40	2.33	0.49	15.50	2.62	5.94	**0.81**	**0.66**	1.24
0911 [e]	16	0.41	0.12	0.27	1.60	0.82	0.60	0.85	0.53	0.49	0.07	0.00	1.45	0.34	0.12	1.47	0.29	0.19	3.08	2.17	2.71	0.11	0.01	0.63
0404	16	1.36	0.25	0.10	6.97	1.14	0.66	3.42	0.61	0.64	0.30	0.15	1.52	0.41	0.17	4.37	0.66	0.29	6.57	3.16	3.74	0.22	0.08	1.35
0405	16	1.84	0.37	0.16	14.81	1.86	1.09	6.15	0.91	0.92	**0.59**	0.44	1.85	0.56	0.47	11.60	1.39	0.33	11.70	4.93	5.49	0.49	0.34	1.21
0406	16	5.43	0.54	0.29	41.95	3.65	1.90	21.57	1.83	1.57	**1.68**	**1.54**	6.43	1.24	0.85	33.10	3.69	0.64	30.60	7.75	8.76	**1.44**	**1.29**	1.17
0407	16	0.35	0.09	0.04	3.30	0.68	0.39	1.62	0.46	0.34	0.13	0.03	0.39	0.18	0.19	2.09	0.32	0.14	2.73	1.50	1.90	0.09	0.00	1.42
0408	16	2.81	0.41	0.22	23.34	2.40	1.32	10.28	1.13	1.05	**0.93**	**0.78**	2.47	0.74	1.37	20.60	2.52	0.56	11.10	3.20	8.03	**0.82**	**0.67**	1.13
Summary Statistics (excluding sample 0911 [e])																								
Count:		22			22			22			22	22	22			22			22			22	22	22
Average:		1.72			8.75			4.95			0.38	0.24	1.79			6.88			7.45			0.32	0.19	1.20
Median:		1.37			3.41			2.45			0.16	0.03	1.50			2.44			4.33			0.14	0.02	1.18
Standard Dev.:		1.02			10.75			5.20			0.41	0.40	1.28			8.71			7.30			0.35	0.34	0.22
Minimum:		0.35			1.44			1.25			0.10	0.00	0.39			1.15			0.88			0.08	0.00	0.83
Maximum:		5.43			41.95			21.57			**1.68**	**1.54**	6.43			33.10			30.60			**1.44**	**1.29**	1.71
Range:		5.08			40.51			20.33			1.59	1.54	6.04			31.95			29.72			1.35	1.29	0.88

[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 25.2.2.
[e] Sample 0905 was collected as a 15 cm soil sample, but was later re-sampled as a 30 cm soil sample (0911). The lower result (sample 0911) was excluded from the summary statistics and all other assessments.

Table 25-2 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		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]	
GWS Biased Samples																							
0410	16	1.83	0.26	0.12	8.80	1.55	1.02	9.09	0.93	0.82	0.39	0.24	2.40	0.46	0.42	6.02	0.81	0.27	14.50	4.77	5.33	0.33	0.18	1.19
0411	16	1.57	0.27	0.07	5.12	0.99	0.59	2.74	0.49	0.50	0.24	0.10	1.29	0.34	0.14	3.39	0.51	0.29	4.46	2.67	4.26	0.18	0.03	1.39
0899	16	1.13	0.21	0.14	1.43	0.91	0.69	1.96	0.55	0.49	0.10	0.00	1.34	0.30	0.20	1.77	0.32	0.12	*1.60*	0.93	2.62	0.12	0.00	0.83
0900	16	1.36	0.26	0.11	1.64	0.69	0.48	1.37	0.38	0.43	0.11	0.00	1.44	0.31	0.21	1.29	0.28	0.21	*0.61*	0.75	3.03	0.10	0.01	1.09
0901	16	1.40	0.26	0.13	5.30	1.20	0.79	3.08	0.56	0.56	0.24	0.10	1.88	0.43	0.22	3.67	0.52	0.20	3.23	1.03	2.80	0.21	0.06	1.17
0908	16	1.94	0.40	0.14	8.29	1.64	1.08	7.18	0.92	0.85	0.37	0.23	1.84	0.38	0.37	6.03	0.79	0.23	9.14	3.57	4.20	0.29	0.15	1.27

[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 25.2.2.

25.2.3 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 SU19: BH-055. Table 25-3 provides the data for the location. The results indicate that beyond the excavation extent, additional subsurface contamination is not reasonably expected.

Table 25-3 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-055	2.5 - 3.5	0.70	2.00	13.80	0.12	0.01
	4 - 5		2.06	4.39	0.08	0.00
	5 - 6		1.48	*2.92*	0.05	0.00
	6.5 - 7.5		2.63	*2.58*	0.09	0.00
	9 - 10	0.90	2.50	242.70	0.46	0.33
	10.5 - 11.5	1.30		17.50	0.08	0.02
	12 - 13	2.90		16.70	0.14	0.08
	14.5 - 15.5	2.20	60.70	18.70	**2.18**	**2.04**
	18.5 - 19.5		2.97	*2.69*	0.10	0.02
	20 - 21		2.50	*3.55*	0.09	0.00

[a] Italicized results indicate <MDC. No value indicates no result was provided.
[b] **Bolded red** SOF values indicate a result >1.
[c] Calculated as discussed in Section 25.2.2.

AECOM Technical Services (AECOM) also collected numerous supplemental characterization core boring samples within the extent of SU19. Table 25-4 provides these results. During the sampling effort, AECOM noted that the clay layer depth ranged between 14.2 and 16.5 ft bgs.

Table 25-4 AECOM Supplemental Characterization Borehole Results

Location ID	Sample ID	Sample Depth (m)	Activity Concentration (pCi/g)			Sample SOF [a]		Column SOF [a]	
			^{232}Th	^{226}Ra	^{238}U	Gross	Net [b]	Gross	Net [b]
D9-4	4638	0 - 1	1.10	2.97	4.12	0.15	0.02	0.15	0.02
	Refusal at 4.5 ft bgs								
D9-4A	4639	0 - 1	0.96	3.76	4.03	0.17	0.04	0.17	0.04
	4640	1 - 2	0.94	1.48	1.23	0.09	0.00	0.13	0.00
	4641	2 - 3	1.04	3.34	10.39	0.17	0.04	0.15	0.01
	4642	3 - 4	8.20	76.76	41.12	**3.01**	**2.87**	**0.86**	**0.72**
		4 - 5	No recovery						
	4643	5 - 6	1.12	1.18	1.71	0.09	0.00	**0.71**	**0.56**
D9-5	4644	0 - 1	0.91	2.25	2.57	0.12	0.00	0.12	0.00
	4645	1 - 2	0.92	2.33	2.45	0.12	0.00	0.12	0.00
	4646	2 - 3	0.15	1.34	2.32	0.06	0.00	0.10	0.00
	4647	3 - 4	3.18	18.67	12.57	**0.79**	**0.64**	0.27	0.12
	4648	4 - 5	1.13	1.91	2.10	0.12	0.00	0.24	0.10

Table 25-4 AECOM Supplemental Characterization Borehole Results (continued)

Location ID	Sample ID	Sample Depth (m)	Activity Concentration (pCi/g)			Sample SOF [a]		Column SOF [a]	
			^{232}Th	^{226}Ra	^{238}U	Gross	Net [b]	Gross	Net [b]
SB-050	6525	0 - 1	3.26	15.47	13.19	**0.68**	**0.54**	**0.68**	**0.54**
	6526	1 - 2	2.07	24.53	6.73	**0.93**	**0.78**	**0.81**	**0.66**
	6527	2 - 3	1.67	24.96	9.83	**0.93**	**0.79**	**0.85**	**0.70**
	6528	3 - 4	5.09	133.88	37.28	**4.82**	**4.67**	**1.84**	**1.69**
	6529	4 - 5	8.16	193.88	55.46	**7.01**	**6.87**	**2.87**	**2.73**
SB-051	6530	0 - 1	5.95	55.50	16.49	**2.16**	**2.01**	**2.16**	**2.01**
	6531	1 - 2	2.15	11.57	6.46	0.49	0.35	**1.33**	**1.18**
	6532	2 - 3	2.27	90.66	13.19	**3.20**	**3.05**	**1.95**	**1.80**
	6533	3 - 4	2.43	38.82	7.30	**1.43**	**1.29**	**1.82**	**1.67**
	Refusal at 12 ft bgs								
SB-052	6534	0 - 1	1.30	13.09	6.59	**0.51**	0.36	**0.51**	0.36
	6535	1 - 2	1.21	5.93	5.33	0.26	0.12	0.38	0.24
	6536	2 - 3	1.79	32.88	8.36	**1.20**	**1.06**	**0.66**	**0.51**
	No recovery below 9.75 ft bgs								
SB-053	6537	0 - 1	1.54	38.24	19.69	**1.39**	**1.25**	**1.39**	**1.25**
	6538	1 - 2	2.89	38.13	15.73	**1.44**	**1.29**	**1.42**	**1.27**
	6539	2 - 3	2.40	67.59	15.21	**2.42**	**2.27**	**1.75**	**1.61**
	6540	3 - 4	3.38	20.67	18.90	**0.87**	**0.73**	**1.53**	**1.39**
	6541	4 - 5	6.77	51.79	30.82	**2.09**	**1.94**	**1.64**	**1.50**
SB-055	Refusal at 1.5 ft bgs								
SB-055A		0 - 1	No recovery						
	6553	1 - 2	0.68	1.68	1.54	0.09	0.00	0.09	0.00
	6554	2 - 3	2.86	7.44	3.24	0.38	0.23	0.23	0.09
	6555	3 - 4	6.06	18.84	11.67	**0.91**	**0.77**	0.46	0.31
	6556	4 - 5	18.05	109.06	47.69	**4.53**	**4.39**	**1.48**	**1.33**
SB-056	6543	0 - 1	0.86	3.28	1.98	0.15	0.03	0.15	0.03
	6544	1 - 2	0.97	3.19	2.97	0.15	0.02	0.15	0.03
	6545	2 - 3	0.77	2.91	2.02	0.13	0.01	0.15	0.02
	6546	3 - 4	2.69	21.12	15.55	**0.85**	**0.71**	0.32	0.18
	6547	4 - 5	8.72	101.91	76.56	**3.94**	**3.79**	**1.05**	**0.90**
SB-057	6557	0 - 1	2.93	8.71	4.38	0.42	0.28	0.42	0.28
	6558	1 - 2	3.94	12.46	5.38	**0.60**	0.45	**0.51**	0.36
	6559	2 - 3	11.43	37.00	10.39	**1.75**	**1.61**	**0.92**	**0.78**
	6560	3 - 4	20.90	65.31	22.64	**3.13**	**2.98**	**1.47**	**1.33**
	6561	4 - 5	28.92	130.14	45.98	**5.70**	**5.55**	**2.32**	**2.17**
SB-058	6562	0 - 1	1.10	5.50	2.33	0.24	0.10	0.24	0.10
	6563	1 - 2	1.30	6.02	4.83	0.27	0.12	0.25	0.11
	6564	2 - 3	5.44	18.52	7.72	**0.87**	**0.72**	0.46	0.31
	6565	3 - 4	10.66	37.09	19.34	**1.73**	**1.59**	**0.78**	**0.63**
	6566	4 - 5	19.11	98.27	34.50	**4.19**	**4.04**	**1.46**	**1.31**
SB-060		0 - 1	No Recovery						
	6577	1 - 2	0.67	1.95	1.94	0.10	0.00	0.10	0.00
	6578	2 - 3	1.61	5.43	1.93	0.25	0.11	0.18	0.04
	6579	3 - 4	13.90	42.97	16.16	**2.07**	**1.92**	**0.81**	**0.66**
	6580	4 - 5	35.91	149.40	53.11	**6.66**	**6.51**	**2.27**	**2.12**

Table 25-4 AECOM Supplemental Characterization Borehole Results (continued)

Location ID	Sample ID	Sample Depth (m)	Activity Concentration (pCi/g)			Sample SOF [a]		Column SOF [a]	
			^{232}Th	^{226}Ra	^{238}U	Gross	Net [b]	Gross	Net [b]
SB-061	6581	0 - 1	0.97	3.07	2.97	0.15	0.02	0.15	0.02
	Refusal at 3.3 ft bgs								
SB-061A	6582	0 - 1	0.48	2.00	2.35	0.09	0.00	0.09	0.00
	6583	1 - 2	3.43	9.55	4.72	0.47	0.33	0.28	0.14
	6584	2 - 3	4.40	15.25	3.66	**0.71**	**0.56**	0.42	0.28
	6585	3 - 4	12.55	47.36	17.02	**2.16**	**2.01**	**0.86**	**0.71**
	6586	4 - 5	14.18	72.76	42.09	**3.13**	**2.98**	**1.31**	**1.17**
SB-062	6587	0 - 1	0.96	3.85	2.53	0.17	0.05	0.17	0.05
		1 - 2	No recovery						
	6588	2 - 3	3.39	10.61	5.93	**0.51**	0.37	0.34	0.20
	6589	3 - 4	14.18	52.64	20.84	**2.41**	**2.27**	**1.03**	**0.89**
	6590	4 - 5	18.62	132.67	59.72	**5.37**	**5.23**	**2.12**	**1.97**
SB-063	6591	0 - 1	1.03	4.37	3.09	0.20	0.06	0.20	0.06
	6592	1 - 2	3.47	9.40	5.47	0.47	0.33	0.33	0.19
	6593	2 - 3	6.03	21.25	9.02	**0.99**	**0.84**	**0.55**	0.41
	6594	3 - 4	5.98	32.12	22.61	**1.37**	**1.23**	**0.76**	**0.61**
		4 - 5	No recovery						
SB-064	6567	0 - 1	3.69	615.85	6.15	**21.11**	**20.96**	**21.11**	**20.96**
	6568	1 - 2	3.42	377.42	7.74	**12.99**	**12.85**	**17.05**	**16.91**
	6569	2 - 3	17.60	104.85	14.58	**4.32**	**4.18**	**12.81**	**12.66**
	6570	3 - 4	19.85	86.52	33.19	**3.82**	**3.67**	**10.56**	**10.42**
	6571	4 - 5	14.03	82.40	31.19	**3.43**	**3.29**	**9.14**	**8.99**
SB-066	6600	0 - 1	1.52	10.94	10.05	0.45	0.30	0.45	0.30
	6601	1 - 2	1.27	4.34	5.29	0.21	0.06	0.33	0.18
	6602	2 - 3	7.08	24.76	14.01	**1.16**	**1.01**	**0.61**	0.46
	6603	3 - 4	9.64	47.29	26.32	**2.05**	**1.90**	**0.97**	**0.82**
	6604	4 - 5	12.56	55.50	35.40	**2.46**	**2.32**	**1.27**	**1.12**
SB-067	6605	0 - 1	0.63	5.08	8.53	0.21	0.09	0.21	0.09
	6606	1 - 2	1.14	2.44	4.01	0.14	0.00	0.17	0.05
	6607	2 - 3	1.35	8.89	9.60	0.37	0.23	0.24	0.11
	6608	3 - 4	19.17	70.55	39.95	**3.26**	**3.11**	**0.99**	**0.85**
	6609	4 - 5	23.91	100.07	45.14	**4.47**	**4.32**	**1.69**	**1.54**

[a] **Bolded orange** SOF values indicate a result >0.5 but ≤1 and **bolded red** SOF values indicate a result >1.
[b] Calculated as discussed in Section 25.2.2.

The soil was fully excavated over the entire survey unit footprint to a depth between 16 to 18 ft bgs to the indigenous clay consistent with the AECOM characterization. Therefore, in accordance with Page 14-22 of the C-T Phase II DP, FSS core sampling or measurements were not performed because additional subsurface contamination was not reasonably suspected. Figure 25-5 shows the characterization and FSS sampling locations.

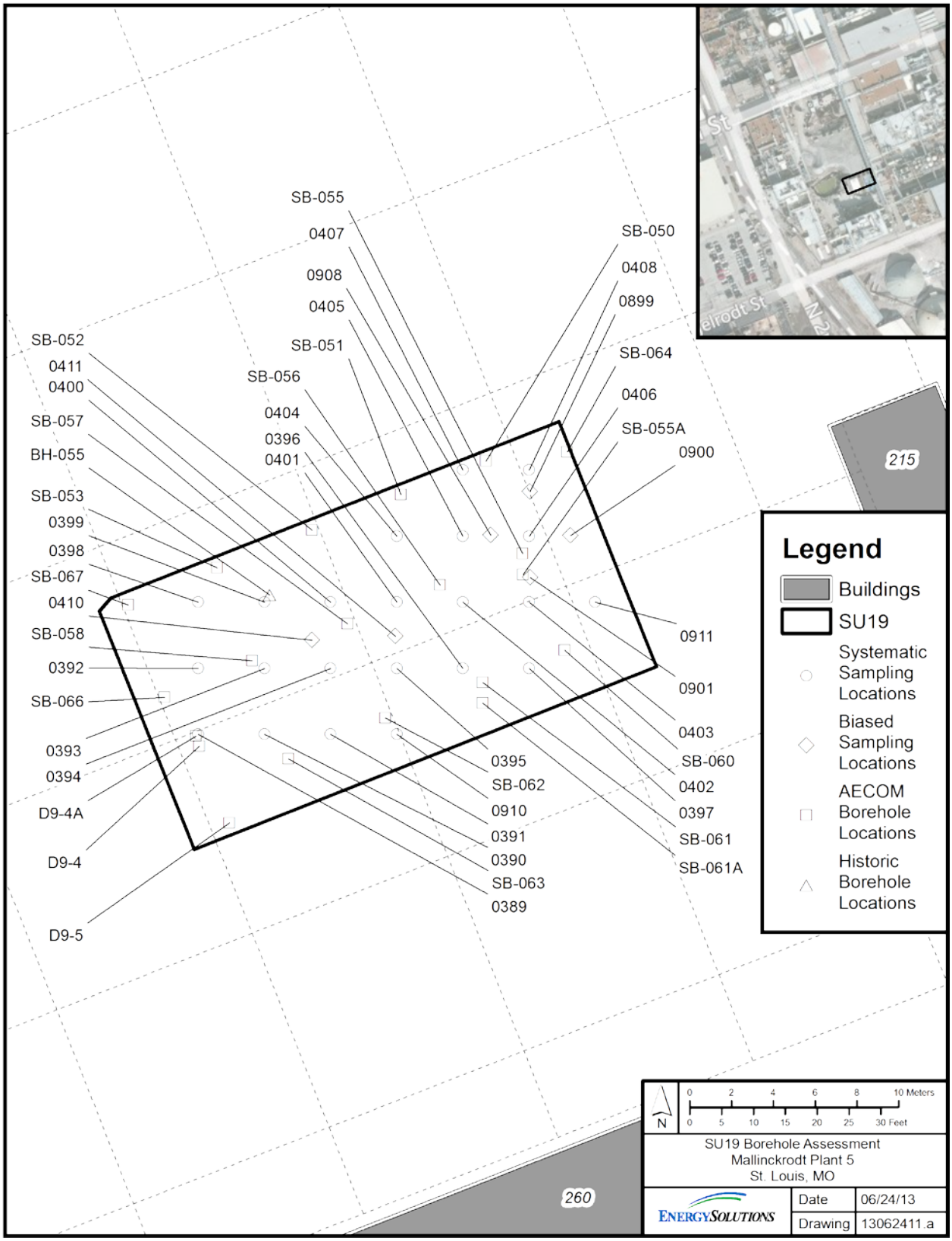

Figure 25-5 Characterization and FSS Sampling Locations

25.3 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.

25.3.1 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. There was one elevated area identified via GWS and sampling within SU19 located by sample 0406. Four bounding samples around the elevated sample were collected with all samples having an SOF of less than unity. Parameters necessary to calculate the *Index* value for the area at systematic sample 0406:

- The elevated area activity levels, represented conservatively by sample 0406, were 6.43, 33.10, and 30.60 pCi/g for ^{232}Th, ^{226}Ra, and ^{238}U, respectively (from Table 25-1);
- Mean background activity levels were 1.3, 2.5, and 4.4 pCi/g for ^{232}Th, ^{226}Ra, and ^{238}U, respectively (from C-T Phase II DP Table 4-17);
- The size of the elevated area was determined to be approximately 13 m^2; and,
- The area factors from C-T Phase II DP Figure 5-3 for the elevated area were 2, 2.2, and 2.9 for ^{232}Th, ^{226}Ra, and ^{238}U, 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.

$$Index = \frac{(6.43 - 1.3)\ pCi/g}{(2 \times 23.9\ pCi/g)_{Th\ series}} + \frac{(33.10 - 2.5)\ pCi/g}{(2.2 \times 29.4\ pCi/g)_{Ra226}} + \frac{(30.60 - 4.4)\ pCi/g}{(2.9 \times 721\ pCi/g)_{U}} = 0.59$$

25.3.2 Data Set Screening Analysis

Table 25-5 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 25-5 Screening Tests Results

Screening Test	Test Value	Conclusion
Min/Max	1.42	FAIL; conduct DCGL test
Low Level	N/A	Not applicable; Class 1 survey unit
DCGL	0.17	PASS; conduct WRS test
EMC Limit	0.28	PASS

25.3.2.1 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 0406 with a gross SOF of 1.44 (from Table 25-1) 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 1.42. Because the test value was greater than one, further computations are required, i.e., $DCGL_W$ screening and Wilcoxon Rank Sum (WRS) tests.

25.3.2.2 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.

25.3.2.3 $DCGL_W$

In accordance with Page 14-28 of the C-T Phase II DP and because the Min/Max test value was greater than one, the $DCGL_W$ screening test value was calculated by subtracting the reference area average gross SOF from the survey unit average gross SOF. The survey unit average gross SOF was 0.32 (from Table 25-1). The reference area average gross SOF was calculated to be 0.15 using average activity concentrations from C-T Phase II DP Table 4-17. The $DCGL_W$ screening test value was calculated to be 0.17. Because the test value was less than one, the WRS test is required per C-T Phase II DP Table 14-6.

25.3.2.4 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 identified at systematic sample 0406. 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 13 m^2,
- The area factor from C-T Phase II DP Figure 5-3 for the elevated area was conservatively set to 2 (based on thorium series only),
- The elevated area activity level was conservatively represented by sample 0406 with a gross SOF = 1.44, and
- The survey unit average was a gross SOF = 0.26 (from Table 25-1, but excluding sample 0604).

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

$$F = \left[\frac{13\ m^2}{303\ m^2} \times \frac{1.44}{2 \times 1}\right] + \left[\frac{(303 - 13)\ m^2}{303\ m^2} \times \frac{0.26}{1}\right] = 0.28$$

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.

25.3.3 WRS Test

In accordance with Page 14-29 of the C-T Phase II DP, because the Min/Max test value was greater than one and the $DCGL_W$ test was less than one, the WRS Test was required to demonstrate compliance. The test was completed in accordance with Pages 14-29 and 14-30 of the C-T Phase II DP. The result was that the survey unit passed, with the calculation details provided in Table 25-6.

Table 25-6 WRS Test Results

Sample ID	Area	On-Site Results				Off-Site Results			
		Data (SOF)	Adjusted Data (SOF)	Ranks	RA Ranks	Data (SOF)	Adjusted Data (SOF)	Ranks	RA Ranks
BH-013	RA	0.11	1.11	29	29	0.11	1.11	29	29
BH-016	RA	0.42	1.42	36	36	0.42	1.42	36	36
BH-028	RA	0.10	1.10	28	28	0.10	1.10	28	28
BH-031	RA	0.09	1.09	25	25	0.09	1.09	25	25
BH-034	RA	0.29	1.29	35	35	0.29	1.29	35	35
BH-037	RA	0.22	1.22	32	32	0.22	1.22	32	32
BH-045	RA	0.10	1.10	27	27	0.10	1.10	27	27
BH-053	RA	0.16	1.16	30	30	0.16	1.16	30	30
BH-065	RA	0.23	1.23	33	33	0.23	1.23	33	33
BH-083	RA	0.07	1.07	24	24	0.07	1.07	24	24
BH-091	RA	0.24	1.24	34	34	0.24	1.24	34	34
BH-093	RA	0.10	1.10	26	26	0.10	1.10	26	26
BH-099	RA	0.22	1.22	31	31	0.22	1.22	31	31
BH-Z-02	RA	0.07	1.07	23	23	0.07	1.07	23	23
BH-Z-09	RA	0.05	1.05	22	22	0.05	1.05	22	22
0389	SU	0.10	0.10	1	0	0.12	0.12	8	0
0390	SU	0.13	0.13	4	0	0.12	0.12	9	0
0391	SU	0.14	0.14	9	0	0.08	0.08	1	0
0910	SU	0.13	0.13	7	0	0.10	0.10	4	0
0392	SU	0.15	0.15	11	0	0.12	0.12	7	0
0393	SU	0.13	0.13	8	0	0.14	0.14	11	0
0394	SU	0.18	0.18	12	0	0.18	0.18	14	0
0395	SU	0.21	0.21	14	0	0.19	0.19	15	0
0396	SU	0.11	0.11	3	0	0.10	0.10	5	0
0397	SU	0.14	0.14	10	0	0.10	0.10	3	0
0398	SU	0.11	0.11	2	0	0.11	0.11	6	0
0399	SU	0.13	0.13	6	0	0.13	0.13	10	0
0400	SU	0.24	0.24	15	0	0.15	0.15	12	0
0401	SU	0.86	0.86	19	0	0.78	0.78	19	0
0402	SU	0.68	0.68	18	0	0.57	0.57	18	0
0403	SU	0.21	0.21	13	0	0.18	0.18	13	0
0905	SU	1.00	1.00	21	0	0.81	0.81	20	0
0404	SU	0.30	0.30	16	0	0.22	0.22	16	0
0405	SU	0.59	0.59	17	0	0.49	0.49	17	0

Table 25-6 WRS Test Results (continued)

Sample ID	Area	On-Site Results				Off-Site Results			
		Data (SOF)	Adjusted Data (SOF)	Ranks	RA Ranks	Data (SOF)	Adjusted Data (SOF)	Ranks	RA Ranks
0406	SU	1.68	1.68	37	0	1.44	1.44	37	0
0407	SU	0.13	0.13	5	0	0.09	0.09	2	0
0408	SU	0.93	0.93	20	0	0.82	0.82	21	0
			Sum:	703	435		Sum:	703	435
			Critical Value:	338			Critical Value:	338	
			Conclusion:	**PASS**			**Conclusion:**	**PASS**	

25.3.4 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 25-7 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 25-7 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	0.32
Spatial Variability (standard deviation)	1/6 x DCGL = 0.17	0.35
Type I Error (false positive)	0.05	0.05
Type II Error (false negative)	0.05	0.05
Relative Shift	3	1.9
Calculated N/2 Sample Size	15 [a]	13
Actual N/2 Sample Size	--	22

[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.

25.4 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. Two deviations were noted.

1. 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.

2. A 100% GWS was not performed over the bottom of the excavation. The GWS was performed over as much of the survey unit as safely possible; however due to the depth of the excavation and the presence of vertical walls, a full GWS scan was not performed along the southern and western edges of the excavation. The soil was fully excavated over the entire survey unit footprint to a depth between 16 to 18 ft bgs to the indigenous clay layer. AECOM noted in the completion of other survey units that excavation to the clay layer was a successful remediation strategy. Considering the excavation to the clay layer over the entire survey unit footprint with the survey results in accessible areas, the probability of significant residual contamination of concern being left unidentified is low.

25.5 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, and independent confirmatory surveys conducted by the NRC after backfilling. Inspection Report 04006563/12001 noted that the NRC reviewed the FSS data package for SU19 to ensure the licensee conducted the survey in accordance with the requirements as stated in the DP. No violations were identified. No findings of significance were identified.

25.6 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.

SU19 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.

25.7 REFERENCES

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