

# Phase II Final Status Survey Report Mallinckrodt Columbium-Tantalum Plant

St. Louis, Missouri

## Chapter 27

**Project No. 137131**

**Revision 0**

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**ABBREVIATIONS AND ACRONYMS**

%	percent
$\sigma$	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
EnergySolutions	EnergySolutions, LLC
EPA	U.S. Environmental Protection Agency
FSS	Final Status Survey
FSSR	Final Status Survey Report
ft	feet
GWS	gamma walk-over survey
IQR	inter-quartile range
m <sup>2</sup>	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
Q-Q	quantile-quantile
Ra	radium
RA	reference area
SOF	sum of fractions
Th	thorium
U	uranium
WRS	Wilcoxon Rank Sum

## 27.0 RESULTS SUMMARY FOR PLANT 5 SUBSURFACE SU21

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 SU21 in accordance with Columbium-Tantalum (C-T) Phase II Decommissioning Plan (DP) Section 14.5. Extensive characterization data was collected from this Class 3 survey unit and the data were provided in Chapter 4 of the C-T Phase II DP. Additional characterization data were collected by AECOM Technical Services (AECOM) in September and November 2011 and by EnergySolutions, LLC (EnergySolutions) in February 2013. Together, the characterization data serve as the FSS data set as allowed per C-T Phase II DP Section 14.4.3.6. The SU21 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.

### 27.1 OVERVIEW

SU21 is a Class 3 survey unit located in the eastern portion of C-T Plant 5. The survey unit is approximately 11,131 square meters (m<sup>2</sup>) in size—C-T Phase II DP, Table 14-4 does not specify a size limit for Class 3 subsurface survey units. Class 3 was the appropriate classification because the survey unit contained residual radioactivity at levels less than the DCGL<sub>w</sub>. Figure 27-1 shows the location of SU21 within the Plant 5 area.



Figure 27-1 Location of Subsurface SU21 in C-T Plant 5

## **27.2 DATA COLLECTION**

An FSS was not strictly 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; however, Section 27.4 discusses the deviation and how the intent of the DQOs were met with the collected characterization data sets discussed in this chapter of the FSSR. 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.

### **27.2.1 Gamma Scans**

A gamma walk-over surveys (GWS) was performed by *EnergySolutions* (Figure 27-2). All areas surveyed were paved with thicknesses ranging up to approximately six inches. The information from the GWS was considered qualitative due to the shielding effect of the pavement.



Figure 27-2 EnergySolutions GWS

### 27.2.2 Soil Sampling

The C-T Phase II DP provides tables of characterization soils sample results, with a total of 287 historic characterization samples from 85 locations from within the extent of SU21. Table 27-1 provides the results.

AECOM collected 15 additional characterization samples from 3 biased locations. Table 27-2 provides the results—all samples were analyzed on-site. AECOM sample location INV-1 was collected using the DQOs specified in the C-T Phase II DP at location BH-035, which exhibited an elevated result.

EnergySolutions collected 11 additional characterization samples from 6 biased locations. All locations were selected based on the GWS. Table 27-3 provides the results—all samples were sent off-site for analysis except for location B-02 samples which were analyzed on-site and not sent to the off-site laboratory because the SOF results were less than 0.5.

In total, 313 characterization samples from 94 locations were collected. Figure 27-3 shows all 94 locations.

For AECOM and EnergySolutions characterization 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 ( $^{232}\text{Th}$ ), radium-226 ( $^{226}\text{Ra}$ ), and uranium-238 ( $^{238}\text{U}$ ), 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.



Table 27-1 Historic Characterization Sample Results

Location ID	C-T Phase II DP Table	Depth (ft)	Activity Concentration (pCi/g) <sup>a</sup>			SOF <sup>b</sup>	
			<sup>232</sup> Th	<sup>226</sup> Ra	<sup>238</sup> U	Gross	Net <sup>c</sup>
BH-001	4-7	0.5 - 2.5	1.10	3.30		0.16	0.03
		2.5 - 4.5	0.67	2.30		0.11	0.00
		4.5 - 6.5	0.70	2.00		0.10	0.00
BH-002	4-7	0.5 - 2.5	1.80	2.30	2.50	0.16	0.02
		2.5 - 4.5	1.10	2.30		0.12	0.00
		4.5 - 6.5	0.91	1.30		0.08	0.00
		16.5 - 18.5	0.94	1.20		0.08	0.00
BH-003	4-7	0.5 - 2.5	1.40	3.50	7.10	0.19	0.04
		4.5 - 6.5	1.10	4.60		0.20	0.07
		16 - 17	1.60	2.50		0.15	0.01
		18 - 19	1.30	1.30		0.10	0.00
BH-004	4-7	1.5 - 2.5	0.39	1.40		0.06	0.00
		2.5 - 4.5	0.72	3.60		0.15	0.04
		17.5 - 18.5	1.10	4.30		0.19	0.06
		18.5 - 19.5	1.40	1.50		0.11	0.00
BH-005	4-7	0.5 - 1.5	1.10	4.30		0.19	0.06
		4.5 - 5.5	1.30	4.00		0.19	0.05
		6.5 - 7.5	1.20	2.60		0.14	0.00
BH-006	4-7	0.5 - 1.5	1.00	3.10		0.15	0.02
		4.5 - 5.5	1.10	2.70		0.14	0.01
		6.5 - 7.5	1.40	3.40		0.17	0.03
BH-007	4-7	0.5 - 1.5	1.20	2.90		0.15	0.01
		3.5 - 4.5	1.50	4.10		0.20	0.06
		5.5 - 6.5	0.73	2.60		0.12	0.00
		11.5 - 12.5	1.30	5.10		0.23	0.09
BH-008	4-7	0.5 - 2.5	1.60	4.20	5.20	0.22	0.07
		5.5 - 6.5	0.80	4.40	7.70	0.19	0.07
		15.5 - 16.5	1.00	1.20		0.08	0.00
		17.5 - 18.5	1.50	2.20		0.14	0.01
BH-033	4-7	0.75 - 2	1.90	2.60	20.70	0.20	0.05
		2.5 - 3.5		0.89	31.60	0.07	0.04
		6 - 7	0.76	1.74	3.61	0.10	0.00
		10.5 - 11.5	2.49	2.67	13.10	0.21	0.07
		12 - 13	1.40	2.90	49.70	0.23	0.08
		16 - 17	3.20	1.40	33.10	0.23	0.12
BH-034	4-7	3 - 4	1.20	6.90	5.20	0.29	0.15
		9 - 10	2.60	4.60	4.20	0.27	0.13
		15 - 16	1.50	1.30	2.50	0.11	0.01
BH-035	4-7	0 - 0.75	1.80	3.90	15.20	0.23	0.08
		0.75 - 2	1.15	3.70	5.50	0.18	0.04
		3 - 4	0.90	2.46	2.21	0.12	0.00
		5 - 6	1.05	3.17	3.42	0.16	0.02
		7 - 8	1.20	36.30	3.50	<b>1.29</b>	<b>1.15</b>
		16 - 17	1.20	1.50	1.40	0.10	0.00
		28.5 - 29.5	1.10	0.86	0.92	0.08	0.00
BH-036	4-7	0 - 0.75	0.99	3.20	3.00	0.15	0.02
		5 - 6	1.00	4.50	3.40	0.20	0.07
		16 - 17	1.20	2.40	6.00	0.14	0.00

Table 27-1 Historic Characterization Sample Results (continued)

Location ID	C-T Phase II DP Table	Depth (ft)	Activity Concentration (pCi/g) <sup>a</sup>			SOF <sup>b</sup>	
			<sup>232</sup> Th	<sup>226</sup> Ra	<sup>238</sup> U	Gross	Net <sup>c</sup>
BH-037	4-7	0.7 - 2	1.40	0.44	9.90	0.09	0.01
		6.5 - 7.5	1.70	4.30	5.30	0.22	0.08
		11 - 12	1.70	6.00	4.40	0.28	0.14
BH-046	4-7	2 - 3	1.40	1.40	2.00	0.11	0.00
		9 - 10	0.61	3.50	6.50	0.15	0.04
		13 - 14	2.60	7.40	5.50	0.37	0.22
BH-047	4-7	3 - 4	1.10	2.90	6.20	0.15	0.02
		7 - 8	1.30	2.30	5.80	0.14	0.00
		19 - 20	1.00	1.30	1.50	0.09	0.00
BH-048	4-7	3 - 4	1.00	1.60	1.30	0.10	0.00
		9 - 10	1.10	2.40	2.60	0.13	0.00
		16 - 17	0.59	1.40	0.79	0.07	0.00
BH-050	4-7	2.5 - 3.5	1.10	2.40	60.90	0.21	0.08
		5 - 6	0.81		1.50	0.04	0.00
		14 - 15	0.87	4.10	22.90	0.21	0.08
		18 - 19	1.20	1.40	10.60	0.11	0.01
BH-051	4-7	2 - 3	0.99	3.60	8.60	0.18	0.04
		6 - 7	0.66	2.50	1.90	0.12	0.00
		13 - 14	2.20	7.90	5.80	0.37	0.22
		18 - 19	1.00	1.40	5.60	0.10	0.00
BH-056	4-7	2 - 3	0.70	0.79	3.07	0.06	0.00
		4 - 5	1.10	3.10	3.90	0.16	0.02
		11 - 12	0.96	4.80	6.20	0.21	0.08
		14 - 15	0.81	4.40	8.70	0.20	0.07
		28.5 - 29.5	0.74	0.69	1.17	0.06	0.00
BH-062	4-8	0.5 - 1	1.24	3.04	10.80	0.17	0.03
		1 - 2	0.77	3.45	29.34	0.19	0.07
		4 - 5	1.07	1.52	5.07	0.10	0.00
		6 - 7	1.25	2.92	6.24	0.16	0.02
		7 - 8	2.35	6.15	4.95	0.31	0.17
		15 - 16	0.78	5.85	29.97	0.27	0.15
BH-063	4-8	1 - 2	1.42	4.77	7.62	0.23	0.09
		4 - 6	1.26	2.25	6.45	0.14	0.00
		12 - 13	1.80	4.08	28.49	0.25	0.11
BH-064	4-8	1 - 2	0.84	4.19	11.88	0.19	0.07
		4 - 5	0.87	4.07	5.06	0.18	0.05
		11 - 12	1.52	2.58	3.75	0.16	0.01
BH-065	4-8	0 - 1	1.01	5.35	5.92	0.23	0.10
		3 - 4	1.53	4.18	1.68	0.21	0.07
BH-066	4-8	1 - 3	1.31	3.56	66.01	0.27	0.12
		2 - 3	1.03	3.07	18.90	0.17	0.04
		3 - 4	1.18	4.19	5.69	0.20	0.06
BH-067	4-8	1 - 2	0.85	4.07	9.81	0.19	0.06
		4 - 6	1.03	4.66	6.47	0.21	0.08
		15 - 16	0.83	7.37	3.90	0.29	0.17
BH-068	4-8	0 - 1.5	1.12	3.74	11.63	0.19	0.05
BH-068A	4-8	5 - 6	1.29	6.45	7.89	0.28	0.14

Table 27-1 Historic Characterization Sample Results (continued)

Location ID	C-T Phase II DP Table	Depth (ft)	Activity Concentration (pCi/g) <sup>a</sup>			SOF <sup>b</sup>	
			<sup>232</sup> Th	<sup>226</sup> Ra	<sup>238</sup> U	Gross	Net <sup>c</sup>
BH-069	4-8	0.5 - 1	0.85	5.05	17.31	0.23	0.10
		2 - 3	0.94	4.82	11.09	0.22	0.09
		2 - 3	0.81	3.51	11.47	0.17	0.04
BH-070	4-14	0 - 4	1.41	2.42	3.37	0.15	0.00
		4 - 8	1.44	5.23	5.50	0.25	0.10
		8 - 12	1.23	2.70	2.38	0.15	0.01
BH-071	4-14	0 - 4	1.00	3.84	4.31	0.18	0.05
		4 - 8	0.95	0.91	2.09	0.07	0.00
		8 - 12	0.89	1.82	2.04	0.10	0.00
BH-072	4-14	0 - 4	1.26	2.48	9.90	0.15	0.01
		4 - 8	0.71	1.55	4.40	0.09	0.00
		8 - 12	1.08	4.37	6.50	0.20	0.07
BH-073	4-14	0 - 4	0.99	1.15	1.58	0.08	0.00
		4 - 8	1.02	3.23	3.73	0.16	0.02
		8 - 12	1.01	3.38	1.82	0.16	0.03
BH-074	4-14	0 - 4	1.17	3.74	3.14	0.18	0.04
		4 - 8	1.33	4.13	4.90	0.20	0.06
		8 - 12	1.23	3.04	2.39	0.16	0.02
BH-075	4-14	0 - 4	0.90	2.81	1.40	0.14	0.01
		4 - 8	0.80	2.18	1.82	0.11	0.00
		8 - 12	0.54	3.56	2.00	0.15	0.04
BH-076	4-14	0 - 4	0.86	2.01	2.42	0.11	0.00
		4 - 8	1.08	4.34	3.17	0.20	0.06
		8 - 12	0.44	1.69	0.58	0.08	0.00
BH-077	4-14	0 - 4	1.31	1.71	2.55	0.12	0.00
		4 - 8	1.25	3.46	2.86	0.17	0.03
		8 - 12	0.67	4.34	6.60	0.18	0.07
BH-078	4-14	0 - 4	0.72	3.89	2.37	0.17	0.05
		4 - 8	1.06	2.46	2.08	0.13	0.00
		8 - 12	0.81	3.24	1.96	0.15	0.03
BH-079	4-14	0 - 4	0.97	1.09	1.14	0.08	0.00
		4 - 8	0.81	1.23	0.98	0.08	0.00
		8 - 12	1.01	3.80	3.36	0.18	0.04
BH-080	4-14	0 - 4	1.16	2.05	3.21	0.12	0.00
		4 - 8	1.22	1.78	3.08	0.12	0.00
		8 - 12	1.03	1.39	3.05	0.09	0.00
BH-081	4-14	0 - 4	1.08	1.05	1.14	0.08	0.00
		4 - 8	1.19	4.31	3.22	0.20	0.06
		8 - 12	1.20	3.68	4.70	0.18	0.04
BH-092	4-15	1 - 1.5	0.79	2.18	5.40	0.11	0.00
		3 - 4.5	1.07	3.85	3.00	0.18	0.05
		6 - 7.5	0.67	1.56	1.37	0.08	0.00
		9 - 10.5	0.59	1.59	2.23	0.08	0.00
		12 - 13.5	3.01	5.36	18.00	0.33	0.19
15 - 16.5	0.94	1.22	4.19	0.09	0.00		
BH-095	4-9	0 - 3	1.14	3.48	2.10	0.17	0.03
		3 - 5	0.99	1.61	1.80	0.10	0.00

Table 27-1 Historic Characterization Sample Results (continued)

Location ID	C-T Phase II DP Table	Depth (ft)	Activity Concentration (pCi/g) <sup>a</sup>			SOF <sup>b</sup>	
			<sup>232</sup> Th	<sup>226</sup> Ra	<sup>238</sup> U	Gross	Net <sup>c</sup>
BH-096	4-9	0 - 3	1.42	4.32	4.30	0.21	0.07
		3 - 5.5	1.16	1.52	0.12	0.10	0.00
BH-097	4-9	0 - 3	0.61	1.39	1.70	0.08	0.00
		3 - 6	0.75	2.17	1.20	0.11	0.00
BH-098	4-9	0 - 3	1.01	1.27	2.70	0.09	0.00
		3 - 5	1.17	2.27	3.50	0.13	0.00
BH-099	4-10	0 - 3	6.49	1.01	2.25	0.31	0.22
		3 - 6	4.79	2.04	1.69	0.27	0.15
		6 - 9	4.50	0.87	1.43	0.22	0.13
BH-100	4-10	0 - 3	2.84	0.86	9.26	0.16	0.07
		3 - 6	6.12	1.06	2.00	0.29	0.20
		6 - 8.5	2.61	1.46	7.02	0.17	0.06
BH-101	4-10	0 - 3	8.15	2.09	8.06	0.42	0.29
		3 - 6	2.61	1.92	1.90	0.18	0.05
		6 - 9	4.31	1.97	1.07	0.25	0.13
BH-102	4-10	0 - 3	5.73	1.54	7.62	0.30	0.19
		3 - 6	3.00	2.04	1.20	0.20	0.07
		6 - 9	3.60	2.38	1.79	0.23	0.10
BH-103	4-11	0 - 2	1.34	0.86	6.72	0.09	0.00
		2 - 4	1.06	0.85	5.94	0.08	0.00
BH-104	4-11	0 - 2	1.10	1.04	6.18	0.09	0.00
		2 - 4	1.23	0.87	3.53	0.09	0.00
		4 - 6	1.00	1.05	2.67	0.08	0.00
BH-120	4-8	0 - 9	1.04	3.00	2.40	0.15	0.02
BH-Z-01	4-13	0 - 1	0.82	0.39	4.18	0.05	0.00
		1 - 3	1.56	0.78	5.00	0.10	0.01
		3 - 6	1.56	0.41	4.02	0.08	0.01
		6 - 9	1.48	0.34	4.77	0.08	0.01
		9 - 12	0.86	0.14	4.14	0.05	0.00
BH-Z-02	4-13	0 - 1	1.16	0.27	6.25	0.07	0.00
		1 - 3	1.01	0.38	7.21	0.07	0.00
		3 - 6	1.27	0.21	3.80	0.07	0.00
		6 - 9	1.31	0.23	4.27	0.07	0.00
		9 - 12	1.65	0.19	5.36	0.08	0.02
BH-Z-03	4-13	0 - 1	1.01	0.25	7.52	0.06	0.00
		1 - 3	1.05	0.13	7.58	0.06	0.00
		3 - 6	1.08	0.37	4.36	0.06	0.00
		6 - 9	1.13	0.41	4.66	0.07	0.00
		9 - 12	0.94	0.29	3.49	0.05	0.00
BH-Z-04	4-13	0 - 1	2.34	2.13	17.07	0.19	0.06
		1 - 3	1.64	1.16	8.16	0.12	0.02
		3 - 6	0.87	1.02	7.27	0.08	0.00
		6 - 9	1.40	0.64	4.44	0.09	0.00
		9 - 12	1.18	0.48	5.24	0.07	0.00

Table 27-1 Historic Characterization Sample Results (continued)

Location ID	C-T Phase II DP Table	Depth (ft)	Activity Concentration (pCi/g) <sup>a</sup>			SOF <sup>b</sup>	
			<sup>232</sup> Th	<sup>226</sup> Ra	<sup>238</sup> U	Gross	Net <sup>c</sup>
BH-Z-05	4-13	2.5 - 3.5	1.03	0.64	3.17	0.07	0.00
		3.5 - 5.5	1.30	0.41	2.60	0.07	0.00
		5.5 - 8.5	1.59	0.63	4.82	0.09	0.01
		8.5 - 11.5	0.84	0.34	4.43	0.05	0.00
		11.5 - 14.5	0.93	0.53	3.68	0.06	0.00
BH-Z-06	4-13	3 - 4	1.67	0.61	4.00	0.10	0.02
		4 - 6	1.14	0.79	3.66	0.08	0.00
		6 - 9	0.92	0.48	3.53	0.06	0.00
		9 - 12	1.05	0.42	4.13	0.06	0.00
		12 - 15	1.24	0.09	5.09	0.06	0.00
BH-Z-07	4-13	0 - 1	1.10	0.57	15.90	0.09	0.02
		1 - 3	0.93	0.74	25.38	0.10	0.03
		3 - 6	0.77	0.30	10.38	0.06	0.01
		6 - 9	1.06	0.52	1.78	0.06	0.00
		9 - 12	1.00	0.22	4.62	0.06	0.00
BH-Z-08	4-13	0 - 1	0.27	0.20	1.99	0.02	0.00
		1 - 3	0.75	0.54	3.75	0.05	0.00
		3 - 6	1.47	0.30	5.12	0.08	0.01
		6 - 9	0.90	0.25	3.89	0.05	0.00
		9 - 12	1.45	0.15	3.47	0.07	0.01
BH-Z-09	4-13	0 - 1	0.89	0.27	11.24	0.06	0.01
		1 - 3	1.15	0.26	7.36	0.07	0.00
		3 - 6	1.07	0.30	4.59	0.06	0.00
		6 - 9	0.60	0.45	4.19	0.05	0.00
		9 - 12	0.94	0.25	4.30	0.05	0.00
BH-Z-10	4-13	0 - 1	0.48	0.35	1.45	0.03	0.00
		1 - 3	0.78	0.42	1.05	0.05	0.00
		3 - 6	1.06	0.41	1.66	0.06	0.00
		6 - 9	1.05	0.32	4.16	0.06	0.00
		9 - 12	0.99	0.12	4.43	0.05	0.00
BH-Z-11	4-13	0 - 1	1.05	0.51	10.91	0.08	0.01
		1 - 3	0.98	1.26	10.04	0.10	0.01
		3 - 6	1.17	0.69	3.83	0.08	0.00
		6 - 9	0.86	0.20	2.80	0.05	0.00
		9 - 12	1.41	0.46	4.94	0.08	0.01
BH-Z-12	4-13	0 - 1	1.19	0.43	6.34	0.07	0.00
		1 - 3	1.19	0.69	2.39	0.08	0.00
		3 - 6	0.94	0.33	2.66	0.05	0.00
		6 - 9	0.86	0.23	7.00	0.05	0.00
		9 - 12	0.41	0.15	2.14	0.03	0.00
BH-Z-13	4-13	0 - 1	0.35	0.28	1.26	0.03	0.00
		1 - 3	1.10	0.30	4.08	0.06	0.00
		3 - 6	0.94	0.67	3.79	0.07	0.00
		6 - 9	1.29	0.52	3.13	0.08	0.00
		9 - 12	1.05	0.84	3.47	0.08	0.00

Table 27-1 Historic Characterization Sample Results (continued)

Location ID	C-T Phase II DP Table	Depth (ft)	Activity Concentration (pCi/g) <sup>a</sup>			SOF <sup>b</sup>	
			<sup>232</sup> Th	<sup>226</sup> Ra	<sup>238</sup> U	Gross	Net <sup>c</sup>
BH-Z-14	4-13	0 - 1	0.74	0.78	3.12	0.06	0.00
		1 - 3	0.88	0.67	4.41	0.07	0.00
		3 - 6	0.62	0.42	3.17	0.04	0.00
		6 - 9	0.92	0.39	3.54	0.06	0.00
		9 - 12	0.99	0.40	5.65	0.06	0.00
BH-Z-15	4-13	0 - 1	0.74	1.71	12.45	0.11	0.01
		1 - 3	0.63	0.93	9.43	0.07	0.01
		3 - 6	0.81	0.90	6.22	0.07	0.00
		6 - 9	0.58	1.04	4.16	0.07	0.00
		9 - 12	0.84	0.75	6.24	0.07	0.00
BH-Z-16	4-13	0 - 1	0.56	1.13	10.67	0.08	0.01
		1 - 3	0.42	0.72	14.11	0.06	0.01
		3 - 6	0.80	0.73	9.64	0.07	0.01
		6 - 9	0.85	0.77	9.82	0.08	0.01
		9 - 12	1.25	0.97	4.94	0.09	0.00
BH-Z-17	4-13	0 - 1	0.73	0.54	2.97	0.05	0.00
		1 - 3	1.37	0.55	3.67	0.08	0.00
		3 - 6	1.52	0.38	5.22	0.08	0.01
		6 - 9	1.34	0.46	4.57	0.08	0.00
		9 - 12	1.10	0.19	4.76	0.06	0.00
BH-Z-18	4-13	0 - 1	0.61	0.41	4.83	0.05	0.00
		1 - 3	0.68	0.28	2.71	0.04	0.00
		3 - 6	0.80	0.35	3.18	0.05	0.00
		6 - 9	1.29	0.48	4.50	0.08	0.00
		9 - 12	0.91	0.43	4.27	0.06	0.00
BH-Z-19	4-13	9 - 12	1.30	0.49	3.50	0.08	0.00
		12 - 15	1.42	0.20	9.94	0.08	0.01
		15 - 18	1.59	0.74	6.56	0.10	0.02
BH-Z-20	4-13	9 - 12	1.15	0.21	6.02	0.06	0.00
		12 - 15	1.10	0.13	5.29	0.06	0.00
		15 - 18	1.03	0.28	8.87	0.06	0.01
BH-Z-21	4-13	0 - 3	0.85	0.56	3.59	0.06	0.00
		3 - 6	1.11	0.63	5.15	0.08	0.00
		6 - 9	1.17	0.40	4.43	0.07	0.00
		9 - 12	1.15	0.20	8.46	0.07	0.01
		12 - 15	1.19	0.33	7.47	0.07	0.00
BH-Z-22	4-13	0 - 3	0.81	0.83	11.48	0.08	0.01
		3 - 6	0.99	0.86	24.43	0.10	0.03
		6 - 9	1.18	0.31	12.37	0.08	0.01
		9 - 12	0.96	0.10	3.58	0.05	0.00
		12 - 15	0.99	0.06	9.68	0.06	0.01
BH-Z-23	4-13	0 - 3	0.88	1.14	10.48	0.09	0.01
		3 - 6	1.17	0.61	15.55	0.09	0.02
		6 - 9	1.35	0.25	5.88	0.07	0.00
		9 - 12	1.56	0.12	13.12	0.09	0.02
		12 - 15	0.99	0.23	11.96	0.07	0.01
JA-11	4-16	0 - 1	2.02	3.97	172.48	0.46	0.31
JA-12	4-16	0 - 1	2.10	2.90	166.50	0.42	0.27

Table 27-1 Historic Characterization Sample Results (continued)

Location ID	C-T Phase II DP Table	Depth (ft)	Activity Concentration (pCi/g) <sup>a</sup>			SOF <sup>b</sup>	
			<sup>232</sup> Th	<sup>226</sup> Ra	<sup>238</sup> U	Gross	Net <sup>c</sup>
JA-13	4-16	0 - 0.5	0.40	0.66	2.70	0.04	0.00
JA-14	4-16	0 - 0.5	1.70	2.00	9.20	0.15	0.02
JA-16	4-16	0 - 4.25	1.90	2.00	8.00	0.16	0.03
JA-17A	4-16	0 - 3	2.32	3.79	14.50	0.25	0.10
JA-21	4-16	0 - 4	0.68	3.96	3.30	0.17	0.05
JA-22	4-16	0 - 4	1.19	1.91	4.69	0.12	0.00
JA-23	4-16	0 - 4	0.70	2.29	2.37	0.11	0.00
JA-24	4-16	0 - 0.5	1.30	2.50	3.50	0.14	0.00

<sup>a</sup> Empty cells indicate no result provided. Italicized results indicate <MDC.

<sup>b</sup> **Bolded orange** SOF results indicate a result >0.43 (discussed in Section 27.3.4.2) but ≤1 and **bolded red** SOF values indicate a result >1.

<sup>c</sup> Calculated as discussed in Section 27.2.2.

Table 27-2 AECOM Characterization Sample Results

Location ID	Sample ID	Depth (m)	Activity Concentration (pCi/g)			Sample SOF		Column SOF <sup>a</sup>	
			<sup>232</sup> Th	<sup>226</sup> Ra	<sup>238</sup> U	Gross	Net <sup>b</sup>	Gross	Net <sup>b</sup>
G11-2	4563	0 - 1	1.02	2.72	4.77	0.14	0.01	0.14	0.01
	4564	1 - 2	0.88	1.15	2.79	0.08	0.00	0.11	0.00
	4565	2 - 3	0.96	2.07	2.27	0.11	0.00	0.11	0.00
	4566	3 - 4	1.14	2.96	6.10	0.16	0.02	0.12	0.00
	4567	4 - 5	0.47	1.64	4.19	0.08	0.00	0.11	0.00
INV-1	4701	0 - 1	1.42	4.15	2.73	0.20	0.06	0.20	0.06
	4702	1 - 2	1.12	3.11	3.43	0.16	0.02	0.18	0.04
	4703	2 - 3	0.81	1.04	1.59	0.07	0.00	0.14	0.01
	4704	3 - 4	0.76	1.92	6.01	0.11	0.00	0.13	0.00
	4705	4 - 5	1.00	2.89	7.09	0.15	0.02	0.14	0.00
INV-2	4696	0 - 1	0.91	3.48	3.31	0.16	0.03	0.16	0.03
	4697	1 - 2	1.12	3.02	3.58	0.15	0.02	0.16	0.03
	4698	2 - 3	0.91	1.39	2.88	0.09	0.00	0.13	0.00
	4699	3 - 4	1.19	3.16	4.56	0.16	0.02	0.14	0.01
	4700	4 - 5	1.02	1.37	1.88	0.09	0.00	0.13	0.00

<sup>a</sup> Calculated per Section 14.4.3.7 of C-T Phase II DP.

<sup>b</sup> Calculated as discussed in Section 27.2.2.

Table 27-3 EnergySolutions Characterization Sample Results

Loc. ID	Sample ID	Depth (m)	Activity Concentration (pCi/g) <sup>a</sup>									Sample SOF <sup>b</sup>		Column SOF <sup>b, c</sup>	
			<sup>232</sup> Th			<sup>226</sup> Ra			<sup>238</sup> U			Gross	Net <sup>d</sup>	Gross	Net <sup>d</sup>
			Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC	Result	Uncert. (2σ)	MDC				
B-01	1450	0 - 1	3.96	0.68	0.50	9.52	1.17	0.31	3.24	1.48	4.03	<b>0.49</b>	0.35	--	--
B-02	0916	0 - 1	1.31	0.28	0.09	10.65	2.79	2.09	22.07	2.50	1.28	<b>0.45</b>	0.30	<b>0.45</b>	0.30
	0917	1 - 2	1.21	0.28	0.12	10.45	2.65	1.97	27.01	1.80	1.22	<b>0.44</b>	0.30	<b>0.45</b>	0.30
	0918	2 - 3	0.84	0.19	0.08	6.38	2.06	1.56	15.83	1.48	0.66	0.27	0.15	0.39	0.25
	0919	3 - 4	1.09	0.25	0.07	4.71	1.20	0.83	5.51	0.67	0.53	0.21	0.08	0.34	0.21
	0920	4 - 5	0.65	0.20	0.06	5.60	1.47	1.07	10.37	1.22	0.59	0.23	0.11	0.32	0.19
	0921	5 - 6	0.68	0.16	0.08	5.02	1.59	1.18	9.76	1.26	0.62	0.21	0.09	0.30	0.17
B-03	1453	0 - 1	1.45	0.43	0.80	21.80	2.44	0.35	<i>-1.78</i>	6.61	4.60	<b>0.80</b>	<b>0.66</b>	--	--
B-04	1454	0 - 1	1.21	0.33	0.18	3.31	0.49	0.20	4.48	1.96	2.57	0.17	0.03	--	--
B-05	1451	0 - 1	2.20	0.46	0.28	6.35	0.78	0.22	4.39	2.11	2.61	0.31	0.17	--	--
B-06	1452	0 - 1	1.68	0.35	0.11	2.19	0.37	0.20	6.23	2.38	2.78	0.15	0.02	--	--

<sup>a</sup> Samples at location B-02 were analyzed at the on-site laboratory and were not sent to the off-site laboratory due to low results (SOF < 0.5). Samples at locations B-01 and B-03 through B-06 were collected after the on-site laboratory was demobilized and therefore were analyzed at the off-site laboratory. Off-site laboratory results as reported by TestAmerica after sufficient in-growth time to reach <sup>226</sup>Ra progeny equilibrium. Italicized results indicate <MDC.

<sup>b</sup> **Bolded orange** SOF results indicate a result >0.43 (discussed in Section 27.3.4.2) but ≤1.

<sup>c</sup> Calculated per Section 14.4.3.7 of C-T Phase II DP.

<sup>d</sup> Calculated as discussed in Section 27.2.2.



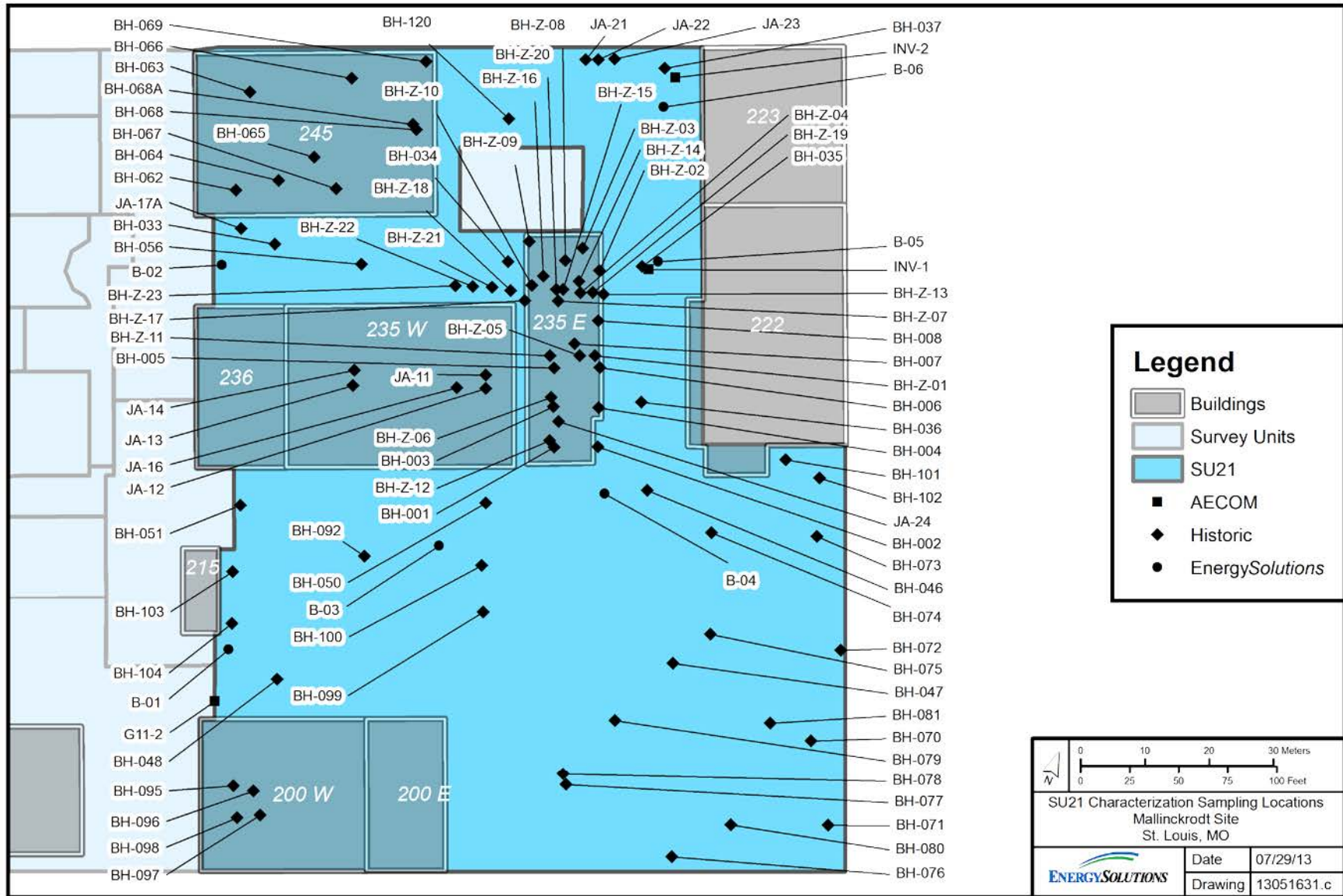


Figure 27-3 Characterization Sample Locations

### 27.3 DATA ANALYSIS

Collected data were reviewed for suitability for use as FSS data and 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.

#### 27.3.1 Elevated Area Evaluation

The historical sample collected at location BH-035 at a depth of 7 to 8 ft had a gross SOF of 1.29. AECOM collected verification samples at location INV-1, which was co-located with BH-035. AECOM's samples were collected over 1-m increments consistent with the DQOs of the C-T Phase II DP. The historical characterization data collected at location BH-035 is considered replaced by the AECOM characterization data at location INV-1. The maximum sample gross SOF of the five samples collected at location INV-1 was 0.20, therefore, there were no elevated areas identified in SU21.

#### 27.3.2 Statistical Review

The DP, AECOM, and EnergySolutions characterization sample data sets discussed above were merged and statistical summaries calculated. The statistical summaries are provided in Table 27-4.

**Table 27-4 Characterization Sample Results Statistical Summary**

Summary Statistic	Sample SOF		Column Avg. SOF	
	Gross	Net	Gross	Net
Count:	306	306	21	21
Count SOF > 0.43 <sup>a</sup> :	5	--	2	--
Average:	0.14	0.04	0.22	0.09
Median:	0.11	0.01	0.16	0.03
Standard Deviation:	0.09	0.07	0.11	0.10
Minimum:	0.02	0.00	0.13	0.01
Maximum:	0.80	0.66	0.45	0.30
Range:	0.78	0.66	0.32	0.29

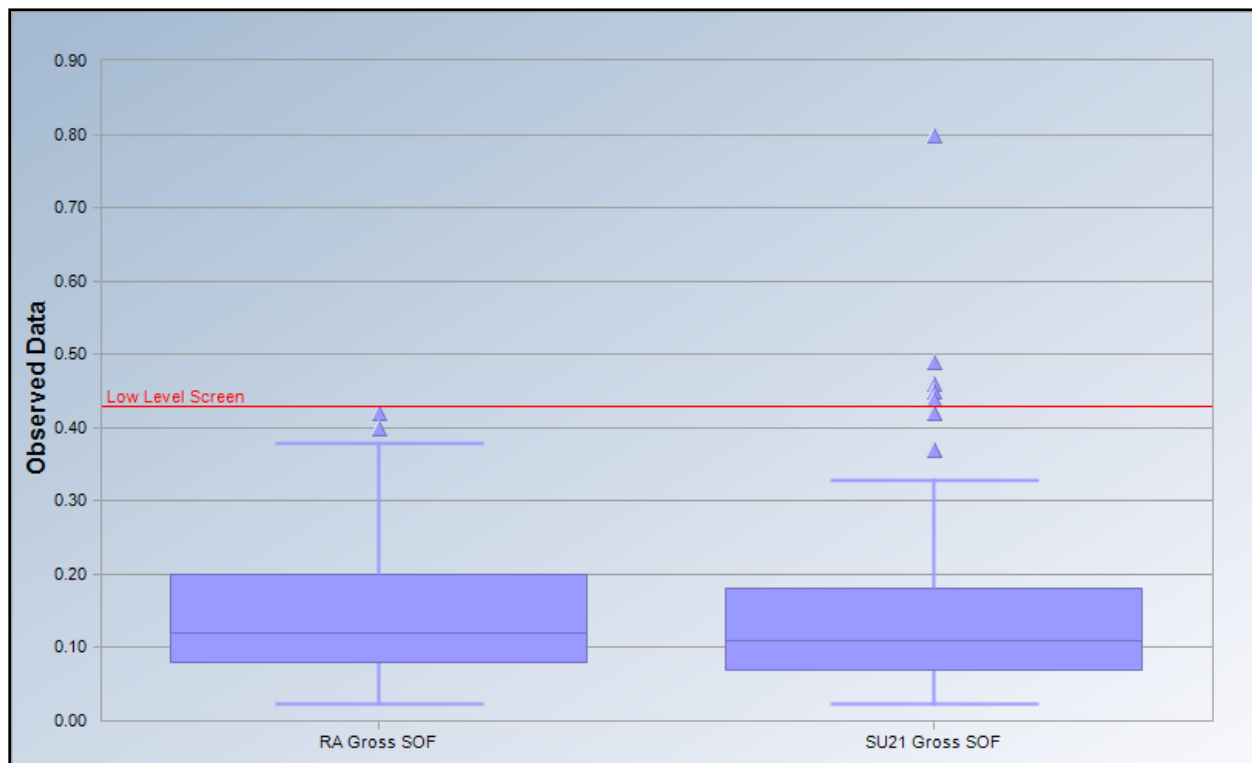
<sup>a</sup> Discussed in Section 27.3.4.2.

#### 27.3.3 Graphical Review

The merged characterization data set and the background reference area (RA) data from C-T Phase II DP Table B-1 were plotted using the U.S. Environmental Protection Agency's (EPA) ProUCL v4.1 statistical software package<sup>1</sup>. The first type of plot created was a box plot, also referred to as box-and-whisker diagram, of the gross SOF values, shown in Figure 27-4. The box plot is used to depict groups of data through five-number summaries: minimum, lower quartile

<sup>1</sup> <http://www.epa.gov/osp/hstl/tsc/software.htm>

(25<sup>th</sup> percentile of the data), median (50<sup>th</sup> percentile of the data), upper quartile (75<sup>th</sup> percentile of the data), and maximum. Box plots are useful to display differences between data populations without assuming an underlying statistical distribution (non-parametric). On Figure 27-4, the box represents the range of values between the lower quartile and upper quartile with the line inside the box indicating the median value. The minimum and maximum are indicated by horizontal lines connected to the box by a vertical line—note that these extend to a maximum of 1.5 times the inter-quartile range (IQR), which is the difference between the third and first quartiles. Data beyond this range of data are considered outliers. Figure 27-4 also includes the Low Level screening limit, discussed in Section 27.3.4.2.



**Figure 27-4 Gross SOF Box Plot**

The second type of plot created using ProUCL v4.1 was a normal quantile-quantile (Q-Q) plot of the gross SOF values, shown in Figure 27-5. A normal Q-Q plot is a graph that displays the entire distribution of a data set, ranging from the lowest to the highest value, with the vertical axis representing the ordered data points and the horizontal axis representing the theoretical quantiles of a normal distribution based on the data set. From the ProUCL documentation<sup>2</sup>, a “normal Q-Q plot can also help identify outliers and multiple populations that may be present in a data set. On a Q-Q plot, observations well separated from the majority of the data may represent potential outliers, and jumps and breaks of significant magnitude may suggest the presence of observations from multiple data populations (i.e., distributions) in the data set.”

<sup>2</sup> EPA; *ProUCL Version 4.1 Tech Guide*, EPA/600/R-07/041; May 2010.

Both plots illustrate that the merged characterization data set is consistent with the background reference area, with the exception of a few high outliers, which are discussed in subsequent sections.

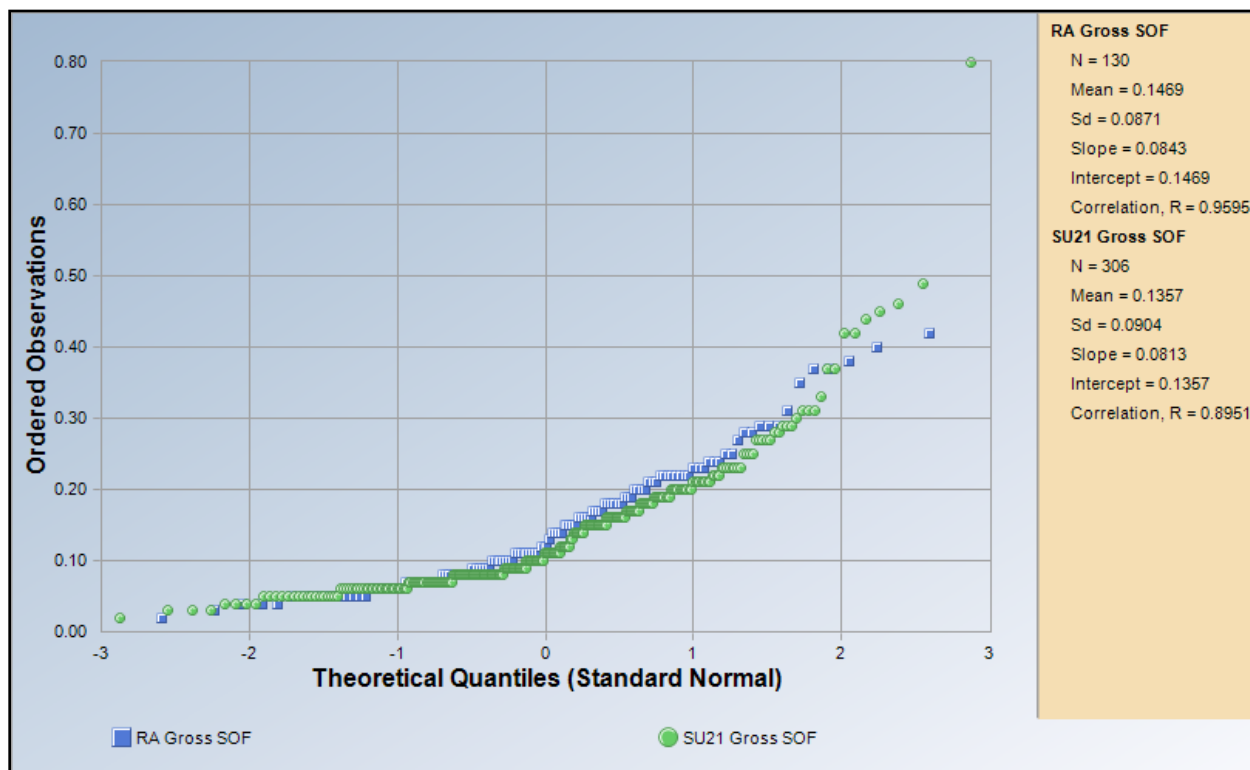


Figure 27-5 Gross SOF Q-Q Plot

### 27.3.4 Data Set Screening Analysis

Table 27-5 summarizes the results of the screening tests performed in accordance with Pages 14-27 through 14-29 of the C-T Phase II DP. The Min/Max screening test demonstrated compliance; however, the Low Level screening test failed.

Table 27-5 Screening Tests Results

Screening Test	Test Value	Conclusion
Min/Max	0.78	PASS
Low Level	5	FAIL; Investigated
DCGL <sub>W</sub>	N/A	Not applicable; Min/Max < 1
EMC Limit	N/A	Not applicable; No elevated areas

#### 27.3.4.1 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 (C-T Phase II DP Table B-1) from the maximum survey unit result (Table 27-1, Table 27-2, and Table 27-3). Location B-03, sample

1453 with a gross SOF of 0.80 was the maximum survey unit result. Sample BH-Z-08 with a calculated gross SOF of 0.02 was the minimum reference area result. The Min/Max screening test value was calculated to be 0.78. Because the test value was less than one, no further computations are required, i.e., DCGL<sub>W</sub> screening and Wilcoxon Rank Sum (WRS) tests.

#### 27.3.4.2 Low Level

In accordance with Page 14-27 of the C-T Phase II DP, the Low Level screening test was conducted for this Class 3 survey unit. The Low Level screening test limit was calculated according to the stationary investigation level equation provided in Table 14-5 of the C-T Phase II DP. Minimum detectable activities of the gamma spectroscopy analyses were typical small fractions of the DCGLs and therefore the action level was calculated using the reference area data. The average gross SOF was calculated to be 0.15 using average <sup>232</sup>Th, <sup>226</sup>Ra, and <sup>238</sup>U results provided in Table 4-17 of the C-T Phase II DP. The gross SOF standard deviation of 0.09 was calculated using the data provided in Table B-1 of the C-T Phase II DP. The Low Level screening test limit was calculated to be 0.43, as shown below.

$$0.1 \times 1 + 0.15 + 2 \times 0.09 = 0.43$$

As shown in Table 27-4, five samples exceeded the Low Level screening test limit of 0.43. In accordance with the C-T Phase II DP, Page 14-28, the survey unit was to be “evaluated for additional analysis, remediation, or other appropriate action”—the further analysis is presented below.

1. Historic location JA-11, with the sample collected from 0 to 1 ft, with a gross SOF of 0.46. This value was just above the 2-sigma calculated Low Level screening test limit of 0.43. This result was reviewed in accordance with the C-T Phase II DP and determined to be acceptable for the following reasons: a) nearby samples (JA-12 and JA-16) did not exceed the Low Level screening test limit and b) given the number of samples collected, it is expected that a very limited number of results could exceed the 2-sigma uncertainty but fall within the 3-sigma uncertainty—a Low Level screening test limit calculated using the 3-sigma uncertainty would be equal to 0.52 and this location falls within that range.
2. EnergySolutions location B-01 with a gross SOF of 0.49. Elevated contamination (gross SOF>1) was identified at the northeast corner of Building 215, within Class 1 survey unit SU12. EnergySolutions location B-01 was collected at a location southeast of Building 215 (Figure 27-2), which was the highest activity reading measured in that area during EnergySolutions’ GWS. Reviewing Figure 27-3, EnergySolutions location B-01, along with historic locations BH-051, BH-103, and BH-104 and AECOM location G11-2 demonstrate that elevated contamination does not extend into SU21 and this is appropriately designated as a Class 3 survey unit. In addition, the discussion point regarding 3-sigma uncertainty discussed above also applies to this location.

3. EnergySolutions location B-02 with gross SOFs of 0.45 and 0.44. These values were just above the 2-sigma calculated Low Level screening test limit of 0.43. This result was reviewed in accordance with the C-T Phase II DP and determined to be acceptable for the following reason: given the number of samples collected, it is expected that a very limited number of results could exceed the 2-sigma uncertainty but fall within the 3-sigma uncertainty—a Low Level screening test limit calculated using the 3-sigma uncertainty would be equal to 0.52 and this location falls within that range.
4. EnergySolutions location B-03 with a gross SOF of 0.80. This sample location was collected at a location south of Building 235W (Figure 27-2), which was the highest activity reading measured in that area during EnergySolutions' GWS. The GWS, gamma scanning after exposing the soil and sampling, and the sample results verified that this area of elevated contamination exceeding the Low Level screening test limit but less than a gross SOF of 1 was very limited in size and did not warrant a re-classification of the survey unit.

#### 27.3.4.3 DCGL<sub>w</sub>

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<sub>w</sub> screening test was not applicable to this survey unit.

#### 27.3.4.4 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.

#### 27.3.5 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.

#### 27.3.6 Retrospective Analysis

A retrospective analysis was performed of the survey 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 27-6 provides the results of the retrospective analysis, using summary statistics from Table 27-4. Because the actual sample size exceeded the retrospective value sample size, the conclusion is that the survey design objectives were met.

Table 27-6 Retrospective Analysis

Parameter	<i>A Priori</i> Value	Retrospective Value Based on Actual 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	0.09
Type I Error (false positive)	0.05	0.05
Type II Error (false negative)	0.05	0.05
Relative Shift	3	9.5
Calculated N/2 Sample Size	15 <sup>a</sup>	9
Actual N/2 Sample Size	--	306

<sup>a</sup> 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.

#### 27.4 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. Deviations are discussed below.

- C-T Phase II DP Section 14.2 notes that “in serving as elements in the FSS,” characterization data “may comprise the entire data set for a particular survey unit.” With the breadth of data collected during characterization, the SU21 characterization data set is considered the FSS data set. The deviation is that the characterization data was not collected following one of the FSS DQOs—sampling locations were generally chosen in a biased fashion rather than a random sampling pattern as required for Class 3 survey units by C-T Phase II DP, Section 14.4.3.6. However, given the breadth of samples collected (306 samples from 93 locations), the DQOs of the C-T Phase II DP are considered exceeded even with this deviation.
- 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<sup>®</sup> Excel<sup>®</sup> spreadsheets and hand calculations was utilized. This deviation is not significant and does not affect the data collection or assessment.

#### 27.5 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 of affected areas conducted by the NRC. No violations were identified. No findings of significance were identified.

## 27.6 CONCLUSION

Collected data were reviewed for suitability for use as FSS data. The review concluded that the data collected were adequate to serve as FSS data and 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 either passed or were evaluated in accordance with the C-T Phase II DP, the retrospective analysis found that the survey design objectives were met, and additional subsurface contamination was not reasonably suspected. SU21 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.

## 27.7 REFERENCES

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