U.S. Department of Energy
200 Grand Avenue
Grand Junction, CO 81501

July 14, 2008

Mr. Myron Fliegel
Office of Nuclear Material Safety & Safeguards
U.S. Nuclear Regulatory Commission
Mail Stop T78J
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11545 Rockville Pike
Rockville, MD 20852-2747

Subject: Transmittal of the Moab Site Project Completion Report appendix Package Off-Pile Remediation

Dear Mr. Fliegel:

Enclosed for your review are four copies of the *Moab Site Project Completion Report Appendix Package for Off-Pile Remediation*, located along the northern edge of the site. This Appendix to the final completion report summarizes the results of the remediation for the area. After all areas of the site have been remediated, a final completion report will be prepared to summarize all remedial action activities.

If you have any questions, please call me on my new office number, (970) 257-2115.

Sincerely,

Donald R. Metzler
Moab Federal Project Director

cc w/o enclosures:
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Project File MOA 44.2

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SM-4224-081180

Moab Site Project Completion Report

Appendix Package Off-Pile Remediation

July 2008

Stoller

Work Performed by S.M. Stoller Corporation Under Purchase Order No.4064
for Energy Solutions, Moab Utah. Energy Solutions performs work for the
U.S. Department of Energy Under Task Order No. DE-AT30-07CC00014

Moab Site Project Completion Report Appendix Package

Off-Pile Remediation

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1.0 Introduction and Background

The Moab Uranium Mill Tailings Remedial Action (UMTRA) Project Site (site) is a former uranium-ore processing facility located about 3 miles northwest of the city of Moab in Grand County, Utah. It is located on the west bank of the Colorado River at the confluence with Moab Wash. The site encompasses approximately 400 acres, of which approximately 130 acres are covered by a mill tailings pile.

In 2001 the Floyd D. Spence National Defense Authorization Act (Act) was passed which required that the property title and the responsibility for cleanup be transferred from the Moab Mill Reclamation Trust to the U.S. Department of Energy (DOE). The Act mandated remediation of the site in accordance with Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978. The site is managed by the DOE Office of Environmental Management.

After all areas of the site have been remediated, a final Moab mill site completion report will be prepared to summarize all remedial action land verification activities at the site.

This Appendix to the final completion report summarizes the results of the remediation and radiological survey data of a portion of the site known as the Off-Pile Remediation. The location is shown in Figure 1.

2.0 Basis for Remedial Action

Remedial action for the site has been conducted in accordance with UMTRCA; applicable provisions of the *Code of Federal Regulations* (40 CFR Part 192.12, Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings; and 40 CFR 192.22, Supplemental Standards); *Radiation Protection of the Public and the Environment* (DOE Order 5400.5); *Environment, Safety, and Health Program for Department of Energy Operations* (DOE Order 5480.1B); the National Environmental Policy Act (42 *United States Code* 4321); and all other applicable environmental regulations with an emphasis on maintaining all health and safety risks as low as reasonably achievable.

3.0 Authorized Limits

3.1 Regulatory Standards

The Authorized Limits, based on compliance with 40 CFR 192.12, are summarized in Table 1. This standard requires that the concentration of radium-226 (Ra-226) for the 0 to 15 centimeter (cm) soil layer must be 5 picocuries per gram (pCi/g) above background or less. Since the Ra-226 background for the site is 0.8 pCi/g (see section 3.2), the cleanup standard is 5.8 pCi/g for surface soil. For soil layers deeper than 15 cm, the requirement is that Ra-226 must be 15 pCi/g above background or less. Therefore, the cleanup standard is 15.8 pCi/g for subsurface soil layers.

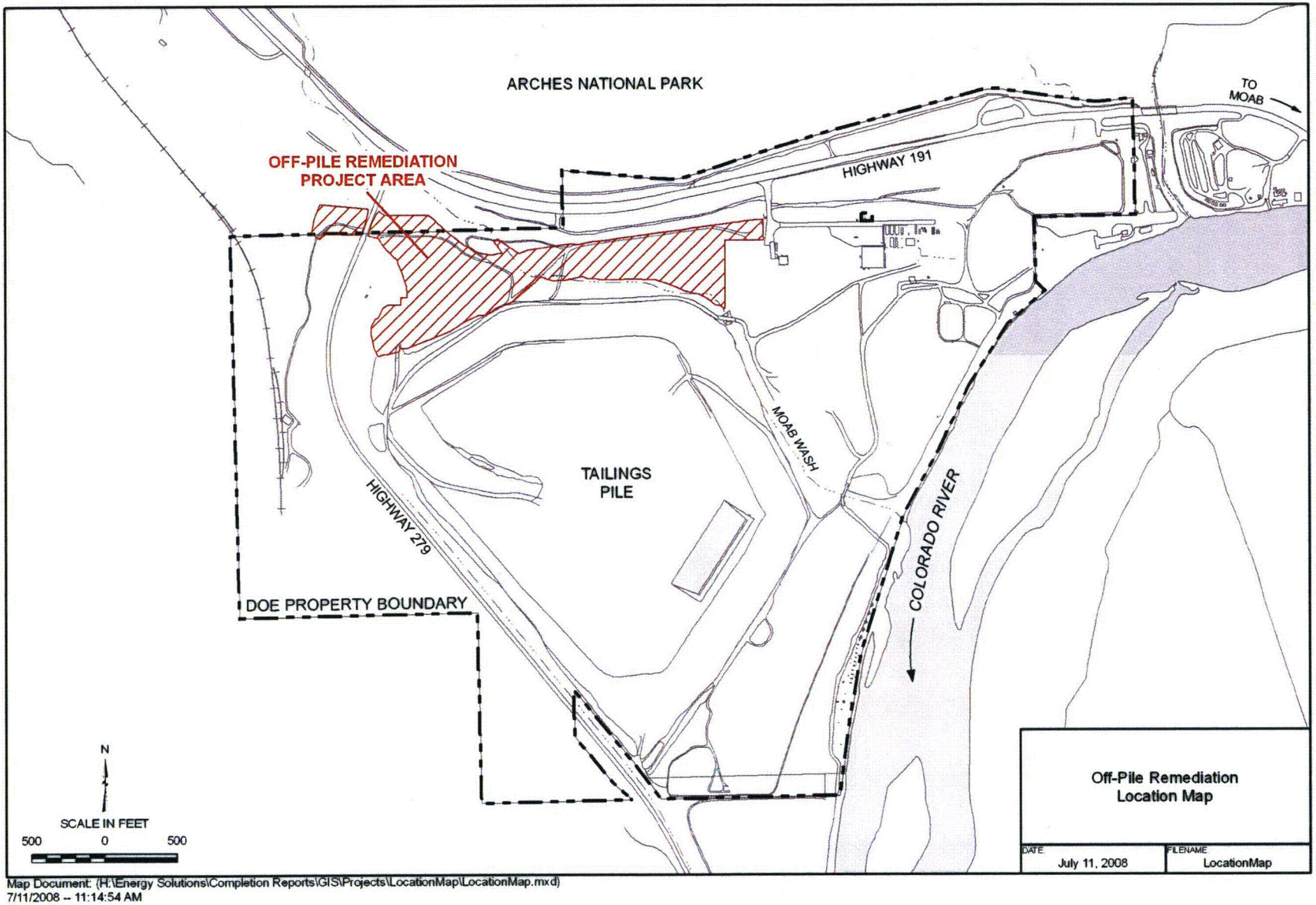

Figure 1. Site Location Map Showing the Off-Pile Remediation Area

Table 1. Authorized Limits for Thorium-230 with Radium-226

Remediation Goals				
Radionuclide	**Surface (including background)**		**Subsurface (including background)**	
Ra-226	5.8 pCi/g		15.8 pCi/g	
Th-230	Ra-226 (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)	Th-230 (pCi/g)
	1.0	14.6	1.0	43.2
	2.0	12.7	2.0	41.2
	3.0	10.9	3.0	39.5
	4.0	9.0	4.0	37.6
	5.0	7.2	5.0	35.7
	5.8	5.8	6.0	33.9
			7.0	32.0
			8.0	30.2
			9.0	28.3
			10.0	26.5
			11.0	24.6
			12.0	22.8
			13.0	20.9
			14.0	19.1
			15.0	17.2
			15.8	15.8
Total Uranium	Not applicable in this remediation area		Not applicable in this remediation area	

Because thorium-230 (Th-230) decays to Ra-226, the Th-230 goals are based on a level of Th-230 that will ensure the site meets the Ra-226 standard over a 1,000 year performance period. The amount of Th-230 that can be left in place is dependent upon the amount of Ra-226 that is also left, as shown in Table 1. The Th-230 concentrations measured during assessment of this area ranged from 0.74 to 19.6 pCi/g. The average ratio of Th-230 to Ra-226 was 1.37. Uranium concentrations found during assessment ranged from 1.4 to 21.0 pCi/g. The average ratio of total uranium to Ra-226 was 1.40. This indicates that remediation activities to meet the Ra-226 standard will also reduce the Th-230 and uranium to levels that will ensure the site will not exceed the Ra-226 standard over the 1,000 year performance period specified in the standard.

3.2 Background Soil Radionuclide Concentrations

Soil radionuclide-concentration background values are summarized in Table 2. Background soil values for the site were determined from laboratory analysis of eight samples collected from four offsite background locations in November 2001.

Table 2. Background Soil Radionuclide Concentrations

Criterion	Background Value
Radium-226 Concentration in Soil	0.8 pCi/g
Thorium-230 Concentration in Soil	0.5 pCi/g
Total Uranium Concentration in Soil	1.2 pCi/g

4.0 Description of Area of Remediation

The Off-Pile Remediation project area includes approximately 108,500 square meters (m^2) (27 acres). The project area is located along the northern edge of the site. The project also includes a portion of the southwestern corner of Moab Vicinity Property VP 023 which is owned by the Bureau of Land Management (BLM). This parcel is located at the intersection of State Highways 279 and 191 in the NE ¼ of Section 28, Township 2 South Range 21 East.

The original property characterization is reported in the *Radiological Assessment for the Non-Pile Areas of the Moab Project Site* (DOE 2005). The areas and depths of contamination that were assessed for the Off-Pile Remediation are shown in Plate 1.

5.0 Work Performed

5.1 Instrumentation

Gamma scintillometers were used to identify areas where elevated gamma levels indicate possible Ra-226 contamination. The types of scintillometers used included handheld crutch Mount Sopris SC-132s, and Ludlum 44-10 sodium-iodide detectors mounted on an All-Terrain Vehicle (ATV) or in a backpack unit. Both types of scintillometers can be shielded (collimated) with lead around the sides of the detector. Collimated instruments were used to minimize elevated gamma (shine) caused by adjacent areas that were not yet remediated. Uncollimated instruments were used to maximize sensitivity for locating gamma anomalies. The ATV and backpack scintillometers were linked with a global positioning system (GPS) for mapping the location of the gamma measurements. These systems are referred to as gamma-scanning GPS (GS/GPS) and the accuracy is approximately 1 m (3.3 ft) to 4.6 m (15 ft).

Soil samples were analyzed on-site using a sodium iodide-based Opposed Crystal System (OCS) for Ra-226. Verification to the 40 CRF 192 soil standards was based upon the OCS data. In accordance with quality control procedures a minimum of 5 percent of the OCS verification samples were submitted to an independent analytical laboratory.

Soil samples were also analyzed on-site for uranium using an Ortec Gamma Gauge© high-purity germanium (HPGe) detector. The HPGe is used for screening and is considered a semi-quantitative method.

Instrument procedures are included in *Field Services Procedures Manual* (TAC STO-203). All instruments had daily operation checks performed in accordance with the TAC STO-203.

5.2 Characterization Survey Prior to Remediation

In order to determine which areas of the mill site required remediation to meet the Authorized Limits, the mill site was characterized by S.M. Stoller between November 2001 and February 2005. A map of the areas and depths of assessed contamination within the Off-Pile Remediation are shown in Plate 1 and discussed in the *Radiological Assessment for Non-Pile Areas of the Moab Project Site* (DOE 2005). That report also provides a description of the methods used to characterize the site. It

was approved by DOE and was submitted to the Nuclear Regulatory Commission (NRC) for review. Review comments received from the NRC were resolved prior to the start of remediation.

5.3 Remediation

Remediation began in November of 2007 and was completed in March of 2008. Surveys of the remediated areas were performed in accordance with the TAC STO-203. After excavation to the assessed depth of contamination, the excavations were 100 percent gamma scanned with handheld crutch gamma scintillometers to locate any areas above the background gamma range that required further investigation. Where required, excavation control soil samples were collected to further delineate areas for removal.

Residual radioactive material that was removed from the Off-Pile Remediation consisted of uranium mill tailings, uranium ore contaminated soils, and uranium contaminated wood chips. The depth of remediation ranged from 15 to 244 cm (6 to 96 inches). The deepest area of removal was in Block KH where a large pit was remediated that contained wood chips that had been used in the milling process. Excavated contaminated material was stockpiled on-site in the tailings pile area. After completion of the disposal cell at Crescent Junction, Utah, the material will be transported there for disposal.

Plates 1 and 2 show the areas which were backfilled. The backfilled areas are small and are located in block KH (the wood chip pit); on the eastern edge of the excavation in block LH; and under the pad for the lidding-delidding building that is being constructed in the vicinity of block KE-256.

5.4 Verification

Verification was based on meeting the 40 CFR 192 standards for Ra-226 concentrations in soil. Gamma scanning and soil sampling were used to verify that the Authorized Limits were achieved. Areas that are designated on Plate 1 and Plate 2 as "backfilled" were verified to the subsurface radium-in-soil standard of 15.8 pCi/g. All other areas were verified to meet the surface standard of 5.8 pCi/g.

Verification of the remediated areas was performed by Energy Solutions, the Remedial Action Contractor (RAC) for the Moab Project. Independent verification of the remediation was performed by S&K Technologies, the Technical Assistance Contractor (TAC).

5.4.1 Reference Grids

After excavation was complete, a predetermined grid measuring 210 by 180 m was overlain on the verification area. The verification grid areas are identified by a "V" for verification, plus two letters (e.g., grid V-KL). Each grid area was subdivided into 378 smaller verification blocks measuring 10 by 10 m (100 m^2). Blocks are uniquely identified by the alphabetic identifier and location number within the larger grid (e.g., V-KL-370). Composite verification soil samples were collected from the verification blocks are shown in Plates 1 and 2.

5.4.2 Gamma Scan Measurements

The accessible excavated surface was 100 percent scanned for gamma using the handheld crutch scintillometers. To minimize the amount of soil sampling required, field personnel determined a range of gamma readings that were representative of the background in the excavated area. A working cutoff of 9.6 microroentgens per hour (μR/h) was used for excavation control during remediation.

To determine the background ranges for the excavated area, the GS/GPS data were used to calculate the average gamma for verification blocks where soil sampling showed the block met the cleanup standard. Each gamma value represents the average of approximately 30 GS/GPS measurements within that block. A summary of the block averages is shown in Table 3. The paired average gamma and Ra-226 soil results for the gamma data are shown in Table 4 and graphically presented in Figure 2. The block locations are shown in Plates 1 and 2.

Table 3. Verification Background Gamma Levels

Type of Measurement	Range of Background Values	Average Background Value	Excavation Control Gamma Cutoff
Collimated Surface Excavation (0–15 cm)	3.5 to 12.8 μR/h	6.1 μR/h	9.6 μR/h

*μR/h microroentgens per hour

The results of the GS/GPS scans prior to backfilling and final grading are shown in Plate 2. No GS/GPS data were collected for blocks V-KH-89, -109, -110, -111, -131, -132, and -153, V-LD-248, -249, 258, -259, -269, and -270, and V-LH-204A, -225, -246, -267, and -288 because they were verified by 100 percent soil sampling due to deep excavations, steep terrain, or other access problems. The other areas on Plate 2 which do not show gamma measurements are gaps in the plot due to imprecision in the GPS locations.

5.4.3 Soil Measurements

After remediation, the level of Ra-226 in soil was verified by collecting composite soil samples from selected 100 m^2 verification blocks. The blocks were randomly selected by verification personnel to give a representative coverage of the remediated area. Composite samples were taken by dividing a block into approximately nine equal sub-blocks and then collecting an aliquot at the center of each sub-block. Soil samples were analyzed for Ra-226 using the OCS method. Soil analyses are provided in Table 4.

A total of 180 locations (Table 4) were sampled by the RAC and TAC. The RAC collected 158 OCS soil samples, and 16 were submitted to an independent laboratory for confirmatory analysis. Fifteen samples were from areas verified to the surface (0 to 15 cm) standard and one was from an area verified to the subsurface standard (>15 cm). This exceeds the quality control guidance in the Field Services Procedures Manual that requires 5 percent of the samples be submitted to an outside laboratory. The results of the OCS and laboratory analyses are provided in Table 4. The laboratory analytical results validated the use of OCS for soil verification. The 16 verification samples measured by both the RAC (OSC method) and the independent laboratory averaged 1.8 pCi/g and 1.7 pCi/g, respectively.

The independent laboratory that performed the quality control analyses was Paragon Analytics (PA), Fort Collins, Colorado. PA analyzed Ra-226 by EPA method 901.1M (PA SOP 739), Th-230 by ASTM method D3972-90M (PA SOP 714), and uranium by EPA method SW 6020A (PA SOP 827). All methods are approved by DOE.

Table 4. Summary of Soil Data and Gamma Data After Remedial Excavation

Verification Block ID	Sample Ticket No.	Sample Date	Sample Depth (cm)	OCS Ra-226 (pCi/g)	Lab Ra-226 (pCi/g)	HPGe U pCi/g	Lab U (pCi/g)	Lab Th-230 (pCi/g)	Average Collimated Gamma (µR/h)
V-KD-209	RAA-164	06/23/08	0-15	2.7					8.1
V-KD-292	PAA 436	02/11/08	0-15	1.0					6.9
V-KD-315	RAA 011	12/17/07	0-15	3.4					7.1
V-KD-334	RAA 008	12/17/07	0-15	4.6					6.9
V-KD-357	RAA 009	12/17/07	0-15	2.3					7.0
V-KD-376	RAA 010	12/17/07	0-15	4.7					8.4
V-KE-017	RAA 067	01/10/08	0-15	4.3					6.3
V-KE-025	PAA 433	02/11/08	0-15	1.7					5.7
V-KE-027	RAA 012	12/19/07	0-15	3.3					7.0
V-KE-032	RAA 079	01/10/08	0-15	1.9					4.5
V-KE-041	RAA 068	01/10/08	0-15	1.6					5.8
V-KE-058	RAA 073	01/10/08	0-15	3.1	1.5		0.9	1.28	5.7
V-KE-070	RAA 013	12/19/07	0-15	2.8					6.6
V-KE-081	RAA 031	12/27/07	0-15	1.9					6.2
V-KE-089	RAA 014	12/19/07	0-15	2.3					5.8
V-KE-099	RAA 032	12/27/07	0-15	2.9					5.8
V-KE-114	RAA 015	12/19/07	0-15	0.3		7.4			5.5
V-KE-124	RAA 033	12/27/07	0-15	3.5					5.8
V-KE-142	RAA 034	12/27/07	0-15	3.1					6.0
V-KE-152	RAA 019	12/20/07	0-15	3.5	2.1		0.8	1.10	6.0
V-KE-156	RAA 020	12/20/07	0-15	4.6					6.9
V-KE-160	PAA 434	02/11/08	0-15	2.4					6.3
V-KE-165	RAA 035	12/27/07	0-15	3.3		6.8			5.3
V-KE-175	RAA 021	12/20/07	0-15	2.7					7.5
V-KE-183	RAA 036	12/27/07	0-15	2.4					5.5
V-KE-200	RAA 022	12/20/07	0-15	4.3					7.1
V-KE-208	RAA 037	12/27/07	0-15	1.4					6.4
V-KE-210	RAA 052	01/03/08	0-15	2.6					7.7
V-KE-214	RAA 023	12/20/07	0-15	3.3		11.5			6.8
V-KE-226	PAA 435	02/11/08	0-15	1.8					7.2
V-KE-242	RAA 024	12/20/07	0-15	3.3					6.9
V-KE-245	RAA 042	12/28/07	0-15	3.8					8.2
V-KE-246	RAA 043	12/28/07	0-15	4.4		11.4			10.7
V-KE-247	RAA 159	06/23/08	0-15	2.2					10.1
V-KE-256	RAA 025	12/20/07	>15	4.9					9.0
V-KE-257	RAA 160	06/23/08	>15	4.2					8.3
V-KE-258	PAA 437	02/11/08	0-15	1.5					6.7
V-KE-260	RAA 026	12/20/07	0-15	0.5					7.0

Table 4. Summary of Soil Data and Gamma Data After Remedial Excavation (continued)

Verification Block ID	Sample Ticket No.	Sample Date	Sample Depth (cm)	OCS Ra-226 (pCi/g)	Lab Ra-226 (pCi/g)	HPGe U pCi/g	Lab U (pCi/g)	Lab Th-230 (pCi/g)	Average Collimated Gamma (µR/h)
V-KE-266	RAA 039	12/27/07	0-15	1.8					7.1
V-KE-267	RAA 044	12/28/07	0-15	4.3					8.2
V-KE-274	RAA 006	12/17/07	0-15	3.3					6.5
V-KE-298	RAA 161	06/23/08	0-15	5.0					8.5
V-KE-301	RAA 027	12/20/07	0-15	0.6					7.1
V-KE-304	RAA 162	06/23/08	0-15	0.8					10.2
V-KE-305	RAA 163	06/23/08	0-15	1.1					9.5
V-KE-318	RAA 028	12/20/07	0-15	3.3		15.4			9.1
V-KE-324	RAA 029	12/20/07	0-15	3.4					8.1
V-KE-325	RAA 030	12/20/07	0-15	2.6					8.1
V-KF-006	RAA 128	02/13/08	0-15	1.5					4.4
V-KF-009	RAA 115	01/30/08	0-15	2.2		7.4			5.1
V-KF-020	RAA 117	01/30/08	0-15	1.2					4.4
V-KF-023	RAA 078	01/10/08	0-15	2.0	1.0		1.7	1.11	5.7
V-KF-032	RAA 108	01/30/08	0-15	1.2					5.8
V-KF-038	PAA 432	02/07/08	0-15	0.5					5.0
V-KF-047	RAA 080	01/10/08	0-15	3.3					5.7
V-KF-050	RAA 129	02/13/08	0-15	1.0					4.8
V-KF-055	RAA 106	01/30/08	0-15	2.4					5.3
V-KF-057	RAA 111	01/30/08	0-15	1.8	1.0		2.1	0.66	5.3
V-KF-066	RAA 157	06/23/08	0-15	3.0					8.5
V-KF-087	RAA 045	12/28/07	0-15	4.5					8.6
V-KF-088	RAA 158	06/23/08	0-15	1.9					7.3
V-KF-091	RAA 074	01/10/08	0-15	1.4		8.3			6.8
V-KF-107	RAA 040	12/27/07	0-15	1.7					7.1
V-KF-110	RAA 069	01/10/08	0-15	1.8					6.5
V-KF-128	RAA 165	06/23/08	0-15	4.1					8.0
V-KF-132	RAA 105	01/30/08	0-15	0.7					6.2
V-KF-149	RAA 046	12/28/07	0-15	4.7					7.1
V-KF-169	RAA 041	12/27/07	0-15	1.8					7.1
V-KF-170	PAA 440	02/12/08	0-15	2.2					8.2
V-KF-171	RAA 047	12/28/07	0-15	1.9					12.8
V-KF-190	RAA 050	01/03/08	0-15	3.7					8.2
V-KF-191	RAA 051	01/03/08	0-15	2.4					9.1
V-KG-002	RAA 107	01/30/08	0-15	1.3	1.5		1.0	1.45	4.7
V-KG-005	RAA 109	01/30/08	0-15	3.3					5.0
V-KG-028	RAA 053	01/05/08	0-15	3.9					6.3
V-KG-035	RAA 054	01/05/08	0-15	1.2					6.6
V-KG-044	RAA 113	01/30/08	0-15	0.7					5.5
V-KG-047	RAA 118	01/30/08	0-15	2.7					5.7
V-KG-052	PAA 429	02/07/08	0-15	3.5					5.9
V-KG-062	RAA 056	01/05/08	0-15	2.2					5.3
V-KG-074	PAA 438	02/11/08	0-15	2.8					6.3

Table 4. Summary of Soil Data and Gamma Data After Remedial Excavation (continued)

Verification Block ID	Sample Ticket No.	Sample Date	Sample Depth (cm)	OCS Ra-226 (pCi/g)	Lab Ra-226 (pCi/g)	HPGe U pCi/g	Lab U (pCi/g)	Lab Th-230 (pCi/g)	Average Collimated Gamma (µR/h)
V-KG-078	RAA 061	01/05/08	0-15	2.3	2.6		1.0	1.33	6.5
V-KG-103	RAA 057	01/05/08	0-15	2.2					6.3
V-KH-001	RAA 154	06/23/08	0-15	0.9					6.2
V-KH-003	PAA 414	12/03/07	0-15	0.7					5.7
V-KH-044	RAA 058	01/05/08	0-15	1.3	1.4	6.2	0.5	0.73	6.4
V-KH-048	RAA 059	01/05/08	0-15	2.7					6.9
V-KH-089	RAA 083	01/15/08	>15	4.8					7.1
V-KH-107	RAA 060	01/05/08	0-15	1.4					6.0
V-KH-109	RAA 155	06/23/08	>15	3.0					
V-KH-110	RAA 084	01/15/08	>15	4.6					
V-KH-111	RAA 085	01/15/08	>15	4.0	6.7		7.4	6.00	
V-KH-130	RAA 082	01/15/08	0-15	3.7					6.2
V-KH-131	RAA 087	01/15/08	>15	4.4					
V-KH-132	RAA 088	01/15/08	>15	4.8					
V-KH-153	RAA 089	01/15/08	>15	3.3					
V-KH-174	PAA 427	02/07/08	0-15	3.2					6.1
V-LD-133	PAA 453	02/27/08	0-15	0.65					8.2
V-LD-159	RAA 138	02/26/08	0-15	2.6					3.9
V-LD-162	PAA 454	02/27/08	0-15	1.48					4.2
V-LD-176	RAA 139	02/26/08	0-15	0.4					4.9
V-LD-183	RAA 140	02/26/08	0-15	3.0					3.5
V-LD-201	RAA 143	03/03/08	0-15	0.4					3.7
V-LD-208	RAA 136	02/20/08	0-15	2.7		12.2			4.3
V-LD-217	RAA 144	03/03/08	0-15	3.1					4.6
V-LD-224	RAA 142	03/03/08	0-15	0.9					4.3
V-LD-230	RAA 137	02/20/08	0-15	1.2					4.6
V-LD-241	RAA 141	03/03/08	0-15	0.6					4.6
V-LD-248	RAA 148	03/04/08	0-15	0.3					
V-LD-249	PAA 494	06/30/08	0-15	1.3					
V-LD-258	RAA 145	03/03/08	0-15	1.9					
V-LD-259	RAA 146	03/03/08	0-15	2.5					
V-LD-266	RAA 147	03/03/08	0-15	0.1					4.6
V-LD-269	RAA 149	03/04/08	0-15	0.4					
V-LD-270	RAA 150	03/04/08	0-15	1.5					
V-LD-315	RAA 064	01/09/08	0-15	1.8	1.4		0.8	1.05	5.0
V-LE-192	RAA 132	02/20/08	0-15	3.1		12.2			4.3
V-LE-211	RAA 133	02/20/08	0-15	1.3					4.2
V-LE-215	RAA 134	02/20/08	0-15	3.1					4.2
V-LE-279	RAA 062	01/09/08	0-15	2.1		7.9			5.1
V-LE-282	RAA 063	01/09/08	0-15	4.3					5.3
V-LE-298	RAA 065	01/09/08	0-15	1.7					4.9
V-LE-306	RAA 070	01/10/08	0-15	1.1					5.2
V-LE-317	RAA 066	01/09/08	0-15	0.7		5.1			4.9

Table 4. Summary of Soil Data and Gamma Data After Remedial Excavation (continued)

Verification Block ID	Sample Ticket No.	Sample Date	Sample Depth (cm)	OCS Ra-226 (pCi/g)	Lab Ra-226 (pCi/g)	HPGe U pCi/g	Lab U (pCi/g)	Lab Th-230 (pCi/g)	Average Collimated Gamma (µR/h)
V-LE-325	RAA 071	01/10/08	0-15	1.3	0.9		0.4	0.41	4.4
V-LE-331	RAA 072	01/10/08	0-15	1.4					6.0
V-LE-340	RAA 018	12/19/07	0-15	0.2					5.2
V-LE-364	RAA 016	12/19/07	0-15	0.4					7.4
V-LE-369	RAA 076	01/10/08	0-15	0.6					4.6
V-LE-376	RAA 077	01/10/08	0-15	1.1					5.7
V-LF-296	RAA 130	02/13/08	0-15	1.3					4.4
V-LF-308	RAA 127	01/30/08	0-15	2.6					5.0
V-LF-329	RAA 121	01/30/08	0-15	0.9		16.9			5.2
V-LF-334	RAA 122	01/30/08	0-15	1.3	0.8		1.3	1.13	4.3
V-LF-340	RAA 131	02/13/08	0-15	2.2					4.6
V-LF-344	RAA 112	01/30/08	0-15	1.3	1.5		0.6	1.33	4.7
V-LF-359	RAA 075	01/10/08	0-15	1.8					5.4
V-LF-367	RAA 125	01/30/08	0-15	4.1					5.0
V-LF-370	PAA 430	02/07/08	0-15	1.0					5.1
V-LF-375	RAA 126	01/30/08	0-15	1.2					4.6
V-LG-271	RAA 092	01/16/08	0-15	4.0		14.5			7.2
V-LG-285	PAA 431	02/07/08	0-15	2.8					6.8
V-LG-290	RAA 091	01/16/08	0-15	1.0	2.3		1.8	1.22	6.0
V-LG-296	RAA 123	01/30/08	0-15	3.4		9.4			5.4
V-LG-302	RAA 094	01/16/08	0-15	4.1					7.1
V-LG-304	RAA 095	01/16/08	0-15	4.4		15.0			6.5
V-LG-309	RAA 096	01/16/08	0-15	4.2					6.2
V-LG-314	PAA 419	12/04/07	0-15	0.5					4.9
V-LG-315	PAA 421	12/04/07	0-15	0.2					5.6
V-LG-320	RAA 119	01/30/08	0-15	1.0	1.9		1.4	1.20	4.9
V-LG-339	RAA 110	01/30/08	0-15	2.3					5.1
V-LG-346	RAA 093	01/16/08	0-15	2.8					5.2
V-LG-354	RAA 097	01/16/08	0-15	1.2					5.4
V-LG-357	PAA 413	12/03/07	0-15	1.4					5.9
V-LG-358	RAA 114	01/30/08	0-15	0.6					4.4
V-LG-362	RAA 124	01/30/08	0-15	2.7					4.7
V-LG-364	RAA 098	01/16/08	0-15	0.6					5.3
V-LG-371	RAA 099	01/16/08	0-15	1.0		4.3			5.5
V-LH-204A	PAA 405	11/27/07	>15	0.8					
V-LH-222	PAA 410	11/29/07	0-15	2.0	0.5		2.5	0.28	4.2
V-LH-225	PAA 406	11/27/07	>15	0.6					
V-LH-238	PAA 428	02/07/08	0-15	3.4					4.4
V-LH-241	PAA 411	11/29/07	0-15	0.6					5.9
V-LH-246	PAA 407	11/27/07	>15	1.2					
V-LH-254	RAA 002	12/12/07	0-15	4.8					4.5
V-LH-257	RAA 003	12/12/07	0-15	4.7					4.9
V-LH-265	PAA 412	11/29/07	0-15	1.5					7.1

Table 4. Summary of Soil Data and Gamma Data After Remedial Excavation (continued)

Verification Block ID	Sample Ticket No.	Sample Date	Sample Depth (cm)	OCS Ra-226 (pCi/g)	Lab Ra-226 (pCi/g)	HPGe U pCi/g	Lab U (pCi/g)	Lab Th-230 (pCi/g)	Average Collimated Gamma (µR/h)
V-LH-267	PAA 408	11/27/07	>15	1.1					
V-LH-277	RAA 004	12/12/07	0-15	1.9					5.7
V-LH-279	PAA 439	02/12/08	0-15	4.9					6.2
V-LH-280	PAA 441	02/12/08	0-15	2.8					6.6
V-LH-288	PAA 409	11/27/07	>15	4.0		9.4			
V-LH-295	PAA 417	12/04/07	0-15	2.4					9.7
V-LH-296	PAA 422	12/04/07	0-15	2.0					5.0
V-LH-297	PAA 418	12/04/07	0-15	1.9					6.4
V-LH-301	RAA 156	06/23/08	0-15	1.1					8.4
V-LH-316	PAA 415	12/03/07	0-15	1.1					5.7
V-LH-317	PAA 420	12/04/07	0-15	0.4	0.6		2.3	0.56	5.7
V-LH-322	RAA 005	12/12/07	0-15	4.6					5.7
V-LH-340	PAA 416	12/03/07	0-15	0.5					5.7
Surface (0-15 cm) Statistics									
Number of Samples				166	15	17	15	15	153
Minimum				0.1	0.5	4.3	0.4	0.3	3.5
Maximum				5.0	2.6	16.9	2.5	1.5	12.8
Average				2.2	1.4	10.1	1.3	1.0	6.1
Standard Deviation				1.3	0.6	3.9	0.7	0.4	1.5
Subsurface (>15 cm) Statistics									
Number of Samples				14	1	1	1	1	2
Minimum				0.6	6.7	9.4	7.4	6.0	8.3
Maximum				4.9	6.7	9.4	7.4	6.0	9.0
Average				3.3	6.7	9.4	7.4	6.0	8.6
Standard Deviation				1.6	NA	NA	NA	NA	2.0

Note: Blank cells indicate no measurement for that analyte or by that method were taken.
*Average gamma is based on multiple collimated GS/GPS readings for the verification block.

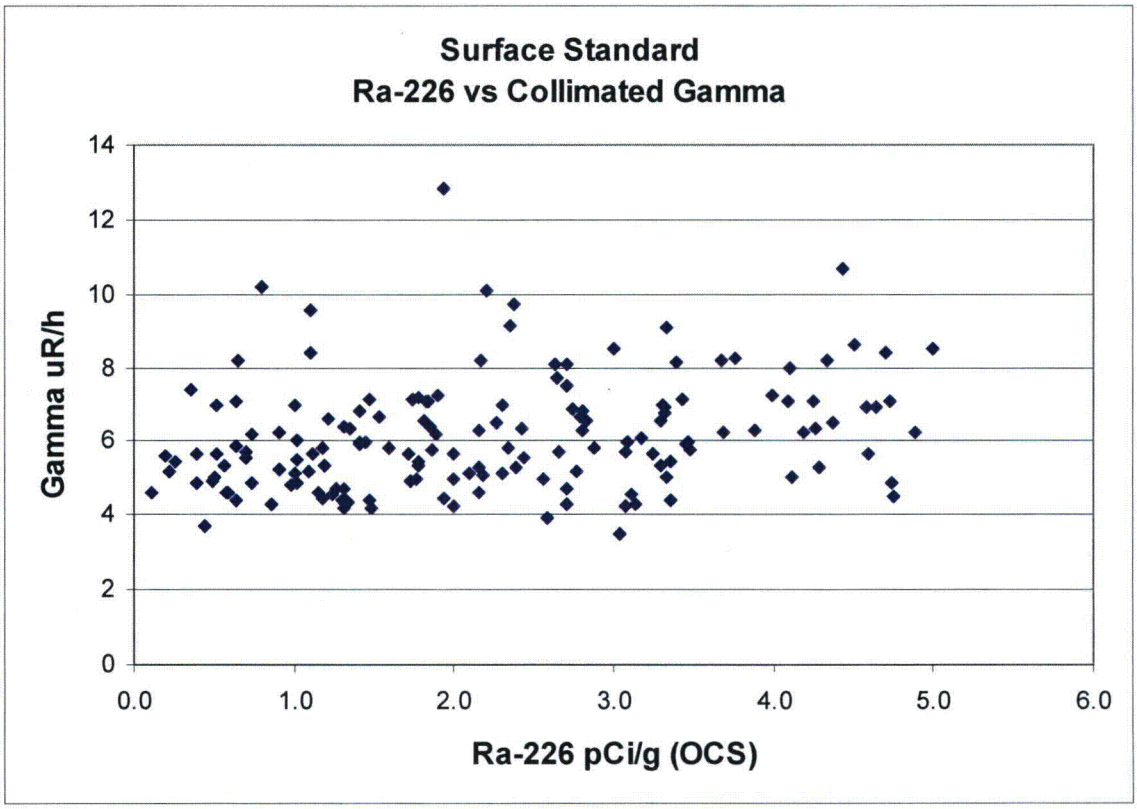

Figure 2. Collimated Data for Areas Verified to the Surface Standard

The TAC evaluated the gamma scan data and selected 22 grid blocks for independent sampling. Samples were collected in areas where the average gamma reading exceeded the working gamma cutoff of 9.6 μR/h. Elevated gamma levels may be due to adjacent unremediated areas such as the tailings pile, supplemental standards area (Plate 1), or material in the excavation that is slightly elevated in radium concentration but still below the radium in soil standard. Not all blocks that exceeded the gamma cutoff were sampled, but the blocks with the highest gamma were selected. All independently sampled blocks meet the relevant Ra-226 in soil criteria. This helps demonstrate that the areas with gamma levels that are above the site background still meet the Ra-226 criteria. A total of 180 locations (Table 4) were sampled by the RAC and the TAC.

The TAC independently collected duplicate soil samples at 12 grid blocks. The TAC samples were collected separately from the RAC samples, and the aliquots which made up the samples may have been taken from slightly different locations within each grid block. This may account for some of the variability between the results. All samples were from areas verified to the surface (0 to 15 cm) standard and all results are below this standard. The result of the comparison between the RAC and TAC samples are shown in Table 5.

Table 5. Comparison of OCS Ra-226 Results for the TAC and RAC Soil Samples

Verification Block ID	RAC Ticket Number	TAC Ticket Number	Sample Date	TAC OCS Ra-226	RAC OCS Ra-226
V-KD-292	RAA 007	PAA 436	12/17/2007	1.01	4.66
V-KE-025	RAA 017	PAA 433	12/19/2007	1.72	3.77
V-KE-226	RAA 038	PAA 435	12/27/2007	1.77	2.43
V-KF-038	RAA 116	PAA 432	1/30/2008	0.5	1.29
V-KF-170	RAA 048	PAA 440	1/3/2008	2.17	1.65
V-KG-052	RAA 055	PAA 429	1/5/2008	3.45	1.99
V-KH-174	RAA 086	PAA 427	1/15/2008	3.17	2.46
V-LD-201	RAA 143	PAA 455	3/3/2008	0.39	0.44
V-LD-230	RAA 137	PAA 451	2/20/2008	3.44	1.15
V-LF-370	PAA 430	RAA 120	1/30/2008	1	0.8
V-LG-285	PAA 431	RAA 090	1/16/2008	2.8	2.28
V-LH-238	PAA 428	RAA 001	12/12/2007	3.35	2.9
Average				2.38	2.20

6.0 Final Condition

A summary of radiological results after remediation is provided in Table 6. Because of limitations of current technology and procedures for identifying and remediating residual radioactive material (RRM), unknown deposits of contamination may exist below the levels excavated during this remediation. The remediated area will be contoured and planted with native vegetation.

6.1 Areas Verified to the Subsurface Standard (>15 cm)

The 40 CFR 192 standard for subsurface areas is 15.8 pCi/g Ra-226. For subsurface areas the maximum concentration by the OCS method was 4.9 pCi/g, the maximum laboratory concentration was 6.7 pCi/g. Both values are below the cleanup standard (Table 6). The mean Ra-226 concentration by the OCS method was 3.3 pCi/g. The projected upper limit of the mean concentration, calculated at the 95 percent confidence level, was 4.0 pCi/g. These results indicate that the radionuclide concentrations do not exceed the Authorized Limits; therefore, all cleanup criteria have been met for the areas verified to the subsurface standard.

All areas verified to the subsurface standard were backfilled with a minimum of 15 cm (6 inches) of material. Backfill material was taken from clean material stockpiled onsite and was gamma scanned prior to placement.

6.2 Areas Verified to the Surface Standard

For areas verified to the surface standard, the maximum concentration of Ra-226 was 5.0 pCi/g, which is below the cleanup standard of 5.8 pCi/g (Table 6). The mean concentration was 2.2 pCi/g. The projected upper limit of the mean concentration, calculated at the 95 percent confidence level, was 2.35 pCi/g. These results indicate that the radionuclide concentrations do not exceed the Authorized Limits; therefore, all cleanup criteria have been met for the areas verified to the surface standard.

Table 6. Summary of Radiological Release Survey Results

Certification Criteria	Number of Observations	Cleanup Standard	Cleanup Standard Including Background	Results pCi/g
Ra-226 (pCi/g) Surface	166	Shall not exceed 5 pCi/g above background over the first 15 cm of soil below the surface, averaged over 100 m^2	5.8	OCS Analysis Sample mean = 2.2 Maximum = 5.0 Std. dev = 1.3 $z_{95\%}$ = 1.65 $\mu_{95\%}$ = 2.35
Th-230 (pCi/g) Surface	15	Shall not exceed 5 pCi/g above background over the first 15 cm of soil below the surface, averaged over 100 m^2	5.8	Laboratory Analysis Sample mean = 1.0 Maximum = 1.5
Uranium Surface	15	Not determined	Not determined	Laboratory Analysis Sample mean = 1.3 Maximum = 2.5
Ra-226 (pCi/g) Subsurface	14	Shall not exceed 15 pCi/g above background in any 15 cm of soil more than 15 cm below the surface, averaged over 100 m^2	15.8	OCS Analysis Sample mean = 3.3 Maximum = 4.9 Std. dev = 1.6 $z_{95\%}$ = 1.65 $\mu_{95\%}$ = 4.0
Th-230 (pCi/g) Subsurface	1	Shall not exceed 15 pCi/g above background in any 15 cm of soil more than 15 cm below the surface, averaged over 100 m^2	15.8	Laboratory Analysis Sample mean = 6.0 Maximum = 6.0
Uranium Subsurface	1	Not determined	Not determined	Laboratory Analysis Sample mean = 7.4 Maximum = 7.4

NA = not applicable
n = number of measurements
$z_{95\%}$ = z distribution statistic at 95 percent confidence (n=166 for > 15 cm surface), (n = 14 for 0 to 15 cm subsurface)
$\bar{x}$ = sample mean
S = Std. dev., the sample standard deviation
$\mu_{95\%}$ = upper limit of the true population mean at the 95 percent confidence level, using the following equation:

$$\mu_{95\%} = \bar{x} + z_{95\%} \frac{s}{\sqrt{n}}$$

7.0 References

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42 U.S.C. 4321. EPA (Environmental Protection Agency), National Environmental Policy Act, *United States Code*, January 2007.

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End of current text

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Assessed Soil Contamination
Off-Pile Remediation Project,
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Gamma Map
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