Moab Project
Verification using Gamma Measurements and Soil Sampling

Background
The Stoller Field Services group is responsible for overseeing the radiological cleanup of the Moab Millsite. The primary standard that guides the cleanup is the radium-in-soil standards from 40 CFR 192. The standard operating procedures (SOPs) that are used to accomplish this are contained in the *Field Services Procedures Manual, Chapter 3, Excavation Control and Verification Procedures (STO-203).*

Historically (for example, at other UMTRA Millsites and at Grand Junction Vicinity Properties) compliance with the radium-in-soil standard was demonstrated by collecting composite soil samples over a grid covering 100 percent of the surface of the remediated area.

During the planning for the Moab Millsite remediation, a new cost savings procedure was proposed that would reduce soil sampling. The procedure was based on NRC-approved procedures used at Title II Sites. The procedure established a correlation between radium concentration in soil (from composite soil samples) and average shielded gamma measurement Paired soil sample and gamma measurements were both taken from the same verification block. Using these data, a statistical analysis was used to determine a cutoff gamma value at which there was a 95% confidence that the radium-in-soil standard would be met. All remediated areas that are 100% gamma scanned with continuous gamma measurements and were at or below that cutoff would not require soil sampling. At least 5 percent of the area would be sampled regardless of the gamma level. The gamma cutoff for the surface standard (5 pCi/g Ra-226) was determined to be 4.6 μR/hr, including background. No gamma cutoff was statistically determined for excavations where the subsurface standard of 15 pCi/g would be applied, because at that time all the areas being remediated were verified to the surface standard.

Implementation During Initial Remediation of the Millsite
During the initial remediation of the Millsite the established gamma cutoff of 4.6 μR/hr was found to be impractical. Even after selective soil sampling had demonstrated an area met the radium-in soil standard, about half the gamma readings within a given area exceeded the cutoff. This was due to natural variability in the background gamma level and the effects of shine from adjacent unremediated areas, even using shielded detectors. If the 4.6 μR/hr cutoff had been strictly applied, most of the excavated areas would still have required soil sampling or the soils would have been cleaned to background.

Field personnel modified the 4.6 μR/hr cutoff by adding a background value of 5.0 μR/hr to the cutoff, making their default cutoff 9.6 μR/hr. (Note, however the 4.6 μR/hr cutoff already included background.) They also collected paired gamma and soil sample data to determine an average gamma range for the excavation in areas with elevated gamma levels due to shine. As a working guideline, gamma exposure rates that were 30% or more above the default cutoff or the average excavation gamma were considered anomalous and were investigated further with soil sampling or gamma measurements

using shielded handheld instruments. Some, but not all, of this additional investigation was documented. The amount of verification soil sampling was also increased from the required 5 percent to approximately 10 to 20 percent of the excavation area.

When Stoller began writing the completion report appendix packages for the millsite it was discovered that the 4.6 μR/hr cutoff had not been strictly followed. As a result of this finding, and to assure that the remediation had met the radium-in-soil standard, Stoller performed additional biased soil sampling in areas which showed gamma exposure rates that were significantly above the average gamma for the excavation. The rationale behind the biased sampling was that if contamination above the standards had been left in place, it would most likely be found in the locations which showed the highest gamma after remediation. Since the biased samples collected from the described areas met the standard, it is likely that the remaining, unsampled areas with lower gamma levels (but still above the 4.6 μR/hr cutoff) would also meet the standard. Some of the areas that had higher gamma were covered (backfilled) by several feet of clean fill and were not sampled. However, we believe the elevated gammas in these areas were due to shine from adjacent areas that had not yet been remediated.

Attachment 1 shows a graph of the gamma vs. radium data collected during verification sampling for two of the large areas verified during this period. All of the radium values for the surface standard fall below 5.8 pCi/g although roughly half of the correlated gamma readings are between 4.6 and 9.6 uR/hr. In addition, for the samples taken for the subsurface standard, all of the radium values fall below the 15.8 pCi/g standard with the majority meeting the 5.8 pCi/g surface standard. Although not a linear correlation between gamma and radium, the cutoff of 9.6 uR/hr leads to a high confidence that the radium in soil standard is met using the gamma measurements.

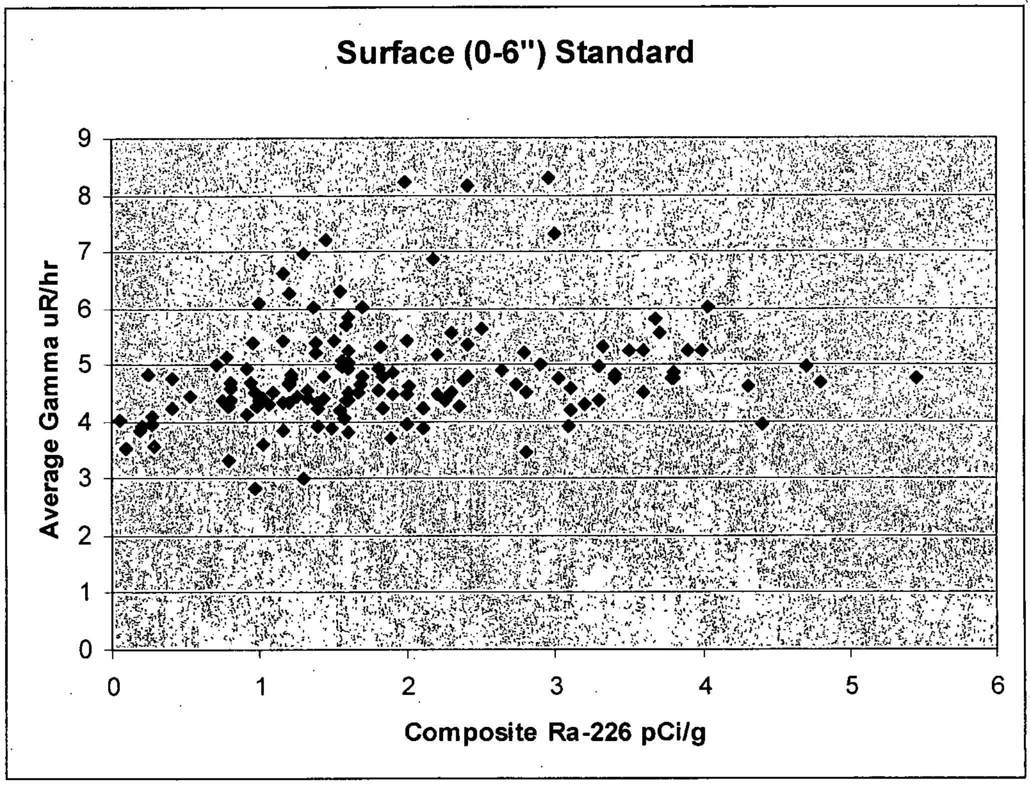
Proposed Verification Procedure for Future Millsite Remediation
To control cost by limiting soil sampling, but still adequately demonstrate that the Millsite meets the radium standard, the Field Services Procedures Manual, Chapter 3, *Excavation Control and Verification Procedures*, section 4.6, *Global Positioning System/Gamma Scan (GS/GPS) Verification Method* will be changed as described below. Attachment 2 contains the revised procedure.

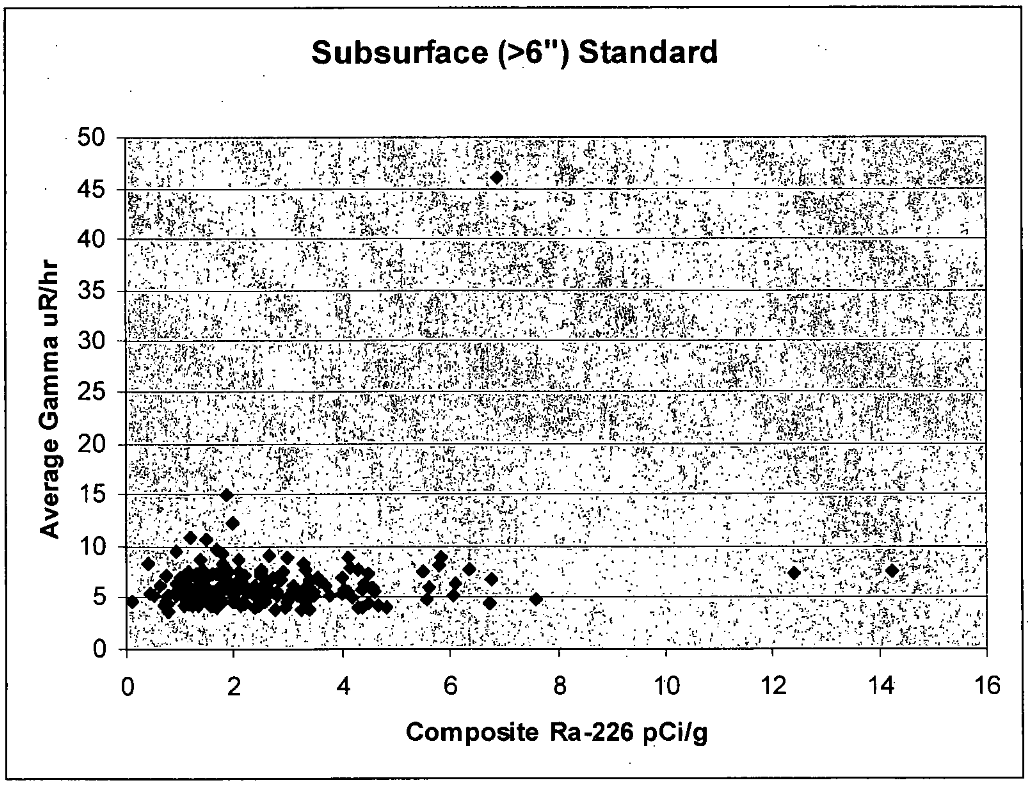
After the Field Services group believes that an excavation is ready for verification, they will mark out the 10-meter by 10-meter verification grid blocks on the excavation. Then they will collect composite soil samples using procedures contained in Chapter 16, "Radiological Soil Sampling" and scan the area to measure the average gamma from a minimum of 10 percent of the grid blocks. The grid blocks will be selected to give representative coverage across the excavation, to present a reasonably uniform gamma over their surface, and to represent a range of gamma levels. The average gamma measurements from the individual grid blocks will be averaged to find an average gamma for the excavation as a whole. This excavation average will be documented in the excavation control and verification log and on the verification field maps. Additional composite soil samples will be taken from any areas of the excavation that exceed the excavation average plus 30 percent. For example, if the average gamma for the

excavation is 9 μR/hr, then additional samples will be collected for the areas of the excavation that exceed 12 uR/hr. Portions of several grid blocks may be combined to create representative samples in the areas which have elevated gammas. The combined grid blocks must be less than or equal to 100 square meters in size. Excavations which are small in size may use the average gamma value determined from an adjacent larger excavated area with similar gamma rates.

The final GS/GPS scan data set for an area in conjunction with the OCS soil sample data will become the final verification record. Together the GS/GPS and OCS soil data will demonstrate the remediated area is either at a gamma level that would indicate successful remediation or sufficient soil sampling has been done to prove that the Ra-226 standard has been met.

Attachment 1: Graphs of Verification Data





Summary

The verification procedure for the Moab Millsite aimed to reduce soil sampling by establishing a gamma exposure rate cutoff correlated with Ra concentration in soil, below which soil sampling would not be required. During remediation, this cutoff proved to be so low that it provided no practical reduction in soil sampling. Instead, field personnel used gamma instruments to find anomalous areas within the excavation and took excavation control soil samples as needed to ensure all contamination was removed. After discovering that the 4.6 μR/hr cutoff had not been correctly used, the gamma data from the already excavated areas were analyzed and additional biased samples were collected from areas which were more than 30% above background. This process is ongoing as completion report data is evaluated and summarized for areas of the millsite that were remediated in 2005 and 2006. For future remediation the Field Services Procedure Manual (STO-203) will be revised to require soil sampling of all areas which exceed the average gamma of the excavation by 30% or more.

3.0 Excavation Control and Verification Procedures

1. Purpose

The purpose of this procedure is to define the radiological release criteria and procedures used for excavation control, verification to U.S. Environmental Protection Agency (EPA) standards, and related activities during remedial action for soils contaminated with residual radioactive material (RRM) associated with the Moab site.

2. Authorized Limits and Background Values

Table 1 summarizes the authorized limits for radiological contaminants in soil for the Moab Project.

Table 1. Authorized Limits for Soils, Including Background

Remediation Goals				
	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 (pCi/g)	Case-by-Case Basis		Case-by-Case Basis	

The Moab millsite will be remediated and soils verified for Ra-226 and Th-230. The Moab vicinity properties will be remediated for Ra-226.

The authorization limits for the millsite are based on compliance with 40 CFR 192.12. Authorized background radionuclide values for the projects in Table 1 are shown in Table 2.

Table 2. Authorized Background Values for Radionuclides

Program	Radium-226 (pCi/g)	Thorium-230 (pCi/g)	Uranium (pCi/g)	Source for Background Values
Moab Millsite and Vicinity Properties	0.8	0.5	1.2	Analytical laboratory values from background field samples collected

NOTE: To allow for the variability of the Opposed Crystal System (OCS) and delta-gamma instrument measurements for Ra-226, criteria of 5 picocuries per gram (pCi/g) and 15 pCi/g, will normally be used for the Moab Project.

A more detailed explanation of the standards follows.

40 CFR 192 contains requirements for radium in soil, interior gamma levels, and radon in habitable buildings. These standards are:

- **Radium in Soil:** The Ra-226 concentration in soil shall not exceed 5 pCi/g above background in the first 6 inches (15 centimeters [cm]) of soil (surface standard), averaged over 1,076 square feet (ft^2) (100 square meters [m^2]); and 15 pCi/g above background in any subsequent 6-inch (15-cm) layer (subsurface standard) averaged over 1,076 ft^2 (100 m^2).
- **Interior Gamma Radiation:** In any occupied or habitable building the level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour (μR/h). The U.S. Department of Energy (DOE) will apply the EPA standard as an average over a room-sized area of 100 ft^2 (9.3 m^2).
- **Radon:** A reasonable effort shall be made to achieve an annual average (or equivalent) radon decay-product concentration (RDC), including background, not to exceed 0.02 working level (WL). In any case, the RDC (including background) shall not exceed 0.03 WL.

Radium in soil is measured using the OCS method according to procedures contained in Chapter 4, "Opposed Crystal System (OCS) Soil Sample Analysis Criteria." Interior gamma measurements are made with handheld scintillometers in accordance with Chapter 5, "Portable Gamma Scintillometer Measurements." Radon is measured in accordance with procedures in Chapter 34, "Radon Decay-Product Concentration (RDC) Measurements."

UMTRA Project Th-230 Protocol: Th-230 undergoes radioactive decay to produce Ra-226. During remediation of Uranium Mill Tailings Remedial Action (UMTRA) Project millsites, a thorium standard was developed which ensures that, as Th-230 decays, the Ra-226 standard will not be exceeded over a 1,000-year performance period. The allowable amount of Th-230 is dependent upon the concentration of Ra-226 left in place. Table 1 shows the relationship of Th-230 to Ra-226 left in place. Thorium is measured by laboratory alpha spectrometry.

Uranium: DOE will negotiate with the Nuclear Regulatory Commission where and if a uranium standard applies. The DOE-developed software program RESRAD may be used to provide dose assessment methodology pertinent to the development of uranium cleanup standards. Uranium cleanup standards may also be based on source term materials, which could affect the long-term cleanup of the site ground water. Uranium is measured semi-quantitatively using a field

laboratory with a High-Purity Germanium spectrometry, and quantitatively using laboratory inductively coupled plasma mass spectrometry.

Radioactive material (RAM): must be transported according to procedures contained in U.S. Department of Transportation (DOT) regulations (49 CFR parts 171–178) or blended on site with contaminated material of a lower activity until it falls below the cut-off criteria. Under no circumstances should a package, which is suspected to contain radioactive or hazardous material, be transported until the appropriate shipping procedures have been completed by a certified shipper.

3. Excavation Control Procedures

3.1 Purpose

Excavation control assures that applicable radiological soil standards are met prior to verification sampling. Monitoring and sampling for Th-230 and uranium soil contamination is typically performed after the Ra-226 standard has been met (if applicable).

3.2 Preconstruction Survey Procedures

Guided by the Radiological and Engineering Assessment (REA) or verification plan, gamma scintillometers are used to relocate and mark previously identified areas of surface contamination. On properties greater than half an acre, a land surveyor or a global positioning system (GPS) may also assist the team in establishing grids and locating deposits based on previous data.

3.3 General Standard Excavation Control Procedure

After contaminated soil is excavated, gamma-scan surveys, beta-gamma surveys, and soil sampling are used to define any remaining contamination in the excavation. Excavation depths and boundaries may be increased or decreased based on the data collected. This process continues until acceptable concentrations of Ra-226, Th-230, or total U, if applicable, are determined within the excavated areas. Soil samples will be analyzed using the OCS for Ra-226 concentrations and by a High Purity Germanium photon detector (HPGe) system for uranium concentrations (semi-quantitative values only), if applicable. Th-230 soil concentrations will be determined using an approved analytical laboratory.

3.4 General Gamma Scan/Global Positioning System/ (GS/GPS) Procedure

A GS/GPS Procedure may be used in lieu of the Standard Excavation Control Procedure described in Section 3.3. This procedure will be used to demonstrate compliance through surface gamma measurements averaged over large areas rather than point-by-point compliance. The procedure will be used primarily where windblown contamination is prevalent and depth of contamination is fairly consistent. The procedure requires less soil sampling than the "standard" procedure.

3.5 Excavation Control Definitions

Background: Typically, the scintillometer background reading is approximately 120 counts per second (cps) at the surface and 200 cps subsurface (greater than 15-cm [6 inches]). The OCS

background is 0.8 pCi/g for Ra-226 for the Moab millsite and vicinity properties (VPs). Action levels specified in the procedures are based on these background levels.

Surface: The surface is gamma scanned and contaminated material is excavated until the 5 pCi/g radium cutoff is met as measured by the OCS. At applicable sites, isolated "hot spots" (up to 300 cps) of contaminated material may remain in place provided it is clearly documented in the Excavation Control and Verification Survey Log (Figure 1) that all authorized limits have been met. For these areas, averaging techniques (Section 7.1) are used.

Subsurface: For subsurface layers (greater than 15-cm [6 inches]), excavation will continue until the 15 pCi/g radium cutoff is met as measured by the OCS at applicable sites. Isolated "hot spots" (up to 400 cps) of contamination may remain in place, provided it is clearly documented in the Excavation Control and Verification Survey Log (Figure 1) that all authorized limits have been met.

An average count rate in the excavation is determined by using handheld scintillometers to scan the excavated area and recording on the verification map the low and high gamma readings observed in the excavation. The most commonly observed gamma reading in the excavation is considered the excavation's average gamma reading. GS/GPS data may also be used to generate an average count rate for the excavation. Excavation considerations may be required, taking into account various site conditions, such as excavation geometry and shine.

Anomalous areas, those with measurements 30 percent above the average count rate in the excavation, will be explored to assure that a buried tailings deposit does not exist. A 4- to 6-inch-deep shovel hole shall be made and a gamma measurement taken in the hole. A 30 percent or greater increase in the gamma count rate shows the need for further excavation. Soil samples may be taken to help determine if additional excavation is required.

Soil samples will be obtained from areas within the excavation. Those samples exceeding the applicable surface or subsurface criteria show the need for further excavation. Guidance for continued excavation will be based on the relative gamma readings within the excavation, or the OCS soil sample result, or both. (See Chapter 16, "Radiological Soil Sampling.")

Excavation Control Value: During excavation the Field Services group will collect soil samples from representative areas of the excavation, paired with gamma measurements from the same locations. The soil samples are from a single point, not a composite area, and the gamma measurements are made with handheld instruments. The gamma measurements may be collimated or uncollimated, depending on the amount of shine, but should be consistent for a given excavation.

The soil samples are analyzed by OCS to ensure they are below the appropriate Ra-226 standard (surface or subsurface). The soil sample/ gamma data is evaluated to determine an appropriate gamma cutoff. This value is the excavation control value, and is used during excavation to locate anomalous areas that would require further soil sampling or removal.

Typically, a gamma scan value equivalent to ~10.0 pCi/g Ra-226 is found to be appropriate for excavation control when applying the subsurface cleanup standard, allowing for inherent

variability in the relationship between gamma exposure rate and soil Ra-226 concentrations. A gamma scan value equivalent to ~3.5 pCi/g Ra-226 is normally appropriate when applying the surface cleanup standard

3.6 Excavation Control on Vertical Surfaces

A gamma scintillometer is used to scan the vertical faces of an excavation. If the following guidelines are exceeded, the anomaly shall be removed or soil sampling will be performed to demonstrate that the area meets the standard:

- The surface (first 6 inches) layer in the wall of the excavation shall not exceed 30 percent above the average gamma reading for the surface area of the excavation.
- Subsequent 6-inch (15-cm) layers in the walls of the excavation shall not exceed 30 percent above the average gamma reading of the excavation face.

The procedure for obtaining composite soil samples from vertical face cuts (e.g., under concrete slabs, asphalt, etc.) will be as follows:

- Composite-sample the area in 6-inch layers for each 10-foot (ft) horizontal interval. The sample aliquot should be taken at the highest gamma location in the interval. A minimum of 500 ml of material is needed.
- For surface concrete slabs that are not contaminated and are less than 6 inches (15 cm) thick, sample only the material under the slab. Then calculate the radium contamination over a full 6-inch (15-cm) interval (including the slab) and compare to the surface standard.
- The average Ra-226 concentration in the composite layer will be calculated using the following equation:

$$\frac{[A \times B] + [(6 - A) \times C]}{6}$$

Where: A = thickness of the interval from which soil sample was taken (inches)
B = concentration determined from soil sample (pCi/g)
C = concentration of interval not sampled (typically this is assumed to be the default background value given in Table 2)
6 = interval over which the EPA standard is applied in inches

Example: 4-inch-thick concrete slab with 2 inches of contaminated material under the slab. The 2-inch-thick lens contains 20 pCi/g Ra-226 and the 4-inch-thick slab is assumed to contain 2 pCi/g Ra-226.

Therefore:

$$\frac{[2 \times 20] + [(6 - 2) \times 2]}{6} = 8\ pCi/g$$

This value exceeds the surface soil standard and the slab and soil under it should be removed. Additional sampling may be required to ensure that the exposed surface is representative of the material under the entire area of the slab.

3.7 GS/GPS Final Excavation Gamma Scan

A GS/GPS may be used to scan applicable areas of the site, as per Section 3.4, providing location and gamma exposure rate data over the areas. The vehicle-based system utilizes the Garmin Legend (WAAS-enabled [accuracy-enhanced]) or equivalent handheld GPS unit to transmit date, time and location (latitude/longitude) data to a portable computer, at the same time exposure rate data from a Ludlum 2350/44-10, 2-inch NaI gamma detector system is recorded on the same computer. The data are jointly logged once per second, and may be plotted, color-coded for exposure rate, using ArcInfo (geographic information system) tools. An alternate system uses the Garmin iQue combination handheld WAAS-enabled GPS and PDA unit, acquiring and storing data directly from its internal GPS system, and accepting radiation data from an external Ludlum 2350/44-10 unit. (This alternate system is often used in a "backpack" configuration, allowing recording of location and exposure rate data by an individual walking over terrain difficult to navigate with a vehicle-based system.) In both systems, the gamma-detecting probe is suspended approximately 3 ft above the soil surface. Typically the probe will be collimated with lead shielding on the sides to reduce shine from adjacent unremediated areas. An uncollimated probe may be used in areas where shine does not influence the measurements. The accuracy of the GPS for the ATV-mounted units is approximately plus or minus 4.6 m (15 ft.). The accuracy of the backpack-mounted units is approximately plus or minus 1 m (3 ft.)

At the beginning of a GS/GPS scan a voltage spike may occur when the instrument is turned on or off. This is presented in the data as a gamma reading for the first or last record which is one or two orders of magnitude higher than other readings. Since it is a not a valid measurement, it should be removed from the data file.

Excavation control is performed by directing the excavation equipment to remove soil from areas that exceed the excavation control value. Following each soil removal pass, additional gamma scanning using handheld instruments is performed until all locations within the remediated area meet the excavation control value or soil sampling demonstrates compliance with the authorized limits.

Where gamma exposure interference from another source (shine) makes it difficult to use unshielded probes to perform excavation control, a shielded probe will be used for excavation control. The shield consists of a lead cylinder covering the outside (but not the bottom) of the 44-10 cylinder and extending above the 2-inch-high NaI detector crystal located inside the 44-10 probe cylinder. Because such shielding is likely to be necessary during the project, shielded systems will be employed at the same time as unshielded systems are being employed during development of correlation data between gamma exposure rates and soil Ra-226 OCS analyses. When excavation control is performed using shielded (columnated) probes, the shielded-probe excavation control exposure rate value will be used in place of the unshielded-probe value.

3.8 Unassessed Surface Areas Located During Construction

Anomalous areas, where surface gamma scintillometer measurements are 30 percent above the background for the property, will be explored to assure that buried tailings deposits do not exist. A 6-inch (15-cm) soil sample will be collected and a scintillometer measurement will be made in the hole. If the OCS analysis is greater than 5 pCi/g Ra-226, or if there is a 30 percent increase of the scintillometer readings in the hole, the area shall be further investigated.

4. Exterior Verification Survey

After tailings are excavated, verification surveys shall be performed in remediated areas to verify that excavated areas meet the soil standards specified in Table 1. Gamma scanning, soil samples, or both will be used to document the post-remediation radiological condition of the property, depending on the verification methodology.

4.1 Verification Mapping

The grid system for both the VP and millsite areas is based on Utah State Plane coordinates; however, a site-specific mapping and grid system will be used for the Moab Project site (millsite).

The mapping and grid system will divide the millsite property into 68 sections measuring 180 by 210 m. Each of these maps has been given a unique double letter designation from an alphabetic system based on an X, Y coordinate system. Each individual map is scaled to a 1:30 drawing with a 10- by 10-m grid. This unique system is used to set 30-m centers across the site, using wooden lath and stakes, establishing a grid system for Field Services personnel to collect radiological measurements for site verification. The 30-m centers are used to further delineate 10- by 10-m verification grids for each of the maps. There are 378 10- by 10-m grid blocks on each of the maps and the following unique numbering system will be used to identify verification areas for each map (Figure 2).

The 10- by 10-m grid blocks will be consecutively numbered beginning with the northwest grid block and moving west to east and north to south across the map. A system of letters and numbers will be used to track the location and identity of the verification soil samples.

V	=	Verification Sample
X	=	Excavation Control Sample
KJ	=	Map Designation Letter
180	=	Grid Block Number

Example: When a soil sample is submitted to the OCS operator and labeled as V-KJ-180, it can be identified as a verification sample from the 180 block of map KJ. A soil sample labeled as X-LG-165 would be identified as an excavation control sample from the 165 block of map LG. Since there is the potential to have more than 25,000 verification areas, this unique system allows the entire site to be pre-numbered and also gives the exact location of the soil sample in the identifying sample number.

A GPS will also be used to help physically locate V-areas, soil samples or gamma anomalies. This GPS may be linked to a portable computer or PDA unit for plotting V-areas/soil locations or color coded gamma exposure rate information. This system will also utilize ArcInfo(geographic information system) tools and will simultaneously be able to transmit date, time and location (latitude/longitude) data to the same portable computer or PDA.

4.2 Verification Definitions

V-areas on vicinity properties are areas of contamination that are excavated to remove residual radioactive materials. V-areas are documented on the vicinity property verification maps as V-1 through V-n ("n" represents the integer identifying the last verification area). The excavated

portions of the property are divided into approximately 100 m^2 areas and numbered appropriately. Verification soil samples are then collected from the V-areas, as required.

For vicinity properties near the millsite, V-Areas may be identified based on the millsite grid system.

Verification Soil Samples are collected using the procedure in Chapter 16, "Radiological Soil Sampling." Verification soil samples are collected to demonstrate compliance with the authorized limits for soil.

Aliquots are individual samples collected from a grid block within a V-area. The verification sample may be composited from two to twelve aliquots.

Standard Verification (SV) is a soil verification method based on subdividing a V-area of approximately 100 m^2 into 3.3 by 3.3 m grid blocks. An aliquot is taken from the center of each grid block, and one to nine aliquots are combined to form the verification samples (Figure 3).

4.3 Gamma Scintillometer Scan

Scintillometers and Exposure Rate Meters used for gamma-scan surveys shall have a current calibration and daily operational check performed.

Two methods of Verification and gamma scanning protocols will be employed on the Moab Project Site, which include the SV and GS/GPS methods. The SV scanning method will involve technicians using hand held gamma instrumentation in the excavation areas obtaining gamma scan information from specific areas of removal. Mapping and documentation of these types of scans will be accomplished through the use of on-site grid systems for physical location and annotation of data onto hard copy field maps for the areas being surveyed.

The GS/GPS scanning method will involve technicians using an integrated scanning system, combining real time GPS technology for physical location. Automated gamma measurements will be taken congruently and stored electronically in either a handheld iQue or pen-top computer. This information is collected from specific excavation areas via an ATV or backpack configured system. Mapping and data management will be accomplished through the use of system software, and may be GIS enhanced, if appropriate. Hard copy gamma maps will then be generated of the scanned excavation areas.

For Standard Verification the excavated area shall be gamma scanned with personnel using hand held Mount Sopris SC-132 crutch scintillometers. The range and average of scintillometer readings shall be recorded on the verification map. Elevated readings from adjacent areas (spillovers) may also be recorded on the map (VPs only). The readings for the SC-132 shall be converted to exposure rates using the factor from the following equation. (The equation is based on a correlation factor that is derived from comparison of readings to a Pressurized Ion Chamber.)

$$\mu R/h = (cps \times 0.0748) + 6.03$$

The range is determined by observing the high and low gamma scintillometer readings; the average is the gamma scintillometer reading most commonly observed during the scan of the excavation.

4.4 Soil Sampling Protocol

Verification sample locations are based on a grid system overlain onto the excavation. For each V-area, a composite sample is collected consisting of one aliquot from each grid block. The aliquots shall be of equal volume and represent a 6-inch (15-cm) depth interval.

For small verification areas, an individual sample may be collected.

If the sample exceeds the applicable soil standard, additional excavation will be performed, and the area will be resampled. Once sampling shows that the contaminant concentration is below the applicable standard, no further sampling is required.

Verification samples may be split (reduced in volume) following protocols contained in Chapter 16, "Radiological Soil Sampling."

4.5 100-m^2 Standard Verification Method

A 100-m^2 V-area will be subdivided into nine 3.3- by 3.3-m grids (Figure 2). Each 100-m^2 V-area shall be gamma scanned, and the range and average of scintillometer readings shall be recorded on the verification field map. The gamma range of the excavated area is determined by observing the high and low gamma scintillometer readings; the average is the gamma reading most commonly observed during the scan of the excavation.

Composite soil samples will be taken from the V-area to verify compliance with soil remediation goals. Aliquots will be taken from the geometric center of each 3.3- by 3.3-m cell and sampled as above.

For both the VP and the millsite areas, verification soil samples will be analyzed for Ra-226 concentrations using the OCS. In addition, soil samples may be analyzed for total uranium (for screening purposes only) by the HPGe system. For both the VPs and millsite, 10 percent of the total samples will be analyzed by an analytical laboratory for Ra-226 for quality control. The total number of samples submitted to the lab may be reduced to 5 percent after a statistically valid correlation between OCS and lab radium results is established.) Selected millsite samples may be analyzed by a subcontracted laboratory for Th-230 and total uranium. OCS results are used to demonstrate compliance with the authorized limits for Ra-226 soils; however, all analytical results for Ra-226, Th-230 and uranium will be reported in the completion report.

4.6 Gamma Scan/Global Positioning System/ (GS/GPS) Verification Method

After the Field Services group believes that an excavation is ready for verification, they will mark out the 10-m by 10-m verification grid blocks on the excavation. Then they will collect composite soil samples using procedures contained in Chapter 16, "Radiological Soil Sampling" and scan the area to measure the average gamma from a minimum of 10 percent of the grid blocks. The grid blocks will be selected to give representative coverage across the excavation, to present a reasonably uniform gamma over their surface, and to represent a range of gamma levels. The average gamma measurements from the individual grid blocks will be averaged to

find an average gamma for the excavation as a whole. This excavation average will be documented in the excavation control and verification log and on the verification field maps. Additional composite soil samples will be taken from any areas of the excavation that exceed the excavation average plus 30 percent. For example, if the average gamma for the excavation is 9 μR/hr, then additional samples will be collected for the areas of the excavation that exceed 12 uR/hr. Portions of several grid blocks may be combined to create representative samples in the areas which have elevated gammas. The combined grid blocks must be less than or equal to 100 m^2 in size. Excavations which are small in size may use the average gamma value determined from an adjacent larger excavated area with similar gamma rates.

The final GS/GPS scan data set for an area in conjunction with the OCS soil sample data will become the final verification record. Together the GS/GPS and OCS soil data will demonstrate the remediated area is either at a gamma level that would indicate successful remediation or sufficient soil sampling has been done to prove that the Ra-226 standard has been met.

This GS/GPS Verification Procedure will not be used in areas where process knowledge or assessment data indicates deep deposits or the potential for significant disequilibrium between Ra-226, and Th-230 and/or U-238 soil concentrations.

The GS/GPS Verification Procedure may not be used where very high gamma exposure interference from another source (such as the tailings pile) makes it difficult to use shielded probes to perform excavation control. Standard Verification Procedures may be used to verify the soils in these areas in accordance with procedures stated in Section 4.4.

4.7 Cobble Soil Sampling

Because of the difficulties in obtaining a representative sample from cobbly soils, this procedure is used to separate the sample into a cobbles and a fine fraction using a 3-inch standard sieve size. This procedure should be applied to material that contains rocks larger than 1 inch in diameter.

Aliquots will be collected from each individual grid area using a shovel. Samples should be of approximate equal volume and represent a 6-inch (15-cm) depth. Rocks larger than 6 inches in diameter should be excluded from the sample. These larger cobbles contribute only background amounts of radionuclides and due to handling difficulties will be discarded. The aliquots will be combined in a clean, lined (using a standard trash bag) 5-gallon bucket to represent a composite verification sample.

The sample, liner, and bucket will be weighed and the weight recorded on the Cobbles-to-Fines Data Form (Figure 4) as total mass (M_t). The composite sample will be passed through a number 4 mesh sieve to separate the cobbles and fine fractions. The cobbles will be collected in the bucket and weighed again. The weight of the cobbles, liner, and bucket will be recorded on the form as Mass of Cobbles (M_c). The difference between the weight of the total and the weight of the cobbles is the mass of the fines or M_f. An average weight for the bucket and liner (M_b) will be determined by weighing at least ten lined buckets and averaging the results. The average bucket weight may be used for all buckets of that type.

When analyses are completed for the sample, the OCS or analytical laboratory results will be input into the following bulk concentration equation (C_B) to determine the true concentration of the sample.

$$C_B = \frac{(C_f * M_f) + (C_c * [M_c - M_b])}{M_t - M_b}$$

Where: C_B = bulk concentration of the sample
C_f = concentration of the fine fraction
M_f = mass of the fine fraction
C_c = concentration of cobble fraction (based on previous analysis of cobbles fraction from that site)
M_c = mass of the cobble fraction, including the bucket and liner
M_b = mass of the average bucket and liner (based on previous determination)
M_t = total mass of the sample

Data may also be collected to establish a generic cobbles-to-fines correction factor for the entire site. This will be accomplished by using previously acquired data, and if necessary to ensure representative coverage, digging test pits (three to six) in the cobbly soil. The bulk samples will be sieved through a number 4 mesh screen and the weight ratios of cobbles-to-fines would be calculated for each test pit. These values will be arithmetically averaged to obtain the generic correction factor for the site. Subsequent bulk subsoil samples will be sieved to recover the fines fraction for analysis, but neither size fraction would be weighed. After analysis, the values would be corrected using the generic value to obtain the true concentration.

4.8 Verification of Deep Excavations

Verification personnel shall not enter excavations greater than 4 ft deep that have not been sloped to OSHA requirements (OSHA 29 CFR 1926, Subtitle B). For such excavations, an EL-0047 MOD scintillometer is used to scan the sides and bottom of the excavation. Any areas found to be 30 percent above the average gamma exposure rate observed in the excavation shall be removed or soil sampled to demonstrate compliance with authorized limits.

The bucket of the equipment used for excavation shall be cleaned of visible dirt and then used to collect soil from the bottom and sides of the excavation. Each 10- by 10-ft area in the excavation shall be sampled and the aliquots combined into a composite sample for an excavation area of 25 to 100 m^2.

4.9 Trees and Stumps From Contaminated Areas

In contaminated areas, trees and shrubs that are cut above the soil line may be removed and disposed of as uncontaminated material.

All stumps shall be gamma scanned to determine their disposition. Gamma readings 30 percent above background indicate further decontamination is needed. Gamma ranges shall be recorded on a daily log.

Soil adhering to stumps 18 inches in diameter or smaller may be composite sampled. No more than four stumps will be sampled for each composite. The aliquots will be collected from the soil

located at the highest gamma reading on each stump. Stumps greater than 18 inches in diameter shall be sampled individually.

Samples from the stumps shall be analyzed; if the OCS reading is 5 pCi/g Ra-226 or less, the stumps may be released to the landfill. If the sample exceeds 5 pCi/g Ra-226, the stumps must be further decontaminated or taken to the tailings repository. Sample results for the stumps shall be recorded on the Excavation Control and Verification Survey Log (Figure 1).

4.10 Stumps From Uncontaminated Areas

As a Best Management Practice, stumps removed from uncontaminated areas shall be scanned by gamma scintillometers. If gamma scintillometer readings do not exceed 30 percent above background, the stumps can be released to the landfill. If scintillometer readings exceed 30 percent of background, a composite soil sample shall be obtained and analyzed.

4.11 Th-230 and Total Uranium Analysis

If screening for total uranium is required (on a case-by-case basis), it will be performed by using the on-site HPGe system on samples taken in accordance with the procedures used for Ra-226 soil sampling.

Final verification analysis for Th-230 and total uranium will be performed by an analytical laboratory using analytical methods as stated in Section 4.4 and on samples taken in accordance with the procedure used for Ra-226 soil sampling.

Analytical laboratory results given in micrograms per gram (μg/g) total uranium may be multiplied by the following factors to convert to pCi/g uranium.

0.334 to convert to pCi/g Uranium-238
0.339 to convert to pCi/g Uranium-234
0.016 to convert to pCi/g Uranium-235
0.689 to convert to pCi/g Total Uranium

For uranium ore and mill tailings, Uranium-238 (U-238) and its decay product Uranium-234 (U-234) are normally in equilibrium and contribute equally to the activity of the sample. Uranium-235 (U-235) is a very minor contributor to the total activity.

5. Interior Verification Survey

5.1 Interior Gamma Survey

If elevated interior gamma readings were measured during the assessment of the property, then a post-construction gamma scan of the habitable areas shall be performed. If no elevated gamma readings were found, no interior scan is required. A separate scan range shall be documented for the areas of interior remediation.

The range of scintillometer readings will be recorded on a verification map of the structure, along with the background for the property. If the upper level of the range does not exceed background plus 30 percent or 160 cps (18 μR/h), no further measurements are required.

If the upper level of the range of scintillometer readings exceeds background plus 30 percent (160 cps), or if contaminated material was left in place, gamma readings will be taken in room-sized 9.3 m^2 (10- by 10-ft) areas of the structure where elevated readings occurred. Readings are taken at 10-ft intervals; a more frequent measurement interval may be used to adequately characterize the area. At least five readings should be taken in every 9.3 m^2(10- by 10-ft) area. Readings adjacent to a wall shall be taken at least 2 ft away from the wall.

The average of the five gamma measurements adjacent to and including the highest measurement must be less than 20 μR/h above background, averaged over a room-sized area. All scintillometer readings are converted to μR/h and recorded on the structure drawing.

If gamma readings are elevated due to contaminated materials left in place, the exposure rates shall be obtained before and after reconstruction has taken place.

5.2 Radon Survey

Where an RDC was not taken before remediation, radon measurements will be taken in habitable structures on all vicinity properties after remediation has been completed. Measurement will be taken in accordance with procedures from Chapter 34, "Radon Decay-Product Concentration (RDC) Measurements." If an RDC measurement was taken before remediation, and was less than 0.02 WL, no further RDC measurements need to be taken. The radon measurement will demonstrate compliance with EPA standards. If the RDC value exceeds 0.03 WL, DOE shall take additional efforts to either implement simple fixes, such as activating floor vents or ventilating crawlspaces, or through some additional exterior soil measurements, to demonstrate that the radon level is due to an elevated background and not RRM.

Radon measurements will be taken with a track-etch device. An annual average is used, which takes approximately 1 year to complete.

Special attention should be taken in placement of track-etch devices to demonstrate an average annual exposure. If basement rooms are used for the measurement, a ground level room should also be used to demonstrate a true average exposure to the resident.

6. Post-Restoration Surveys

A post-restoration survey shall be performed in areas that had elevated readings (shine) due to residual RRM in adjacent areas.

These surveys may also be performed on sites where restoration requires leveling of the ground surface of previously unexcavated areas for drainage or other purposes. In this event, new ground surfaces may be exposed where the radium content does not comply with the surface soil standard of 5 pCi/g above background. For example, an area that prior to leveling was greater than 6 inches in depth and the radium content was compared to the subsurface standard of 15 pCi/g above background, is now at the surface where the radium content must be below 5 pCi/g above background.

The survey will consist of a gamma scan over the areas where leveling occurred using either hand held gamma scintillometers (SC-132's) or utilizing a GS/GPS system following procedures as stated in Section 3. Any area where gamma exposure rates exceed 30 percent above background will be sampled to assure the surface standard of 5 pCi/g above background is met.

7. Tailings Left In Place

Once it is determined that a property exceeds the applicable EPA standards, and the extent of contamination has been assessed, the UMTRA Vicinity Property Management Implementation Manual (VPMIM) directs that tailings deposits shall be removed to the greatest extent possible.

The practice of leaving tailings deposits that cover a relatively small area (such as under stoops, planters, under detached garage slabs, around utility lines extending across the property, or into the interior area) does not comply with the intent of the VPMIM. Additionally, expediting the construction schedule based on an informal cost benefit analysis does not provide appropriate justification for leaving tailings in place.

In certain instances, mill tailings may be left in place by employing mathematical averaging techniques that demonstrate compliance with EPA standards. Such techniques, however, may only be applied in the following unique situations:

- The engineering design cannot provide reasonable assurance that significant structural damage will not occur.
- The safety of workers cannot be assured.
- Mature trees or shrubbery will be permanently damaged and the owner desires to keep them.

In cases where the previously cited situations arise, and averaging shows the EPA standards have not been met, it may be necessary to apply for "Supplemental Standards" per 40 CFR 192.

7.1 Averaging of Tailings Left in Place

The soil criteria specified in Table 1 are stated in terms of a specific concentration averaged over 100 m^2 (1,076 ft^2). The average concentration for a 1,076-ft^2 area containing residual tailings is calculated using the equation:

$$C_{avg} = \frac{C_p \times A_p + (C_r \times [1{,}076 - A_p])}{1{,}076}$$

Where:

	C_{avg}	=	radionuclide concentration (pCi/g) averaged over a 100-m^2 area
	C_p	=	concentration of the radionuclide in the pocket in pCi/g
	A_p	=	area of the radionuclide pocket in ft^2
	C_r	=	concentration of the remainder of the 1,076 ft^2 area, including background, in pCi/g
	1,076	=	total area (in ft^2) over which the EPA guideline is applied

Where the top 6 inches of tailings have been removed, the average concentration must be less than 15 pCi/g above background. For example, assume that a pocket of tailings, greater than 15 cm (6 inches) deep, has an area of 25 ft^2 and a Ra-226 concentration of 150 pCi/g. Also assume that the remainder of the 1,076-ft^2 area has a Ra-226 concentration of 5 pCi/g, which includes the background of 2 pCi/g. The following calculation shows average concentration for the 1,076-ft^2 area:

$$C_{avg} = 8.4\ pCi/g$$

This value would not exceed the subsurface guideline since it does not exceed 15 pCi/g above background.

This averaging technique can be applied only when the concentration of the radionuclide pocket and the average concentration of the surrounding area are known. The concentration of the pocket can be determined by soil sampling, or for concrete, by taking an in-situ delta scintillometer measurement. The concentration of the surrounding area is determined by analyzing a composite soil sample of the area. The average background value of the radionuclide may be used if the background of the surrounding area is unknown (Table 2). Figure 5 shows an example of the form used to document average radium concentration. The form also may be used to document average Th-230 or uranium concentrations by lining out the word radium and writing in "Th-230" or "uranium".

The Explanation of Data Collection form (Figure 6) is used in conjunction with the radium averaging form to document situations which require a more detailed explanation than can be written in the Excavation Control and Verification Survey Log (Figure 1).

If two or more deposits would fit within a 15- by 70-ft rectangle or wrap around a structure, those areas shall be averaged together. The intent of this criterion is to provide a conservative estimate of radium left in place in the event the current structure expands or a new structure is built over the deposit.

7.2 Supplemental Standards

When necessary, Field Services personnel will provide project personnel with the radiological data required for supplemental standards applications. This radiological data shall include all applicable items listed in the Radiological Checklist for the Application of Supplemental Standards form (Figure 7).

8. OCS and Laboratory Soil Analysis

OCS analysis for Ra-226 is performed on all samples and these results are used for the Completion Report. As a QC check for OCS, laboratory analysis for Ra-226 using gamma spectroscopy is performed on 5 to 10 percent of the total samples analyzed with the OCS. OCS and laboratory test results shall be reviewed for comparison and kept with the project records

9. Backfill Surveys

Backfill material must be below the criteria for radium in soil as stated in Section 2. The radiological characteristics of the backfill will be determined by gamma scanning the area and

collection of composite-soil samples of the material. The scanning may be performed using any portable handheld scintillometer that has a current calibration and daily operational check or the GS/GPS system after development of a correlation data set per Section 3.7.

Backfill may be uncontaminated material from the on-site excavation or it may be off-site material such as pit run, topsoil, or sod.

Documentation of backfill verification surveys is sent to Records Management for placement in the project records file..

9.1 On-Site Backfill

Whenever possible, uncontaminated soil that has been removed from an excavation should be stockpiled on site and used as backfill in the original excavation. The following guidelines are used:

- Soil may be used for subsurface (below 6 inches in depth) backfill if the radium concentration is 5 pCi/g or less, as measured by the OCS.
- No on-site materials may be used as backfill for the surface 6-inch layer. (Note: on-site backfill may be used as surface cover if a variance to procedure is documented and the on-site borrow source is appropriately characterized, documenting radium-in-soil values less than or equal to 5pCi/g Ra-226).

Representative samples may also be selected for hazardous characteristics or additional radionuclide analyses.

On-site material that is to be used for backfill will be excavated in 12-inch lifts. The sampling methodology is described below:

- Each candidate area will be completely scanned for anomalous gamma readings using either handheld gamma scintillometers (SC-132s) or the GS/GPS system. The gamma scan range will be recorded on a field map, and Excavation Control and Verification Survey Log (Figure 1), or color-coded and mapped for gamma exposure rate, using ARC/INFO GIS tools.
- Any 30- by 30-ft section of the borrow area with exposure rates in excess of 30 percent above background will be appropriately characterized and have samples collected from the borrow area. Any material found to exceed 5 pCi/g Ra-226, will not be suitable for use as fill or cover.

9.2 Other Sources of Backfill Material

Personnel will perform gamma surveys on all sources of off-site backfill to verify that it is free of contamination.

Pit-run sources and sod farms used on a regular basis will be surveyed only once. Other backfill sources will be surveyed at the discretion of the site supervisor based on the size and frequency of use of the source.

Documentation of the survey will include the map showing the exposure-rate scan range, surveyor's name, survey date, instruments used, and the address or location of the backfill source area.

Backfill from DOE-owned land or other included properties will be surveyed and used according to the procedures for on-site backfill.

10. Records

The following records may be generated by use of this procedure:

- Excavation Control and Verification Survey Log.
- Calculation of Average Radium Concentration Form.
- Explanation of Data Collection Form.
- Radiological Checklist for Application of Supplemental Standards.
- Backfill Verification Survey Map and Memo.
- Soil Sample Catalog.
- OCS Data Sheet.
- Verification Map.

Verification records will be reviewed within two months of the final verification. A Field Supervisor or Manager reviews for accuracy, completeness, legibility, and reproducibility. All other records are forwarded to the project records coordinator.

11. References

40 CFR 192. *Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings,* Code of Federal Regulations.

49 CFR 171-178, *Hazardous Material Packaging, Shipping, and Transportation*, Code of Federal Regulations.

DOE (U.S. Department of Energy), 1987. *Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites*, Revision 2, March.

DOE (U.S. Department of Energy) 1987. Memorandum, *Vicinity Property Excavation,* dated September 25.

DOE (U.S. Department of Energy), 1988. *Vicinity Properties Management and Implementation Manual,* Revision D, UMTRA DOE/AL-050601, March.

DOE (U.S. Department of Energy), 1989, RESRAD Computer Code, Version 4.0, DOE/CH/8901, June.

DOE (U.S. Department of Energy), 1990, *GJO Remedial Action Program Radiological Assessment for Construction Phase 1-b*, UNC Geotech for US DOE, April 1990.

DOE (U.S. Department of Energy), 1993. UMTRA Project, *Generic Protocol for Thorium-230 Cleanup/Verification at UMTRA Project Sites*, December.

DOE Order 5400.5, 1989. *Radiation Protection of the Public and the Environment* and RESRAD Computer Code, Version 4.0, DOE/CH/8901, June.

DOE/CDHE, 1987. Memorandum, *Interface Meeting*, dated May 18.

DOE/CDHE, 1989. Memorandum, *Interface Meeting,* dated October 4.

Federal Register, Volume 40, Number 205, p. 56062, October 23, 1981.

Ford, Bacon, and Davis, Utah, Inc., 1977, Phase II, Title I, *Engineering Assessment of Inactive Uranium Mill Tailings*, Grand Junction Site, Grand Junction, Colorado, GJT-9.

Rush, S.M., and P.J. Bonner, 1985, *Radiologic Characterization of the Grand Junction, Colorado, Uranium Mill Tailings Remedial Action Site*, Report GJ-28, U.S. Department of Energy, UMTRA Office, Grand Junction, Colorado.

EXCAVATION CONTROL AND VERIFICATION SURVEY LOG

PROPERTY ID NUMBER	PROPERTY ADDRESS
SURVEY DATE	CONSTRUCTION INSPECTOR
VERIFICATION TECHNICIANS	SUBCONTRACTOR

INSTRUMENTATION

INSTRUMENT NUMBER	INSTRUMENT TYPE	CALIBRATION EXPIRES	COMMENTS

AREA INFORMATION

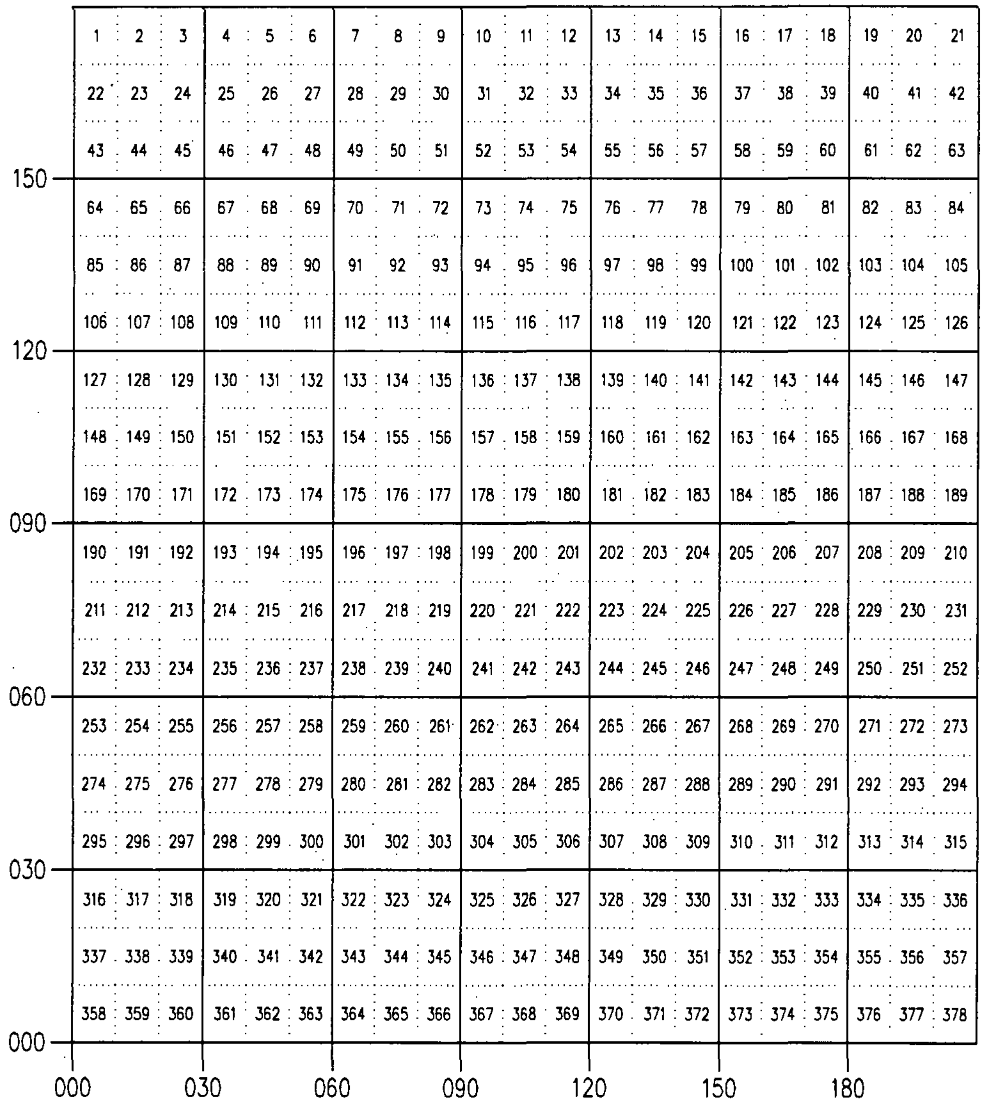
PARTIAL VERIFICATION	FINAL VERIFICATION	EXCAVATION CONTROL

AREA UNDER EXCAVATION (INTERIOR/EXTERIOR)

SIGNATURE	DATE

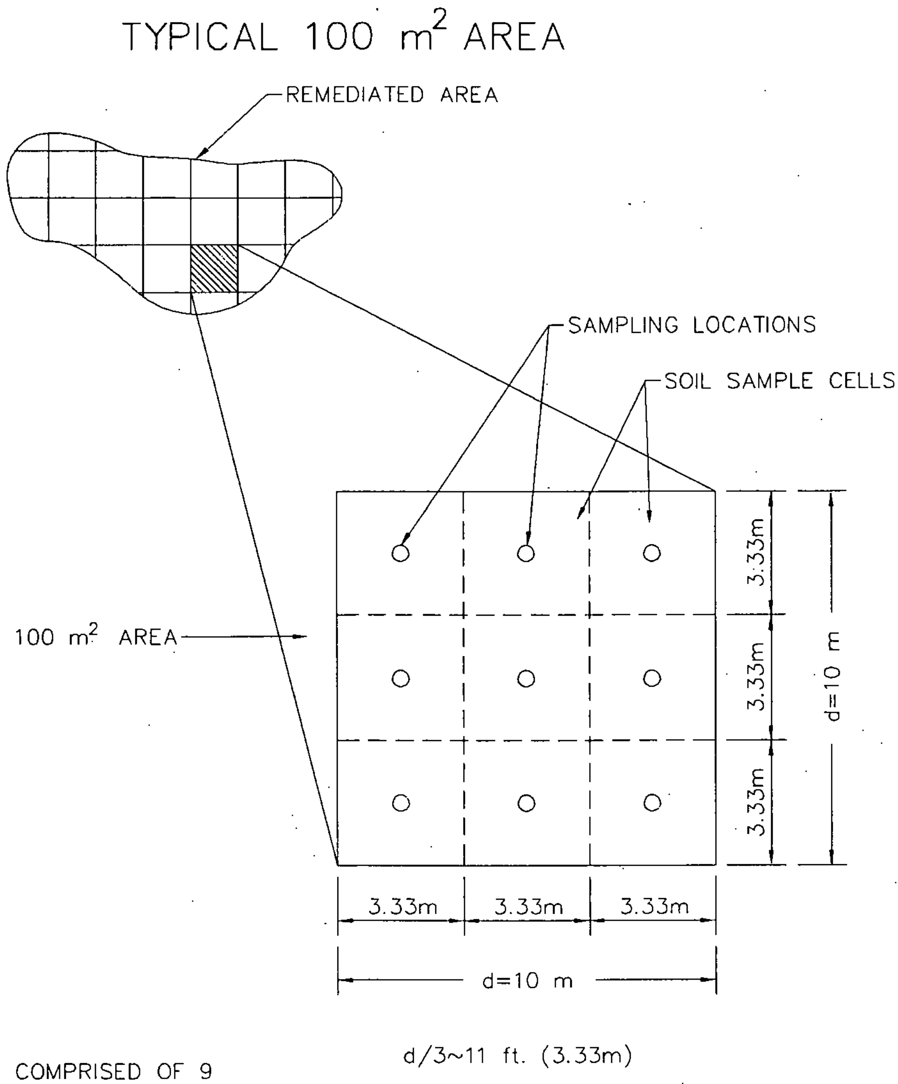
EC: BLANK FORMS – FEB 2003

Figure 1. Excavation Control and Verification Survey Log



M: \ENG\190\0012\00\E04565\E0456500.DWG 05/13/04 10:31am WhitneyJ

Figure 2. Grid System



- 100m^2 AREAS COMPRISED OF 9 CONTIGUOUS SAMPLE CELLS
- SAMPLES COLLECTED AT APPROXIMATE CENTERS OF SAMPLE CELLS
- ONE SOIL ALIQUOT COLLECTED PER SOIL SAMPLE CELL
- SOIL ALIQUOTS COMBINED TO FORM COMPOSITE SAMPLE FOR ANALYSIS

U.S. DEPARTMENT OF ENERGY GRAND JUNCTION, COLORADO	Work Performed by S.M. Stoller Corporation Under DOE Contract No. DE-AC01-02GJ79491
STANDARD VERIFICATION	
DATE PREPARED: MAY 6, 2004	FILENAME: E0456400

M:\ENG\190\0012\00\E04564\E0456400.DWG 05/06/04 10:23am J50191

Figure 3. Standard Verification 100-m^2 Grids

COBBLES-TO-FINES DATA FORM

Note: The average weight of the bucket and liner (M_b) = 4.1 lbs. Masses of are in decimal pounds. To convert to decimal pounds. divide the ounces by 16 and add to the pounds. for example 50 lbs 4 ounces would be 50.25 lbs.

Sample Number	**Total Mass w/bucket** (M_t)	**Mass of Cobbles w/bucket** (M_c)	**Mass of Fines** (Optional) $M_f = M_t - M_c$	**Conc. Fines** (optional) (C_f)	**Conc. Cobbles** (optional) (C_c)	**Bulk Concentration** (optional) $C_B = \frac{[C_f * M_f] + [C_c * (M_c - M_b)]}{M_t - M_b}$

VERIFIED BY: **DATE:**

H:\forms\cobbles.frm

Figure 4. Cobbles-to-Fines Data Form

CALCULATION OF AVERAGE RADIUM CONCENTRATION

PROPERTY NUMBER	**PROPERTY ADDRESS**
LOCATION OF AREA	

$$C_{avg} = \frac{C_p \, x \, A_p \;\; + (C_r \, x \, [1,076 - A_p])}{1,076}$$

Where:

C_{avg}	=	Radium concentration (pCi/g) averaged over 100 m^2 (1076 ft^2) area
C_p	=	Concentration of the tailings in the pocket in pCi/g
A_p	=	Area of the tailings pocket in ft^2
C_r	=	Concentration of the remainder of the 100 m^2 (1076 ft^2) area.

$$C_{avg} = \frac{\_\_ \, x \, \_\_ + (\_\_ \, x \, [1,076 - \_\_])}{1,076}$$

$$C_{avg} = \_\_$$

☐ OCS ANALYSIS: The radium concentration does not exceed the EPA standard of 5.0 pCi/g plus background for the surface soil layers or 15 pCi/g plus background for subsurface soil layers.

☐ ANALYTICAL LABORATORY: The radium concentration does not exceed the EPA standard of 7.0 pCi/g for the surface soil layers or 17 pCi/g for subsurface soil layers.

Note: The background radium concentration for this area is approximately 2.0 pCi/g. For conservatism, the background is not added to the OCS value.

CALCULATED BY:	DATE:
VERIFIED BY:	DATE:

Figure 5. Calculation of Average Radium Concentration

EXPLANATION OF DATA COLLECTION

PROPERTY NUMBER:	PROPERTY ADDRESS
LOCATION OF AREA:	
DOES THIS AREA CONTAIN MULTIPLE DEPOSITS WITH A 70 FT X 15 FT RECTANGULAR AREA? ☐ YES ☐ NO	
DOES THIS DEPOSIT WRAP AROUND A STRUCTURE? ☐ YES ☐ NO	
MAP ATTACHED? ☐ YES ☐ NO	

TYPE OF DATA COLLECTED		
SAMPLE NUMBER	☐ INDIVIDUAL ☐ COMPOSITE	SAMPLE DEPTH
SAMPLE NUMBER	☐ INDIVIDUAL ☐ COMPOSITE	SAMPLE DEPTH
SAMPLE NUMBER	☐ INDIVIDUAL ☐ COMPOSITE	SAMPLE DEPTH
COMMENTS		

EXPLANATION FOR DATA COLLECTION

CONCLUSIONS

PREPARED BY:	DATE:
VERIFIED BY:	DATE:

EXDATA.FRM (11-96)

Figure 6. Explanation of Data Collection

RADIOLOGICAL CHECKLIST FOR APPLICATION OF SUPPLEMENTAL STANDARDS

PROPERTY NUMBER	
PROPERTY ADDRESS	
DATE	INSTRUMENT NUMBERS

AREA REMAINING UNDERLAIN BY CONTAMINATION	
ESTIMATED VOLUME OF CONTAMINATED MATERIAL TO REMAIN	
RANGE OR AVERAGE RADIUM CONCENTRATION IN SOIL IN THE CONTAMINATED AREA	
IF TAILINGS ARE BELOW OR WITHIN 10 FEET OF THE STRUCTURE, RADON DECAY-PRODUCT CONCENTRATION	

RANGE AND AVERAGE EXPOSURE RATE OVER THE CONTAMINATED AREA		
RANGE AT CONTAMINATION CONTACT AVERAGE	CPS CPS	μR/hr μR/hr
RANGE 3 FEET ABOVE CONTACT AVERAGE	CPS CPS	μR/hr μR/hr
RANGE AT GROUND SURFACE AVERAGE	CPS CPS	μR/hr μR/hr

PREPARED BY:	DATE:
REVIEWED BY:	DATE:

SUPSTDS.FRM (5/1/97)

Figure 7. Radiological Checklist for Application of Supplemental Standards

BACKFILL VERIFICATION SURVEY

LOCATION:	
DATE SURVEYED	TECHNICIAN:
INSTRUMENT NUMBERS:	

DESCRIPTION OF BACKFILL (INCLUDE TYPE OF FILL, GEOLOGY AND OTHER CHARACTERISTICS OF THE DEPOSIT.

RADIOLOGICAL SURVEY RESULTS (ATTACH MAPS, DATA SHEETS, AND PHOTOGRAPH OF SITE)

VERIFICATION SUPERVISOR	DATE

BACKFILL.FRM (11-96)

Figure 8. Backfill Verification Survey