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Office of Environmental Management – Grand Junction

MOAB UTAH UMTRA Project

Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Residual Radioactive Material at the Crescent Junction, Utah, Disposal Site

Addendum E. Remedial Action Inspection Plan

Revision 6

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Moab UMTRA Project Remedial Action Plan Addendum E
Remedial Action Inspection Plan

Revision 6

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6/16/2020

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Statement of Policy

This Remedial Action Inspection Plan identifies the means by which the remedial action activities associated with the U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project disposal cell at Crescent Junction, Utah, are controlled, verified, and documented.

This Plan has been developed within the scope of the *Moab UMTRA Project Quality Assurance Plan for the Remedial Action Contractor* (QAP) (DOE-EM/GJRAC1766) and complies with the applicable parts of American Society of Mechanical Engineers (ASME) Nuclear Quality Assurance (NQA)-1-2008, and addenda through 2009, "Quality Assurance Program for Nuclear Facilities," Title 10 Code of Federal Regulations Part 830 Subpart A (10 CFR 830A), "Quality Assurance," and DOE Order 414.1D, "Quality Assurance."

The testing and inspection activities discussed in this Plan are performed in accordance with the following applicable sections of the QAP: Section 1.0, Organization; Section 2.0, Quality Assurance Program; Section 12.0, Control of Measuring and Testing Equipment; Section 15.0, Nonconforming Materials, Parts, or Components; Section 16.0, Corrective Action; and Section 17.0, Quality Assurance Records.

Testing and Inspection

1.0 Purpose

The purpose of this Plan is to describe the methods by which the construction activities will be tested and inspected to verify compliance with the design specification requirements.

2.0 Scope

This Plan defines the testing and inspection of remedial action construction activities at the Crescent Junction site. Types of tests, test frequencies and acceptability, and documentation and reporting requirements are contained in this Plan. Procedures for performing the individual tests shall be in accordance with the applicable ASTM International (ASTM) standards, the referenced or other approved methods, and the design specifications.

3.0 Acronyms

ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials International
CFR	Code of Federal Regulations
D_{50}	median stone diameter
DOE	U.S. Department of Energy
GPS	global positioning system
GLONASS	Global Orbiting Navigation Satellite System
GNSS	Global Navigation Satellite System

ISRM	International Society for Rock Mechanics
NQA	Nuclear Quality Assurance
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
RAC	Remedial Action Contractor
RRM	residual radioactive material
UMTRA	Uranium Mill Tailings Remedial Action

4.0 Attachment

None.

5.0 References

10 CFR 830 (Code of Federal Regulations), "Nuclear Safety Management," Subpart A, "Quality Assurance."

ASME (American Society of Mechanical Engineers), Nuclear Quality Assurance (NQA)-1 2008 and addenda through 2009 consensus standard, "Quality Assurance Requirements for Nuclear Facility Applications (QA)."

ASTM (ASTM International) C88 – Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.

ASTM (ASTM International) C117 – Standard Test Method for Materials Finer than 75 μm (No. 200) Sieve in Mineral Aggregates by Washing.

ASTM (ASTM International) C127 – Standard Test Method for Density, Relative Density, Specific Gravity, and Absorption of Coarse Aggregates.

ASTM (ASTM International) C131 – Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.

ASTM (ASTM International) C136 – Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

ASTM (ASTM International) D422 – Standard Test Method for Particle-Size Analysis of Soils.

ASTM (ASTM International) D698 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort.

ASTM (ASTM International) D1140 – Standard Test Method for Amount of Material in Soils Finer than the No. 200 (75-micrometer) Sieve.

ASTM (ASTM International) D1556 – Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.

ASTM (ASTM International) D2216 – Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.

ASTM (ASTM International) D2922 – Standard Test Method for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

ASTM (ASTM International) D4318 – Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

ASTM (ASTM International) D4643 – Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating.

ASTM (ASTM International) D4944 – Standard Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester.

ASTM (ASTM International) D4959 – Standard Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating Method.

ASTM (ASTM International) D6938 – Standard Test Method for In-Place Density and Water content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

DOE (U.S. Department of Energy), *Moab UMTRA Project Quality Assurance Plan for the Remedial Action Contractor* (DOE-EM/GJRAC1766).

DOE (U.S. Department of Energy), *Moab UMTRA Project Records Management Manual*

(DOE-EM/GJ1545).

DOE (U.S. Department of Energy) Order 414.1D, "Quality Assurance."

ISRM (International Society for Rock Mechanics) Method, Schmidt Rebound Hardness. ISRM (International Society for Rock Mechanics) Method, Splitting Tensile Strength.

6.0 General Requirements

6.1 General Approach to Soil Compaction and Compaction Testing

Typically, soil is tested in a laboratory to determine the maximum density that the particular soil can achieve. The maximum dry density will be achieved at the optimum moisture content for that soil type. The laboratory maximum dry density and optimum moisture content for the soil type becomes the basis of comparison for the compaction of the soil type in the field.

In the field, the soil is placed in loose layers, compacted with specialized compaction equipment, and the relative density tested to confirm the soil density falls within the specified range of the previously determined laboratory maximum dry density. A variety of field tests have been used to determine soil density, including sand cone, rubber balloon, drive cylinder, and nuclear gauge methods. Moisture content tests are also needed to determine the in-place soil density.

All of these test methods determine the density of a small quantity of soil at a single point in a large quantity of placed and compacted soil. A number of tests are required to infer that an entire layer of soil is adequately compacted. The documentation of soil compaction has typically consisted of a visual inspection report combined with a map of the compacted layer and the field moisture density test results.

6.1.1 Computer-based Compaction System

Global Navigation Satellite System (GNSS), comprised of both the U.S. Global Position System (GPS) and the Russian Global Orbiting Navigation Satellite System (GLONASS) and computer terrain modeling technology have been combined to provide a new method of performing soil compaction.

The system works as follows:

- A digital terrain model of the site receiving fill material is loaded into an on-site computer and onboard heavy equipment computer (CB-460). The on-site computer is linked to the CB-460 in the cab of the compaction equipment utilizing Trimble Vision Link. A GNSS receiver is also linked to the CB-460. When the machine moves across the site, the GNSS equipment provides an accurate position (to within 0.1 foot) and elevation of the equipment at all times.
- Soil is dumped and spread into a layer of fill. As the compactor spreads and compacts the layer of soil, the position of the machine is compared to the terrain model to determine the location and thickness of the fill layer being placed and/or compacted. The CB-460 provides real-time cut/fill information to the equipment operator so that the operator may place the material in a layer with uniform specified thickness. This lift may also be graded to uniform thickness utilizing a dozer, also equipped with GNSS and a CB-460 with the terrain model loaded into it.
- After a layer has been placed with uniform thickness, the compactor makes multiple passes over the fill to compact the fill material in place. The number of passes required to achieve the specified relative compaction is determined using an assessment test where pass count is correlated to nuclear density gage readings. Assessment tests are conducted of each material/soil type to determine the pass count/relative density correlation, or whenever a new material type is encountered. Each pass of the compactor is tracked using the computer-based compaction system. The compacted surface elevation is also tracked with the pass count and position information.
- As the compactor traverses the soil to compact it, the computer-based compaction system records the position data, comparison to previous lift/or terrain model, and pass count allowing the QA/QC personnel to generate reports and verification that the lift met the specified compaction and thickness requirements.

Visual inspection, correct placement and compaction techniques, and good moisture control are still required to ensure fill is properly placed and compacted, but the computer-based compaction system method has distinct advantages over traditional field density testing. Lift thicknesses are computer-controlled and are more uniform than when layers are installed based on visual estimates by the equipment operators.

Additionally, the computer tracks compaction over the entire surface of every layer, whereas the in-place test methods only check a few points on each layer. Soil density verification tests and independent land surveys will be performed to demonstrate the effectiveness of the computer-based compaction system.

In the following sections of this Plan, the verification testing and surveying will be described in detail for each element of the cell in which fill is placed.

6.2 Cell Excavation

Part of the proposed disposal cell will be below the ground surface in an excavation. The excavation will be constructed in phases. The overall cell floor and side slopes are described below.

6.2.1 Floor and Side Slopes

The cell floor slopes 2.3 percent from northwest to southeast. The cut slopes on the northern, western, and southern sides of the cell slope at 2:1 or 3:1.

6.2.2 Final Floor and Embankment Elevations

The cell floor coordinates and elevations are shown on the design plans. When each section of the cell is excavated to the elevations indicated on the plans, a verification survey shall be performed to confirm the excavation meets proposed lines and grades. The verification survey shall be signed and submitted to the Remedial Action Contractor (RAC) Crescent Junction Operation/Site Manager.

6.2.3 Cell Floor in Weathered Mancos Shale

The cell floor elevation has been set based on test pit, and soil boring data and is at least 2 feet below the top of the Mancos Shale at each data point. The cell floor shall be visually inspected to confirm that it is in the Mancos Shale formation. If an area is observed where the overburden soil extends below the cell floor, the area will be undercut, backfilled with prepared Mancos Shale, and compacted.

6.2.4 Inspection and Testing

The RAC QC Representative shall visually inspect the material and ground preparation and verify the cell floor is constructed in accordance with plans and specifications by checking and confirming:

- Floor and side slopes follow the design plans.
- Final floor and side slopes survey match the coordinates and elevations in the plans.
- Floor is weathered Mancos Shale, or low spots have been compacted with Mancos Shale.

6.3 Embankment Construction

Part of the proposed disposal cell will be below the existing ground surface in an excavation, and part will be above the existing ground surface within a constructed embankment. The proposed embankment will have 3:1 or 2:1 interior slopes, 5:1 exterior slopes, and a minimum 30-foot-wide, level top. Excavated material from the cell excavation will be used to construct the cell perimeter embankment.

6.3.1 Material

Excavated material from the cell excavation shall be segregated into four types of soil: topsoil, weathered Mancos Shale, common fill, and unsuitable material. Materials shall be separately stockpiled. The perimeter and spoils embankments will be constructed of common fill. The fill shall be tested to determine its maximum dry density in accordance with ASTM D698, and the moisture content shall be modified to bring the fill near (±5 percent) its optimum moisture for compaction.

6.3.2 Ground Preparation

The ground beneath the proposed perimeter and spoils embankments shall be prepared by stripping vegetation and loose soil from the site, scarifying and compacting the top 6 inches of soil.

6.3.3 Lift Placement and Thickness

The embankment shall be constructed of fill materials placed in continuous and approximately horizontal lifts. The method of dumping and spreading fill shall result in loose lifts of nearly uniform thickness, not to exceed 12 inches. At the RAC's option, the compactor may be equipped with a computer-based compaction system and soil placement, and compaction shall be controlled by the computer-based compaction system. The contractor may use the computer-based compaction system to determine and document compaction or perform soil density tests is in accordance with the Inspection and Testing section below.

6.3.4 Inspection and Testing of Cell Perimeter Embankment

QC shall visually inspect the material preparation, ground preparation, and fill placement operations. QC shall perform in-place density tests with companion moisture tests to verify at least 95 percent of the laboratory maximum dry density in accordance with ASTM D698.

QC shall verify the perimeter embankment is constructed in accordance with plans and specifications by checking and confirming:

- Interior slopes are 3:1 or 2:1, and exterior slopes are 5:1 with a minimum 30-foot-wide, level top verified once at the end of excavation.
- Fill material is properly moisture conditioned near optimum moisture.
- Fill material is placed in continuous and approximately horizontal lifts. The method of dumping and spreading material shall result in loose lifts of nearly uniform thickness, not to exceed 12 inches.
- Embankment construction soil is common fill and/or Mancos shale.
- Compaction is properly performed.
- Embankment fill shall be compacted with a minimum 45,000-pound static weight compactor. The compactor shall be a footed roller type, capable of kneading compaction, with feet a minimum of 6 inches in length.
- In-place density and moisture content tests are performed on compacted fill material in accordance with the In-Place Density Testing sections below.
- In-place density verification tests of shall be performed on initial layers of soil placed and on any specific type of material for which the computer-based compaction system is used.

Testing and verification frequencies for lifts constructed without the computer-based compaction system shall be in accordance with the following requirements.

Testing Cell Perimeter Embankment

For material compacted by other than hand-operated machines: One test per 50,000 square feet or 1,850 cubic yards of material placed (or fraction thereof), a minimum of one test for each lift of fill or backfill, and a minimum of two tests per day that fill is compacted in accordance with ASTM D6938.

One test per 500 square feet (or fraction thereof) of each lift of fill or backfill areas for material compacted by hand-operated machines.In-place density and moisture content tests shall be performed in accordance with:

- ASTM D1556
- ASTM D2216
- ASTM D4643
- ASTM D6938

Check Tests on In-Place Densities

If ASTM D6938 is used, check in-place densities by ASTM D1556 as follows:

- One check test for each 20 tests of fill or backfill compacted by other than hand-operated machines (per ASTM D698).
- One check test for each 10 tests of fill or backfill compacted by hand-operated machines (per ASTM D6938).

Optimum Moisture and Laboratory Maximum Density

Perform laboratory density and moisture content tests (ASTM D698 and ASTM D2216) for each type of fill material to determine the optimum moisture and laboratory maximum density values. Perform one representative density test per material type and every 20,000 cubic yards thereafter or when any change in material occurs that may affect the optimum moisture content or laboratory maximum dry density.

One correlation test for moistures every 10 tests per ASTM 6938 will be performed in accordance with ASTM D4643 or D2216. In the stockpile, excavations, or borrow areas, perform moisture tests to control the moisture content of material being placed as fill.

Control of moisture content of fill shall be performed by conducting routine testing of moisture content by one of the following tests:

- ASTM D2216
- ASTM D4643
- ASTM D4944
- ASTM D4959

During unstable weather, perform tests as dictated by local conditions and approved by the Crescent Junction Operations/Site Manager.

6.3.5 Disposal Cell Spoils Embankment (Wedge)

The spoils embankment is a fill embankment to be constructed north of the cell. The embankment will divert storm water from the Book Cliffs around the cell and shall be constructed of surplus excavated material (spoils material) from the cell excavation.

Before placement, spoils material shall be tested to determine its maximum dry density in accordance with ASTM D698, and the moisture content shall be modified to bring the fill to (±5 percent) optimum for compaction.

Constructing the Spoils Embankment

1. Prepare the ground beneath the proposed perimeter embankment by stripping vegetation and loose soil from the site.
2. Dump and spread fill in loose lifts of nearly uniform thickness, not to exceed 12 inches.
3. Compact material with rollers, equipment tracks, or successive passes of scrapers. Fill shall be compacted to a density of 90 percent of the laboratory-determined maximum density in accordance with ASTM D698.

QC shall verify the spoils embankment is constructed in accordance with plans and specifications by checking and confirming:

- Exterior slopes are 3:1.
- Fill material is properly moisture conditioned near (±5 percent) optimum moisture.
- Fill material is placed in continuous and approximately horizontal lifts.
- The method of dumping and spreading material shall result in loose lifts of nearly uniform thickness, not exceed 12 inches.
- Embankment construction soil is surplus excavated material.
- Compaction is properly performed.
- Embankment fill shall be compacted with rollers, equipment tracks, or successive passes of scrapers at a minimum 45,000-pound static weight.
- In-place density and moisture content compaction verification, tests are performed on compacted fill material in accordance with the In-Place Density Testing sections below.
- In-place density verification tests shall be performed on initial layers of soil placed and on any specific type of material for which the computer-based compaction system is used.

Testing and verification frequencies for lifts constructed without the computer-based compaction system shall be in accordance with the following tests.

Testing Spoils Embankment

- One test per 100,000 square feet or 3,700 cubic yards of material placed for material compacted by other than hand-operated machines.
- One test per 500 square feet (or fraction thereof) of each lift of fill or backfill areas for material compacted by hand-operated machines.

In place density and moisture content tests shall be performed in accordance with the following methods:

- ASTM D1556
- ASTM D2216
- ASTM D6938
- ASTM D4643

Check Tests on In-Place Densities

If ASTM D6938 is used, check in-place densities with ASTM D1556 as follows.

- One check test for each 20 tests of fill or backfill compacted by other than hand-operated machines (per ASTM D6938).
- One check test for each 10 tests of fill or backfill compacted by hand-operated machines (per ASTM D6938).

Optimum Moisture and Laboratory Maximum Density
Perform laboratory density and moisture content tests (ASTM D698 and D2216) for each type of fill material to determine the optimum moisture (optimum moisture content ±5 percent) and laboratory maximum density values.

Perform one representative density test per material type and every 20,000 cubic yards thereafter or when any change in material occurs that may affect the optimum moisture content or laboratory maximum dry density. One correlation test for moistures every 10 tests per ASTM D6938 will be performed in accordance with ASTM D4643 or D2216.

In the stockpile, excavations, or borrow areas, perform moisture tests to control the moisture content of material being placed as fill. Control of moisture content of fill shall be performed by conducting routine testing of moisture content by one of the following tests:

- ASTM D2216
- ASTM D4643
- ASTM D4944
- ASTM D4959

During unstable weather, perform tests as dictated by local conditions and approved by the Crescent Junction Operations/Site Manager.

6.4 Residual Radioactive Material

The objective is to place and compact the residual radioactive material (RRM) in the waste cell to create a stable waste mass. QC shall visually inspect the material preparation, ground preparation, RRM placement operations, and shall perform in-place density tests with companion moisture tests for the computer-based compaction system to verify RRM compaction meets the compaction requirements.

QC shall verify RRM placement is performed in accordance with plans and specifications and that the top of the placed waste matches the final grades identified in Section 6.4.5. RRM shall not be placed when frozen or over frozen subgrade. If rainwater ponding has occurred, placement of RRM shall only be performed after the area is dewatered, and approval of the Crescent Junction Operations/Site Manager and QC to place has been obtained.

6.4.1 Moisture Modification
RRM material should be shipped from the Moab site dried to moisture necessary to meet required compaction specifications Some RRM may require minor moisture modification when received at Crescent Junction site.

6.4.2 Residual Radioactive Material Placement
Scarify at a minimum the top 1 inch of subsoil or preceding RRM lift using a footed roller or a dozer before placing subsequent RRM layers. Fill materials shall be placed in continuous and planar lifts. The method of dumping and spreading RRM shall result in loose lifts of nearly uniform thickness, with average thickness not to exceed 24. Compaction equipment shall consist of footed rollers or dozers. Footed rollers shall have a minimum weight of 45,000 pounds and at least one tamping foot shall be provided for each 110 square inches of drum surface.

The length of each tamping foot from the outside surface of the drum shall be at least 6 inches. During compaction operations, the spaces between the tamping feet shall be maintained clear of materials that would impair the effectiveness of the tamping foot rollers. Dozers shall have a minimum ground pressure of 1,650 pounds per feet. The computer-based compaction system may be used to direct fill placement, monitor compaction, and record the location and thickness of each soil layer being placed.

6.4.3 Inspection and Testing

QC shall visually inspect the ground preparation and fill placement operations. RRM shall be compacted to meet 90 percent of the laboratory-determined maximum dry density in accordance with ASTM D698. QC shall verify the RRM placement is constructed in accordance with design plans and specifications by checking and confirming:

- Assessment tests shall be performed on RRM to ensure compliance with specified requirements and to develop compaction requirements for placement. A minimum of three tests for maximum dry density (ASTM D698) and optimum moisture content (ASTM D2216) shall be performed for each type of RRM soil observed.
- Fill material is properly moisture conditioned; one moisture content quick test will be performed each day material is placed in accordance with ASTM D4643, D4944, or D4959 until a sufficient number have been performed to demonstrate a clear correlation allowing a reduction in testing.
- Fill material is placed in continuous and planar lifts. The method of dumping and spreading RRM shall result in loose lifts of nearly uniform thickness, with average thickness of fill area not to exceed 24 inches.
- Compaction meets specifications.
- Compaction by computer-based system shall be monitored by QC by visually inspecting the process and reviewing the computer records for each layer of soil placed.
- In-place density verification tests shall be performed on the initial layer of RRM and on any layers in which the computer-based compaction system indicates problems occurred obtaining compaction. In-place density will be taken every 6 months to verify the performance of the computer-based compaction system.

NOTE: Companion sand cone and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

If the computer-based compaction system is not used, the following testing requirements shall be followed:

- In-place density and moisture content compaction verification tests are performed on compacted fill material in accordance with the following requirements:
  - A verification representative sample from each principal type or combination of blended RRM materials shall be tested to establish compaction curves using ASTM D698.
  - A minimum of one set of compaction curves shall be developed per 10,000 cubic yards of RRM material.
  - In-place density and moisture content tests are performed on a soil layer; a minimum of two tests shall be performed per 5,000 cubic yards or 135,000 square feet of fill material placed.

- Compaction and moisture content tests shall be performed in accordance with the following methods:
  - ASTM D1556
  - ASTM D2216
  - ASTM D6938
  - ASTM D4643
- Erosion that occurs in the RRM layers shall be repaired and grades re-established before proceeding.
- Freezing and desiccation of the RRM soil shall be prevented. If freezing or desiccation occurs, the affected soil shall be reconditioned.
- Areas that have been repaired shall be retested. Repairs to the RRM layers shall be documented, including location and volume of soil affected, corrective action taken, and results of retests.

6.4.4 Demolition Debris

Demolition debris will be placed in the cell along with RRM. Debris shall not contain free liquids. Debris shall be sized to minimize voids. Pipes and ducts 6 inches or greater in diameter shall be crushed or, if crushing is impractical, shall be longitudinally cut in half or filled. Rubber tires shall be cut and placed to minimize void space. Debris shall be spread and/or oriented in a manner that results in a minimum of voids.

Debris may be placed as a sacrificial lift at the bottom of the disposal cell in a 2-foot lift. Debris in sacrificial lifts shall contain no free liquids and shall be oriented in a manner that minimizes voids, and contained within the 2-foot lift profile. Sacrificial debris lifts are not subject to moisture and compaction criteria.

6.4.5 Final RRM Geometry

The top surface of the RRM shall be no greater than 2 inches above the lines and grades shown on the drawings and verified by survey or the use of the computer-based compaction system. No minus tolerance will be permitted.

6.5 Interim Cover

After a section the RRM has been placed in the waste cell to final grade and verified by survey, an interim cover consisting of 1 foot of clean, compacted soil shall be placed over the RRM. Interim cover material will be placed and compacted directly on top of RRM to provide a buffer of uncontaminated soil before placement of the final multi-layer cap. A protective layer may be placed as mentioned in Section 6.5.5.

6.5.1 Material

Interim cover soil will be from the excavation of the Crescent Junction waste cell. It will be material that has been produced on site by modifying the existing overburden soil and weathered Mancos Shale excavated on site. Overburden and weathered Mancos Shale shall be excavated, pulverized, wetted, and mixed to produce a uniform, fine-grained soil near optimum moisture content compaction. Soil shall be free of roots, debris, and organic or frozen material.

6.5.2 Ground Preparation

The RRM beneath the proposed interim cover shall be prepared by scarifying to a minimum depth of 1 inch before placing the initial lift of interim cover soil.

6.5.3 Lift Placement and Thickness

The interim cover shall be constructed of fill materials placed in continuous lifts of uniform thickness. The method of dumping and spreading interim cover soil over the RRM shall result in loose lifts with average thickness not to exceed 14 inches.

6.5.4 Inspection and Testing

QC shall visually inspect the ground preparation and fill placement operations. The interim cover layer shall be compacted to meet 90 percent of the laboratory-determined maximum dry density in accordance with ASTM D698.

QC shall verify the interim cover is constructed in accordance with plans and specifications by checking and confirming:

- A representative sample from each type or combination of stockpiled excavated soil for use as interim cover soil shall be tested to establish a compaction curve using ASTM D698.
- Interim cover is properly moisture conditioned tested in accordance with ASTM D4643, D4944, or D4959, and moisture content shall be within the range needed to achieve a minimum of 90 percent of the laboratory-determined maximum dry density of each material type.
- Interim cover is placed in continuous and approximately horizontal lifts. The method of dumping and spreading interim cover shall result in loose lifts of nearly uniform thickness, with average uncompacted thickness not to exceed 14 inches. Compaction testing should alternate between checking compaction in the top half of each lift and the bottom half of each lift.
- Compaction is properly performed.
- Compaction by computer-based compaction system is monitored by QC by visually inspecting the process and reviewing the computer records for each layer of soil placed.
- Verification tests of in-place density shall be performed on the first 5,000 cubic yards of interim cover and on any layers in which the computer-based compaction system indicates that problems occurred obtaining compaction.

NOTE: Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

If the computer-based compaction system is not used, the following requirements shall be followed:

- In-place density and moisture content compaction verification tests are performed on compacted fill material in accordance with the following requirements:
    - When verification, in-place density, and moisture content tests are performed on a soil layer, a minimum of two tests shall be performed per 5,000 cubic yards or 135,000 square feet of fill material placed.
    - A representative sample from each type or combination of stockpiled excavated soil for use as interim cover soil shall be tested to establish a compaction curve using ASTM D698.
    - Interim cover is properly moisture conditioned and tested in accordance with ASTM D4643, D4944, or D4959. The moisture content range needed to achieve a minimum of 90 percent of the laboratory-determined maximum dry density of each material type.

- Interim cover is placed in continuous and approximately horizontal lifts. The method of dumping and spreading interim cover shall result in loose lifts of nearly uniform thickness, with average uncompacted thickness not to exceed 14 inches.
- Compaction is properly performed.
- Compaction testing should alternate between checking compaction in the top half of each lift and the bottom half of each lift
- Compaction and moisture content tests shall be performed in accordance with the following methods:
  - ASTM D1556
  - ASTM D2216
  - ASTM D6938
  - ASTM D4643
  - ASTM D698

NOTE: Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

- After lift placement, moisture content shall be maintained until the next lift is placed.
- Erosion that occurs in the interim cover layer shall be repaired and grades re-established.
- Freezing and desiccation of the interim cover soil shall be prevented. If freezing or desiccation occurs, the affected soil shall be reconditioned.
- Areas that have been repaired shall be re-tested. Repairs to the interim cover layer shall be documented, including location and volume of soil affected, corrective action taken, and results of retests.

6.5.5 Final Interim Cover Geometry

The top surface of the interim cover shall be no greater than 2 inches above the lines and grades shown on the drawings. No minus tolerance will be permitted. If the radon barrier is not placed immediately after completion of the interim cover, it is acceptable to use a best management practice of placing a protective layer of 8 inches (minimum) on the interim cover, which will protect the interim cover from damaged caused by erosion and roots and self-sown vegetation. The vegetation does not have to be removed until the radon barrier placement. The protective layer can be cleared of vegetation and re-used as a part of the radon barrier.

6.6 Cap Construction

An UMTRA cover (a multi-layer cap) will be constructed over the RRM and interim cover. The cap materials and configuration are intended to protect the RRM from exposure due to water erosion, wind erosion, and burrowing animals for a design life of 1,000 years. The proposed cap layers are shown in the UMTRA cover design figure in Section 6.7.1.

6.7 Radon Barrier Layer

The initial cap layer is a 4-foot-thick radon barrier layer constructed of compacted clay soil. The radon barrier will be a low-permeability clay layer that limits radon emissions from the RRM and limits the infiltration of water from above.

6.7.1 Material

The radon barrier layer will be constructed of processed Mancos Shale. The clay soil will be produced on site by processing excavated Mancos Shale into a fine-grained soil and adding water to bring the Mancos Shale to near optimum moisture content for compaction.

Assessment tests shall be performed on radon barrier material to ensure compliance with specified requirements and to develop compaction requirements for placement. A minimum of three tests for maximum dry density (ASTM D698); optimum moisture content tests (ASTM D2216) shall be performed for each type of soil observed to establish the optimum moisture for radon barrier material placement.

At a minimum, perform the following soil tests on each 10,000 cubic yards of soil:

- ASTM D4318
- ASTM D1140
- ASTM D422
- ASTM D698
- ASTM D2216 or D4643

6.7.2 Ground Preparation

The interim cover layer beneath the proposed radon barrier layer shall be prepared by scarifying to a minimum depth of 1 inch before placing the initial lift of radon barrier soil. Scarification shall be performed on the upper surface of each underlying soil layer before placement of the next lift.

The final lift of radon barrier shall not be scarified; it shall be smooth-rolled with a minimum of three passes with a smooth, steel-wheeled roller with a minimum weight of 20,000 pounds to provide a smooth surface.

6.7.3 Lift Placement and Thickness

The radon barrier layer shall be constructed of fill materials placed in continuous lifts of uniform thickness. The method of dumping and spreading radon barrier shall result in loose lifts not to exceed 12 inches. Compaction equipment shall consist of rubber-tired or footed-roller compaction equipment with a minimum weight of 45,000 pounds. The in-place material may contain particles up to 4 inches.

Placement of Mancos Shale will be visually inspected to make sure there are no locations where rock-type particles accumulate in a concentrated location. Particles found in a concentrated location will be removed or reworked per QC direction.

6.7.4 Inspection and Testing

QC shall visually inspect the processing of Mancos Shale into clay soil, ground preparation, and fill-placement operations. QC shall perform in-place density tests with companion moisture tests to verify optimum moisture plus or minus 3 percent and at least 95 percent of the material’s maximum dry density according to ASTM D698.

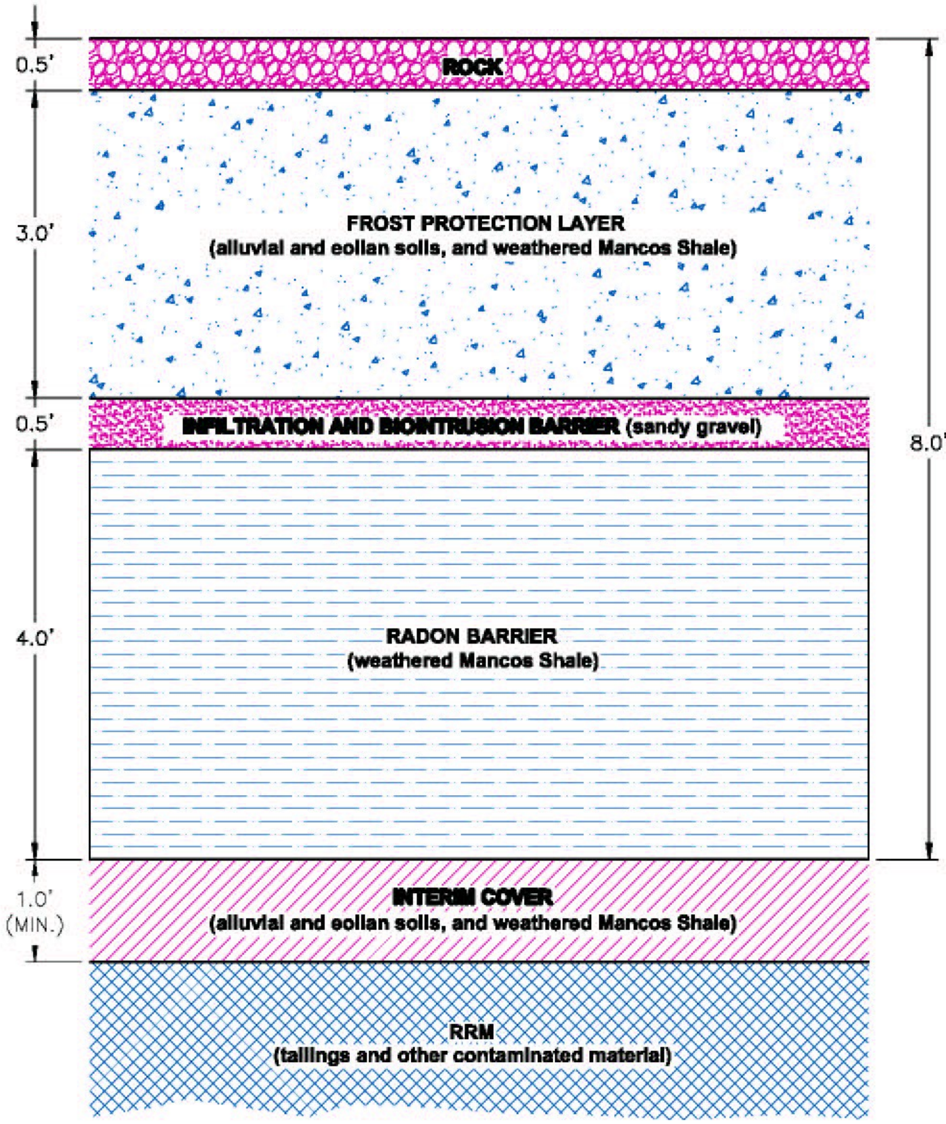
QC shall verify the radon barrier is constructed in accordance with plans and specifications by checking and confirming:

- Fill material is properly moisture conditioned; one moisture content test will be performed each day material is placed in accordance with ASTM D4643, D4944, or D4959, with moisture content plus or minus 3 percent.
- Material is placed in continuous uniform thickness lifts. The method of dumping and spreading the radon barrier shall result in loose lifts not to exceed 12 inches.
- Radon barrier soil is processed Mancos Shale.
- Tests have been performed on the processed shale soil to determine its maximum dry density and optimum moisture content.
- Radon barrier fill is compacted with rubber-tired or footed-roller compaction equipment.
- QC shall monitor the computer-based compaction system by visually inspecting the process and reviewing the computer records for each layer of soil placed.
- Verification tests of in-place density shall be performed on the initial layer of radon barrier placed and on any layers in which the computer-based compaction system indicates problems occurred obtaining compaction.
- Maximum particle size in the fill material shall be 4 inches.
- Placement of Mancos shale will be visually inspected to make sure there are no locations where rock-type particles accumulate in a concentrated location.
- Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

NOTE: If the computer-based compaction system is not used, the following testing requirements shall be followed.

- In-place density and moisture content tests compaction verification tests are performed on compacted fill material in accordance with the following requirements:
    - A verification representative sample from each principal type or combination of blended radon barrier materials shall be tested to establish compaction curves using ASTM D698. A minimum of one set of compaction curves shall be developed per 10,000 cubic yards of radon barrier material.
    - In-place density and moisture content tests are performed on a soil layer; a minimum of two tests shall be performed per 5,000 cubic yards or 135, 000 square feet of fill material placed.
    - Fill material is properly moisture conditioned in accordance with ASTM D4643, D4944, or D4959, with moisture content plus or minus 3 percent.
    - Material is placed in continuous uniform thickness lifts. The method of dumping and spreading radon barrier shall result in loose lifts not to exceed 12 inches.
    - Radon barrier soil is processed Mancos Shale.
    - Tests have been performed on the processed shale soil to determine its maximum dry density and optimum moisture content.
    - Radon barrier fill is compacted with rubber-tired or footed-roller compaction equipment.
    - Maximum particle size in the fill material shall be 4 inches.
    - Placement of Mancos Shale will be visually inspected to make sure there are no locations where rock-type particles accumulate in a concentrated location

- o Compaction and moisture content tests shall be performed in accordance with the following methods:
  - ASTM D1556
  - ASTM D2216
  - ASTM D6938
  - ASTM D4643
  - ASTM D698



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NOTE: Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

- After placement, moisture content shall be maintained or adjusted to meet criteria.
- Erosion that occurs in the fill layers shall be repaired and grades re-established.
- Freezing and desiccation of the radon barrier layer shall be prevented. If freezing or desiccation occurs, the affected soil shall be removed or reconditioned.
- Areas that have been repaired shall be retested. Repairs to the radon barrier layer shall be documented, including location and volume of soil affected, corrective action taken, and results of retests.

6.7.5 Initial and Confirmatory Surveys

Verification of the thickness of the radon barrier layer will be performed by comparing before and after surveys of the layer by surveying or using the computer-based compaction system. Before placing the radon barrier layer, an initial survey shall be performed of the section to be capped.

The initial survey will document the pre-cap geometry of the site. After the radon barrier layer has been installed, a post-installation survey will be performed on the top of the radon barrier fill to confirm that the total fill thickness is in accordance with the plans and specifications.

6.8 Infiltration and Biointrusion Barrier (Gravel)

Above the radon barrier layer, a 6-inch-thick infiltration and biointrusion layer of gravel will be placed to provide a barrier to burrowing animals and a pathway for drainage of water that has infiltrated through upper layers of the cap. The gravel will be a sandy gravel with a gradation in accordance with Project plans and specifications.

Rock shall be spread to the thickness indicated on the drawings or in accordance with oversizing due to scoring criteria. Rock placement shall be guided by GPS grade control to ensure the appropriate thickness has been placed at all locations. The biointrustion layer shall be compacted with a smooth steel drum.

6.8.1 Erosion Protection Materials Testing

Rock for the infiltration and biointrusion barrier layer shall be tested by a commercial testing laboratory during production in accordance with the following:

Test Method	Reference
SSD Specific Gravity	ASTM C127 Sodium Sulfate Soundness (5 cycles)
	ASTM C88
L.A. Abrasion (100 cycles)	ASTM C131
Schmidt Rebound Hardness	International Society of Rock Engineers (ISRM) Method

Test results shall be submitted to a commercial testing lab for analysis and subsequent acceptance or rejection or the material represented by the test results, based on engineering calculations.

Rock for the infiltration and biointrusion barrier layer shall be tested for gradation in accordance with ASTM C-117 and C-136 and other approved testing methods. Test results shall be in accordance with the design specifications. Rock for the final cover layers shall be tested a minimum of three times. The materials shall be tested initially before the delivery of any of the materials to the site for gradation and durability, then from the on-site stockpile at the beginning of placement for gradation. Lastly, testing shall be performed for every 5,000 square yards of material delivered.

All placed material shall be visually inspected during and after placement. The visual inspections shall verify (1) no nesting of fines, (2) no nesting of small-large aggregates in a concentrated area, and (3) all aggregate material is interlocking. Rock for the infiltration and biointrusion barrier layer shall be material that has long-term chemical and physical durability. The material shall achieve an acceptable score for its intended use in accordance with the rock scoring and acceptance criteria.

6.8.2 Rock Acceptance Criteria

An acceptable rock score depends on the intended use of the rock. The rock's score must meet the following criteria:

- For occasionally saturated areas, which include the top and sides of the final cover, the rock must score at least 50 percent, or the rock is rejected. If the rock scores between 50 percent and 80 percent, the rock may be used, but a larger median stone diameter (D_{50}) must be provided (oversizing). If the rock score is 80 percent or greater, no oversizing is required.
- For frequently saturated areas, which include all channels and buried slope toes, the rock must score 65 percent, or the rock is rejected. If the rock scores between 65 and 80 percent, the rock may be used, but must be oversized. If the rock score is 80 percent or greater, no oversizing is required.

Oversizing Rock

- Subtract the rock score from 80 percent to determine the amount of oversizing required. For example, a rock with a rating of 70 percent will require oversizing of 10 percent (80 percent less 70 percent = 10 percent).
- The D_{50} of the stone shall be increased by the oversizing percent. For example, a stone with a 10 percent oversizing factor and a D_{50} of 12 inches will increase to a D_{50} of 13.2 inches.
- The final thickness of the stone layer shall increase proportionately to the increased D_{50} rock size. For example, a layer thickness equals twice the D_{50}, such as when the plans call for
- 24 inches of stone with a D_{50} of 12 inches; if the stone D_{50} increases to 13.2, the thickness of the layer of stone with a D_{50} of 13.2 should be increased to 26.4 inches.

QC shall verify the infiltration and biointrusion layer is installed in accordance with plans and specifications by checking and confirming:

- Gravel material gradation matches the gradation required in the specifications.
- Gravel material is placed and compacted to produce a continuous uniform thickness of at least 6 inches.
- Compaction is performed by a smooth steel-drum roller with a minimum of two passes over the placed gravel fill.

6.9 Frost Protection Layer

Above the infiltration and biointrusion layer a 3-foot-thick frost protection layer will be installed. This soil layer will provide protection for the low-permeability radon barrier layer beneath. The frost protection layer will consist of 3 feet of clean, compacted soil that shall be placed directly on the gravel infiltration and biointrusion layer.

6.9.1 Material

The frost protection layer will be constructed of common fill. The fill shall come from the cell excavation, tested to determine its maximum dry density, and the moisture content modified to bring the fill to optimum for compaction in accordance with ASTM D698.

6.9.2 Ground Preparation

The frost protection layer will be placed directly on the gravel infiltration and biointrusion layer.

6.9.3 Lift Placement and Thickness

The frost protection layer shall be constructed of fill materials placed in continuous lifts of uniform thickness. The method of dumping and spreading the frost protection layer shall result in loose lifts, with average thickness not to exceed 12 inches. Scarification shall be performed on all areas of the upper surface of each underlying soil layer before placing the next lift. The final lift of soil shall not be scarified. The final lift shall be smooth-rolled with at least three passes of the approved smooth, steel-wheeled roller weighing a minimum of 20,000 pounds.

6.9.4 Inspection and Testing

QC shall visually inspect the material preparation, ground preparation, and fill placement operations. QC shall perform in-place density tests with companion moisture tests. Frost protection soil shall be placed and compacted within a moisture content range that will achieve at least 90 percent of the material's maximum dry density on the initial layer according to ASTM D698.

QC shall verify the frost protection layer is constructed in accordance with plans and specifications by checking and confirming:

- Frost protection layer soil is common fill.
- Tests have been performed on the common fill to determine its maximum dry density and optimum moisture content per ASTM D698.
- Fill material is properly moisture conditioned to near optimum moisture.
- Fill material is placed in continuous and approximately horizontal lifts. The method of dumping and spreading the frost protection layer shall result in loose lifts of nearly uniform thickness, with average thickness not to exceed 12 inches.
- Compaction is properly performed.
- Frost protection fill will be compacted with rubber-tired or footed-roller compaction equipment.
- Compaction by the computer-based compaction system shall be monitored by QC by visually inspecting the process and reviewing the computer records for each layer of soil placed.
- Verification tests of in-place density shall be performed on initial layers of soil placed and on any layers in which the computer-based compaction system indicates problems occurred obtaining compaction.

NOTE: Companion sand cone and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

If the computer-based compaction system is not used, testing requirements below shall be followed.

- Perform in-place density and moisture content compaction verification tests on compacted fill material in accordance with the following requirements:
  - When verification, in-place density, and moisture content tests are performed on a soil layer, a minimum of two tests per 5,000 cubic yards or 135,000 square feet of fill material placed.
  - Frost protection layer soil is common fill.
  - Tests have been performed on the common fill to determine its maximum dry density and optimum moisture content per ASTM D698.
  - Fill material is properly moisture conditioned.
  - Fill material is placed in continuous and approximately horizontal lifts. The method of dumping and spreading the frost protection layer shall result in loose lifts of nearly uniform thickness, with average thickness not to exceed 12 inches.
  - Compaction is properly performed.
  - Frost protection fill will be compacted with rubber-tired or footed-roller compaction equipment.
  - Compaction and moisture content tests shall be performed in accordance with the following methods:
    - ASTM D1556
    - ASTM D698
    - ASTM D2216
    - ASTM D2922
    - ASTM D6938
    - ASTM D4643

NOTE: Companion sand cone tests and moisture tests must be performed along with nuclear tests until a sufficient number have been performed to demonstrate a clear correlation.

6.9.5 Initial and Confirmatory Surveys

Verification of the thickness of the frost protection layer will be performed by comparing before and after surveys of the layer. Before placing the frost protection layer, an initial survey of the section to be capped shall be performed. The initial survey will document the geometry of the top of the infiltration and biointrusion layer.

After the frost protection layer has been installed, a post-installation survey will be performed on the top of the frost protection layer to confirm the total fill thickness is in accordance with the plans and specifications.

6.10 Rock Armoring

The final cap layer is rock armoring placed over the frost protection layer. The rock armoring will vary in size and thickness at different locations on the cap and shall be installed in accordance with Project plans and specifications. Rock shall be spread to the thickness indicated on the drawings or in accordance with oversizing due to scoring criteria. Rock placement shall be guided by a GPS system to ensure the appropriate thickness has been placed at all locations. Stone shall be compacted with a smooth steel drum.

6.10.1 Erosion Protection Materials Testing

Rock for the final cover layers shall be tested by a commercial testing laboratory during production in accordance with the following:

Rock Armoring	Reference
Specific Gravity (SSD)	ASTM C127 (Absorption) Sodium Sulfate Soundness (five cycles) ASTM C88 (Coarse Aggregate)
L.A. Abrasion (100 cycles)	ASTM C131 (Abrasion)
Schmidt Rebound Hardness	ISRM Method

Test samples shall be submitted to a commercial testing lab for analysis and subsequent acceptance or rejection of the material represented by the test results, based on engineering calculations. Rock for the final cover layers shall be tested for gradation in accordance with ASTM C-117 and C-136 and other approved testing methods. Test results shall be in accordance with the design specifications.

Rock for the final cover layers shall be tested a minimum of three times. The materials shall be tested initially before the delivery of any of the materials to the site for gradation and durability, then from the on-site stockpile at the beginning of placement for gradation. Lastly, testing shall be performed for every 5,000 cubic yards of material delivered.

All placed material shall be visually inspected during and after placement. The visual inspections shall verify: (1) no nesting of fines, (2) no nesting of small to large aggregates in a concentrated area, and (3) all aggregate material interlocks.

Rock for the final cover layers shall be rock material that has long-term chemical and physical durability. Rock for final cover layers shall achieve an acceptable score for its intended use, in accordance with the rock scoring and acceptance criteria.

A geologist will periodically inspect the stockpiles at the quarry operations to ensure the percentage of other than gray basalt does not exceed 10 percent for rock for the final cover layers.

6.10.2 Rock Acceptance Criteria

An acceptable rock score depends on the intended use of the rock. A rock's score must meet the following criteria:

- For occasionally saturated areas, which include the top and sides of the final cover, the rock must score at least 50 percent, or the rock is rejected. If the rock scores between 50 and 80 percent, the rock may be used, but a larger D_{50} must be provided (oversizing). If the rock score is 80 percent or greater, no oversizing is required.
- For frequently saturated areas, which include all channels and buried slope toes, the rock must score 65 percent, or the rock is rejected. If the rock scores between 65 and 80 percent, the rock may be used, but must be oversized. If the rock score is 80 percent or greater, no oversizing is required.

Oversizing Rock

- Subtract the rock score from 80 percent to determine the amount of oversizing required. For example, a rock with a rating of 70 percent will require oversizing of 10 percent (80 percent less 70 percent = 10 percent).

- The D_{50} of the stone shall be increased by the oversizing percentage. For example, a stone with a 10 percent oversizing factor and a D_{50} of 12 inches will increase to a D_{50} of 13.2 inches.
- The final thickness of the stone layer shall increase proportionately to the increased D_{50} rock size. For example, a layer thickness equals twice the D_{50}, such as when the plans call for 20 inches of stone with a D_{50} of 12 inches; if the stone D_{50} increases to 13.2, the thickness of the layer of stone with a D_{50} of 13.2 should be increased to 26.4 inches.

QC shall verify the rock armoring is installed in accordance with plans and specifications by checking and confirming stone material is placed to produce the thickness required by the plans for each area. At a minimum, depth verification will be performed every 10,000 cubic yards.

Settlement Monitoring
A grid system shall be established for periodic surveys to monitor cell settlement. This system will be transferred to DOE Legacy Management for continued cell settlement monitoring.

Cell Construction Material Installation Summary Table

Cell Component	Material of Construction	Compaction Requirements	Lift Thickness max/approx loose/compact	Frequency of Verification Tests
Cell Excavation	NA	NA	NA	NA
Perimeter Embankment	Common Fill	95 percent	12 inches/ 10 inches	Initial layer/Section 6.3.4
RRM Placement	RRM	90 percent	Average thickness 24 inches/ 20 inches	Initial layer/Section 6.4.3
Interim Cover	Common Fill	90 percent	Average 14 inches/ 10 inches	Initial layer/Section 6.5.4
Radon Barrier	Weathered Mancos Shale	95 percent	12 inches/ 10 inches	Initial layer/Section 6.7.4
Infiltration and Biointrusion Barrier	Stone	NA	NA	NA
Frost Protection	Common Fill	90 percent	Average thickness 12 inches/ 10 inches	Initial layer/Section 6.9.4
Cap Armoring	Stone	NA	NA	NA

7.0 Records

All documentation created as a result of compliance with this Plan is considered a Project record and will be managed in accordance with the *Moab UMTRA Project Records Management Manual* (DOE-EM/GJ1545), which follows DOE orders, policies, and regulations for retention and maintenance of records.

Test and inspection records shall be reported and filed in a timely manner, consistent with the status of work performed. Inspection and test status shall be available at all times to prevent inadvertent by-passing of an inspection or test. Test and inspection records shall contain the following, at a minimum:

- Items tested or inspected
- Date of test or inspection
- Tester/inspector
- Type of test or inspection
- Results and acceptability, including the test or inspection acceptance criteria
- Identification number of instrument used in performing the test or inspection
- Action taken in connection with any deviations noted
- Person evaluating test results, if different from person named in paragraph

Test and inspection records shall be filed and maintained in accordance with the *Records Management Manual*. Surveillances shall be performed by QA of measure and test equipment used by QC. Daily Inspection Reports shall be generated, describing the adequacy, discrepancies, progress, dispositions, and details of each day's construction activities. Permanent QA/QC records shall be periodically evaluated through internal and external surveillances and audits. QC reports shall be generated daily, summarizing the volume of placed materials and the number of lifts approved. A summary of this information shall be included in the RAC's weekly Project status report submitted to DOE.