U.S. Department of Energy
200 Grand Avenue
Grand Junction, CO 81501
December 21, 2012

Ms. Kimberly Conway
FSME Division of Waste Management and Environmental Protection
U.S. Nuclear Regulatory Commission
Mail Stop T8F5
Washington, DC 20555-0001

Subject: Transmittal of Revised Sections of the Remedial Action Plan for the Crescent Junction, Utah, Disposal Cell, Moab Uranium Mill Tailings Remedial Action (UMTRA) Project

Dear Ms. Conway:

We appreciate the recent attention to the Moab UMTRA Project during your site visits in July and September. You witnessed steady progress and we have now placed 5.7 million tons of residual radioactive material (RRM) in the Crescent Junction disposal cell. We also reached the RRM design height on approximately 200,000 square feet and placed interim cover over this area in October. We placed the interim cover in preparation for an operational shutdown of three months that began December 1.

The purpose of this letter is to transmit the following revised documents that are part of the Remedial Action Plan. NRC has previously agreed to the changes reflected in these documents.

1) Remedial Action Selection Report, updated December 2012 (only changed pages)
2) Addendum B – Final Design Specifications, August 2011
   - 31-00-30 R7, Placement and Compaction of Final Cap Layers
   - 32-11-23 R8, Aggregate and Riprap
3) Addendum E – Remedial Action Inspection Plan, June 2011 (without attachments)

If you have any questions or concerns, do not hesitate to contact me at (970) 257-2115.

Sincerely,

Donald R. Metzler
Federal Project Director

cc w/enclosure:
C. Nakahara, UDEQ
K. Wethington, DOE
J. Biagini, RAC
C. Niemeyer, RAC
J. Ritchey, TAC
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Project File CRJ 2.12 (C. Smith)
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Add'l copies were sent to K. Conway

DOE–EM/GJ1547

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

Remedial Action Selection Report

Revision 2

July 2008
Updated December 2012

U.S. Department of Energy

Office of Environmental Management

Prepared by the Remedial Action Contractor under contract number DE-AT30-07CC00014 for the U.S. Department of Energy Office of Environmental Management, Grand Junction, Colorado.

DOE–EM/GJ1547

Moab UMTRA Project
Final Remedial Action Plan and Site Design for Stabilization of Moab Title I Uranium Mill Tailings at the Crescent Junction, Utah, Disposal Site

Remedial Action Selection Report

Revision 2

July 2008
Updated December 2012

Work Performed by Energy*Solutions* Federal Services under DOE Contract No. DE–AT30–07CC00014 and S.M. Stoller Corporation under DOE Contract No. DE–AC01–02GJ79491 for the U.S. Department of Energy Office of Environmental Management, Grand Junction, Colorado

Tables

Addenda

Attachments
(Previously Provided in the Draft RAP)

only a RRM layer and a layer of interim cover material did, however, indicate that a side slope thickness of 11 feet would be sufficient to limit the radon flux rate to less than 20 pCi/m2/s. Information on layer thicknesses is in Attachment 1, Appendix B, and Addendum D, Calculation C-05.

For all model runs, RRM thickness of 1310.7 centimeters (cm) (43 ft) is used. This is the maximum thickness of the RRM in the design of the disposal cell. The tailings consist of two layers, a lower layer that is 1,097.3 cm (36 ft) thick and an upper layer that is 213.4 cm (seven feet) thick. This configuration was chosen to allow higher activity waste to be placed in the lower layer providing that the radium activity of the RRM in the upper layer is 707 picoCuries per gram (pCi/g) or less.

The UMTRA Project cover design evaluated for radon flux consists of a one-foot-thick interim cover constructed of uncontaminated native alluvial materials and a compacted clay radon barrier constructed from conditioned on-site weathered Mancos Shale. The drainage and biointrusion layer, frost protection layer, and rock mulch erosion protection layer are not considered in the modeling.

5.2.6 Radium-226 Activity

Radium-226 activities for the tailings pile materials were assessed (by gamma spectroscopy) on 104 samples of tailings sands, slimes, transitional tailings, and other contaminated materials. The estimated volumes of tailings material are provided in Attachment 1, Appendix K, and Addendum D, Calculation C-05. The average radium-226 activity of these 104 samples is 707 pCi/g. The number of samples per unit volume of slimes was greater than for the other materials to be placed in the disposal cell. Because the average radium activity of the samples collected from the slimes (1,349.3 pCi/g) is greater than for any of the other materials, this simple average overestimates the radium activity of RRM that will be well mixed before being placed in the cell. Accounting for the volumes and the radium activities of the different materials, the radium activity of completely mixed contaminated material from the Moab Site would be 565 pCi/g.

As the RRM is placed in the lower layer of the cell, the radium activity will be monitored only occasionally. As the RRM is placed in the upper layer (seven feet) the radium activity will be carefully monitored to ensure that the average radium activity in the upper seven feet does not exceed 707 pCi/g. In modeling the rate of radon emission from the top of the radon barrier, the radium activity of the lower layer has been set equal to the average of the slimes (1,349.3 pCi/g) and the upper layer to the average of all samples (707 pCi/g). This is a conservative approach as the overall volume-weighted average radium activity is 565 pCi/g and the modeled volume-weighted average is 1,245 pCi/g.

The radium-226 activity of the alluvial materials to be used for the interim cover and the clean fill perimeter dikes is based on five samples of native materials collected from the Crescent Junction Site. The radium-226 activity of the alluvial material ranged from 1.4 to 2.3 pCi/g, with a mean value of 1.9 pCi/g.

The radium-226 activity value for the compacted clay layer is based on two samples of Mancos Shale collected from the Crescent Junction Site that will be used to construct the compacted clay

ADDENDUM B

Final Remediation Action Plan
DOE-EM/GJ1547
August 2011

Final Design Specifications

Number	Title
31-00-00 R4	Earthwork
31-00-20 R4	Placement and Compaction of Tailings and Interim Cover
31-00-30 R7	Placement and Compaction of Final Cap Layers
31-32-11 R1	Surface Water management and Erosion Control
32-11-23 R8	Aggregate and Riprap

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MOAB UMTRA PROJECT MOAB, UTAH PROJECT NO: 35DJ2600	DOCUMENT NO.: 35DJ2600-056-SPEC-31-00-30 SECTION NO.: 31-00-30 PLACEMENT AND COMPACTION OF FINAL CAP LAYERS

This title sheet is the first page of the specification and a record of each issue or revision. The pages revised and the description of the revision should be noted under remarks.

REV.	DATE	BY	CKD	APPROVED	PAGES	REMARKS
0	12/17/07	WDB	FMP	W. Barton	ALL	ISSUED FOR CONSTRUCTION
1	1/30/08	WDB	FMP	W. Barton	ALL	Page 7, Section 3.2.2: Revised lift thickness Page 8, Section 3.2.6: Added bentonite Page 8, Section 3.3.2: Revised lift thickness Page 9, Section 3.3.6: Added bentonite Page 9, Section 3.4.1: Revised final sentence.
2	4/14/08	WDB	FMP	W. Barton	ALL	Page 6, Section 1.5: Add section 1.5, NQA-1 Quality Level. Page 8, Section 3.2.2: Revised from 10" loose lift thickness to 12" loose lift thickness. Page 9, Section 3.3.2: Revised from 10" loose lift thickness to 12" loose lift thickness.
3	06/02/08	WDB	FMP	W. Barton	ALL	Page 5, Section 1.3: Deleted "Relative". Page 7, Section 2.2: Added reference to Aggregate Spec. Page 8, Section 3.2.1: Added grain size distribution to list of tests on Radon Barrier Material. Page 9, Section 3.2.5: Added reference to ASTM D698. Page 9, Section 3.2.3: Revised moisture requirement to add "optimum plus or minus 3%. Page 9, Section 3.3.3: Revised moisture requirement to add "optimum plus or minus 5%.
4	08/03/10	WDB	FMP	W. Barton	ALL	Page 6, Section 2.1: Change maximum clod size from 1 inch to 3 – 4 inches. Page 7, Table 1: Change maximum particle size from 1 inch to 3 – 4 inches.
5	09/02/10	WDB	FMP	W. Barton	ALL	Page 6, Section 2.1: Change word "clod" to "particle". Page 6, Section 2.1: Add new 3rd paragraph about placement and inspection of Mancos shale.

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6	09/08/10	WDB	FMP	W. Barton	ALL	Page 8, Section 2.1, Table 1: Revised the minimum Liquid Limit from 35 to 30 and added a maximum Liquid Limit of 50. Page 12, Section 3.6.1: Added a paragraph describing sampling and testing of in-place aggregate. The paragraph includes criteria for evaluating results of testing and any deviation from the specified range of aggregate.
7	08/18/11	WDB WDB	FMP	W. Barton W. Barton	ALL	Page 12, Section 3.5: Added Section 3.5.1 Tolerance of RRM and Interim Layers Added Section 3.5.2 Tolerances of Cover Layers New sections revise the tolerances of each layer of material placed.

REGISTERED PROFESSIONAL ENGINEER
No. 5789?-2202
FRANKLIN M. PARTON JR.
STATE OF UTAH

SECTION TABLE OF CONTENTS

DIVISION 32 - EARTHWORK

SECTION 31 00 30

PLACEMENT AND COMPACTION OF FINAL CAP LAYERS

-- End of Section, Table of Contents --

SECTION 31 00 30

PLACEMENT AND COMPACTION OF FINAL CAP LAYERS

PART 1 GENERAL

1.1 SCOPE

This specification covers material characteristics, placement, compaction, and testing of final cap layers, including:

- Radon barrier layer;
- Stone infiltration and bio-barrier;
- Frost protection layer; and
- Rock armoring.

1.2 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D 1140	(2000) Amount of Material in Soils Finer than the No. 200 (75-micrometer) Sieve
ASTM D 1556	(2000) Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D 698	(2002e1) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu ft)
ASTM D 2167	(1994; R 2001) Density and Unit Weight of Soil in Place by the Rubber Balloon Method
ASTM D 2216	(2005) Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D 2488	(2006) Description and Identification of Soils (Visual-Manual Procedure)
ASTM D 6938	(2007b) In-place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM D 3740	(2004a) Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
ASTM D 422	(1963; R 2002e1) Particle-Size Analysis of Soils

ASTM D 4220	(1995; R 2000) Preserving and Transporting Soil Samples
ASTM D 4318	(2005) Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D 4643	(2000) Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
ASTM D 4944	(2004) Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
ASTM D 4643	(2000) Determination of Water (Moisture) Content of Soil by Direct Heating

1.3 SUBMITTALS

Approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. All submittals shall be provided to the Construction Manager in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-03 Product Data

Equipment

Submit specifications for equipment for the processing, scarification, placement, compaction, and smooth rolling of fill, including type, model number, weight and critical dimensions of equipment.

SD-06 Test Reports

Moisture Content and Density Tests of Fill Materials, G;

Moisture Content Tests of Soil Fill, G;

Moisture Content and In-Place Density Tests of Soil Fill (Verification Testing), G;

CAES Soil Placement and Compaction Records, G;

Test reports shall be submitted to the Energy Solutions Construction Quality Control Manager within 48 hours of the completion of soil placement and field testing.

1.4 EQUIPMENT

Equipment used to place and compact the Radon Barrier material and Frost Protection common fill shall not brake suddenly, turn sharply, or be operated at excessive speeds.

1.4.1 Compaction Equipment

Compaction equipment shall consist of footed rollers which have a minimum weight of 45,000 pounds and at least one foot for each 110 square inches of drum surface. The length of each tamping foot shall be at least 6 inches from the outside surface of the drum. During compaction operations, the spaces between the tamping feet shall be maintained clear of materials which would impair the effectiveness of the tamping foot rollers.

1.4.2 Scarification Equipment

Disks, rotor tillers, or other approved means shall be provided to scarify the surface of each lift of soil prior to placement of the next lift. The scarification equipment shall be capable of uniformly disturbing the upper 1 - 2 inches of the soil surface to provide good bonding between lifts.

1.4.3 Steel Wheeled Rollers

A smooth, non-vibratory steel wheeled roller shall be used to produce a smooth compacted surface on finished compacted soil layers. Steel wheeled rollers shall weigh a minimum of 20,000 pounds.

1.4.4 Hand Operated Tampers

Hand operated tampers shall consist of rammers or other impact type equipment. Vibratory type equipment will not be allowed.

1.5 NQA-1 QUALITY LEVEL

All construction and testing activities included in this specification: PLACEMENT AND COMPACTION OF FINAL CAP LAYERS for the Disposal Cell at Crescent Junction, are designated as Quality Level 2.

PART 2 PRODUCTS

2.1 RADON BARRIER LAYER

Radon Barrier is the layer constructed on top of the interim cover layer and the contaminated tailings material in the waste cell and underlying the protection layers in the final cap. The purpose of this layer is to retard the emanation of radon gas from the tailings into the atmosphere and to minimize infiltration of incident precipitation into the tailings material.

Radon Barrier Layer soil shall be produced by modifying the weathered Mancos Shale excavated on site. Weathered Mancos Shale shall be excavated, separated from other excavated materials, pulverized, wetted, and mixed to produce a uniform fine-grained fill soil at or above optimum moisture content for compaction. It shall be free of roots, debris, organic or frozen material, and shall have a maximum particle size of 3 - 4 inches at the time of compaction. Fill material shall comply with the criteria listed in Table 1. Testing of Radon Barrier soil to verify conformance with the following table is described in Section 3.2.1 Radon Barrier Material.

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.

TABLE 1
REQUIRED PHYSICAL PROPERTIES OF RADON BARRIER FILL SOIL

Test Property	Test Value	Method
Max. particle size (inches)	3 - 4	ASTM D 422
Min. percent passing No. 4 sieve	80	ASTM D 422
Min. percent passing No. 200 sieve	50	ASTM D 1140
Min. liquid limit	30	ASTM D 4318
Max. liquid limit	50	ASTM D 4318
Min. plasticity index	10	ASTM D 4318
Max. plasticity index	40	ASTM D 4318

2.2 STONE FOR FINAL COVER LAYERS

Stone for the final cover layers, infiltration and bio-barrier layer and rock armoring, shall be rock material that has long-term chemical and physical durability. Rock for final cover layers shall be in accordance with Section 32 11 23 Aggregate and Riprap. Rock for final cover layers shall achieve an acceptable score for its intended use, in accordance with the following rock scoring and acceptance criteria:

TABLE 2
NRC TABLE OF SCORING CRITERIA FOR ROCK QUALITY

Laboratory Test	**Weighing Factor**													
	L*	**S***	**I***	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair				Poor		
Specific Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.30	2.25
Absorption, %	13	5	2	0.10	0.30	0.50	0.67	0.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	0.0
LA Abrasion, %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmitt Hammer	11	13	3	70	65	60	54	47	40	32	24	16	8	0

* L = Limestone, S = Sandstone, I = Igneous

Notes:
1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642, Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review, 1982.
2. Weighing Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G.W. Dupuy, Engineering Geology, July 1965. Weighing factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighing factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.
3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR2642, so that proper correlations can be made.

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% or the rock is rejected. If the rock scores between 50% and 80% the rock may be used, but a larger D50 must be provided (oversizing). If the rock score is 80% or greater, no oversizing is required.
- For frequently saturated areas, which include all channels and buried slope toes, the rock must score 65% or the rock is rejected. If the rock scores between 65% and 80%, the rock may be used, but must be oversized. If the rock score is 80% or greater, no oversizing is required.

Oversize rock as follows;

- Subtract the rock score from 80% to determine the amount of oversizing required. For example, a rock with a rating of 70% will require oversizing of 10 percent (80% - 70% = 10%).
- The D50 of the stone shall be increased by the oversizing percent. For example, a stone with a 10% oversizing factor and a D50 of 12 inches will increase to a D50 of 13.2 inches.
- The final thickness of the stone layer shall increase proportionately to the increased D50 rock size. For example, a layer thickness equals twice the D50, such as when the plans call for 24 inches of stone with a D50 of 12 inches, if the stone D50 increases to 13.2, the thickness of the layer of stone with a D50 of 13.2 should be increased to 26.4 inches.

2.3 FROST PROTECTION LAYER

The Frost Protection Layer is the top soil layer constructed of the waste cell cover. The purpose of this layer is to protect underlying cover layers from degradation due to environmental factors such as freeze-thaw cycles. The Frost Protection Layer shall be constructed of common fill material, which can be any soil material from the waste cell excavation.

PART 3 EXECUTION

3.1 EXCAVATION, SEGREGATION, AND STOCKPILING OF CAP MATERIALS

Cap materials shall be soil material from the waste cell excavation. Materials shall be excavated, segregated into common fill and weathered Mancos Shale, and stockpiled for use as cap materials. Stockpiles shall be at locations shown in the project plans or as directed by the Construction Manager.

3.2 INSTALLATION OF RADON BARRIER MATERIAL

3.2.1 Radon Barrier Material

The Radon Barrier Layer will be constructed of processed Mancos Shale soil. The soil will be produced on site by processing excavated Mancos Shale into a fine-grained soil and adding water to bring the Mancos Shale soil to near optimum moisture content for compaction. Mancos Shale soil produced for Radon Barrier fill shall be tested to determine its material properties and its maximum dry density and moisture content. As a minimum, perform the following soil tests on each 10,000 cu yds of soil:

ASTM D 4318, Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D 422, Particle-Size Analysis of Soils
ASTM D 1140, Amount of Material in Soils Finer than the No. 200 Sieve
ASTM D 698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort.
ASTM D 2216, Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass and/or ASTM D 4643, Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating

3.2.2 Radon Barrier Material Placement

Radon Barrier shall be placed to the lines and grades shown on the drawings. The soil shall be placed in loose lifts not to exceed 12 inches in thickness after compaction. In areas where hand operated tampers must be used, the loose lift thickness shall not exceed 4 inches.

3.2.3 Moisture Control

Radon Barrier soil shall be placed and compacted within a moisture content range that will achieve the specified compaction (optimum plus or minus 3%). The moisture content shall be maintained uniform throughout each lift. Water added shall be thoroughly incorporated into the soil to ensure uniformity of moisture content prior to compaction.

3.2.4 Scarification and Dressing of Final Lift Surface

Scarification shall be performed on all areas of the upper surface of each underlying soil layer prior to placement of the next lift. Scarification shall be accomplished with approved equipment. The final lift of Radon Barrier soil shall not be scarified. The final lift shall be smooth rolled with at least 3 passes of the approved smooth steel wheeled roller to provide a smooth surface.

3.2.5 Compaction

Radon Barrier soil shall be compacted to at least 95% of its laboratory maximum dry density determined in accordance with ASTM D698. The Computer Aided Earthmoving System may be used to direct fill placement, monitor compaction, and record the location and thickness of the each soil layer being placed. If the CAES is not used for compaction, fill shall be compacted with a minimum 45,000 lb static weight footed roller capable of kneading compaction, with feet a minimum of 6 inches in length.

3.2.6 Repair of Voids

Voids created in the Radon Barrier layer during construction (including, but not limited to, penetrations for test samples, grade stakes, and other penetrations necessary for construction) shall be repaired by removing any unsuitable material, backfilling with soil and compacting by tamping each lift with a steel rod, or by backfilling with bentonite.

3.3 INSTALLATION OF FROST PROTECTION LAYER SOIL

3.3.1 Frost Protection Material

The Frost Protection layer will be constructed of common fill soil. The soil will be produced on site by adding water to bring the excavated and stockpiled soil to near optimum moisture content for compaction. Test soil in accordance with ASTM D 698, Laboratory Compaction Characteristics of Soil Using Standard Effort. Perform at least 3 tests on each type of material stockpiled for use as fill. Perform additional lab density tests on stockpiled material if changes in material characteristics are observed.

3.3.2 Frost Protection Layer Placement

Frost Protection soil shall be placed to the lines and grades shown on the drawings. The soil shall be placed in loose lifts not to exceed 12 inches in thickness after compaction. In areas where hand operated tampers must be used, the loose lift thickness shall not exceed 4 inches.

3.3.3 Moisture Control

Frost Protection soil shall be placed and compacted within a moisture content range that will achieve the specified compaction (optimum plus or minus 5%). The moisture content shall be maintained uniform throughout each lift. Water added shall be thoroughly incorporated into the soil to ensure uniformity of moisture content prior to compaction.

3.3.4 Scarification and Dressing of Final Lift Surface

Scarification shall be performed on all areas of the upper surface of each underlying soil layer prior to placement of the next lift. Scarification shall be accomplished with approved equipment. The final lift of soil shall not be scarified. The final lift shall be smooth rolled with at least 3 passes of the approved smooth steel wheeled roller to provide a smooth surface.

3.3.5 Compaction

Soil shall be compacted to 90% of the laboratory determined maximum dry density in accordance with ASTM D 698. The Computer Aided Earthmoving System shall be used to direct fill placement, monitor compaction, and record the location and thickness of each soil layer being placed.

3.3.6 Repair of Voids

Voids created in the Radon Barrier layer during construction (including, but not limited to, penetrations for test samples, grade stakes, and other penetrations necessary for construction) shall be repaired by removing any unsuitable material, backfilling with soil and compacting by tamping each lift with a steel rod, or by backfilling with bentonite.

3.4 INSTALLATION OF ROCK LAYERS

This section describes the material and installation of rock layers for the Infiltration and Biobarrier and Rock Armoring of the final cover.

3.4.1 Rock Placement and Compaction

Rock shall be spread to the thickness indicated on the drawings or in accordance with oversizing due to scoring criteria (see Section 2.2 of this specification). Rock placement shall be guided by the Computer Aided Earthmoving System to ensure that the appropriate thickness has been placed at all locations. Stone with a D50 of 2 inches or less shall be shall be compacted with a vibratory steel drum.

3.5 CONSTRUCTION TOLERANCES

3.5.1 Tolerance of RRM and Interim Layers

- RRM Layer - The top surface of the RRM layer shall be no greater than 2 inches above the lines and grades shown on the drawings. No minus tolerance will be permitted.
- Interim Layer - The top surface of the Interim Layer shall be no greater than 2″ above the lines and grades shown on the drawings. No minus tolerance will be permitted.

3.5.2 Tolerances of Cap Layers

The following layers shall be installed to the thicknesses indicated for each layer, no minus tolerance will be permitted. Excess soil or rock is permitted to assure that the minimum thickness is achieved, but shall be as little as practically achievable. Final layer thickness shall be uniform, smooth and continuous, without humps or thickened edges or other defects.

- Radon Barrier - Layer minimum thickness is 4′, no minus tolerance permitted. Confirm 4′ minimum thickness by performing a pre and post survey.
- Infiltration and Biointrusion - Layer minimum thickness is 6″, no minus tolerance permitted.
- Frost Protection - Layer minimum thickness is 3′, no minus tolerance permitted. Confirm 3′ minimum thickness by performing a pre and post survey.
- Cap Rock - The final thickness of the Cap Rock depend on the location in which the rock is placed and shall be in accordance with the drawings and the Aggregate and Riprap Specification 32-11-23, Table 3. No minus tolerance permitted.

3.6 CONSTRUCTION TESTS

3.6.1 Material Tests

For placement and compaction of soils, moisture content tests shall be performed daily prior to placement to maintain moisture control and uniformity of soil to be used for fill. Computer Aided Earthmoving System shall be used to place, compact and document compaction of all soil layers. CAES acceptance of an installed layer of soil will constitute proof of satisfactory compaction. Computer output of the CAES will be acceptable documentation for location, thickness and compaction of installed layers.

Aggregate Particle Size Tests on In-Place Stone - When particle size tests are performed on in-place stone, obtain bulk samples of aggregate and perform sieve analyses in accordance with ASTM D 422 - Particle Size Analysis of Soils. Aggregate shall be considered acceptable if the result of particle size testing:

- for any sieve size >#4 sieve, is within 5% of the specified gradation range (Specification 32 11 23, Table 3); or
- for any sieve size <#4 sieve, is within 3% of the specified gradation range (Specification 32 11 23, Table 3).

Compaction Verification Tests - Perform in-place density and moisture content tests on compacted fill material in accordance with the following requirements:

- Verification tests of in-place density shall be performed on initial layer of soil placed, and on any layers in which the CAES indicates that problems occurred obtaining compaction.
- 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 of fill material placed.
- Compaction and moisture content tests shall be performed in accordance with the following methods:
  - o ASTM D 1556 - Density and Unit Weight of Soil in Place by the Sand-Cone Method
  - o ASTM D 2216 - Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
  - o ASTM D 6938(2007b) - In-place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

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

3.6.2 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. Prior to placement of the Radon Barrier Layer, a survey shall be performed of the top of the Interim Cover layer. 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.

3.7 PROTECTION

3.7.1 Moisture Content

After placement, moisture content shall be maintained or adjusted to meet criteria.

3.7.2 Erosion

Erosion that occurs in the fill layers shall be repaired and grades re-established.

3.7.3 Freezing and Desiccation

Freezing and desiccation of the Radon Barrier layer shall be prevented. If freezing or desiccation occurs, the affected soil shall be removed or reconditioned as directed.

3.7.4 Retests

Areas that have been repaired shall be retested as directed. Repairs to the Radon Barrier layer shall be documented including location and volume of soil affected, corrective action taken, and results of retests.

-- End of Section --

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MOAB UMTRA PROJECT MOAB, UTAH PROJECT NO: 35DJ2600	DOCUMENT NO.: 35DJ2600-056-SPEC-32-11-23
	SECTION NO.: 32-11-23
	AGGREGATE AND RIPRAP

This title sheet is the first page of the specification and a record of each issue or revision. The pages revised and the description of the revision should be noted under remarks.

REV.	DATE	BY	CKD	APPROVED	PAGES	REMARKS
0	12/17/07	WDB	FMP	W. Barton	ALL	ISSUED FOR CONSTRUCTION
1	1/30/08	WDB	FMP	W. Barton	ALL	Page 11, Table 3, Revised Gradations to allow small amount of fines
2	2/27/08	WDB	FMP	W. Barton	ALL	Page 8, Section 1.5, Revised weather limitations. Page 11, Section 2.1.6.2. revised riprap thicknesses.
3	4/15/08	WDB	FMP	W. Barton	ALL	Page 8, Section 1.7: Added Section 1.7, NQA-1 Quality Levels.
4	06/03/08	WDB	FMP	W. Barton	ALL	Revised Section 1.4.2.2, deleted requirements to check Liquid Limit and Plasticity Index. Revised Section 1.4.3.1, deleted requirements to check Liquid Limit and Plasticity Index.
5	07/03/08	WDB	FMP	W. Barton	ALL	Revised Section 2.1.4, Riprap. Added sentence clarifying: TABLE 1 for non-disposal cell aggregate TABLE 3 for disposal cell aggregate/riprap Revised Section 2.1.8.1 Biobarrier: Added sentence describing the filter requirements of biobarrier material. Revised TABLE 3: Adjusted gradations to increase sizes of materials as follows: Cover Top - D50 = 2 in Cover N, E & W edge - D50 = 4 in Cover South Edge/Slope - D50 = 6 in CJ East and West Apron - D50 = 8 in CJ North Apron - D50 = 8 in CJ South Apron - D50 = 12 in Added note to TABLE 3: Contractor to limit the amount of fines associated with riprap to minimize segregation of riprap during installation. Revised Section 3.6 Installation of Riprap: Added paragraph requiring Contractor to minimize fines and install riprap such that it does not segregate.
6	09/09/10	WDB	FMP	W. Barton	ALL	Revise Table 3, Cover Biobarrier gradation: change range for 1 ½ inch sieve from 40-50 to 40-60.
7	05/20/11	WDB	FMP	W. Barton	ALL	Revise Spec Section 2.1.0, Stone Layers for the Waste Cell Final Cover, to change riprap D50 sizes, and gradations. Table 3 was extensively revised.
8	08[illegible]	[illegible]	FMP	W. Barton	ALL	Revise Table 3, Gradation of fines in accordance with CID 065 and CID 067.

REGISTERED PROFESSIONAL ENGINEER
FRANKLIN M. PARTON JR.
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SECTION 32 11 23

AGGREGATE AND RIPRAP

PART 1 GENERAL

1.1 REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

AASHTO T 11 (2005) Standard Method of Test for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing

AASHTO T 19 (2004) Standard Method of Test for Bulk Density ("Unit Weight") and Voids in Aggregate

AASHTO T 27 (2006) Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates

AASHTO T 99 (2001; R 2004) Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in) Drop

AASHTO T 180 (2004) Standard Method of Test for Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in) Drop

AASHTO T 193 (2003) Standard Method of Test for The California Bearing Ratio

AASHTO T 224 (2001; R 2004) Correction for Coarse Particles in the Soil Compaction Test

ASTM INTERNATIONAL (ASTM)

ASTM C 1260 (2005a) Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

ASTM C 127 (2004) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate

ASTM C 128 (2004a) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate

ASTM C 131	(2006) Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C 29/C 29M	(1997; R 2003) Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate
ASTM C 88	(2005) Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM D 698	(2000ae1) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu ft)
ASTM D 1556	(2000) Density and Unit Weight of Soil in Place by the Sand-Cone Method
ASTM D 1557	(2002e1) Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft3) (2700 kN-m/m3)
ASTM D 2167	(1994; R 2001) Density and Unit Weight of Soil in Place by the Rubber Balloon Method
ASTM D 2487	(2006) Soils for Engineering Purposes (Unified Soil Classification System)
ASTM D 6938	(2007b) In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
ASTM D 75	(2003) Standard Practice for Sampling Aggregates
ASTM E 11	(2004) Wire Cloth and Sieves for Testing Purposes

1.2 DEFINITIONS

For the purposes of this specification, the following definitions apply.

1.2.1 Untreated Base Course

Untreated Base Course (UBC) is well graded, durable aggregate uniformly moistened and mechanically stabilized by compaction.

1.2.2 Degree of Compaction

Degree of compaction required, except as noted in the second sentence, is expressed as a percentage of the maximum laboratory dry density obtained by the test procedure presented in AASHTO T 99 or AASHTO T 180 abbreviated as a percent of laboratory maximum dry density. The degree of compaction for material having more than 30 percent by weight of their particles retained on the 3/4 inch sieve shall be expressed as a percentage of the laboratory maximum dry density in accordance with AASHTO T 99 or AASHTO T 180 Method D and corrected with AASHTO T 224.

1.3 SUBMITTALS

Approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. All submittals shall be provided to the Construction Manager in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-06 Test Reports

Sampling and Testing, G;

Field Density Tests, G;

Certified copies of test results for approval not less than 10 days before material is required for the work.

Calibration curves and related test results prior to using the device or equipment being calibrated.

Copies of field test results within 24 hours after the tests are performed.

1.4 SAMPLING AND TESTING

Sampling and testing shall be the responsibility of the Contractor. The materials shall be tested to establish compliance with the specified requirements; testing shall be performed at the specified frequency. The Contracting Officer may specify the time and location of the tests. Copies of test results shall be furnished to the Contracting Officer within 24 hours of completion of the tests.

1.4.1 Sampling

Samples for laboratory testing shall be taken in conformance with ASTM D 75. When deemed necessary, the sampling will be observed by the Contracting Officer.

1.4.2 Tests

The following tests shall be performed in conformance with the applicable standards listed.

1.4.2.1 Sieve Analysis

Sieve analysis shall be made in conformance with AASHTO T 27 and AASHTO T 11. Sieves shall conform to ASTM E 11.

1.4.2.2 Moisture-Density Determinations

The laboratory maximum dry density and optimum moisture content shall be determined in accordance with AASHTO T 99 or AASHTO T 180, Method D and corrected with AASHTO T 224.

1.4.2.3 Field Density Tests

Density shall be field measured in accordance with ASTM D 1556, ASTM D 2167 or ASTM D 6938. For the method presented in ASTM D 6938 the calibration curves shall be checked and adjusted if necessary using only the sand cone method as described in paragraph Calibration, of the ASTM publication. Tests performed in accordance with ASTM D 6938 result in a wet unit weight of soil and when using this method, ASTM D 6938 shall be used to determine the moisture content of the soil. The calibration curves furnished with the moisture gauges shall also be checked along with density calibration checks as described in ASTM D 6938. The calibration checks of both the density and moisture gauges shall be made by the prepared containers of material method, as described in paragraph Calibration of ASTM D 6938, on each different type of material being tested at the beginning of a job.

1.4.2.4 Wear Test

Wear tests shall be made on aggregate material in conformance with ASTM C 131.

1.4.2.5 Soundness

Soundness tests shall be made on aggregate in accordance with ASTM C 88.

1.4.3 Testing Frequency

1.4.3.1 Tests on Proposed Material

To demonstrate that the proposed material meets all specified requirements, one of each of the following tests shall be performed on the proposed material prior to commencing construction, and subsequently for every 5,000 cubic yards of material. If materials from more than one source are going to be utilized, this testing shall be completed for each source.

a. Sieve Analysis.

b. Moisture-density relationship.

c. Wear.

d. Soundness.

1.4.4 Approval of Material

The source of the material shall be selected prior to the time the material will be required in the work. Approval of material will be based on test results.

1.5 WEATHER EFFECTS

Completed areas damaged by freezing, rainfall, or other weather conditions shall be corrected to meet specified requirements.

1.6 PLANT, EQUIPMENT, AND TOOLS

All plant, equipment, and tools used in the performance of the work shall be subject to approval before the work is started and shall be maintained in satisfactory working condition at all times. The equipment shall be adequate and shall have the capability of producing the required compaction, meeting grade controls, thickness control, and smoothness requirements as set forth herein.

1.7 NQA-1 QUALITY LEVEL

All rock armoring activities for the Disposal Cell at Crescent Junction, including: the Cover Biobarrier, Top, Apron Riprap, Slope Riprap, and Channel Armor are designated as Quality Level 2. All other work (not on the Disposal Cell) is non-Quality related (Quality Level 3).

PART 2 PRODUCTS

2.1 AGGREGATES

Aggregate shall consist of clean, sound, durable particles of crushed stone, crushed gravel, angular sand, or other approved material. Untreated Base Course shall be free of lumps of clay, organic matter, and other objectionable materials or coatings. Gravel shall be free of silt and clay as defined by ASTM D 2487, organic matter, and other objectionable materials or coatings. Aggregates will be used for the following applications, and the material properties for each of these application will be provided in the following section:

Application	**Name of Material**	**Gradation**
Road Base	Untreated Base Course	UDOT UBC
Pipe Bedding	Coarse sand/gravel	ASTM D448 #9
Drainage Stone	Open graded gravel	ASTM D448 #57
Riprap slope armor	Riprap	D50 per plans
Riprap channel armor	Riprap	D50 per plans
Cover Biobarrier	Sandy gravel	D50 2 in
Cover Top	Sandy gravel	D50 2 in
Cover Apron Riprap	Riprap, 1,000 yr	D50 per plans
Cover Slope Riprap	Riprap, 1,000 yr	D50 per plans
CJ Channel Armor	Riprap, 1,000 yr	D50 per plans

2.1.1 Road Base

Aggregate for road base beneath asphalt pavement and for unpaved gravel roads and pads shall be UDOT Untreated Base Course. The UBC coarse aggregate shall not show more than 50 percent loss when subjected to the Los Angeles abrasion test in accordance with ASTM C 131. The amount of flat and elongated particles shall not exceed 30 percent. A flat particle is one having a ratio of width to thickness greater than 3; an elongated particle is one having a ratio of length to width greater than 3. In the portion retained on each sieve specified, the crushed aggregates shall contain at least 50 percent by weight of crushed pieces having two or more freshly fractured faces with the area of each face being at least equal to 75 percent of the smallest midsectional area of the piece. When two fractures are contiguous, the angle between planes of the fractures must be at least 30 degrees in order to count as two fractured faces. Crushed gravel for road base shall be provided in the gradation listed in TABLE 1. When the coarse aggregate is supplied from more than one source, aggregate from each source shall meet the specified requirements and shall be stockpiled separately.

2.1.2 Pipe Bedding

Pipe bedding shall be coarse sand, or fine gravel, free from deleterious materials and rocks larger than 3/8 inch. Sandy soil or excavated shaly soil may be used for pipe bedding if it is excavated or processed such that the material size is similar to the gradation listed in TABLE 1.

2.1.3 Drainage Stone

Drainage stone is an open graded stone material intended as a capillary break beneath concrete slabs. Drainage stone will also be used for French Drains and seepage collection drains for retaining structures and mechanically stabilized earth structures. Drainage stone shall be provided in the gradation listed in TABLE 1.

2.1.4 Riprap

Riprap for slope and channel protection shall be provided at locations indicated on the drawings. Riprap shall be sized in accordance with plans and as listed in TABLE 1. Materials listed in TABLE 1 are not intended for use on the Disposal Cell at Crescent Junction. Disposal Cell materials are included in TABLE 3, below.

TABLE I. GRADATION OF AGGREGATES

Percentage by Weight Passing Square-Mesh Sieve

Sieve Designation	Road Base	Pipe Bedding	Drainage Stone	Riprap Slope Armor	Riprap Channel Armor
12 inch	-------	-------	-------	-------	100
10 inch	-------	-------	-------	100	80-100
8 inch	-------	-------	-------	80-100	20-80
6 inch	-------	-------	-------	20-60	0-20
4 inch	-------	-------	-------	0-20	0
2 inch	-------	-------	-------	0	-------
1-1/2 inch	100	-------	100	-------	-------
1 inch	90-100	-------	95-100	-------	-------
3/4 inch	70-85	-------	-------	-------	-------
1/2 inch	65-80	-------	25-60	-------	-------
3/8 inch	55-75	100	-------	-------	-------
No. 4	40-65	85-100	10-20	-------	-------
No. 8	-------	20-40	5-10	-------	-------
No. 16	25-40	10-20	0	-------	-------
No. 50	-------	5-10	-------	-------	-------
No. 200	7-11	0-5	-------	-------	-------

2.1.5 Stone For Final Cover Layers

Stone for the final cover layers, infiltration and bio-barrier layer and rock armoring, shall be rock material that has long-term chemical and physical durability. Rock for final cover layers shall achieve an accpetable score for its intended use, in accordance with the following rock scoring and acceptance criteria:

TABLE 2.
NRC TABLE OF SCORING CRITERIA FOR ROCK QUALITY

Laboratory Test	Weighing Factor L*	S*	I*	10	9	8	7	6	5	4	3	2	1	0
					Good			Fair				Poor		
Specific Gravity	12	6	9	2.75	2.70	2.65	2.60	2.55	2.50	2.45	2.40	2.35	2.30	2.25
Absorption, %	13	5	2	0.10	0.30	0.50	0.67	0.83	1.0	1.5	2.0	2.5	3.0	3.5
Sodium Sulfate, %	4	3	11	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
LA Abrasion, %	1	8	1	1.0	3.0	5.0	6.7	8.3	10.0	12.5	15.0	20.0	25.0	30.0
Schmdt Hammer	11	13	3	70	65	60	54	47	40	32	24	16	8	0

* L = Limestone, S = Sandstone, I = Igneous

Notes:
1. Scores were derived from Tables 6.2, 6.5, and 6.7 of NUREG/CR-2642, Long-Term Survivability of Riprap for Armoring Uranium Mill Tailings and Covers: A Literature Review, 1982.
2. Weighing Factors are derived from Table 7 of "Petrographic Investigations of Rock Durability and Comparisons of Various Test Procedures," by G.W. Dupuy, Engineering Geology, July 1965. Weighing factors are based on inverse of ranking of test methods for each rock type. Other tests may be used; weighing factors for these tests may be derived using Table 7, by counting upward from the bottom of the table.
3. Test methods should be standardized, if a standard test is available and should be those used in NUREG/CR2642, so that proper correlations can be made.

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% or the rock is rejected. If the rock scores between 50% and 80% the rock may be used, but a larger D50 must be provided (oversizing). If the rock score is 80% or greater, no oversizing is required.
- For frequently saturated areas, which include all channels and buried slope toes, the rock must score 65% or the rock is rejected. If the rock scores between 65% and 80%, the rock may be used, but must oversized. If the rock score is 80% or greater, no oversizing is required.

Oversize rock as follows;
- Subtract the rock score from 80% to determine the amount of oversizing required. For example, a rock with a rating of 70% will require oversizing of 10 percent (80% - 70% = 10%).
- The D50 of the stone shall be increased by the oversizing percent. For example, a stone with a 10% oversizing factor and a D50 of 12 inches will increase to a D50 of 13.2 inches.
- The final thickness of the stone layer shall increase proportionately to the increased D50 rock size. For example, a layer thickness equals twice the D50, such as when the plans call for 24 inches of stone with a D50 of 12 inches, if the stone D50 increases to 13.2, the thickness of the layer of stone with a D50 of 13.2 should be increased to 26.4 inches.

2.1.6 Stone Layers for the Waste Cell Final Cover

Stone shall be provided and installed for the following Final Cover Layers:

Application	**Type of Material**	**Material Size**
Cover Biobarrier	Sandy gravel, 1,000 yr	D50 2 in

Cover Top	Sandy gravel, 1,000 yr	D50 2 in
Cover E,& W Edge/Slope	Riprap, 1,000 yr	D50 2.3 in
Cover N Edge/Slope	Riprap, 1,000 yr	D50 4 in
Cover South Edge/Slope	Riprap, 1,000 yr	D50 5.8 in
CJ Apron Armoring (East & West Apron)	Riprap, 1,000 yr	D50 4.7 in
CJ Apron Armoring (North Apron)	Riprap, 1,000 yr	D50 8 in
CJ Apron Armoring (South Apron)	Riprap, 1,000 yr	D50 11.8 in

2.1.6.1 Biobarrier and Cover Top

The Biobarrier and Top of Cover Stone shall meet the 1,000 year lifespan rock scoring criteria and shall be a mix of 2 inch stone and finer materials. The Cover Biobarrier material is overlain by the Frost Protection soil layer and includes fines to act as an aggregate filter and retain the overlying soil. The gradation shall be as listed in TABLE 3, below.

TABLE 3. GRADATION OF FINAL COVER AGGREGATES
Percentage by Weight Passing Square-Mesh Sieve

Sieve Designation	Cover Biobarrier	Cover Top	Cover E & W Edge Riprap	Cover N Edge Riprap	Cover S Edge, Riprap	E & W Apron Armor & Bedding	N Apron Armor & Bedding	S Apron Armor & Bedding
D50:	2"	2"	2.3"	4.0"	5.8"	4.7"	8.0"	11.8
Min. Thickness:	6"	6"	6"	8"	12"	16"	24"	36"
Bedding Thickness:							4"	4"
30 inch	-------	-------	-------	-------	-------	-------	-------	80-100
25 inch	-------	-------	-------	-------	-------	-------	-------	55-90
22 inch	-------	-------	-------	-------	-------	-------	-------	25-60
18 inch	-------	-------	-------	-------	-------	-------	-------	10-40
16 inch	-------	-------	-------	-------	-------	-------	-------	5-25
12 inch	-------	-------	-------	-------	-------	-------	90-100	0-15
10 inch	-------	-------	-------	-------	-------	-------	45-90	0-10
8 inch	-------	-------	-------	-------	90-100	90-100	35-50	-------
7 inch	-------	-------	-------	-------	45-90	-------	-------	-------
6 inch	-------	-------	90-100	90-100	35-55	35-90	0-30	-------
5 inch	-------	-------	-------	-------	-------	35-55	-------	-------
4 inch	100	100	35-90	35-50	10-40	-------	-------	-------
3 inch	-------	-------	20-60	-------	-------	-------	-------	-------
2 inch	50-100	40-50	8-45	10-36	-------	-------	-------	-------
1-1/2 inch	40-60	20-30	-------	-------	5-30	0-30	100	100
1 inch	20-40	10-20	0-30	5-30	-------	-------	60-100	60-100
1/2 inch	15-25	5-15	0-30	0-30	0-30	0-30	50-90	50-90
No. 4	10-20	0-5	0-5	0-5	0-5	0-5	20-70	20-70
No. 8	5-15	-	-	-	-	-	10-40	10-40
No. 16	5-10	-	-	-	-	-	0-30	0-30
No. 200	0-5	-	-	-	-	-	0-15	0-15

Note: The Contractor is not required to provide washed riprap, and the gradations shown in TABLE 3 allow a small percentage of fines. The Contractor shall, however, minimize the amount of fine material to prevent segregation of fines from riprap and the concentration of fine materials in any location. See Section 3.6 Installation of Riprap for more direction on placement of riprap to limit concentration of undersized material.

2.1.6.2 Final Cover Edge Riprap

The Cover Edge consists of the Waste Cell slope and a 10 ft transition zone along the top of the slope. Cover Edge stone sizes, thicknesses, and gradations shall be as listed in Table 3, above. Riprap shall be placed on the Final Cover Edges in accordance with the locations shown on the Final Cover Plans. The Riprap must meet the 1,000 year lifespan rock scoring criteria. The Cover edge riprap shall contain up to 15% material less than 1/2 inch in size to fill in around the riprap to prevent erosion beneath the riprap.

2.1.6.3 Apron Armor Riprap

Apron armor riprap for the Waste Cell shall have stone sizes, thicknesses, and gradations as listed in Table 3, above; and riprap armoring shall be placed in accordance with locations shown in the Final Cover plans and gradations listed. The riprap must meet the 1,000 year lifespan rock scoring criteria. The apron armor riprap with D50 8 inches or larger shall be installed with a 4" bedding layer.

PART 3 EXECUTION

3.1 GENERAL REQUIREMENTS

Adequate drainage shall be provided during the entire period of construction to prevent water from collecting or standing on the working area. Line and grade stakes shall be provided as necessary for control.

3.2 OPERATION OF AGGREGATE SOURCES

Clearing, stripping, and excavating shall be the responsibility of the Contractor. The aggregate sources shall be operated to produce the quantity and quality of materials meeting these specifications requirements in the specified time limit.

3.3 STOCKPILING MATERIAL

Prior to stockpiling of material, storage sites shall be cleared and leveled by the Contractor. All materials, including approved material available from excavation and grading, shall be stockpiled in the manner and at the locations designated. Aggregates shall be stockpiled on the cleared and leveled areas designated by the Contracting Officer to prevent segregation. Materials obtained from different sources shall be stockpiled separately.

3.4 PREPARATION OF UNDERLYING COURSE

Prior to constructing the base course(s), the underlying course or subgrade shall be cleaned of all foreign substances. At the time of construction of the base course(s), the underlying course shall contain no frozen material. The surface of the underlying course or subgrade shall meet specified compaction and surface tolerances. The underlying course shall conform to Section 31 00 00 EARTHWORK. Ruts or soft yielding spots in the underlying courses, areas having inadequate compaction, and deviations of the surface from the requirements set forth herein shall be corrected by loosening and removing soft or unsatisfactory material and by adding approved material, reshaping to line and grade, and recompacting to specified density requirements. The finished underlying course shall not be disturbed by traffic or other operations and shall be maintained by the Contractor in a satisfactory condition until the base course is placed.

3.5 INSTALLATION OF UNTREATED BASE COURSE

3.5.1 Placing

The material shall be placed on the prepared subgrade or subbase in layers of uniform thickness. When a compacted aggregate layer 6 inches or less in thickness is required, the material shall be placed in a single layer. When a compacted aggregate layer in excess of 6 inches is required, the material shall be placed in layers of equal thickness. No layer shall be thicker than 6 inches or thinner than 3 inches when compacted. The layers shall be so placed that when compacted they will be true to the grades shown in the plans.

3.5.2 Grade Control

The finished and completed base course shall conform to the lines, grades, and cross sections shown. Underlying material(s) shall be excavated and prepared at sufficient depth for the required base course thickness so that the finished base course and the subsequent surface course will meet the designated grades.

3.5.3 Compaction of Untreated Base Course

Each layer of the Untreated Base Course (UBC) shall be compacted as specified with approved compaction equipment. In all places not accessible to the rollers, the mixture shall be compacted with hand-operated power tampers. Compaction of UBC shall continue until each layer has a degree of compaction that is at least 95 percent of laboratory maximum density through the full depth of the layer. The Contractor shall make such adjustments in compacting or finishing procedures as may be directed to obtain true grades, to minimize segregation and degradation, to reduce or increase water content, and to ensure a satisfactory base course. Any materials that are found to be unsatisfactory shall be removed and replaced with satisfactory material or reworked, as directed, to meet the requirements of this specification.

3.5.4 Thickness

Compacted thickness of the base course shall be as indicated. No individual layer shall be thicker than 6 inches nor be thinner than 3 inches in compacted thickness.

3.5.5 Finishing

The surface of the top layer of base course shall be finished after final compaction by cutting any overbuild to grade and rolling with a steel-wheeled roller. Thin layers of material shall not be added to the top layer of base course to meet grade. If the elevation of the top layer of base course is 1/2 inch or more below grade, then the top layer should be scarified to a depth of at least 3 inches and new material shall be blended in and compacted to bring to grade.

3.5.6 Smoothness of Base Stone for Pavement

The surface of the top layer shall show no deviations in excess of 1/2 inch when tested with a 12 foot straightedge. Measurements shall be taken in successive positions parallel to the centerline of the area to be paved.

Measurements shall also be taken perpendicular to the centerline at 50 foot intervals. Deviations exceeding this amount shall be corrected by removing material and replacing with new material, or by reworking existing material and compacting it to meet these specifications.

3.6 INSTALLATION OF RIPRAP

Riprap shall be placed at locations, thicknesses, and sizes indicated on the drawings. At all locations except the Waste Cell at Crescent Junction, riprap shall be placed over a geotextile in accordance with Section 31 05 19GEOTEXTILE. For the Waste Cell cover slopes, bedding aggregate shall be placed and the riprap installed over the bedding aggregate.

For the Crescent Junction Disposal Cell, the Contractor must supply and install riprap such that the riprap material does not segregate. The objective is a uniform distribution of the specified riprap gradation. If excessive fine material is present in the riprap, it may settle to the bottom of a truck during transport and segregate from the riprap when dumped. The Contractor shall minimize the fines in the riprap, and spread the stone in a manner that prevents concentration of fine materials. Visual inspection of the riprap placement will be performed by the inspection personnel and any pockets of fines observed will be required to be replaced with material containing a uniform distribution of the specified material gradation. The Contractor shall minimize segregation of materials when bedding material is placed in conjunction with the installation of riprap and when no bedding material is required.

3.7 TRAFFIC

Completed portions of the base course for pavement may be opened to limited traffic, provided there is no marring or distorting of the surface by the traffic. Heavy equipment shall not be permitted except when necessary to construction, and then the area shall be protected against marring or damage to the completed work.

3.8 MAINTENANCE

The base course shall be maintained in a satisfactory condition until the full pavement section is completed and accepted. Maintenance shall include immediate repairs to any defects and shall be repeated as often as necessary to keep the area intact. Any base course that is not paved over prior to the onset of winter, shall be retested to verify that it still complies with the requirements of this specification. Any area of base course that is damaged shall be reworked or replaced as necessary to comply with this specification.

3.9 DISPOSAL OF UNSATISFACTORY MATERIALS

Any unsuitable materials that must be removed shall be disposed of as directed.

-- End of Section --

Addendum E. Remedial Action Inspection Plan

Revision 3

June 2011

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* (RAC) (DOE-EM/GJ1766), and complies with the applicable parts of American Society of Mechanical Engineers Nuclear Quality Assurance-1-2004, and addenda through 2007, "Quality Assurance Program for Nuclear Facilities," Title 10 Code of Federal Regulations Part 830 Subpart A (10 CFR 830A), "Quality Assurance," and DOE Order 414.1C, "Quality Assurance."

The testing and inspection activities discussed in this plan are performed in accordance with the following applicable sections of the Quality Assurance Plan: 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

ASTM	American Society for Testing and Materials International
CAES	Computerized Aided Earthmoving System
CFR	Code of Federal Regulations
D50	median stone diameter
DOE	U.S. Department of Energy
GPS	global positioning system
QC	Quality Control
RAC	Remedial Action Contractor
RRM	residual radioactive material
UMTRA	Uranium Mill Tailings Remedial Action

4.0 Attachment

Attachment 1. Computerized Aided Earthmoving System Brochure

5.0 References

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

American Society of Mechanical Engineers (ASME), Nuclear Quality Assurance (NQA)-1 2004 and addenda through 2007 consensus standard, "Quality Assurance Requirements for Nuclear Facility Applications (QA)."

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

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

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

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

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

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

ASTM D698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort.

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

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

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

ASTM D2922 – Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)

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

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

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

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

ASTM 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), March 2011.

DOE (U.S. Department of Energy), *Moab UMTRA Project Records Management Manual* (DOE-EM/GJ1545), June 2011.

DOE (U.S. Department of Energy) Order 414.1C, "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 density will be achieved at the optimum moisture content for that soil. The laboratory maximum density and optimum moisture content for the soil becomes the basis of comparison for the compaction of the soil in the field.

In the field, the soil is placed in layers, compacted with specialized compaction equipment, and tested to confirm that the soil density is close to the previously determined laboratory maximum 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 test results.

6.1.1 Computer Aided Earthmoving System

Global positioning system (GPS) and computer terrain modeling technology have been combined to provide a new method of performing soil compaction. The equipment is called Computer Aided Earthmoving System (CAES). The system works as follows:

- A digital terrain model of the site to receive fill material is fed into an on-site computer linked to a computer in the cab of the compaction equipment. A GPS receiver is also linked to the compaction machine's on-board computer. When the machine moves across the site, the GPS equipment provides the exact position and elevation of the equipment at all times.
- Soil is dumped and spread into a layer of fill. As the compaction machine spreads and compacts the layer of soil, the position of the machine is compared to the original terrain model to determine the location and thickness of the fill layer being installed. The on-board computer assists the equipment operator to place the material in a layer with uniform thickness by informing the operator of thick or thin areas of the fill.

- After a layer has been placed with uniform thickness, the compaction equipment makes multiple passes over the fill to compact the fill. A compaction machine, compacting material at the correct moisture content, will eventually compact the fill to near its maximum density such that additional compaction passes produce negligible change. The computer recording the GPS location data interprets the passes that produce no vertical change to indicate that the soil is at its maximum density.
- A record of each soil layer's location, thickness, and compaction is generated by the computer.

Visual inspection, correct placement and compaction techniques, and good moisture control are still required to ensure that fill is properly placed, but the CAES 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. The computer checks compaction over the entire surface of every layer, whereas the in-place test methods only check a few points on each layer. See Attachment 1 for vendor data on the CAES.

Soil density verification tests and independent land surveys will be performed to demonstrate the effectiveness of the CAES. 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 with interim dikes that will be removed as operations require or as subsequent phases are constructed. 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 northeast to southwest. The cut slopes on the north, west, and south 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 that the excavation is to the proposed lines and grades. The verification survey shall be signed by the Contractor and submitted to the RAC Construction 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

Quality Control (QC) shall visually inspect the material and ground preparation. QC shall verify that the cell floor is constructed in accordance with plans and specifications by checking and confirming:

- Floor and side slopes are per the design plans.
- Final floor and side slopes survey match the coordinates and elevations in the plans.
- The 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 stockpiled separately. 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, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort, and the moisture content shall be modified to bring the fill to 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 CAES and soil placement, and compaction shall be controlled by the CAES. The contractor may use CAES to determine and document compaction, or perform soil density tests 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 that the perimeter embankment is constructed in accordance with plans and specifications by checking and confirming:

- Interior slopes are 3:1, and exterior slopes are 5:1 with a minimum 30-foot-wide level top verified one time 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.
- Compaction is properly performed.
- Compaction – Embankment fill shall be compacted with a minimum 45,000 pounds static weight compactor. The compactor shall be a footed roller capable of kneading compaction, with feet a minimum of 6 inches in length.
- Compaction Verification Tests – Perform in-place density and moisture content tests on compacted fill material in accordance with the In-Place Density Testing sections below.
- Verification tests of in-place density shall be performed on initial layers of soil placed and on any specific type of material in which the CAES is used.

Testing and verification frequencies for lifts constructed without the CAES system shall be in accordance with the following:

Testing of 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 the following methods:

- ASTM D1556 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
- ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
- ASTM D6938 – In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
- 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 per ASTM D6938, of fill or backfill compacted by other than hand-operated machines.
- One check test for each 20 tests per ASTM D6938, of fill or backfill compacted by hand-operated machines.

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 (optimum moisture content plus or minus 5 percent) and laboratory maximum density values. 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 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
- ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
- ASTM D4944 – Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
- ASTM D4959 – Determination of Water (Moisture) Content of Soil by Direct Heating

During unstable weather, perform tests as dictated by local conditions and approved by the Construction 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. Prior to 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 near 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. 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 that 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 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 common fill.
- Compaction is properly performed.
- Compaction – Embankment fill shall be compacted with rollers, equipment tracks, or successive passes of scrapers at a minimum 45,000 pounds static weight.
- Compaction Verification Tests – Perform in-place density and moisture content tests on compacted fill material in accordance with the In-Place Density Testing sections below.
- Verification tests of in-place density shall be performed on initial layers of soil placed, and on any specific type of material in which the CAES is used.

Testing and verification frequencies for lifts constructed without the CAES system shall be in accordance with the following.

Testing of 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 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
- ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- ASTM D6938 – In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
- ASTM D643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating

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

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 plus or minus 5 percent) and laboratory maximum density values.

One representative density test per material type and every 20,000 cubic yards thereafter or when any change in material occurs which 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 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
- ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
- ASTM D4944 – Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester
- ASTM D959 – Determination of Water (Moisture) Content of Soil by Direct Heating

During unstable weather, perform tests as dictated by local conditions and approved by the Construction 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, and RRM placement operations, and shall perform in-place density tests with companion moisture tests for the CAES to verify that RRM compaction meets the compaction requirements. QC shall verify that the 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 Construction Manager and QC to place is obtained.

6.4.1 Moisture Modification

RRM material should be shipped from the Moab site at or near optimum moisture for compaction. Some RRM may require minor moisture modification when received at Crescent Junction site.

6.4.2 RRM Placement

Scarify at a minimum the top 1 inch of subsoil or preceding RRM lift using a footed roller or a dozer prior to placement of 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, average thickness not to exceed 12 inches. 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 CAES 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 as determined by ASTM D698. QC shall verify that 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 (optimum moisture plus or minus 3 percent) (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, average thickness of fill area not to exceed 12 inches.
- Compaction meets specifications.
- Compaction by CAES – QC shall monitor CAES compaction 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 RRM and on any layers in which the CAES indicates that problems occurred obtaining compaction. In-place density will be taken every 6 months to verify the performance of the CAES.

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 CAES is not used, the following testing requirements shall be followed.

- Compaction Verification Tests – Perform in-place density and moisture content tests 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 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
  - ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
  - ASTM D6938 – In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
  - ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
- After lift placement, moisture content shall be maintained until the next lift is placed.
- Erosion that occurs in the RRM layers shall be repaired and grades re-established.
- Freezing and desiccation of the RRM soil shall be prevented. If freezing or desiccation occurs, the affected soil shall be reconditioned as directed.
- Areas that have been repaired shall be retested as directed. 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 waste cell along with RRM. Each container of demolition debris shall be spread in a single layer, not stacked, and placed in a manner that results in a minimum of voids around the debris. The following materials will be placed in the waste cell:

- Wood, Concrete, Masonry: Cut or break up to a maximum 3-foot size measured in any dimension.
- Structural Steel Member, Pipes, Ducts, other Long Items: Cut into maximum 10-foot lengths.

- Concrete, Clay Tile, and other Pipes: Crush concrete and clay tile pipes. Crush other pipes and ducts that are 6 inches or greater in diameter or, if crushing is impractical, cut pipes and ducts in half longitudinally. Do not crush asbestos-cement pipe.
- Rubber Tires Excavated at the Site: Cut into two halves around the circumference.
- Geomembranes and other Sheet Material: Cut into strips a maximum of 4 feet wide by 4 feet long.
- Tree Limbs 4 inches in Diameter and Larger: Cut into lengths of 8 feet or less.

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 CAES. 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 prior to the placement of the final multi-layer cap.

6.5.1 Material

Interim cover soil will be soil 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 for 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 one inch prior to the placement of 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 12 inches.

6.5.4 Inspection and Testing

The 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 as determined by ASTM D698. QC shall verify that 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, one moisture content test will be performed each day material is placed in accordance with ASTM D4643, D4944, or D4959, moisture content shall be plus or minus 5 percent.
- 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 thickness not to exceed 12 inches.

- Compaction is properly performed.
- Compaction by CAES – QC shall monitor CAES compaction 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 CAES 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 CAES is not used, the following testing requirements shall be followed.

- Compaction Verification Tests – Perform in-place density and moisture content 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 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; one moisture content test will be performed each day material is placed in accordance with ASTM D4643, D4944, or D4959, moisture content shall be plus or minus 5 percent.
  - 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 thickness not to exceed 12 inches.
  - Compaction is properly performed.
  - Compaction and moisture content tests shall be performed in accordance with the following methods:
    - ASTM D1556 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
    - ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (Oven Moisture)
    - ASTM D6938 – In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
    - ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
    - ASTM D698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort

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 as directed.
- Areas that have been repaired shall be re-tested as directed. 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

Proof roll the interim cover with rubber-tired construction equipment, such as a loaded dump truck or loaded scraper, with a minimum weight of 45,000 pounds to produce a smooth compacted surface on the top of the completed interim cover layer, such that direct rainfall causes minimal erosion. 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.

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.

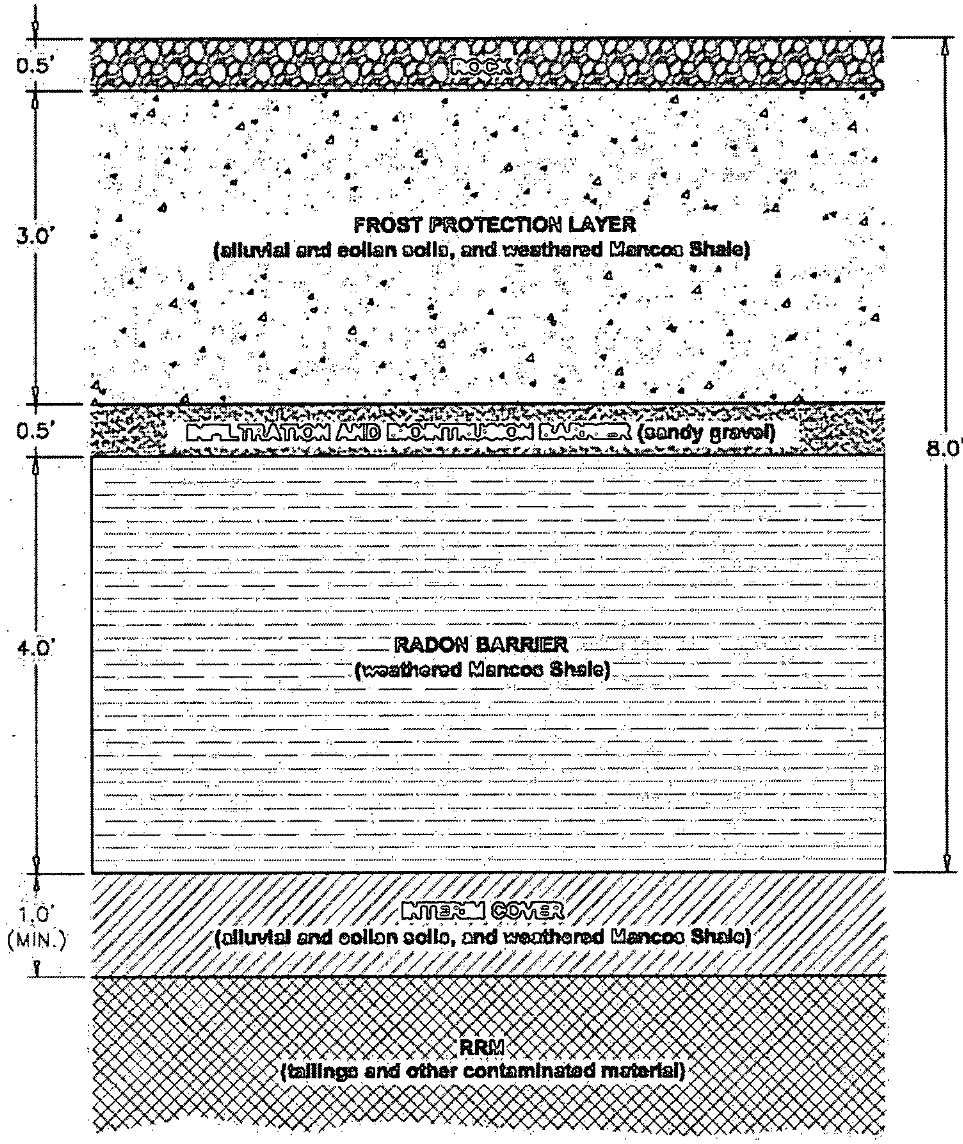
Assessment tests shall be performed on radon barrier material to ensure compliance with specified requirements and to develop compaction requirements for placement. A minimum of three tests for maximum dry density (ASTM D698); optimum moisture content (ASTM D2216) shall be performed for each type of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

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

- ASTM D4318, Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- ASTM D1140, Amount of Material in Soils Finer than the No. 200 Sieve
- ASTM D422, Standard Test Method for Particle-Size Analysis in Soil
- ASTM D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
- ASTM D2216, Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass and/or ASTM D4643, Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating

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 prior to the placement of the initial lift of radon barrier soil.



UMTRA COVER DESIGN

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 that 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 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.
- Compaction – Radon barrier fill is compacted with rubber tired or footed roller compaction equipment.
- Compaction by CAES – QC shall monitor CAES compaction 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 layer of radon barrier placed, and on any layers in which the CAES indicates that 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

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 CAES is not used, the following testing requirements shall be followed.

- Compaction Verification Tests – Perform in-place density and moisture content tests 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; 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 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.

- Compaction – 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
- Compaction and moisture content tests shall be performed in accordance with the following methods.
  - ASTM D1556 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
  - ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
  - ASTM D6938 – In-Place Density and Water content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth
  - ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating
  - ASTM D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort.

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 as directed.
- Areas that have been repaired shall be retested as directed. 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 CAES. Prior to placement of 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 vibratory 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.

Riprap Type A and B, and Bedding Material	Reference
Specific Gravity (SSD)	ASTM C127 (Absorption)
Sodium Sulfate Soundness (5 cycles)	ASTM C88 (Coarse Aggregate)
L.A. Abrasion (100 cycles)	ASTM C131 (Abrasion)

Riprap Type C and D	Reference
Schmidt Rebound Hardness	International Society for Rock Mechanics (ISRM) Method
Splitting Tensile Strength	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 ASTMs C-117 and C-136, and other approved testing methods. Test results shall be in accordance with the Design Specification.

Rock for the infiltration and biointrusion barrier layer shall be tested a minimum of four times. The materials shall be tested initially prior to the delivery of any of the materials to the site. Thereafter, the tests shall be performed in place at a minimum frequency of one test for each 5,000 cubic yards or fractions thereof produced/placed (durability tests for materials produced/gradation tests for materials placed). A final set of durability tests shall be performed near completion of production for each type material. A final gradation test shall be performed near completion of placement for each type material.

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 (D50) 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 percent 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 – 70 percent = 10 percent).
- The D50 of the stone shall be increased by the oversizing percent. For example, a stone with a 10 percent oversizing factor and a D50 of 12 inches will increase to a D50 of 13.2 inches.
- The final thickness of the stone layer shall increase proportionately to the increased D50 rock size. For example, a layer thickness equals twice the D50, such as when the plans call for 24 inches of stone with a D50 of 12 inches, if the stone D50 increases to 13.2, the thickness of the layer of stone with a D50 of 13.2 should be increased to 26.4 inches.

QC shall verify that 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 vibratory steel drum roller, and that the roller makes 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 of the frost protection layer shall result in loose lifts average thickness not to exceed 12 inches. Scarification shall be performed on all areas of the upper surface of each underlying soil layer prior to placement of 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 optimum moisture plus or minus 5 percent and at least 90 percent of the material's maximum dry density according to ASTM D698 on the initial layer.

QC shall verify that 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, average thickness not to exceed 12 inches.
- Compaction is properly performed.
- Compaction – Frost Protection fill will be compacted with rubber tired or footed roller compaction equipment.
- Compaction by CAES – QC shall monitor CAES compaction 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 CAES indicates that 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 CAES is not used, the testing requirements below shall be followed.

- Compaction Verification Tests – Perform in-place density and moisture content 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 2 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 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.
  - Compaction – 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 – Density and Unit Weight of Soil in Place by the Sand-Cone Method
    - ASTM D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort.
    - ASTM D2216 – Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
    - ASTM D2922 – Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
    - ASTM D6938 – In-Place Density and Water content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
    - ASTM D4643 – Determination of Water (Moisture) Content of Soil by the Microwave Oven Heating

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. Prior to placement of the frost protection layer, an initial survey shall be performed of the section to be capped. 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 that 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 the 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 GPSsystem to ensure the appropriate thickness has been placed at all locations. Stone shall be compacted with a vibratory 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 (5 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 ASTMs C-117 and C-136, and other approved testing methods. Test results shall be in accordance with the Design Specification.

Rock for the final cover layers shall be tested a minimum of four times. The materials shall be tested initially prior to the delivery of any of the materials to the site and at the beginning of placement. Thereafter, the tests shall be performed in place at a minimum frequency of one test for each 5,000 cubic yards or fractions thereof produced/placed (durability tests for materials produced/gradation tests for materials placed).

A final set of durability tests shall be performed near completion of production for each type material. A final gradation test shall be performed near completion of placement for each type material.

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.

Periodically, a geologist will inspect the stockpiles at the quarry operations periodically to ensure the percentage of other than grey 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. 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 D50 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 percent 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 – 70 percent = 10 percent).
- The D50 of the stone shall be increased by the oversizing percent. For example, a stone with a 10 percent oversizing factor and a D50 of 12 inches will increase to a D50 of 13.2 inches.
- The final thickness of the stone layer shall increase proportionately to the increased D50 rock size. For example, a layer thickness equals twice the D50, such as when the plans call for 24 inches of stone with a D50 of 12 inches; if the stone D50 increases to 13.2, the thickness of the layer of stone with a D50 of 13.2 should be increased to 26.4 inches.

QC shall verify that 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. As a minimum, depth verification will be performed every 10,000 cubic yards.

6.11 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 12 inches/ 10 inches	Initial layer/Section 6.4.3
Interim Cover	Common Fill	90 percent	Average 12 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

approx = approximate; max = maximum; NA = not applicable

7.0 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 *Moab UMTRA Project Records Management Manual* (DOE-EM/GJT1545). Surveillances shall be performed by Quality Assurance of measuring 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 Quality Assurance//QC records shall be periodically evaluated through internal and external surveillances and audits.

A weekly QC Report shall be generated, summarizing the volume of in-placed materials and the number of field and laboratory tests performed for each type of material. A copy of the weekly QC Report shall be transmitted to the RAC Quality Manager.