Tailings Cell Design Report
Piñon Ridge Project
Montrose County, Colorado

Prepared for:

Energy Fuels Resources Corporation

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EXECUTIVE SUMMARY

Energy Fuels Resources Corporation (EFRC) is in the process of completing designs for a new uranium mill, termed the Piñon Ridge Project, located in Montrose County, Colorado. Golder Associates Inc. (Golder) was contracted to provide geotechnical design for construction of the tailings cells, evaporation ponds and ore pads at the Piñon Ridge Project. Golder's tailings cell design scope of work includes:

- Conducting a geotechnical field and laboratory investigation of the proposed tailings cell areas (Golder, 2008a);
- Reviewing available data and regulatory requirements, and development of project design criteria;
- Evaluation of tailings cell alternative layouts and selection of the preferred alternative;
- Conducting engineering analyses and design for the tailings cells, including design of liner systems, underdrain system, leak collection and recovery system, water balance, and stability evaluations; and
- Development of design drawings and specifications for three tailings cells with a total combined capacity to contain tailings at a production rate of 500 tons per day (tpd) and a mill life of approximately 40 years, with expansion capacity for a production rate of 1,000 tpd.

The tailings cells are designed to have a total capacity of approximately 7.3 million tons (Mt). Three tailings cells (A, B, and C) of approximately equal tailings storage volume have been designed to meet this total capacity. The plan area of the lined portions of each tailings cell is 30.5 acres. Tailings Cell A has been designed as essentially two ponds within a pond, with a central divider berm constructed to mid-height of the facility, and two independent leak collection and recovery systems and tailings underdrain systems. The purpose for dividing this cell is to allow contingency storage in the early years of production in case the liner system within one of the sub-cells is not operating properly and requires inspection and/or repair. Expansion Tailings Cells B and C are each designed as single cells, with one leak collection and recovery system in each cell, as well as one underdrain outlet location. However, depending upon operations at the time of construction, Tailings Cells B and/or C may be constructed with a split cell configuration similar to Tailings Cell A.

Based on a production rate of 500 tpd, each tailings cell has a design life of approximately 13 years and a minimum capacity to accommodate storage of 2.45 Mt of tailings with three feet of freeboard.

The tailings cells are designed as permanent, zero-discharge, single-use facilities and are lined accordingly.

The tailings cells are designed for stability and tailings containment under static and seismic (pseudo-static) loading conditions for both operating and post-closure conditions. The tailings will be deposited into the cells via pumping from the mill to perimeter discharge pipes located at the surface of the active tailings cells, feeding perforated drop pipes extending down the lined slope on textured geomembrane rubsheets. Near the end of tailings deposition within each of the tailings cells, tailings discharge pipes will be extended onto the tailings beach to allow discharge near the center of the cells, assisting in development of grades consistent with the proposed closure cover design (presented elsewhere).

The tailings cells are each designed with a primary and secondary liner system, an intervening leak collection and recovery system, and a tailings underdrain system, consistent with the State of Colorado Rules and Regulations Pertaining to Radiation Control (6 CCR 1007-1, Part 18). Additionally, the tailings pool within each cell will be equipped with a surface water pump-back system as the water input rate is expected to exceed the rate at which water can percolate through the tailings to the underdrain system.

Leak collection and recovery system (LCRS) sumps have been included in the design of each tailings cell, with Tailings Cell A having two LCRS sumps. The LCRS design provides for capture and conveyance of the seepage through the upper (primary) tailings cell liner to a sump. Water collected in the LCRS sumps will be pumped back into the tailings pond. A critical consideration of this system is to maintain minimal hydraulic head on the lower (secondary) composite liner, thereby preventing a driving hydraulic force required for any seepage to occur to the environment.

Per Criterion 5E(3) of 6 CCR 1007-1, Part 18, Appendix A, the tailings cells have been designed with an underdrain system installed on top of the primary geomembrane liner at the base of the impoundment. This feature provides added effectiveness to the proposed liner system by lowering the hydraulic pressure within the overlying tailings, thereby reducing the driving head for seepage.

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1.0 INTRODUCTION

Energy Fuels Resources Corporation (EFRC) is in the process of completing designs for a new uranium mill, termed the Piñon Ridge Project, located in Montrose County, Colorado. Golder Associates Inc. (Golder) was contracted to provide geotechnical design for construction of the tailings cells, evaporation ponds and ore pads at the Piñon Ridge Project. Golder's tailings cell design scope of work includes:

- Conducting a geotechnical field and laboratory investigation of the proposed tailings cell areas (Golder, 2008a);
- Reviewing available data and regulatory requirements, and development of project design criteria;
- Evaluation of tailings cell alternative layouts and selection of the preferred alternative;
- Conducting engineering analyses and design for the tailings cells, including design of liner systems, underdrain system, leak collection and recovery system, water balance, and stability evaluations; and
- Development of design drawings and specifications for three tailings cells with a total combined capacity to contain tailings at a production rate of 500 tons per day (tpd) and a mill life of approximately 40 years, with expansion capacity for a production rate of 1,000 tpd.

The tailings cells are designed to have a total cumulative capacity of approximately 7.3 million tons (Mt). Three tailings cells (A, B and C) of approximately equal tailings storage volume have been designed to meet this total capacity. The plan area of the lined portions of each tailings cell is 30.5 acres.

1.1 Property Location

The Piñon Ridge Project is located in Montrose County, Colorado in the Paradox Valley, approximately 15 miles northwest of the town of Naturita on Highway 90. The physical address of the site is 16910 Highway 90, Bedrock, Colorado. The site coordinates are approximately latitude 38° 15' N and longitude 108° 46' W, at approximately 5,500 feet above mean sea level (amsl). The property is located within Sections 5, 8, and 17, Township 46 North, and Range 17 West. The site lies in the gently sloping base of the northwest-trending Paradox Valley with steep ridges on either side. Drawing 1 presents a general location map for the Piñon Ridge property.

1.2 Tailings Cell Facility Alternatives Analyses

As part of the work conducted by Golder, an alternatives analysis was conducted to evaluate various design options for the tailings cells. For the initial alternatives concept evaluation, only two tailings cells were considered (Tailings Cells A and B), each with a tailings storage capacity of 2.45 Mt. A third cell of approximately the same volume and dimensions of these tailings cells will be required to store the design tailings volume for the ultimate mine life. The primary focus of the alternatives analysis was to compare tailings cell design concept options:

- ***Option A*** – Balanced Below Grade Disposal (local cut-to-fill balance);
- ***Option B*** – Full Below Grade Disposal; and
- ***Option C*** – Mostly Below Grade Disposal (incorporating site-wide mass balance considerations, which include generating excess cut for future closure cover construction).

The three alternatives evaluated are presented in Figures 1, 2, and 3, respectively. Although 6 CCR 1007-1 Part 18, Appendix A, Criterion 3 states "*the 'prime option' for disposal of tailings is placement below grade*," the regulations also state that "*flexibility is provided in the criteria to allow achieving an optimum tailings disposal program on a site-specific basis*," and that the "*Department may find that the proposed alternatives meet the Department's requirements if the alternative will achieve a level of stabilization and containment of the sites concerned…which is equivalent to, to the extent practicable, or more stringent than the level which would be achieved by the…standards promulgated by the Environmental Protection Agency in 40 CFR Part 192, Subparts D and E*."

Based on site-specific considerations at the Piñon Ridge Project, Golder recommends construction of Option C, which is the mostly below grade disposal option with generation of excess cut for future closure cover construction, for all of the tailings cells. The primary reasons for this recommendation are:

- Full below grade disposal is most applicable to relatively flat, wide open sites where relatively shallow excavation depths over large areas can be used to generate fill as needed for miscellaneous construction activities as well as interim and long-term cover materials. The Piñon Ridge site is not well-suited for this application as it has a natural ground slope (approximately two percent) and the available area for the tailings cells is constrained by natural drainages, other important project facilities, and ultimately, the property boundary. To stay fully below grade with a sloping ground surface and the noted spaced limitations, a

substantial percentage of the excavation volume would be devoted to site leveling, without contributing materially to tailings storage and potentially impacting other facilities;

- A mostly below grade design will reduce the amount of excavated material to be stockpiled, temporarily or permanently, elsewhere on site. A large stockpile would be difficult to site within the property boundary without impacting natural drainages and/or other facilities;

- Though the depth to groundwater at the tailings cell location is in excess of 450 feet below the ground surface, the mostly below grade option results in a greater separation between groundwater and the base of the tailings cells than Option B;

- Improved surface water management, using the raised perimeter berms to divert and control upgradient runoff, such that the only surface water impacting the tailings cells is the result of direct precipitation (per Criterion 4A, 6 CCR 1007-1, Part 18, Appendix A);

- Potentially less wind disturbance of deposited tailings due to the presence of surrounding perimeter berms (per Criterion 4B, 6 CCR 1007-1, Part 18, Appendix A); and

- Shallow bedrock has been encountered in several areas across the tailings cell site, increasing the difficulty of attaining full below grade tailings disposal.

Accordingly, the recommended approach for tailings cell development includes achieving a site-wide material mass balance which accommodates construction of the mill facilities for the operational period, while also providing excess cut for future use as tailings cell closure cover materials. The site-wide mass balance is presented in Appendix K. This approach makes the best use of the available property, while limiting unnecessary site disturbance.

Further optimization of the tailings alternative evaluation resulted in design of Tailings Cell A as essentially two ponds within a pond, with a central divider berm constructed to mid-height of the facility, and two independent leak collection and recovery systems and tailings underdrain systems. The purpose for dividing this cell is to allow contingency storage in the early years of production in case the liner system within one of the sub-cells is not operating properly and requires inspection and/or repair. Tailings Cells B and C are each designed as single cells, with one leak collection and recovery system in each cell. However, depending upon operations at the time of construction, Tailings Cell B and/or C may be constructed in a similar manner to Tailings Cell A.

2.0 GENERAL SITE CONDITIONS

The Piñon Ridge Project is situated in the Paradox Valley of western Colorado at an approximate elevation of 5,500 feet above mean sea level (amsl). The site terrain slopes downward toward the north, with shallow to moderately incised arroyos across the property. The northern half of the site is generally covered in dense sagebrush while the southern half is sparsely vegetated with grass and cacti.

From a geological perspective, the Paradox Valley was formed by an anticline heavy in evaporites. As the evaporites began to dissolve, part of the anticline sank forming the Paradox Valley. The bedrock underlying the site primarily consists of claystone and gypsum of the Hermosa Formation. The gypsum generally shows a massive texture, whereas the claystone is typically highly fractured. Less significant zones of sandstone, conglomerate, and siltstone of the Cutler and Moenkopi Formations were also found during the field investigation. Groundwater in the vicinity of the tailings cells is greater than 450 feet below the ground surface.

2.1 Climate

The macro-climate of the Piñon Ridge Project area is classified by the Koppen Climate Classification System as a BSk, which indicates a semi-arid steppe with much of the characteristics of a desert (Kleinfelder, 2007a).

Meteorological towers have been installed on-site to provide baseline site data; however, on-site climatic data is not yet available. Golder conducted a review of climatic data obtained from the Western Regional Climate Center for the Uravan, Nucla, Grand Junction (Airport and 6 ESE), and Montrose weather stations. The evaluation of climate data for these nearby weather stations indicates that the Uravan weather station is likely to provide reasonable precipitation estimates for the site (see Appendix I-1). Climatic data available for the Uravan weather station included precipitation, air temperature, and snow cover for the years of record of 1960 through 2007.

The Hargreaves (1985) method was used to estimate monthly evaporation values at the Piñon Ridge site, using the available climate data from Uravan. The calculated evaporation values were scaled by a factor of 0.7 to represent lake evaporation. The average monthly climatic data used for design of the Piñon Ridge facilities is summarized in Table 1. Considering this climatic data, the annual evaporation exceeds annual precipitation on average by about three times.

The predominant wind directions for the site are east and east-southeast, with an average wind speed of 5.3 miles per hour (mph) (Kleinfelder, 2007b). The maximum wind speed used for facility design is 23.4 mph, which was recorded at the Grand Junction weather station (see Appendix I-1).

2.2 Seismicity

The design ground motions for the Piñon Ridge Project site were identified by Kleinfelder (2008), including a moment magnitude **M** 4.8 earthquake occurring at a distance of 15.5 kilometers (km) from the site. The design peak ground acceleration (PGA) is 0.11g. The Maximum Credible Earthquake (MCE) event corresponds to a PGA of 0.16g. Kleinfelder (2008) indicates that these values were derived from the International Building Code (IBC).

2.3 Geotechnical Conditions

Based on investigations by EFRC and their consultants, it appears that there have been no historical geotechnical investigations done on the site. Accordingly, EFRC initiated a geotechnical investigation to be conducted by Kleinfelder West Inc. (Kleinfelder) and Golder in accordance with Criterion 5(G)(2), 6 CCR 1007 Part 18 (Appendix A). Phase 1 of the investigation was directed by Kleinfelder to develop general characterization of the site. Phase 2 was conducted jointly by Kleinfelder and Golder to support geotechnical design work for the site, including the tailings cells.

As part of the Phase 1 geotechnical investigations, Kleinfelder drilled twenty (20) geotechnical boreholes (PR1-1 to PR-20) spaced across the site to depths ranging from 30.3 to 98.8 feet below the ground surface, installed six monitoring wells (MW-1 to MW-6) at depths of 100 to 600 feet below the ground surface, and completed three seismic reflection/refraction geophysical lines trending north-south across the site.

The Phase 2 geotechnical field investigation conducted by Golder (2008a) consisted of 48 drill holes and 11 test pits within the proposed tailings cells, evaporation pond, and ore pad areas. The geotechnical conditions encountered in the 26 drill holes (GA-BH-18 through GA-BH-43) completed in the tailings cell areas consisted of bedrock depths ranging from 13 feet to 103 feet. Bedrock was not encountered in several borings at exploration depths ranging from 44 to 70 feet. The overburden soils generally consist of windblown loess (i.e., ML, SM, SW) with occasional layers of alluvium (i.e., GW, ML, SM). Bedrock encountered generally consists of claystone, shale, gypsum and anhydrite of the Hermosa Formation; with conglomerate and sandstone of the Cutler Formation; and

sandstone, claystone, and conglomerate of the Moenkopi Formation interpreted in some locations. Blowcounts in the overburden materials underlying the tailings cell areas ranged from 9 to refusal (i.e., greater than 50 blows per 6 inches).

Findings from the geotechnical investigations reveal the following general site characteristics:

- Groundwater was encountered in two monitoring wells (MW-8 and MW-9) located approximately 870 feet and 340 feet, respectively, south of the tailings cell, with no groundwater encountered to the north of these wells. The depth to groundwater was on the order of 380 to 400 feet below the ground surface in these wells. However, it is believed that the water encountered in MW-9 which is nearest to the location of the tailings cells is not groundwater but instead interstitial water, as the low hydraulic conductivity of the unit (2.4×10^{-8} cm/sec) is representative of an aquitard instead of an aquifer. The groundwater has a high sulfur content.

- The site is underlain by a number of aquitards. Additionally, evaporite rock of the Hermosa Group, which does not host any measurable amount of water, underlies the area of the site that is the proposed location of the tailings cells. These site-specific factors significantly reduce any potential impact to groundwater during the Mill's "Active Life" (as defined in Criterion 5A of Appendix A to include the closure period).

- While the geophysical investigation identified some possible fault traces underlying the proposed mill and tailings cell areas, trenching and mapping confirmed that these features are overlain by a minimum of 20 feet of undisturbed alluvial/colluvial soil. Accordingly, this data evidences that the possible faults are at least 10 million years old which demonstrates that the possible faults are not capable faults as defined in section III(g) of Appendix A of 10 CFR Part 100.

3.0 TAILINGS CELL DESIGN

This section provides the engineering analyses and technical details to support design of the tailings cells for the Piñon Ridge Project.

3.1 Design Criteria

3.1.1 Design Regulations

Regulations relevant to the design of the uranium tailings cells presented here in Section 3.0 are summarized below.

Key Regulatory Agencies and Documents:

Colorado Department of Public Health and Environment (CDPHE): 6 CCR 1007-1, Part 18 – "*State Board of Health Licensing Requirements for Uranium and Thorium Processing,*" specifically Appendix A (Criteria relating to the operation of mills and the disposition of the tailings or wastes from these operations).

Environmental Protection Agency (EPA): 40 CFR Part 264 – "*Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,*" Subpart K (Surface Impoundments); and 40 CFR Part 192 – "*Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings,*" Subpart D (Standards for management of uranium byproduct materials pursuant to section 84 of the Atomic Energy Act of 1954, as amended).

Note: Per Rule 17 (Exempt Structures) of the State of Colorado, Department of Natural Resources, Division of Water Resources (Office of the State Engineer [OSE], 2007) "Rules and Regulations for Dam Safety and Dam Construction," uranium mill tailings dams are exempt from these rules with permitting authority provided by the Colorado Department of Public Health and Environment (CDPHE).

3.1.2 Project Design Criteria

Design criteria relevant to the analyses presented here in Section 3.0 are summarized below.

Geometry:

Number of Tailings Cell Expansion Phases: Three (3), with each expansion having a plan area of 30.5 acres.

Milling Operations: Design capacity of 500 tons per day (tpd) of tailings disposal, with potential expansion capacity to 1,000 tpd.

Tailings Storage Capacity: Minimum 2.45 million tons (Mt) per cell, for a total minimum capacity of 7.3 Mt.

Mine Design Life: 40 years (dependent upon milling rate).

Beach Slope: Beach slope assumed as compound slope with 5 percent for the first 50 feet horizontally, 2 percent to the pool, followed by a 10 percent slope below the pool surface (10 feet depth), and 0.5 percent in the slimes zone. Prior to cell closure, tailings discharge pipes will be extended from the cell perimeter to the cell center, changing the beach slope characteristics and more efficiently utilizing the available tailings storage space.

Perimeter Access Road Width (includes allowance for berms): 15 feet.

Tailings Properties:

Average In-Place Tailings Dry Density: 95 pounds per cubic foot (pcf).

Tailings Percent Solids: 27.3 percent by weight (slurry density) (CH2M Hill, 2008).

Tailings Gradation: Tailings are anticipated to classify according to the Unified Soil Classification System (USCS) as silty sand (SM).

Tailings Solution: Sulphuric acid leach with a pH generally ranging between 1.8 and 2.

System Requirements:

Tailings Cell Liner System: Double layer liner system as follows (top to bottom): (1) upper (primary) geomembrane liner; (2) leak collection and recovery system; (3) lower (secondary) geomembrane liner; underlain by (4) minimum 3 feet of low permeability soil liner with a hydraulic conductivity no more than $1x10^{-7}$ centimeters per second (cm/sec), or approved equivalent (per 40 CFR 264.221 by reference from 10 CFR 40 and 6 CCR 1007-1, Part 18).

Leak Collection and Recovery System: Per 40 CFR 264.221 (by reference from 10 CFR 40 and 6 CCR 1007-1, Part 18), the leak detection system shall meet the following requirements: (1) constructed with a bottom slope of one percent or more; (2) constructed of granular drainage materials with a hydraulic conductivity of $1x10^{-1}$ cm/sec or greater and a thickness of 12 inches or more, or constructed of a synthetic or geonet drainage material with a transmissivity of $3x10^{-4}$ square meters per second (m^2/sec) or more; (3) constructed of materials that are chemically resistant to the waste and leachate; (4) designed and operated to minimize clogging during the active life and post-closure care period; and (5) constructed with sumps and liquid removal methods (i.e., pumps).

Underdrain System: Per Criterion 5E of 6 CCR 1007-1 (Part 18, Appendix A), tailings must be dewatered by a drainage system installed on top of the primary liner at the bottom of the impoundment to lower the phreatic surface and reduce the driving head of seepage, unless tests show tailings are not amenable to such a system.

Seismic Design:

Maximum Credible Earthquake (MCE): 0.161g peak ground acceleration (PGA) based on a Magnitude 4.8 earthquake at 15.5 km (Kleinfelder, 2008).

Design Earthquake (DE): 0.107g PGA based on two-thirds of MCE PGA (Kleinfelder, 2008).

Stability Requirements:

Minimum Static Factor of Safety: 1.5 (industry standard practice).

Minimum Pseudo-static Factor of Safety: 1.1 (industry standard practice).

3.2 Design Concepts

This section presents the general tailings cell design concepts with the technical details for these concepts discussed in detail in the following sections.

3.2.1 General Tailings Cell Design Concepts

The Piñon Ridge Mill is designed to operate at 500 tons per day (tpd) with an expected life of 40 years. The tailings cells have been designed to provide capability for expansion to 1,000 tpd operations. Each of the three proposed tailings cells have been designed (i) to provide capacity for 13.3 years, (ii) with plan footprint areas of 30.5 acres, and (iii) minimum capacity to accommodate storage of 2.45 million tons (Mt) of tailings with three feet of freeboard. Applicable criteria of 6 CCR 1007-1, Part 18, Appendix A have been considered in the tailings cell investigation and design work.

The tailings cells were designed for construction predominantly in the existing subgrade, with a combined total excess cut of approximately 2.5 million cubic yards (cy) dedicated primarily to future closure cover construction. The excess cut material will be stockpiled on the west side of the site (see proposed soil stockpile locations illustrated on Drawing 2), or used in construction of other site facilities. The tailings cells were developed by designing a perimeter embankment with a width of 15 feet to facilitate berms and one-way light truck traffic. The top elevations of the tailings cell perimeter berms are 5525 ft amsl, 5511 ft amsl, and 5496 ft amsl for Tailings Cells A, B, and C, respectively. The tailings cells have internal side slopes of 3H:1V, and a minimum base grade of one percent. The limits of the tailings cells are lined with a double layer liner system with an intervening leak collection and recovery system to contain process solutions, enhance solution collection, and protect the groundwater regime. Intermediate benches have been incorporated in the design to

provide additional anchorage of the underlying geosynthetic clay liner (GCL) component of the liner system (discussed in Section 3.3.4), as well as buttressing of the liner to limit wind uplift.

As a precautionary measure, Tailings Cell A has been designed as a split cell to facilitate separate collection of process solutions for redundancy during facility start-up if unforeseen problems with the liner system develop, allowing half of the cell to be decommissioned and repaired while continuing mill operations. Tailings Cells B and C may also be designed as split cells, depending on operations at the time of construction.

3.2.2 Surface Water Control Design Concepts

Surface water design for the Piñon Ridge Mill includes diversion around the license boundary, including diversion around the tailings cells. Site-wide surface water design was conducted by Kleinfelder, and will be presented under separate cover. Surface water run-on into the tailings cells is limited to surface water run-off from the perimeter access roads and direct precipitation onto the tailings cells.

3.2.3 Closure Design Concepts

The tailings cells for the Piñon Ridge Project have been designed to consider closure and to integrate the design for compatibility with the following concepts:

- Minimize the need for long-term active site care and maintenance during the post-closure period;
- Perimeter berms developed with external side slopes of 10H:1V (per Criterion 4C of 6 CCR 1007-1, Part 18, Appendix A);
- Placement of an interim cover over the tailings as deposition is complete within the tailings cell to limit exposure to radiation until construction of the final cover;
- Dewatering of the tailings as feasible prior to placement of closure cover materials;
- Provide additional capacity within the tailings cells to accommodate future closure considerations, such as disposal of the liner systems removed from the evaporation ponds and ore pads, etc., during site closure activities; and
- Construction of a final closure cover which meets the requirements of Criterion 4D (6 CCR 1007-1, Part 18, Appendix A) with regard to erosion protection, as well as limiting radon flux to acceptable levels (per Criterion 6, 6 CCR 1007-1, Part 18, Appendix A), design of which is presented under separate cover.

3.3 Liner System Design

As noted in Section 2.3, investigative drilling did not encounter the presence of any aquifers beneath the planned location of the tailings cells. The nearest discovery of groundwater was to the southeast of the proposed tailings cell location. Additionally, a number of aquitards were identified during the geotechnical field investigation, further limiting any potential impacts to the groundwater regime during the Active Life of the Mill. Despite this site specific characteristic, the tailings cells were nevertheless designed with the standards applicable to hazardous waste treatment, storage and disposal facilities in accordance with 40 CFR 264.221, by reference from 10 CFR 40 and 6 CCR 1007-1 (Part 18), and utilize a double layer liner system with an intervening Leak Collection and Recovery System (LCRS) for groundwater protection, as follows (from top to bottom) (see Figure 4):

- 60-mil high density polyethylene (HDPE) upper (primary) geomembrane;
- LCRS consisting of HDPE geonet on the base of the tailings cells, and a drainage geocomposite on the side slopes;
- 60-mil HDPE lower (secondary) geomembrane;
- Reinforced geosynthetic clay liner (GCL) as the underliner component of the secondary composite liner system; and
- Prepared subgrade.

Liner system details for the tailings cell slope liner and base liner systems are provided as details 2 and 3, respectively, on Drawing 11.

3.3.1 Upper (Primary) Liner

The upper primary liner will consist of a conductive textured 60-mil HDPE geomembrane. An HDPE geomembrane liner was chosen for its long-term performance characteristics. It has excellent chemical resistance properties (see Chemical Resistance Chart in Appendix G), resistance to ultraviolet (UV) radiation, high tensile strength, and high stress-crack resistance (Lupo & Morrison, 2005). Single-sided texturing (textured side down) on the upper primary geomembrane is considered to increase frictional resistance at the contact with the LCRS layer. Textured rubsheets will be extrusion welded where required by mill operations to facilitate tailings deposition and access during operations.

Interface shear testing was conducted to evaluate the performance and stability of the proposed HDPE geomembrane versus drainage geocomposite material. Results of interface shear testing are presented in Golder (2008a), with results from the critical interfaces utilized in the stability evaluation calculation (provided in Appendix H). The peak friction angle for the geomembrane/drainage geocomposite interface is 21 degrees, which compared to the proposed slope angle of 18.4 degrees (i.e., 3H:1V) indicates a stable liner system with a local short-term factor of safety of at least 1.2 (see Appendix H-2). Anchor trenches, anchor benches, and buttressing of the liner were incorporated into the design to further enhance stability of the liner system, as discussed in detail in Appendix C.

With operations at the mill proceeding at the design rate of 500 tpd, the upper portion of the tailings cells could be exposed for 13 to 14 years. Considering this potential long-term exposure combined with the long slope runs and large lined area (i.e., 30.5 acres), the liner system was designed for long-term exposure to solar radiation. The upper primary geomembrane liner has been designed with the upper exposed side of the liner covered with a light-reflective surface. The light-reflective surface is resistant to ultraviolet radiation and coextruded with the primary black geomembrane liner. All of the physical properties of a standard black HDPE geomembrane remain the same but the light-reflective design feature provides the following benefits (www.gseworld.com):

- Minimizes wrinkles caused by liner expansion thereby reducing the risk of damage to liner resulting from wrinkles;
- Reduces heat build-up and thermal expansion of the liner by reflecting solar radiation;
- Reduces desiccation effects to the subgrade soil materials; and
- Improves detection of installation damage.

The light-reflective surface layer is approximately 5 mils thick. If damage to the geomembrane occurs, the black primary layer of the geomembrane will be exposed, making visual inspection of liner defects more reliable. This design enhancement, while not necessary, will reduce UV degradation and should also improve constructability, aid quality assurance, and improve system performance. To further ensure quality assurance during installation of the liner system, the upper primary geomembrane liner will be conductive to facilitate spark testing of the liner surface upon completion of the installation.

3.3.2 Leak Collection and Recovery System

An important feature of the tailings cell liner system is the Leak Collection and Recovery System (LCRS) layer, designed per 40 CFR 264.221 (by reference from 10 CFR 40 and 6 CCR 1007-1, Part 18). The LCRS is designed to minimize the hydraulic heads on the lower geomembrane liner by utilization of HDPE geonet in the base of the tailings cells and a drainage geocomposite on the side slopes. The drainage geocomposite is comprised of a geonet laminated on both sides to a nonwoven geotextile filtration media to increase frictional resistance with the overlying and underlying textured geomembrane liners.

In the event that leakage occurs through the upper geomembrane liner, it will be collected in the LCRS layer and routed (via gravity flow) to a LCRS sump located in each tailings cell (or sub-cell in the case of a divided tailings cell). The LCRS design is discussed in greater detail in Section 3.5.

3.3.3 Lower (Secondary) Composite Liner System

Beneath the LCRS layer is a 60 mil HDPE secondary geomembrane liner. This liner provides secondary containment of process solutions should leakage occur through the upper primary geomembrane liner. The lower secondary geomembrane liner will be double-sided textured to increase frictional resistance with the overlying LCRS layer and the underlying low permeability GCL layer.

The lower secondary geomembrane liner will be underlain by a GCL, which consists of a layer of sodium bentonite encapsulated between two geotextiles with an upper woven geotextile and lower nonwoven geotextile, needle-punched together to form a hydraulic barrier material (i.e., CETCO Bentomat ST, or equivalent). The GCL is approximately 0.4 inches thick with a reported hydraulic conductivity of $5x10^{-9}$ centimeters per second (cm/sec). Since the mid-1980s, GCLs have been increasingly used as an alternative to compacted clay liners on containment projects due to ease of construction/installation, resistance to freeze-thaw and wet-dry cycles, and relatively low cost.

Interface shear testing was conducted to evaluate the performance and stability of the HDPE geomembrane versus the proposed GCL underliner (i.e., Bentomat ST with woven side up). The local stability of the textured HDPE geomembrane versus the proposed drainage geocomposite is discussed in Section 3.3.1. Results of interface shear testing are presented in Golder (2008a), with results from the critical interfaces utilized in the stability evaluation calculation (provided in

Appendix H). The peak friction angle for the geomembrane/GCL interface is 23 degrees, which compared to the proposed slope angle of 18.4 degrees (i.e., 3H:1V) indicates a stable liner system with a local short-term factor of safety of at least 1.3 (see Appendix H-2). Anchor trenches, anchor benches, and buttressing of the liner were incorporated into the design to further enhance stability of the liner system, as discussed in detail in Appendix C.

Compatibility testing of the proposed GCL with the anticipated tailings solution chemistry provided by the process designers (CH2M Hill, 2008) was conducted by TRI/Environmental, Inc. (TRI) under contract to CETCO Lining Technologies (CETCO), the manufacturer of the proposed GCL material. Results of this testing program indicate that the anticipated tailings leachate may result in an increase to the permeability of the standard GCL from $5x10^{-9}$ cm/sec to approximately $1.1x10^{-8}$ cm/sec. Testing of a polymer-treated GCL in contact with the anticipated tailings leachate indicates negligible change in GCL permeability. A more detailed description of the GCL compatibility testing program is provided in Appendix B.

An analysis was conducted using the method proposed by Giroud et al. (1997) to demonstrate that the secondary composite liner system consisting of a 60 mil HDPE geomembrane overlying a GCL has equivalent or improved fluid migration characteristics when compared to a secondary composite liner system consisting of a 60 mil HDPE geomembrane overlying the prescriptive compacted clay liner (i.e., 3 feet of 10^{-7} cm/sec soil, per 40 CFR 264.221). Based on this site-specific analysis (included in Appendix A), which accounts for the loading conditions and anticipated head on the secondary liner system, as well as the potential for an increase in the GCL hydraulic conductivity in the unlikely event that leakage through both the primary and secondary geomembrane liners occurred in sufficient quantity to saturate the GCL with tailings leachate, the amount of flow through the secondary liner system with the prescriptive compacted clay liner was evaluated to be nearly five times greater than the flow through the secondary liner system with a standard GCL underliner, and more than eight times greater than the flow through the secondary liner system with a polymer-treated bentonite GCL underliner. Therefore, the secondary liner system containing a standard GCL performs better than the secondary liner system containing the prescriptive clay liner, and the use of a polymer-treated bentonite within the GCL is not warranted.

3.4 Underdrain Design

Per Criterion 5E(3) of 6 CCR 1007-1, Part 18, Appendix A, the tailings cells have been designed to facilitate dewatering of the tailings (i.e., lower the phreatic surface and reduce the driving head for seepage) via an underdrain system installed at the base of the impoundment. Based on information available, the tailings are expected to consist of silty sand to sandy silt materials, which are considered amenable to dewatering, particularly if some segregation by particle size results from deposition as dilute slurry. The tailings underdrain system is comprised of the following components:

- Perforated corrugated HDPE collection pipes (8-inch diameter) to convey fluids to the underdrain sump. The pipes will be placed in trenches, which are backfilled with imported granular drainage materials;
- An underdrain sump constructed above the leak collection and recovery system sump with a depth of 2 feet to provide head for pumping of collected seepage. The sump will be backfilled with coarse underdrain fill overlain by fine underdrain fill to ensure filter compatibility with the overlying tailings; and
- Two underdrain riser pipes within each sump to add redundancy to the system, consisting of two 10-inch diameter, SDR-11 HDPE pipes. The lower ends of the pipes are slotted in the sump area to provide solution access into the risers. Solution is recovered via an automated submersible pump installed in the riser (designed by others). Collected solutions will be returned to the mill circuit.

The underdrain collection trenches and underdrain sump area will be backfilled with granular drainage materials, with an underlying coarse underdrain fill in contact with the underdrain collection pipes and slotted portion of the underdrain riser pipes, and an overlying fine underdrain fill. The underdrain fill zones (coarse and fine) have been designed for filter compatibility with each other, the pipe perforations, and the overlying tailings materials. The filter design calculations are provided in Appendix D-1.

The perforated corrugated HDPE underdrain collection pipe and the solid HDPE underdrain riser pipes are designed according to the Burns & Richard (1964) method to resist crushing and wall buckling due to the anticipated loading associated with the maximum height of overlying tailings. The pipe deformation analyses are presented in Appendix D-2.

A cushion geotextile has been incorporated within the underdrain collection trenches and underdrain sump to protect the underlying primary HDPE geomembrane liner from puncture due to the overlying

underdrain drainage materials, and the anticipated loading conditions associated with the maximum height of the overlying tailings.

The underdrain sump, constructed above the LCRS sump, will include two sideslope underdrain riser pipes per underdrain sump for redundancy. The underdrain riser pipes will allow installation of a submersible pump for manual collection of tailings liquids. An underdrain plan for Tailings Cell A is included on Drawing 7, while underdrain plans for Tailings Cells B and C are included on Drawing 8. Note that Tailings Cells B and C may be constructed as a divided cell, depending on operations at the time of construction, and therefore the underdrain layout would replicate that of Tailings Cell A. Underdrain sump, riser pipe, and collection trench details are included on Drawing 9.

3.5 Leak Collection and Recovery System Design

As part of the tailings cell design, a leak collection and recovery system (LCRS) has been incorporated to meet the requirements of the regulations. If a leak occurs in the upper primary geomembrane, the LCRS is designed to minimize the hydraulic heads on the lower geomembrane liner. Details of the leak collection and recovery system are shown on Drawing 10.

The LCRS layer has been designed as an HDPE geonet on the base of the tailings cells, and a drainage geocomposite on the side slopes. The drainage geocomposite is comprised of a geonet laminated on both sides to a nonwoven geotextile filtration media to increase frictional resistance with the overlying and underlying textured geomembrane layers. The geonet and drainage geocomposites have been designed with transmissivities of $6x10^{-3}$ square meters per second (m^2/sec) and $2.5x10^{-3}$ m^2/sec, respectively, which exceeds the minimum transmissivity requirement of $3x10^{-4}$ m^2/sec (per 40 CFR 264.221). The drainage layer is designed with a thickness of 275 mil (see calculations provided in Appendix A). Beneath the LCRS layer is a 60 mil HDPE secondary geomembrane liner. This liner provides secondary containment of process solutions should leakage occur through the primary 60-mil HDPE upper geomembrane liner.

In the event that leakage occurs through the upper geomembrane liner, it will be collected in the LCRS layer and routed (via gravity flow) to a LCRS sump located in each tailings cell (or sub-cell). The LCRS sumps were conservatively sized for eight (8) hours of maximum flow in the LCRS layer (i.e., geonet or drainage geocomposite) assuming one liner defect per acre for good installation (Giroud & Bonaparte, 1989), an effective porosity of 30 percent in the sump (i.e., available pore

space within the gravel backfill materials), and applying a factor of safety of 1.5. The LCRS sump sizing calculations are provided in Appendix E-1. Based on these calculations, a sump with base dimensions of 10 feet by 10 feet with 3H:1V side slopes and 5-foot depth provides sufficient containment for leak solutions.

Two LCRS risers are provided within each sump to add redundancy to the system. The risers consist of two 10-inch diameter, SDR-17 HDPE pipes. The lower ends of the pipes are slotted in the sump area to provide solution access into the risers. Solution is recovered via an automated submersible pump (designed by others) installed in the riser. The LCRS risers will be instrumented and fully automated to report to the mill control system with an alarm in the mill. Recovered solutions will be returned to the tailings cells, and then to the mill circuit via tailings return pumps. The perforated solid HDPE LCRS riser pipes are designed according to the Burns & Richard (1964) method to resist crushing and wall buckling due to the anticipated loading associated with the maximum height of overlying tailings (see Appendix E-2).

Action Leakage Rates (ALRs) were evaluated for each of the LCRS sumps using the guidelines published by the U.S. Environmental Protection Agency (EPA, 1992). The ALR is defined in 40 CFR 264.222 as "*the maximum design flow rate that the leak detection system (LDS) can remove without the fluid head on the bottom liner exceeding 1 foot*." The ALR calculations are provided in Appendix F. Based on these calculations, the ALR for the LCRS sumps contained within Tailings Cells A1 and A2 is 4,705 gallons per acre per day (gpad), and the ALR for the LCRS sumps contained within Tailings Cells B and C is 2,376 gpad.

3.6 Stability Evaluation

In addition to the local liner interface stability analyses discussed in Sections 3.3.1 and 3.3.3, Golder conducted global stability analyses for the proposed tailings facility. These analyses are presented in detail in Appendix H. Three cross-sections were developed to represent a typical section through a tailings cell at three critical points in time: (i) end of tailings cell construction (prior to tailings deposition), (ii) post-tailings deposition, and (iii) post-closure of the tailings cell.

Stability analyses were conducted using RocScience's limit equilibrium program *SLIDE* (RocScience, 2000). Stability analyses considered both circular and non-circular slip surfaces when searching for

the critical surface with the minimum factor of safety (*FS*). The stability analyses utilized the Spencer method (Spencer, 1967).

The pseudo-static coefficient for the stability analyses was developed by Kleinfelder (2008) for this evaluation based on the 2006 International Building Code (IBC). This seismicity analysis concluded that the peak ground acceleration (PGA) for the Maximum Credible Earthquake (MCE) is 0.161g. The peak ground acceleration for the design earthquake is 0.107g. Hence, the pseudo-static acceleration used in the stability analyses for operational considerations was 0.05g, or approximately one-half of the design earthquake PGA (Hynes & Franklin, 1984). For the post-closure analyses, the pseudo-static coefficient was increased to 0.08g, half of the PGA for the MCE.

The limit equilibrium stability analyses yielded the estimated minimum safety factors summarized in Table 2 for static and pseudo-static loading conditions for all three evaluated scenarios. As indicated, the stability analyses show that the static and pseudo-static critical failure surfaces have factors of safety greater than the minimum allowable values of 1.5 under static loading conditions, and 1.1 under pseudo-static loading conditions.

3.7 Water Balance Modeling

A probabilistic water balance was developed for the tailings cell design to estimate the available quantity of make-up water available for reclaim using the computer program *Goldsim*™. The water balance is presented in detail in Appendix I.

Since three tailings cells (Cells A, B, and C) of approximately equal tailings storage volume and dimensions have been designed for the Piñon Ridge Project to meet the total design capacity of 7.3 Mt, the probabilistic water balance has been performed only for a single tailings cell (i.e., Tailings Cell A). The water balances for the other tailings cells would produce similar results. Each of the tailings cells is designed for 13.3 years based on a milling capacity of 500 tpd (with expansion capabilities to 1,000 tpd).

For the purpose of developing the water balance for the tailings cell, the following components were considered: (1) the amount of water entering the tailings cell from the mill in the tailings slurry (i.e., based on 27.3 percent solids by weight), (2) water entering the system through meteoric precipitation, (3) the amount of water released to the atmosphere through evaporation, (4) the amount of water

returning to the mill from the tailings cell (provided by CH2M Hill), and (5) the excess water available to be pumped from the tailings cell as mill make-up or sent to the evaporation pond system. Figure 6 presents the tailings cell water balance flow sheet.

3.8 Tailings Deposition Modeling

Tailings deposition within Tailings Cell A was modeled using Golder's proprietary software *GoldTail*. The purpose of the tailings deposition modeling is to provide mill operations personnel with a method for tailings discharge which enhances design of the tailings cells by providing protection to the constructed underdrain system from potential slimes clogging, as well as provides initial buttressing to the geomembrane liner system. The tailings deposition modeling is presented in Appendix J.

Tailings deposition was modeled within Tailings Cell A in the following five simplified phases:

- Phase 1 – Deposition commences within sub-cell A1 (or A2) in the vicinity of the underdrain sump to provide approximately 10 feet of tailings deposition over the sump area. This phase of deposition provides coarse-grained underflow tailings over the underdrain sump to enhance the effectiveness of the tailings underdrain system;
- Phase 2 – Continued deposition within the remainder of the first sub-cell to push the pond toward the sump area;
- Phase 3 – This phase was modeled with deposition commencing within the other sub-cell in the vicinity of the underdrain sump, again providing approximately 10 feet of coarse-grained underflow tailings over the underdrain sump area. During actual operations, Golder recommends reversing the order of the modeled Phases 2 and 3 in order to buttress the geomembrane liner system within both sub-cells at the on-set of operations, prior to completely filling the first sub-cell;
- Phase 4 – Continued deposition within the remainder of the second sub-cell to push the pond toward the sump area; and
- Phase 5 – Once both sub-cells are filled, tailings deposition will proceed along the perimeter of the entire tailings cell in stages (as dictated by tailings operations), until the tailings cell is full (with 3 feet of freeboard provided at the perimeter of the cell).

The perimeter discharge of Phase 5 will leave a depression in the center of the cell resulting from the tailings beach slopes and perimeter discharge arrangement. Although not modeled, a sixth and final phase of deposition would involve extending the tailings discharge pipes to the center of the cell to more efficiently use the available tailings storage space, and develop grades which support closure cover construction.

4.0 CONSTRUCTION CONSIDERATIONS

This section presents considerations for construction of the tailings cells. A number of these items were developed as a result of project meetings with the Colorado Department of Public Health and Environment (CDPHE) during the course of the design, especially those that relate to Construction Quality Assurance (CQA) and addressing CDPHE concerns regarding long-term exposure of the tailings cell liner system.

4.1 Confirmatory Testing

To support permitting-level design of the tailings cell liner system, interface shear testing was conducted using select geosynthetic materials (Golder, 2008a). If use of a geosynthetic material which was not tested is proposed for construction, interface shear testing is required prior to initiation of construction to confirm that the minimum required strength parameters are achieved for the various interfaces. It should be noted that interface shear testing was conducted using a drainage geocomposite material which differs from that specified for construction, as design calculations later revealed that the initially proposed drainage geocomposite did not meet design requirements. The Geosynthetic CQA Plan (Section 1400.2 of the Technical Specifications; Golder, 2008c) includes a requirement for confirmatory testing of the geosynthetic interfaces prior to procurement of geosynthetics for tailings cell construction.

4.2 Electrical Leak Integrity Survey

An electrical leak integrity survey will be conducted after completion of tailings cell liner installation, prior to tailings deposition. Requirements of the electrical leak detection survey have been incorporated into the Geosynthetics CQA Plan (Section 1400.2 of the Technical Specifications; Golder, 2008c).

At present, there are many ways of conducting electrical leak detection surveys of geomembranes. Some of these methods involve filling the lined area with water prior to testing, while others are only applicable to specific liner configurations (such as single liner systems and liners covered with soil). Based on the available methods (ASTM D 6747) and considering the limited supply of locally-available water as well as the expansive size of the tailings cells, the most appropriate method involves installation of an electrically conductive geomembrane as the primary geomembrane in the system.

Electrically conductive geomembrane is constructed with a thin conductive layer adhered to and underneath a polyethylene geomembrane, which is naturally non-conductive. Once installed, the exposed geomembrane is tested for leak paths according to ASTM D 7240 (Conductive Geomembrane Spark Test) in the following manner:

- The conductive (under) side of the geomembrane is charged; and
- A conductive element is swept over the upper surface of the geomembrane, creating a spark where potential leak paths exist. An alarm is built into the system to sound each time a spark is detected.

This system is capable of detecting leak paths smaller than 1 millimeter (mm) in diameter and repairs can be made immediately upon leak path detection. Due to the nature of the test and the fact that the conductive layers of adjacent rolls are not necessarily in good contact, traditional non-destructive seam testing is still needed. This test does not require the use of any water.

4.3 Tailings Deposition

At start-up of tailings deposition within each tailings cell (or sub-cell), the operations plan should provide for deposition to commence in the vicinity of the underdrain sump. The purpose of initiating deposition in this manner is to provide coarse-grained underflow material over the underdrain sump system, in contact with the underdrain filter materials. As discussed previously, the underdrain filter materials were designed for filter compatibility with each other and with the anticipated tailings stream; however, additional protection to the underdrain sump system would be provided by initial placement of the coarse-grained tailings materials over the system preventing clogging due to fine-grained tailings slimes. After initial placement of coarse-grained tailings in this area, then deposition would proceed to maintain the tailings pool area(s) above the underdrain sump(s).

When the tailings cell is constructed with two internal cells, as is the case with Tailings Cell A (and possibly Cells B and C), tailings should be placed within each of the sub-cells immediately after commencement of deposition in order to provide additional buttressing of the liner system. It is recommended to cover the floor of each of the sub-cells with tailings prior to discharging to a single sub-cell. Operations personnel may opt to discharge to both sub-cells simultaneously, which is considered appropriate, pending that initial deposition proceed as discussed.

4.4 Geomembrane Exposure

Where liner will be exposed to ultraviolet (UV) radiation for an extended period of time, such as the case of the tailings cells, standard practice for the mining industry includes incorporation of an upper exposed HDPE geomembrane liner (Golder, 2008b). The HDPE's resistance to UV radiation is one of the primary reasons that it was selected as the geomembrane for the tailings cell (and evaporation pond) construction at the Piñon Ridge Project. To further reduce the risk of UV damage, the upper primary geomembrane liner has been designed with a white light-reflective surface as discussed in Section 3.3.1. Refer to Golder (2008b) for a literature review and presentation of results supporting the use of HDPE geomembrane for the Piñon Ridge Project. Major points from Golder (2008b) are summarized in the following sections.

4.4.1 Exposure Period and Consequences

As tailings are deposited within each tailings cell, the surface area of exposed geomembrane will be reduced incrementally with time. The liner in the pond bottom will be exposed for a few months to a year, and the liner near the top of each cell will remain exposed for the full tailings cell design life. However, the upper perimeter portion of the exposed liner, which will have the greatest UV exposure, will be subject to the lowest operational loads from deposited tailings and stored water and will be required to provide hydraulic containment for only a short period before the cell is drained and decommissioned. Conversely, the lower, centrally located portion of the exposed liner, which will be called upon to resist the highest operational loads, will be exposed to degradation from UV radiation for only a short period. Therefore, considering the combination of potential loading conditions with the potential for degradation from UV exposure, the longer-term exposure of liner at the top of the cells represents, overall, a reduced potential to impact soil and groundwater at the site (Golder, 2008b). In addition, following closure, the cover will control infiltration into the cells, thereby limiting subsequent hydraulic loading on the liner system and further reducing the containment requirement.

4.4.2 Background on the Science

When exposed to atmospheric conditions, plastic materials containing impurities can absorb ultraviolet energy which can excite photons and create free radicals within the plastic (Zeus, 2005). These free radicals then proceed to degrade the plastic by causing a chain reaction of molecule damage that can accelerate breakdown of the material (Layfield, 2008). However, a variety of

methods are available to both limit the production of free radicals and inhibit the chain reaction of molecule degradation in plastics, including use of stabilizers, absorbers or blockers (Zeus, 2005).

HDPE geomembrane is manufactured with 2 to 3 percent carbon black, a material produced by the incomplete combustion of petroleum products, which provides protection to the geomembrane structure by blocking the degradation process (Layfield, 2008). The chemical properties of carbon black further act to absorb molecular-damaging free radicals, preventing them from causing additional damage. Carbon black is universally accepted as being resistant to significant deterioration caused by weathering for 50 years or more (GSE, 2003). In addition to carbon black, many HDPE manufacturers, such as GSE, utilize highly effective chemical UV stabilizers that further extend the life of the material to which it is added (GSE, 2003). Properly formulated and compounded polyethylenes, achieved through the use of carbon black and chemical stabilizers, have an estimated projected life in excess of 100 years for resistance to weathering due to exposure (GSE, 2003).

Koerner & Hsuan (2003) stated that HDPE geomembrane is quite possibly the most stable polymer, resulting in the longest lifetime, but that research is on-going. Review of the literature confirmed numerous cases of proposed and on-going research into the lifetime of HDPE geomembrane under exposed and unexposed conditions (e.g., Hsuan et al., 2005; Koerner et al., 2005a and 2005b; Jeon et al., 2005).

4.4.3 Summary

Evaluations of HDPE geomembrane from field performance and laboratory test data presented in Golder (2008b) provide evidence that exposure of a 60 mil HDPE geomembrane to UV for 20 or more years will not result in significant degradation of the geomembrane. The results of field tests of actual operating facilities utilizing HDPE geomembrane (Golder, 2008b) support the conclusion that the use of HDPE geomembrane as designed for the tailings cells will maintain sufficient integrity despite UV exposure during their estimated lifetimes. Laboratory test results presented in Golder (2008b) predict an even longer life and improved UV resistance for HDPE geomembrane, even when stabilized only with the standard percentages of carbon black (i.e., no additional antioxidants or UV stabilizers).

An additional design feature has been incorporated into the tailings cell design to further reduce the potential for UV damage to the exposed portion of the liner system. The upper primary

geomembrane liner includes a requirement for a light-reflective surface that is resistant to UV radiation and is coextruded with the primary black geomembrane liner. This design enhancement, while not necessary, will reduce UV degradation and should also improve constructability, aid quality assurance, and improve system performance.

It is important to note that standard HDPE geomembrane, without the additional feature of the light-reflective surface, is the industry standard-of-practice for design of mine facilities for exposed applications, such as evaporation ponds, process solution ponds, heap leach perimeter channels and tailings impoundments for mining operations (i.e., gold, uranium), and that the exposure periods are consistent with those proposed for the Piñon Ridge Project. Further, the portions of the tailings cell liner systems that will be exposed to UV radiation are located near the top of the cells, which are the least critical from a hydraulic containment standpoint (i.e., the hydraulic heads will be low to nonexistent during a short operating life followed by negligible hydraulic loading in the post-closure period). The base of the tailings cells, which will be subjected to the highest hydraulic heads, will be covered with tailings at the on-set of operations, and therefore exposed to UV radiation for a very short time.

4.5 GCL Underliner Construction Considerations

Due in part to the lack of locally-available low permeability soil sources for underliner, geosynthetic clay liner (GCL) has been designed as the underliner component of the secondary composite liner system for the tailings cells (see Section 3.3.3). Where geomembrane composite-lined slopes underlain by compacted clay liner materials have been exposed for long periods of time, desiccation and cracking of the clay component often occurs (Giroud, 2005). The use of GCL as the underliner component prevents the issue of clay desiccation, but shrinkage has been documented to occur due to long-term exposure (i.e., numerous drying [i.e., day] and hydration [i.e., night] cycles) of the liner system (Giroud, 2005). In addition to the use of white geomembrane to limit the temperature variations in the liner system, the design drawings and Technical Specifications (Golder, 2008c) include the following provisions to limit effects of GCL shrinkage within the tailings cells:

- Construction of anchor benches to provide additional anchorage to the GCL layer;
- Increasing the manufacturer-recommended longitudinal overlap from 6 inches to 12 inches; and

- Increasing the manufacturer-recommended end-of-roll overlaps from 2 feet to 4 feet.

In addition to the construction considerations discussed previously, pre-hydration of the GCL is provided during the construction process to enhance the permeability characteristics of the GCL. The reader is referred to Shackelford et al. (2000) for the benefits of prehydration of the GCL with regard to the resulting permeability. Prior to GCL placement, the subgrade soils will be moisture-conditioned and compacted to a minimum 95 percent of the standard Proctor (ASTM D 698) maximum dry density at optimum to plus 4 percent of the optimum moisture content. This recommended specification is based on the results of a study conducted by Bonaparte et al. (2002) which shows that prehydration of the GCL is obtained via subgrade moisture absorption.

5.0 USE OF THIS REPORT

This report has been prepared exclusively for the use of Energy Fuels Resources Corporation (EFRC) for the specific application to the Piñon Ridge Project. The engineering analyses reported herein were performed in accordance with accepted engineering practices. No third-party engineer or consultant shall be entitled to rely on any of the information, conclusions, or opinions contained in this report without the written approval of Golder and EFRC.

The site investigation reported herein was performed in general accordance with generally accepted Standard of Care practices for this level of investigation. It should be noted that special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions. Even a comprehensive sampling and testing program implemented in accordance with a professional Standard of Care may fail to detect certain subsurface conditions. As a result, variability in subsurface conditions should be anticipated and it is recommended that a contingency for unanticipated conditions be included in budgets and schedules.

Golder sincerely appreciates the opportunity to support EFRC on the Piñon Ridge Project. Please contact the undersigned with any questions or comments on the information contained in this report.

Respectfully submitted,

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6.0 REFERENCES

6 CCR 1007-1, Part 18 – "*State Board of Health Licensing Requirements for Uranium and Thorium Processing*," specifically Appendix A (Criteria relating to the operation of mills and the disposition of the tailings or wastes from these operations).

10 CFR Part 40 – "*Domestic Licensing of Source Material*," Appendix A to Part 40 (Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for their Source Material Content).

40 CFR Part 192 – "*Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings*," Subpart D (Standards for management of uranium byproduct materials pursuant to section 84 of the Atomic Energy Act of 1954, as amended).

40 CFR Part 264 – "*Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*," Subpart K (Surface Impoundments).

ASTM D 6747. 2004. Standard Guide for Selection of Techniques for Electrical Detection of Potential Leak Paths in Geomembranes.

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