UTAH DIVISION OF RADIATION CONTROL
DENISON MINES (USA) CORPORATION
WHITE MESA MILL
BLANDING, UTAH

CELL 4B DESIGN REPORT

INTERROGATORIES –ROUND TWO

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Acronyms and Abbreviations

ARD	Acid Rock Drainage
ASTM	American Society for Testing and Materials
BAT	Best Available Technology
CFR	Code of Federal Regulations
DI water	De-Ionized water
DRC	Division of Radiation Control (Utah)
DUSA	Denison Mines (USA) Corporation
GCL	Geosynthetic Clay Liner
HDPE	High Density Polyethylene
IPS	inches per second
LCRS	Leachate Collection and Removal System
PMP	Probable Maximum Precipitation event
PPV	Peak particle velocity
PV	pore volume
UDEQ	Utah Department of Environmental Quality
URCR	Utah Radiation Control Rules
UV	Ultra-violet

General Summary of Requested Items

The following items summarize the interrogatories that remain open following URS' review of Denison Mines (USA) Corporation (DUSA's) response to Round 1 interrogatories. Please refer to the following interrogatories for the complete detail of the items requested.

1. INTERROGATORY DUSA R313-24-4-01/02: DIKE INTEGRITY: PROVIDE Information concerning the location and magnitude of blasting, expected to occur during construction of Cell 4B, and an evaluation of the potential impacts from such construction blasting in terms of supporting calculations, and/or supporting literature. Include information regarding potential impacts on slope stability for nearby features (e.g., berms and other features of Cell 4B and adjacent cells) and a definition of "damage(s)" that could be caused by such blasting.
2. INTERROGATORY DUSA R313-24-4-03/02: SPILLWAY CAPACITY DESIGN/CALCULATION AND SURFACE WATER RUNOFF: Provide additional information to demonstrate the capacity of the entire facility tailings cell system to handle the Probable Maximum Precipitation (PMP) under current site conditions and under planned future build-out scenarios. Please provide an estimation of the PMP-related flow rate and volume. Include information to justify that a zero discharge would occur from the furthest downstream cell (Cell 4B) considering all sources of flow or liquids at the facility. Consider the geometry and elevation of the proposed spillway into Cell 4B in the evaluation. In the event that Cell 4A is not self-containing under some future PMP condition, and / or does not comply with the 3-foot freeboard requirement mandated in Part I.D.6(d) of the Ground Water Permit, please demonstrate how Cell 4B will contain and control all tailings solids and liquids without causing any discharge to nearby soil or surface water.

3. INTERROGATORY DUSA R313-24-4-08/02: GCL, PRIMARY LINER, SECONDARY LINER, AND LEAK DETECTION SYSTEM: Provide a revised Cushion Protection Calculation and revisions to the Design Report and Technical Specifications, if needed, to reflect the results of considering/incorporating recently-issued (2008) revised cushion protection criteria in the revised calculation.
4. INTERROGATORY DUSA R313-24-4-08/02: GCL, PRIMARY LINER, SECONDARY LINER, AND LEAK DETECTION SYSTEM: Provide additional information that discusses and compares laboratory test results conducted for the GCL, for use in Cells 4A and 4B, to pertinent published laboratory testing results involving permeability testing of GCLs exposed to acidic permeants. Include an explanation of differences and any inconsistencies between these test results. Include information demonstrating that test termination criteria specified in ASTM D 6766 were achieved during the GCL permeability testing that was reported in the October 28, 2008 test report.

5. INTERROGATORY DUSA R313-24-4-08/02: GCL, PRIMARY LINER, SECONDARY LINER, AND LEAK DETECTION SYSTEM: Provide information that adequately supports the proposed approach of not pre-hydrating the GCL in Cell 4B prior to installing an HDPE geomembrane over it. Address in detail each of the issues described in the Round 2 Interrogatory below as they relate to the Cell 4B GCL pre-hydration design (or, alternatively, provide information indicating that the previously-approved procedure used for installing the GCL in Cell 4A which included pre-hydration of the GCL to achieve a minimum moisture content of 50% in the GCL and maintain that level until completion of geomembrane placement , will be used when constructing Cell 4B).
6. INTERROGATORY DUSA R313-24-4-08/02: GCL, PRIMARY LINER, SECONDARY LINER, AND LEAK DETECTION SYSTEM: Provide a revised GCL permeant travel time calculation that uses GCL hydraulic conductivity values that conservatively bound the range of hydraulic conductivity values that could reasonably be expected to occur in the GCL, in Cell 4B, during the cell’s design life. Include information demonstrating that the hydraulic conductivity values, used in the calculation, bound the range of uncertainty associated with predictions of the effects of acidic permeant exposure on the GCL (e.g., that adequately bound the range of published laboratory GCL permeability testing results using acidic permeants).

INTERROGATORY DUSA R313-24-4-01/02: DIKE INTEGRITY

PRELIMINARY FINDING:

Refer to R313-24-4, 10 CFR 40 Appendix A, Criterion 5A(5): When dikes are used to form the surface impoundment, the dikes must be designed, constructed, and maintained with sufficient structural integrity to prevent massive failure of the dikes. In ensuring structural integrity, it must not be presumed that the liner system will function without leakage during the active life of the impoundment.

Refer to R313-24-4, 10 CFR 40 Appendix A, Criterion 4 (e): The impoundment may not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand. As used in this criterion, the term "capable fault" has the same meaning as defined in section III(g) of Appendix A of 10 CFR Part 100. The term "maximum credible earthquake" means that earthquake which would cause the maximum vibratory ground motion based upon an evaluation of earthquake potential considering the regional and local geology and seismology and specific characteristics of local subsurface material.

INTERROGATORY STATEMENT:

The issue of dike integrity has been satisfactorily addressed in all aspects, except for the concept of construction blasting.

Please provide additional information concerning the location and magnitude of blasting expected to occur during Cell 4B construction, and an evaluation of the potential impacts from such construction blasting, by providing supporting calculations, and/or references to supporting literature. Please identify the proposed horizontal and vertical limits of blasting during the construction of Cell 4B. Please evaluate slope stability issues related to blasting, consistent with the geological drawings/figures that are provided in the design report. Please provide technical drawings that support the analysis discussed below in reference to the distance from blasting to berm slope, buildings, etc.

Please explain and justify the assumption that a Peak Particle Velocity (PPV) of 5 inches per second (IPS) is appropriate for the site, considering protection of the constructed berms. Please evaluate the potential for slope instability, due to construction blasting that:

1. *Demonstrates how the blasting will affect the stability and functionality of the surrounding berms, that will be cut to serve as the side slopes for Cell 4B, as well as any other components of Cell 4B and adjacent Cells; and*
2. *Evaluates what effect blasting will have on the effective permeability and speed of water travel through underlying material.*

Please define "damage" both in terms of nearby dike stability, and foundation permeability under Cell 4B.

BASIS FOR INTERROGATORY:

In response to the request for a revised slope stability evaluation, DUSA provided a calculation entitled "Slope Stability Analyses, White Mesa Mill, Cell 4B, Blanding Utah", for review. The calculation was found to contain the following elements requested in the May 29, 2008 interrogatory letter:

1. *The slope stability analyses were performed for each of the critical slopes for each of the four embankments surrounding Cell 4B;*
2. *The parameters and conditions used in the evaluations were identified and justified, and the resulting assumptions were consistent with those provided in support of Cell 4A;*
3. *The analyses considered the potential conditions associated with Cells 3 and 4A on the berm stability (liquid/soil levels, etc).*
4. *The analyses considered the impacts of various other surrounding conditions including the perimeter haul road and interim stockpiling of material at the top of the berm slope;*
5. *The analyses provided adequate justification for the use of factors of safety of 1.5 and 1.3 for static and operational slope stability.*
6. *The analyses evaluated seismic impacts on slope stability.*

Interrogatory DUSA R313-24-4-06/01 – Subgrade Preparation and Earthwork – (Round 1 Interrogatories) inquired about the extent of construction blasting that DUSA proposing and requested a drawing or figure representing the limits of proposed blasting. The DUSA response was incomplete in resolving this concern. Please address the potential slope instability due to blasting in close proximity to the dike berms.

Other than several schematics of the geologic cross-sections through Cell 4B, there are no technical drawings illustrating the horizontal and vertical extents of blasting.

The analyses briefly discussed the ground motions resulting from blasting operations to remove bedrock. The discussion refers to a peak particle velocity limitation of 5 IPS (not included in the specifications), but does not present a reference or basis for the value.

Based on the reference "Blasting Guidance Manual, US Department of Interior, Office of Surface Mining and Reclamation and Enforcement (1987)", assuming that measured ground vibration frequencies caused by the blasting are greater than 30 Hz, a maximum peak particle velocity of 2 IPS can be allowed or utilized without concern for damage to structures. Further, if ground vibration frequencies caused by the blast are less than 30 Hz, maximum peak particle velocities can not exceed the limits published by the U.S. Bureau of Mines (Report of Investigation #8507). The potential for slope instability due to construction blasting must be adequately addressed.

The current design and Technical Specification Section 02200 places a requirement on the Contractor that blasting shall not cause damage. “Damage” is not defined, and must be fully explained.

REFERENCES:

“Cell 4B Design Report, White Mesa Mill, Blanding, Utah” by GeoSyntec Consultants, December 2007. Prepared for International Uranium (USA) Corporation.

“Slope Stability Analysis, White Mesa Mill, Cell 4B, Blanding, Utah”, by GeoSyntec Consultants, July 2008.

“Cell 4B Lining System Design Report, Response to Division of Radiation Control (“DRC”) Request for Additional Information – Round 1 Interrogatory, Cell 4B Design”, Letter dated January 9, 2009, from Harold R. Roberts of Denison Mines (USA) Corp., to Dane L. Finerfrock, Division of Radiation Control.

*“OSMRE Blasting Guidance Manual, US Department of Interior, Office of S*urface Mining *and Reclamation and Enforcement (*1987*)”, TRG-1, January 1987.*

INTERROGATORY DUSA R313-24-4-03/02: SPILLWAY CAPACITY DESIGN/CALCULATION AND SURFACE WATER RUNOFF

PRELIMINARY FINDING:

Refer to R313-24-4, 10 CFR 40 Appendix A, Criterion 5A(5): When dikes are used to form the surface impoundment, the dikes must be designed, constructed, and maintained with sufficient structural integrity to prevent massive failure of the dikes.

Refer to R313-24-4, 10 CFR Appendix A, Criterion 5A(4): A surface impoundment must be designed, constructed, maintained, and operated to prevent overtopping resulting from normal or abnormal operations, overfilling, wind and wave actions, rainfall, or run-on.

Refer to R313-24-4, 10 CFR Appendix A, Criterion 4 (d): In addition to providing stability of the impoundment system itself, overall stability, erosion potential, and geomorphology of surrounding terrain must be evaluated to assure that there are not ongoing or potential processes, such as gully erosion, which would lead to impoundment instability.

INTERROGATORY STATEMENT:

Please demonstrate the capacity of the entire facility cell containment system to handle the Probable Maximum Precipitation (PMP) event under current conditions and under planned future build-out scenarios. Please provide an estimation of the PMP event. This demonstration should focus on water volume from the PMP storm, not only flow rate between the cells.

Please justify, based on the elevation data supplied, that a zero discharge from the furthest downstream cell (Cell 4B), would occur in light of all sources of water, wastewater, and tributary areas.

Please provide details on the freeboard calculations for Cells 4A and 4B, considering the PMP storm event and the upstream contributions from Cells 1, 2, 3 and 4A.

In addition, the January 9, 2009 Round 1 Interrogatory Response suggested that Cell 4B freeboard will be "set at 3 ft below the top of the liner". Please indicate whether the Response refers to the top of the liner in the Cell 4A/4B spillway (elevation 5596.3 ft – liquid level of 5593.3 ft) or to the South Berm top of liner (elevation 5598 ft – liquid level of 5595 ft). Please clarify what the actual maximum freeboard elevation will be under PMP conditions and demonstrate that there will be no potential for Cell 4B overflow, considering all potential flow from Cell 4A and elsewhere at the facility. Please also identify a point of compliance for freeboard monitoring and all equipment, procedures, and a monitoring frequency to be used to monitor compliance at that Cell 4B location.

BASIS FOR INTERROGATORY*:*

In response to the request for additional information on the Spillway Capacity Design/Calculation and Surface Water Runoff calculations, DUSA provided the following discussions/clarifications:

1. *Revised drawings identifying the flow path and invert elevations for the emergency spillway from Cell 4A to Cell 4B, confirmed the width of the proposed spillway, and provided a appropriate spillway flow capacity design;*
2. *An adequate spillway discharge apron, equal to that designed and approved for the Cell 4A spillway, and;*
3. *An adequate response to the request that plant flows be factored into the PMP flow evaluation.*

It has been indicated that stormwater flow from Cell 4A and upstream cells into Cell 4B has been factored into the design.

We understand that the design is intended to demonstrate a zero discharge from the furthest downstream cell, Cell 4B, which appears to eliminate any further questions regarding discharges from Cell 4B from all sources of water and tributary areas.. However, based on the elevation data provided in the response, additional justification should be provided.

Based on rough calculations, it appears that the tributary areas to Cell 4A during the PMP could be as follows: Mill site (64 Ac), Cell 1 (84 Ac), Cell 2 (80.7 Ac), Cell 3 (78.3 Ac), and Cell 4A (42.1 Ac), for a total tributary area of approximately 349 Ac. Based on a total PMP rainfall of 10 in, the total volume of precipitation would be approximately 12.67 million ft^3*. Based on the area of Cell 4A, this volume would create a pond depth of approximately 7.0 ft (see Figure 1 in Response). Consequently, it would appear that Cell 4A would not contain the PMP flood. Further, the point of compliance for the maximum freeboard must be defined for all tailings cells in the system, and the requirements for compliance monitoring clearly identified.*

DUSA provided an acceptable response to the request for mill operations to be factored into the storm capacity of the cells.

DUSA provided spillway design calculations for Cell 4B. The designs for the spillway dimensions appear adequate.

DUSA has provided design for a discharge apron from the 4A/4B spillway that is equivalent to that approved for the Cell 3 / 4A spillway.

REFERENCES:

"Cell 4B Design Report, White Mesa Mill, Blanding, Utah" by GeoSyntec Consultants, December 2007. Prepared for International Uranium (USA) Corporation.

"Cell 4B Lining System Design Report, Response to Division of Radiation Control ("DRC") Request for Additional Information – Round 1 Interrogatory, Cell 4B Design", Letter dated January 9, 2009, from Harold R. Roberts of Denison Mines (USA) Corp., to Dane L. Finerfrock, Division of Radiation Control.

INTERROGATORY DUSA R313-24-4-08/02: GCL, PRIMARY LINER, SECONDARY LINER, AND LEAK DETECTION SYSTEM

PRELIMINARY FINDING:

Refer to R313-24-4, 10 CFR 40 Appendix A, Criterion 5A(1): Surface impoundments must have a liner that is designed, constructed, and installed to prevent any migration of wastes out of the impoundment to the adjacent subsurface soil, ground water, or surface water at any time during the active life (including the closure period) of the impoundment. The liner may be constructed of materials that may allow wastes to migrate into the liner (but not into the adjacent subsurface soil, ground water, or surface water) during the active life of the facility, provided that impoundment closure includes removal or decontamination of all waste residues, contaminated containment system components (liners, etc.), contaminated subsoils, and structures and equipment contaminated with waste and leachate. For impoundments that will be closed with the liner material left in place, the liner must be constructed of materials that can prevent wastes from migrating into the liner during the active life of the facility.

Refer to R313-24-4, 10 CFR 40 Appendix A, Criterion 5A(2): *The liner required by paragraph 5A(1) above must be: (a) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to pressure gradients (including static head and external hydrogeologic forces), physical contact with the waste or leachate to which they are exposed, climatic conditions, the stress of installation, and the stress of daily operation; (b) Placed upon a foundation or base capable of providing support to the liner and resistance to pressure gradients above and below the liner to prevent failure of the liner due to settlement, compression, or uplift; and (c) Installed to cover all surrounding earth likely to be in contact with the wastes or leachate.*

*Refer to R313-24-4, R317-6-1.13: **Best Available Technology [BAT]** means the application of design, equipment, work practice, operation standard or combination thereof at a facility to effect the maximum reduction of a pollutant achievable by available processes and methods taking into account energy, public health, environmental and economic impacts and other costs.*

*Refer to R313-24-4, R317-6-6.4(A)(3/112): The Executive Secretary may issue a ground water discharge permit for a new facility if the Executive Secretary determines, after reviewing the information provided under R317-6-6.3, that: 1.the applicant demonstrates that the applicable class TDS limits, ground water quality standards protection levels, and permit limits established under R317-6-6.4E will be met; 2. the monitoring plan, sampling and reporting requirements are adequate to determine compliance with applicable requirements; 3. the applicant is using **best available technology** to minimize the discharge of any pollutant; and 4. there is no impairment of present and future beneficial uses of the ground water.*

INTERROGATORY STATEMENT:

Refer to the Cell 4B Design Report and Cushion Fabric Calculations (Appendix D) Attached thereto and the Revised Technical Specifications. *Please provide additional information to demonstrate (in the Design Report, in a revised Appendix D of the Design Report, and in Section 02225 of the Technical Specifications if necessary) that the specified particle size gradation for the drainage aggregate used in the granular material surrounding the PVC pipes in the slimes drain and leak detection systems remains compatible with the specified cushion geotextile, if recently revised criteria (Koerner 2008) are used in the Cushion Fabric Calculations in lieu of the criteria currently used in the cushion calculations.*

Refer to the Design Report (and Exhibit J thereto) and the Cell 4B Revised Technical Specifications Related to GCL Pre-hydration/Placement Procedure. *Please justify the technical appropriateness of the proposed change in approach with respect to pre-hydration of the GCL from the approach that was employed in Cell 4A, i.e., the proposed change to deploy the GCL on the Cell 4B subgrade without hydration prior to covering it with the HDPE geomembrane liner, which is not adequately supported by the information provided in the January 9, 2009 DUSA Round 1 – Interrogatory Response for the Cell 4B Design Report.*

To address inconsistency between the most recent DUSA test results presented in Exhibit J and previously conducted DUSA test results, and other published similar GCL acidic permeant permeability test results, please provide the following additional data/information to the Division:

- *Additional information from the testing laboratory that describes and documents that test criteria specified in ASTM D 6766 were followed, including data indicating that test termination criteria (inflow-outflow criteria; steady hydraulic conductivity; and electrical conductivity and pH ratio criteria in influent vs. effluent) were achieved;*
- *A thorough analysis comparing the October 28, 2008 DUSA test results to: (1) the previous Cell 4A GCL permeability testing results, and (2) other published reported laboratory test results from similar GCL permeation tests conducted using acidic permeants (Note: Published results from selected other laboratory tests are described in the 'Basis for Interrogatory' section below). The analysis and justification needs to explain the differences in results reported, with particular discussion of the reasons why the October 28, 2008 DUSA test results do not appear to suggest the following findings that have been reported by other well published and peer reviewed investigators (see discussion below for additional information):*
    - *Hydraulic conductivity values of non-prehydrated GCL samples that are subjected to exposure to an acidic permeant would be expected to generally increase asymptotically (over pre-exposure levels) in proportion to increasing numbers of pore volumes of flow-though of the acidic*

permeant, with the hydraulic conductivity value typically continuing to rise over a range of permeation volumes between 1 to approximately 20 pore volumes, with the same asymptotically increasing behavior in hydraulic conductivity sometimes reported to continue to occur for a range between 1 and upwards of 40 or more pore volumes of exposure

  - *Other factors being equal, and under similar testing conditions, comparable, GCL samples that were pre-hydrated and subsequently exposed to an acidic permeant typically experienced less of an overall increase in hydraulic conductivity compared to their pre-exposure value than non-prehydrated GCL samples subjected to exposure to the same acidic permeant.*

Please provide additional information to address the following issues that could affect the performance of the GCL after its installation in the Cell 4B liner system:

- *The (known) detrimental effect of acidic permeants on the swelling capacity of bentonite in the GCL, and the degree of correlation between decreased bentonite swell capacity and increased hydraulic conductivity of the GCL*
- *The potential for loss of moisture to occur in the GCL after its placement in the Cell 4B liner system due to the effects of elevated temperature, if exposure to such elevated temperatures were to occur over an extended period of time prior to waste being placed over the liner system.*

Please justify the proposed change in the GCL placement procedure for Cell 4B (i.e, the proposal to not pre-hydrate the GCL prior to covering it with the geomembrane in a manner consistent with the procedure approved by the UDEQ on September 28, 2007 (UDEQ 2007) for use in constructing Cell 4A. As an alternative to providing the above information and analyses, Denison may revise the design and specifications to include installation of the GCL in Cell 4B in the same manner that was previously approved by the Division on September 28, 2007 (UDEQ 2007) for Cell 4A (provided that the GCL used is of the same type and made by the same manufacturer as was used for Cell 4A).

Refer to the January 9, 2009 DUSA Round 1 – Interrogatory Response for the Cell 4B Design Report, pages 15 and 16 of text of Response (and Exhibit J thereto). *Please provide a permanent time of travel calculation that uses hydraulic conductivity values (in the calculation steps) that conservatively bounds the range of hydraulic conductivity values that could reasonably be expected to occur in the GCL component of the Cell 4B liner system during its design life. Hydraulic conductivity values used in the analysis need to reflect the previous laboratory testing results completed for the GCL for use in Cell 4A and account for the information discussed above and described below in the "Basis for Interrogatory" regarding the detrimental effects of acidic permeant on the GCL. When selecting hydraulic conductivity values for use in the calculation, please address the apparent inconsistency between the results of the October 28. 2008 GCL testing results and the previous Cell 4A GCL testing results and the other published GCL permeability test results. Demonstrate that the values used in the calculations adequately* *bound the range of uncertainty associated with predictions of effects of acidic permeants on the GCL (e.g., adequately bound the range of published test results).*

Refer to the Revised Cell 4B Technical Specifications attached to the January 9, 2009 DUSA Round 1 – Interrogatory Response for the Cell 4B Design Report. *Please provide a revised Technical Specification for the Geosynthetic Clay Liner and revised Technical Specifications for the Geomembrane, Geotextile and other liner/containment system components that specify a defined maximum allowed time period within which installation (and seaming) of the lower HDPE geomembrane liner and the remaining components of the containment system up to and including the uppermost geomembrane liner over the GCL must be completed (in order to protect the installed GCL from drying/desiccation effects and/or potential overall moisture loss due to various factors discussed in the Basis for Interrogatory section below).*

BASIS FOR INTERROGATORY:

1. A recent publication (Koerner 2008), issued after the Cushion Fabric Calculation in Appendix D was prepared, recommends the use of revised (updated) criteria for use in the design of cushion protection geotextiles for protecting adjacent geomembranes from damage from puncture. The criteria include recommended revised Reduction Factors for creep (RF_{CR}) *for various particle protrusion heights. These revised* RF_{CR} *values reflect the results of long-term pressurization tests completed by the Geosynthetic Institute. The Cushion Fabric Calculations in Appendix D of the Design Report uses* RF_{CR} *values that do not appear to be not consistent with these recently revised* RF_{CR} *criteria.*

2. Several published and peer reviewed studies of laboratory tests of GCL samples exposed to acidic permeants under similar testing conditions as those used by the laboratory as described in the October 28, 2008 DUSA laboratory test report, as well as the previous testing done on behalf of DUSA to support construction of Cell 4A, indicate or suggest different behavior in the pattern of GCL permeability values with increased exposure to acidic permeant than was reported in the October 28, 2008 report. A summary of selected other laboratory GCL permeation studies involving acidic permeants are discussed in the following paragraphs.

A broad body of published information indicates that pre-hydrating a GCL with freshwater prior to allowing it to come into contact with an acidic permeant helps mitigate against the detrimental effects of acidic liquids on the bentonite component of the GCL.

The laboratory test results of GCL permeability testing using hydrochloric acid submitted to Geosyntec Consultants by TRI Environmental, Inc. on October 28, 2008 (included in Exhibit J of Denison's January 2009 Round 1 Interrogatory Response package) appear to be inconsistent with previous similar testing results completed in August 2007 and submitted by Denison Mines for the GCL used in constructing Cell 4A. Further, the testing results provided in Exhibit J also appear to be inconsistent with several other published and peer reviewed results of similarly-designed and similarly conducted *laboratory GCL permeability tests using acidic permeants. For example, the October 28, 2008 DUSA test results suggest that hydraulic conductivity values appeared to decrease with increasing pore volumes of exposure to acidic permeant over a portion or portions of the exposure period for some GCL samples (e.g., for the GCL sample having an initial moisture content of 17%). GCL permeability testing results obtained from the previous Cell 4A GCL permeability testing using a pH = 1 solution, for the GCL sample having an initial moisture content of 50%, yielded results that are more consistent with other published findings. The use of hydraulic conductivity values that are lower than the initial (pre-exposure) value in the travel time calculations for cases where the GCL has been subjected to permeation with the acidic permeant does not represent a conservative approach, given the general consensus/ convergence of findings reported in the published literature and the previous Cell 4A GCL permeability testing results.*

Results of laboratory testing of GCL permeability using permeants other than water as described by Ruhl and Daniel 1997 and Petrov and Daniel 1997, have been discussed in previous interrogatories developed for Cell 4A, and are summarized again here. Ruhl and Daniel 1997 and Petrov and Rowe 1997 performed tests on the effects of acidic solutions and a simulated municipal waste leachate on the saturated hydraulic conductivity (K_{sat}) of a GCL. Ruhl and Daniel tested acidic solutions of 0.1 M HCl and a simulated waste leachate with a pH of 4.4. The results indicated there was little or no increase in K_{sat} or permeant pH after approximately 8 pore volumes of flow through a pre-hydrated GCL. However, it was found that initial contact of the non-pre-hydrated GCL with acidic solutions led to very high K_{sat} from the beginning of the tests.

Lange et al. (2007) tested a GCL (thermally locked BENTOFIX NW GCL with a scrim reinforced-nonwoven carrier geotextile, and a nonwoven cover geotextile encapsulating a layer of granular Wyoming sodium bentonite [5500–6600 g bentonite/$m^{2]}$) similar to the GCL proposed for use in Cell 4B by initially permeating it with de-aired, De-Ionized (DI) water and then exposing it to a permeant of simulated acid rock drainage (ARD), having a pH of 3.3. The long-term hydraulic conductivity of the GCL samples increased from an initial value of 1.6×10^{-9} cm/sec to 1.3×10^{-8} cm/sec after permeation with the ARD water. The pH in the effluent from the ARD-permeated GCL samples was seen to decline steadily from an initial value of 8.5 to below 4.4 after 21 pore volumes (PVs) of exposure to the permeant with data indicating that pH levels were still declining at 25 PVs. They noted that available data indicate that GCLs would be particularly suitable for short-term containment (i.e. holding ponds) of ARD and that although it may be possible for long-term (i.e. permanent) containment, more compatibility (i.e. hydraulic conductivity testing) and geochemical analyses need to be undertaken for longer periods in the laboratory.

In similar testing, Lange and others (2005) found that at exposure of a GCL sample that was first prehydrated with de-aried, de-ionized water, the pH of the effluent from a GCL that was subsequently permeated with an acid mine drainage simulated permeant remained above 7 until 20-22 PVs, where it first dropped to 4.6, then dropped again to ~3.8. The hydraulic conductivity of the GCL sample was found to increase to 1.6x10-9 cm/sec at 20-22 PVs, compared to its initial value of 2.8×10^{-10} cm/sec, and at 30 PVs, *the hydraulic conductivity began to increase at a faster rate to a final hydraulic conductivity at 44 PVs of 3.7x10^{-9} cm/sec. The largest increase in hydraulic conductivity of the AMD-permeated GCL sample followed the large drop in the pH of the effluent.*

Kolstad et al. 2004 found that hydraulic conductivity tests of a dense prehydrated GCL exposed to a strong acid (pH=1.2) resulted in a hydraulic conductivity that was 39 times the hydraulic conductivity of the same GCL exposed only to DI water, whereas the hydraulic conductivity for a non-prehydrated conventional GCL exposed to the acidic permeant was 12,500 times higher than the hydraulic conductivities obtained for the same GCL exposed only to DI water. The results for the non-prehydrated conventional GCL yielded similar results as those found by Jo et al. (2001).

Shackelford et al. 2000, Jo et al. 2005, and others have discussed termination criteria for hydraulic conductivity tests performed to evaluate interactions between barrier soils and permeant solutions. Several studies recommended that tests not be terminated until a steady hydraulic conductivity is achieved and the ratio of incremental outflow to inflow rates is approximately 1.0, in addition to suggested guidance regarding minimum numbers of pore volumes of exposure that should be investigated. Others recommended that "chemical equilibrium" be established, e.g., comparable concentrations in influent and effluent, be achieved before terminating a test. Specific termination criteria for testing of GCL permeability for GCLs exposed to permeants other than water are specified in ASTM D 5084 and ASTM D 6766. ASTM D6766 requires that the termination criteria of the test include a finding that the ratio of pH and Electrical Conductivity values in the effluent from the exposed GCL sample relative to the influent (permeant) solution both fall between 0.9 and 1.1. The test results provided in Exhibit J of the January 9, 2009 DUSA submittal do not provide documentation that any of the above termination criteria were achieved during the testing.

In addition to the above studies, published information also strongly suggests (e.g., see Gates et al. 2009) that acidity, as well as increased ionic strength of a pore solution, generally leads to a decrease in swelling capacity of bentonite and therefore could result in an increase in the hydraulic conductivity in the GCL. Jo et al. (2001) evaluated the effects of pH on free swell. The GCL used in their study was a sample of granular bentonite placed between a 170 g/m^2 slit-film monofilament-woven geotextile and a 206 g/m^2 staple-fiber nonwoven geotextile, held together by needle-punching. Jo et al. found that the swell volume of the GCL decreased significantly and a major increase in hydraulic conductivity of the GCL occurred below a pH of 2, with the smallest swelling occurring in an acid with a pH=1. In addition, chemical analysis results showed that a decrease in pH produced an increase in dissolution. Certainly the tailings wastewaters anticipated in Cell 4B will have both low pH and high ionic strength.

An additional concern that has been noted is that smectites, the dominant minerals in bentonites, and other minerals containing Al, Fe, Mg and Ca are unstable in acid solutions. Given sufficient contact time with acidic solutions, bentonites can ultimately break down to an amorphous, porous, and hydrated silica (Komadel and Madejová 2006; Gates et al. 2009). Dissolution of smectites in acid solutions has been observed to *increase as pH decreases. Permeants having a pH below 4.5 usually favor dissolution of clay structures (Gates 2007).*

The GCL, once placed on the prepared subgrade, could experience drying/desiccation cracking if not covered promptly by the geomembrane (e.g., Rowe 2006). The GCL should be covered promptly by the secondary geomembrane liner and overlying remaining components of the Cell 4B liner/containment system to minimize the potential for such drying/cracking to occur. No defined timeframes for completing installation of these components over the GCL could be found in the Technical Specifications.

An additional issue of potential concern that needs to be addressed by the design is that if (portions of) the composite geomembrane/GCL liner system in Cell 4B would be left exposed for an extended period of time, the geomembrane components of the liner system above the GCL would be exposed to daily thermal cycles, and the GCL would likely experience associated changes in water content. Depending on the severity and duration of hotter and drier conditions occurring at the site vs. wetter, cooler site conditions, periods of hot, dry conditions could transfer heat to the GCL, subjecting it to a drying cycle, causing evaporation of water from the GCL (e.g., see Rowe 2006; Bostwick et al. 2008). During time periods when temperatures cool, the GCL could experience some degree of re-hydration of the GCL, e.g., from moisture that might be lost to the subgrade soils; however, a potential long-term GCL performance issue exists in that if the liner is located on a slope, and is left exposed for an extended period or periods of time to hot, dry weather (e.g., drought conditions), moisture losses from the GCL during these time periods could flow downslope, resulting in overall moisture loss in the portions of the GCL base low-permeability layer located on the slopes (Bostwick et al. 2008).

The Cell 4B design includes a primary geomembrane with one white side placed upward, and incorporates additional geosynthetic materials between the primary geomembrane and the GCL. Collectively, these features would be expected to help mitigate cyclic moisture changes in the GCL, provided that they are installed over the GCL in a timely manner. The white side of the primary geomembrane, for example, will not reach as high a temperature as would an entirely black geomembrane, and the additional layers of geosynthetics (and other materials) above the GCL would be expected to provide some additional insulating effects. Completion of installation of these components (up to and including the uppermost geomembrane) as soon as possible following placement of the GCL would therefore help reduce potential long-term moisture losses from the GCL. Pre-hydrating the GCL, as was done in the Cell 4A GCL construction, would also be expected to provide some additional "moisture buffering capacity" against potential long-term net losses of GCL moisture content. .

Previous field test results were performed to demonstrate the amount of pre-hydration required for GCL performance at the DUSA White Mesa Mill, Cell 4A. Based on these permeability testing results, that indicated that an optimum level of GCL pre-hydration for mitigating the detrimental effects of an acidic (pH =1) permeant on GCL permeabiilty was 75% moisture content, However, test results with a moisture content greater than 50% were considered to be an acceptable level, and the Utah Department of

Environmental Quality (UDEQ Sept. 28, 2007) approved a revised hydration plan for the GCL in Cell 4A that specified pre-hydration of the GCL to a minimum level of 50% moisture content during cell construction.

An additional concern relating to the issue of GCL pre-hydration is that, according to the August 31, 2007 letter from GeoSyntec Consultants, the pre-installation moisture content of the GCL used in Cell 4A was lower than that of the as-manufactured GCL. Reasons for this were stated to be drying during shipment and/or site storage. This finding will likely offset a statement made in the January 9, 2009 DUSA submittal that "based on Geosyntec's experience with GCL material and manufacturer data (CETCO 2008), the as-achieved moisture content of a GCL is typically greater than 17 % and will be acceptable for deployment without additional hydration".

REFERENCES:

"Cell 4B Lining System Design Report, Response to Division of Radiation Control ("DRC") Request for Additional Information – Round 1 Interrogatory, Cell 4B Design", Letter dated January 9, 2009, from Harold R. Roberts of Denison Mines (USA) Corp., to Dane L. Finerfrock, Division of Radiation Control.

Bostwick, L.E., Rowe, R.K., Take, W.A., and Brachman, R.W. 2008. "Observations of the Dimensional Stability of Four GCL Products under Combined Thermal and Moisture Cycles", The First Pan American Geosynthetics Conference & Exhibition 2-5 March 2008, Cancun, Mexico.

Gates, W.P. 2007. "Geosynthetic Clay Liner Technology: Understanding Bentonite", SmecTech Research Consulting.

Gates, W.P., Bouazza, A., and Churchman, G.C. 2009. "Bentonite Clay Keeps Pollutants at Bay", Elements, Mineralogical Society of America, Vol. 5, No. 2, April 2009, pp. 105-110.

Jo, H.Y., Katsumi, T., Benson, C.H., and Edil, T.B. 2001. "Hydraulic Conductivity and Swelling of Nonprehydrated GCLs Permeated with Single-Species Salt Solutions." Journal of Geotechnical and Geoenvironmental Engineering, pp. 562-565.

Jo, H.Y, Benson, C. H., Shackelford, C.D. Lee, J-M, and Edil, T.B. 2005. "Long-Term Hydraulic Conductivity of a Geosynthetic Clay Liner Permeated with Inorganic Salt Solutions", Journal of Geotechnical and Geoenvironmental Engineering, Vol. 131, No. 4, April 1, 2005, pp. 405-417.

Koerner, R.M. 2008. "Modification to the GRI-Method" for the FR_{CR} – Factor Used in the Design of Geotextiles for Puncture Protection of Geomembranes". GRI White Paper # 14. Geosynthetic Institute, Folsom, PA. November 24, 2008.

Kolstad, D., Benson, C. H., and E.T. 2004. "Hydraulic Conductivity and Swell of Nonprehydrated GCLs Permeated with Multispecies Inorganic Solutions." Journal of Geotechnical and Geoenvironmental Engineering, 130 (12), pp. 1236–1249.

Kolstad, D.C., Benson, C.H., Edil, T. B., and Jo, H. Y. 2004. "Hydraulic Conductivity of a Dense Prehydrated GCL Permeated with Aggressive Inorganic Solutions." Geosynthetics International, 2004, 11, No. 3., pp. 233-241.

Komadel, P, and Madejová, J. 2006. "Acid Activation of Clay Minerals". In: Bergaya F, Theng BKG, Lagaly G (eds), Handbook of Clay Science. Developments in Clay Science Volume 1, Elsevier, Amsterdam, pp. 263 -287.

Lange, K, Rowe, R.K., and Jamieson, H. 2005. "Attenuation of Heavy Metals by Geosynthetic Clay Liners". GRI-18 Geosynthetics Research and Development in Progress, 2005, 8 pp.

Lange, K, Rowe, R.K., and Jamieson, H. 2007. "Metal Retention in Geosynthetic Clay Liners Following Permeation by Different Mining Solutions". Geosynthetics International, 2007, 14, No. 3.

Petrov, R., and Rowe, R.1997. "Geosynthetic Clay Liner (GCL)— Chemical Compatibility by Hydraulic Conductivity Testing and Factors Impacting its Performance." Canadian Geotechnical Journal, 34, pp. 863–885.

Rayhani, M.H.T., R.K. Rowe, R.W.I. Brachman, G. Siemens & A. Take 2008. "Closed-System Investigation of GCL Hydration From Subsoil". Proceeedings GeoEdmonton '08. pp. 324-328. URL:

Rowe, R.K. 2006. "Some Factors Affecting Geosynthetics used for GeoEnvironmental Applications", 5th ICEG Environmental Geotechnics, Thomas Telford, London 2006.

Ruhl, J.L., Daniel, D.E. (1997) "Geosynthetic Clay Liners Permeated with Chemical Solutions and Leachates". Journal of Geotechnical and Environmental Engineering 123: pp. 369 -381.

Shackelford, C., Benson, C., Katsumi, T., Edil, T., and Lin, L. 2000. "Evaluating the Hydraulic Conductivity of GCLs Permeated with Nonstandard Liquids." Geotextiles and Geomembranes. 18 (2–4), pp.133–162.

Utah Department of Environmental Quality (UDEQ) 2007. "Revised GCL Hydration Plan Approval", Letter from Dane Finerfrock, Utah Department of Environmental Quality, to Harold Roberts of Denison Mines (USA) Corporation, dated September 28, 2007.