AquiferTek

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Re: Response to ASLB Contention #2, Hydraulic Containment of Mining Solutions at the Marsland Expansion Area (MEA)

Gentlemen,

I've reviewed the discussion related to hydraulic containment of mining solutions at the Marsland Expansion Area (MEA) as expressed in Contention #2 by the MEA Atomic Safety Licensing Board (ASLB). The following is a summary of my evaluation.

CONTAINMENT OF MINING SOLUTIONS

Existing hydrogeologic and operations data support the conclusion that mining solutions will be fully contained both laterally and vertically at the MEA.

1) The steeply downward hydraulic gradient at the MEA prevents upward migration of mining solutions.

Mining solutions at the MEA are contained vertically given the steeply downward hydraulic gradient observed between the shallow Arikaree/Brule aquifer and the Basal Chadron production aquifer. Baseline water level data collected at the MEA to date indicate water level elevations in the shallow Arikaree/Brule aquifer are 350 to more than 500 feet higher than water levels in the production aquifer. Given an observed thickness of the Upper/Middle Chadron confining unit of 650 to 700 feet at the MEA, the observed downward hydraulic gradient at the site is approximately 0.5 to 0.8. Wellfield operations at the MEA will only act to increase the observed downward hydraulic gradient given the net drawdown produced by the wellfield bleed. Under no circumstances can the observed difference in water levels be overcome during wellfield operations. Given these facts, there is no hydrologic mechanism by which mining solutions could migrate upward from the production aquifer toward the shallow Arikaree/Brule aquifer. Therefore, vertical containment of mining solutions at the MEA can be assured regardless of the physical characteristics of the shallow aquifer, confining unit, or production aquifer.

2) Geological and hydrologic data collected at the MEA indicates the Basal Chadron production aquifer is confined and hydraulically isolated from the shallow Arikaree/Brule aquifer.

Baseline water level data collected at the MEA indicate water level elevations in the Basal Chadron aquifer are more than 400 feet above the top of the Basal Chadron sandstone, indicating confined aquifer conditions exist. This is to be expected given the more than 650 feet of low permeability claystone and siltstone of the Upper/Middle Chadron confining unit that separate the shallow aquifer from the Basal Chadron production aquifer. Further, water level drawdown and recovery data collected during the regional aquifer test at the MEA are indicative of confined aquifer conditions. Further, water level data collected from shallow aquifer monitoring wells during the aquifer test did not show any evidence of drawdown during the test, indicating the production aquifer was isolated from the shallow aquifer. The Basal Chadron storage coefficient (2.6×10^{-4}) calculated from aquifer test data is also indicative of confined conditions. There is no evidence of leaky (e.g. semi-confined) aquifer conditions observed at the site from geologic data including borehole logs, core data, or geophysical well logs. Furthermore, as discussed previously, the strongly downward hydraulic gradient observed between the shallow aquifer and the Basal Chadron production aquifer prevents vertical migration of mining solutions upward from the production aquifer, regardless of the physical characteristics of the aquifers or confining units.

3) The Upper/Middle Chadron confining unit is sufficiently impermeable to hydraulically isolate the production aquifer from the shallow aquifer.

A review of geologic and geophysical logs from boreholes at the MEA indicates the Upper/Middle Chadron confining unit consists of more than 90 percent claystone and less than 10 percent coarser material (e.g. siltstone and sandstone). The average vertical hydraulic conductivity of Upper/Middle Chadron Formation claystone, as measured in two core samples in the laboratory using a falling head permeameter, is 1.3×10^{-7} cm/sec (**Attachment A**). Therefore, the Upper/Middle Chadron claystones can be classified as low permeability (e.g., Norris and others, 2012). The representative vertical hydraulic conductivity of the lesser coarser-grained materials (e.g. siltstone and fine sandstone) in the Upper/Middle Chadron Formation, as calculated from grain-size analysis (Kozeny-Carmen analysis) of six core samples, is 3.9×10^{-5} cm/sec (**Attachment A**).

The representative hydraulic conductivity of a stratified sequence of sediments undergoing vertical flow is characterized as the harmonic mean of the hydraulic conductivities of the individual strata (e.g. Norris and others, 2012). Given a conservative composition of the

Upper/Middle Chadron confining unit of 90 percent claystone and 10 percent coarser material, the representative vertical hydraulic conductivity of the Upper/Middle Chadron confining unit is 1.5×10^{-7} cm/sec. As a point of reference, one to two feet of clay having a vertical hydraulic conductivity of 1×10^{-7} cm/sec is considered sufficiently impermeable to be used as a liner in landfills and waste repositories to isolate waste from groundwater (e.g., Norris and others, 2012). For purposes of comparison, the Upper/Middle Chadron confining unit consists of more than 580 feet of claystone of this character.

4) The rate of vertical groundwater movement is insignificant and further demonstrates vertical containment of mining solutions.

The rate of vertical movement between the shallow aquifer and the production aquifer can be calculated using Darcy's Law and available hydrogeologic data including vertical hydraulic conductivity and effective porosity of the Upper/Middle Chadron confining unit, and the hydraulic gradient between the shallow aquifer the production aquifer.

Given a maximum hydraulic gradient of 0.8, an effective porosity of the confining unit of 0.1, and a representative vertical hydraulic conductivity of 1.5×10^{-7} cm/sec from 3) above, the downward movement of fresh groundwater from the shallow aquifer is about 1.2 ft/year. At this rate of movement, and assuming a minimum thickness of 650 feet for the Upper/Middle Chadron confining unit, it would take more than 540 years for fresh groundwater to move downward from the shallow Arikaree/Brule aquifer to the Basal Chadron production aquifer.

5) Other chemical transport processes including hydrodynamic dispersion and chemical diffusion are insignificant.

Chemical transport processes including hydrodynamic dispersion and diffusion are insignificant relative to the velocity or advective movement of groundwater. Furthermore, movement of chemicals due to hydrodynamic dispersion only occurs in the direction of groundwater flow, which in the case of vertical movement at the MEA is downward. Vertical dispersion is typically only 0.01 to 0.1 percent of the total advective flow distance depending on scale (e.g. Gelhar, 1993). In the case of the MEA, we would expect no more than 0.0012 ft/year of downward chemical movement due to hydrodynamic dispersion based on calculations of vertical groundwater velocity previously provided in 4) above. Vertical diffusion of dissolved chemical constituents in low permeability sediments is less than either the advective or dispersive flow component, and can be ignored over practical time scales.

6) Water quality data indicates the shallow Arikaree/Brule aquifer and the Basal Chadron production aquifer are chemically and hydraulically distinct. Water quality data collected at the MEA indicates the shallow Arikaree/Brule aquifer and the Basal Chadron production aquifer are chemically distinct. Significant differences in major ion chemistry observed between the shallow Arikaree/Brule aquifer and the Basal Chadron aquifer are indicative of relative hydraulic separation of the aquifers. Baseline TDS and major ion concentrations in the Basal Chadron production aquifer are typically two to five times greater than the shallow Arikaree/Brule aquifer, indicating groundwater in the production aquifer is more evolved (older) than the shallow aquifer. Water quality of the shallow aquifer and production aquifer would be expected to be very similar in the event there was significant hydraulic communication between the aquifers.

6) Lateral containment of mining solutions at the MEA has been demonstrated.

Lateral (horizontal) containment of mining solutions within the Basal Chadron production aquifer has been demonstrated through aquifer testing, groundwater modeling, and by analogy to observed containment at the existing Crow Butte ISR facility (CBR operates within the same aquifer system and under similar operating conditions as planned for the MEA). Regional aquifer testing at the MEA indicates excellent hydraulic communication between the pumped well and Basal Chadron monitor wells with a radius of influence of greater than 8,800 feet, indicating hydraulic containment of mining solutions (and excursion recovery) can be accomplished without difficulty. Further, groundwater modeling has been conducted at the MEA that demonstrates mining solutions will be contained under worse-case conditions (e.g. loss of power for extended period of time, etc.). In addition, operating experience at the existing Crow Butte ISR facility, which also produces from the Basal Chadron aquifer, indicates hydraulic containment can be achieved at the MEA given similar operating conditions (e.g. bleed rate, well spacing). Lateral containment of mining solutions is also verified by the installation and frequent sampling of mine unit monitor ring wells.

As further evidence to support the lateral containment of mining solutions at the MEA, a groundwater modeling simulation was performed to demonstrate hydraulic containment of mining solutions under typical operating conditions. The operation of Mine Unit 1 at the MEA was simulated for this purpose, given a total flow rate of 1600 gpm and bleed (net production rate) of 1.2 percent per MEA water balance. Details and results of the simulation are provided in **Attachment B**. Results of the simulation demonstrate hydraulic containment of mining solutions can be fully maintained given proposed operating parameters.

REFERENCES

Gelhar, L.W. (1993). *Stochastic Subsurface Hydrology*. Prentice-Hall, Englewood Cliffs, NJ.

S. Norris, J. Bruno, M. Cathelineau, P. Delage, C. Fairhurst, E.C. Gaucher, E.H. Hohn, A. Kalinichev, P. Lalieux, and P. Sellin (editors) (2012). *Clays in Natural and Engineered Barriers for Radioactive Waste Confinement*, 632p.

If you have any questions or comments concerning this report, please contact me directly at 303-522-1118.

Sincerely,
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