

Exhibit 336/436

Offered by

Cheyenne River Sioux Tribe and Oglala Sioux Tribe

for

Contested Case Hearing in the Matter of Clean Nuclear Energy Corp.

Uranium Exploration Permit Application

EXNI 453



Risk of Surface Water and Groundwater Contamination from Mineral Exploration: Relevance to Proposed Uranium Exploration by CNEC

Prof. Steven H. Emerman
May 19, 2026

Twin waterfalls (“Las Gemelas”):
The waterfall on the right (but not the left) drains a watershed impacted by mineral exploration and exhibits acid mine drainage and elevated levels of arsenic, cadmium, copper, iron, manganese, and zinc.



Expert Qualifications



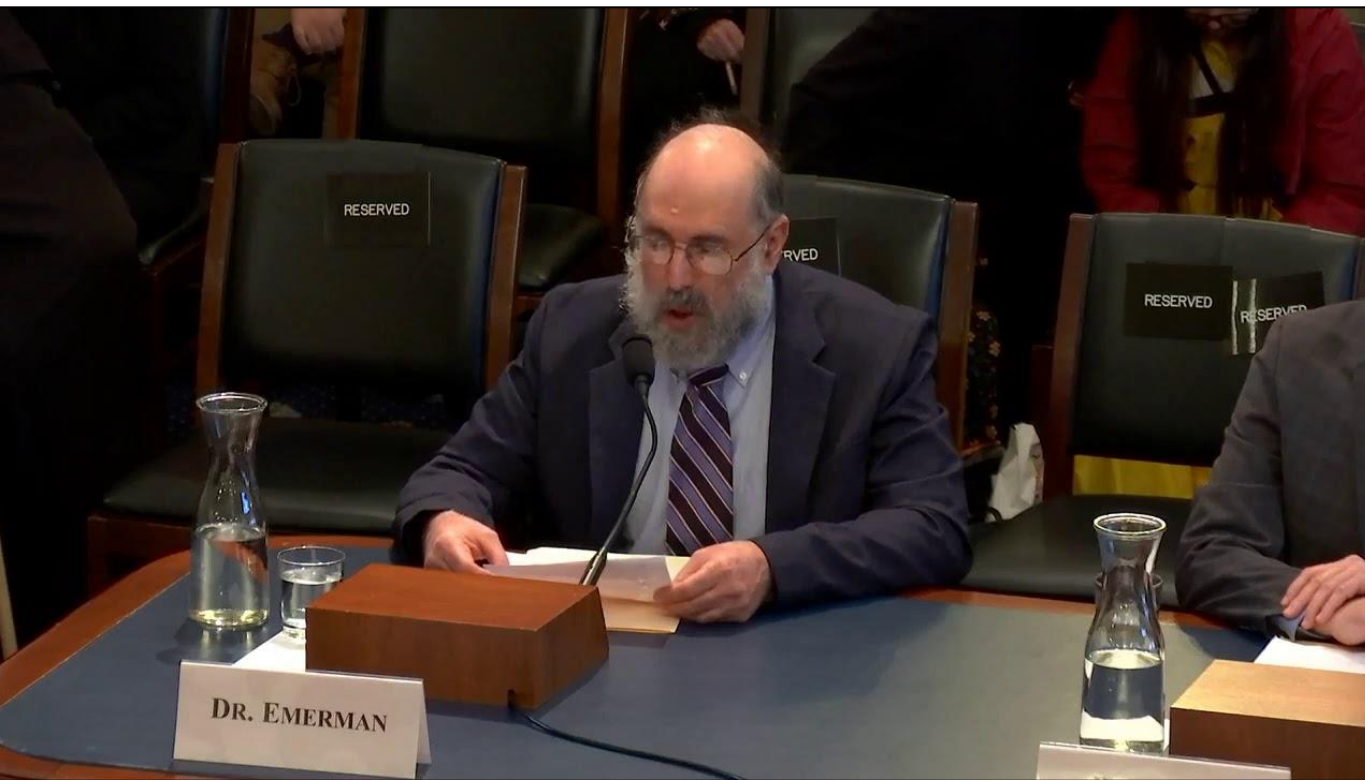
Prof. Emerman's 60th birthday party at Standing Rock Indian Reservation

Prof. Steven H. Emerman

- M.A., Geophysics, Princeton University
- Ph.D., Geophysics, Cornell University
- Professor of Geology for 31 years
- Over 70 peer-reviewed publications in mining, hydrology and geophysics
- Co-Author of Safety First: Guidelines for Responsible Mine Tailings Management
- Owner of Malach Consulting, specializing in environmental impacts of mining



Prof. Emerman has evaluated proposed and existing mining projects in North America, South America, Europe, Africa, Asia, and Oceania. He has testified on issues of mining and water before the US House Subcommittee on Indigenous Peoples of the United States, the European Parliament, the United Nations Permanent Forum on Indigenous Issues, and the United Nations Environment Assembly.



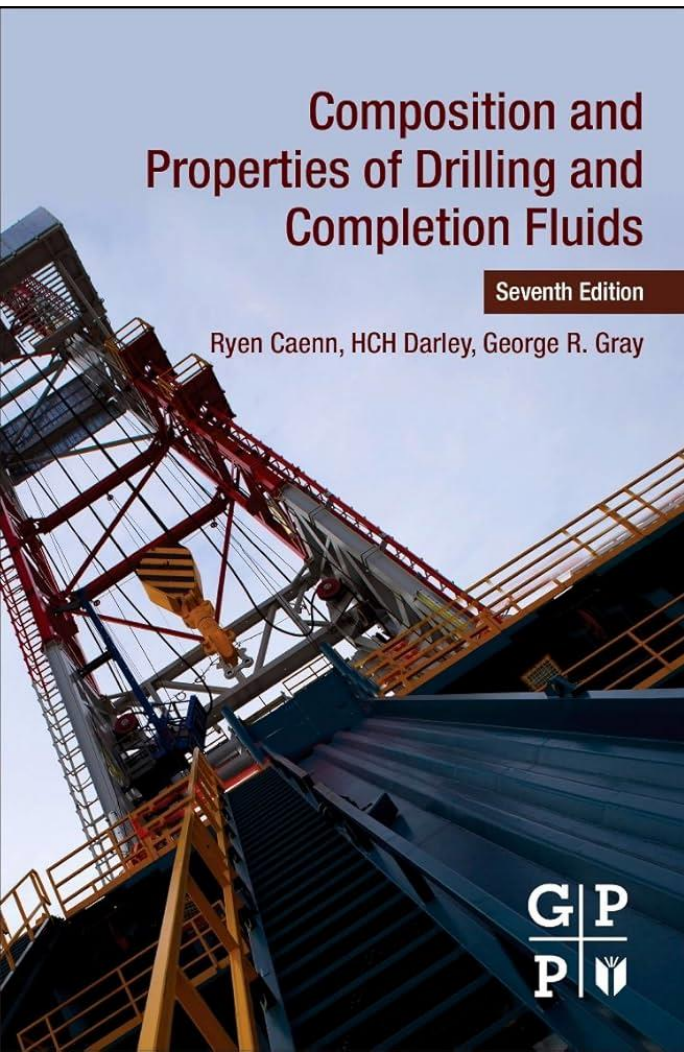
Prof. Emerman is the former Chair of the Body of Knowledge Subcommittee of the U.S. Society on Dams.

Prof. Emerman testifying before the U.S. Congress on March 12, 2020.

Sources of Surface Water and Groundwater Contamination from Mineral Exploration

- Improper plugging of wells in areas with artesian water can allow groundwater with elevated levels of toxins to flow into surface water
- Improper well plugging can create pathways for flow of drilling fluids, fuels, or other contaminants into groundwater
- Drill cores or cuttings left on the surface can result in acid mine drainage or leaching of metals or radionuclides
- Loss of circulation during drilling can introduce drilling fluid and drill cuttings into aquifers
- Drilling through impermeable layers can allow mixing of water between aquifers

Problems with polymer-based and synthetic additives in drilling fluids



- Persistence and incomplete biodegradation
- Formation of degradation byproducts
- Release of toxic monomers from polyacrylamide-based additives
- PFAS (Per- and polyfluoroalkyl substances) and other fluorinated additives
- Aquatic toxicity
- Microplastic-like behavior
- Effects on soil structure and permeability
- Mobilization or binding of contaminants
- Salinity and additive interactions
- Waste disposal problems

Results of Mineral Exploration for Llurimagua Project, Ecuador

Left: Artesian water from exploration well introduces acid mine drainage into surface runoff
Right: Only 5 meters upstream of the well, no acid mine drainage is present



Results of Mineral Exploration for Llurimagua Project, Ecuador

Artesian flow from exploration well results in acid mine drainage and elevated levels of arsenic, cadmium, copper, iron, manganese, and zinc in downstream waterways



Results of Mineral Exploration for Pebble Project, Alaska

Artesian flow into wetlands from broken drill stems on exploration wells



Article

Potential Impacts to Wetlands and Water Bodies Due to Mineral Exploration, Pebble Copper-Gold Prospect, Southwest Alaska

Kendra Zamzow¹ and David M. Chambers^{2,*}

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Received: 1 June 2019; Accepted: 17 July 2019; Published: 19 July 2019



Abstract: There is little information in the literature about the impacts of mineral exploration drilling on natural waters. A copper-gold-molybdenum mining deposit in Alaska was heavily explored until 2012 and partially reclaimed; however, full reclamation of drill sites remained incomplete in 2016. Copper is sub-lethally toxic to salmon, a highly-valued resource in this area. Of 109 sites inspected, 9 sites had confirmed impacts due to un-reclaimed drill-holes or drill waste disposal practices. At seven sites artesian waters at the drill stem resulted in surface water or sediment elevated in aluminum, iron, copper, or zinc with neutral pH. Copper concentrations at artesian sites were <0.4, 0.7, 2.7, 15, 76, and 215 µg/L; the latter four exceed water quality criteria. Drilling waste is known to have been disposed of in ponds and unlined sumps. At one of five ponds sampled, copper declined from 51 to 8 µg/L over nine years. At the one sump area with historical data, copper increased from 0.3 to 1.8 µg/L at a downgradient wetland spring over five years. This research identifies contaminant types and sources and can be used to guide future ecotoxicity studies and improve regulatory oversight.

Keywords: artesian flow; mining exploration; mine water; reclamation; water quality

1. Introduction

Most mining projects do not make it past the exploration stage. This study is a snapshot of the reclamation progress of a major mining exploration site, the Pebble deposit in southwest Alaska. In Alaska mining companies are required to reclaim sites when exploration is suspended, but it can be time-consuming and expensive for regulators to evaluate the progress and success of projects on a regular basis at remote sites. The Pebble site is remote with no roads to or within it.

The site was intensively explored between 2004 and 2012. As mining exploration ceased in 2012 but reclamation activities continued, there was an opportunity to determine the success of reclamation by inspecting the site in 2016. Although the Alaska Department of Natural Resources (DNR) performs annual inspections, they do not include environmental sampling [1,2]. Our goal was to document whether sites appeared fully reclaimed through visual inspection, with a secondary goal to take a limited number of soil and water samples in locations where reclamation did not appear complete to understand potential changes to the environment. This article focuses on observations of water quality at reclamation sites and follows a companion article on soils [3].

1.1. Exploration of the Ore Deposit

The Pebble copper-gold-molybdenum ore (Cu-Au-Mo) deposit in southwest Alaska is porphyry-type ore body with sulfide mineralization and few acid-neutralizing carbonate minerals.



a



b



c

Results of Mineral Exploration for Pebble Project, Alaska

Leakage from drill waste sumps into wetlands resulting in elevated Al, Mn, Fe, Cu, Zn, and Mo in nearby spring



Article

Potential Impacts to Wetlands and Water Bodies Due to Mineral Exploration, Pebble Copper-Gold Prospect, Southwest Alaska

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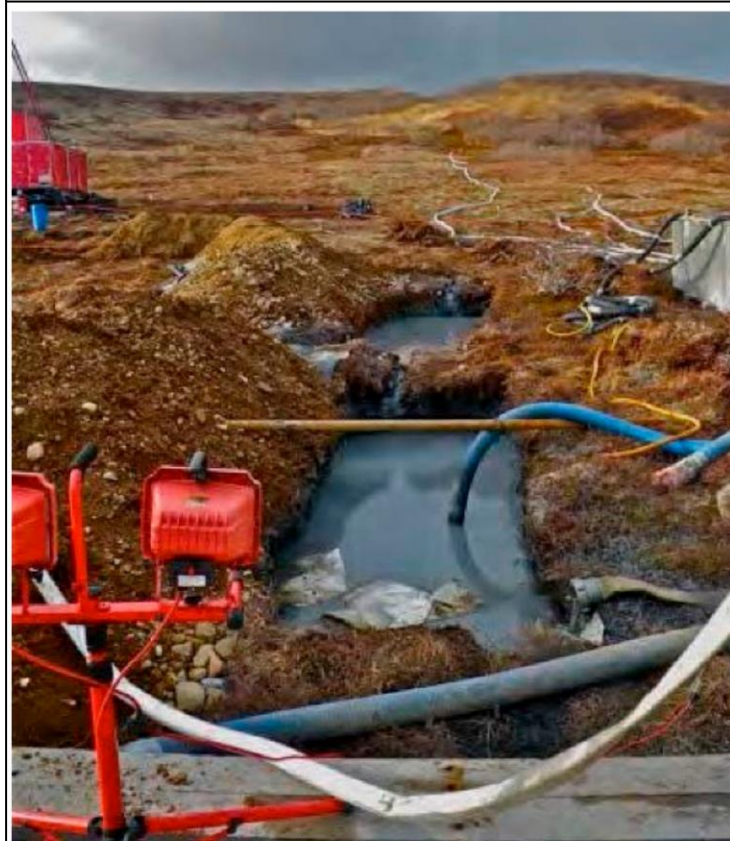
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a



b

Results of Mineral Exploration for Pebble Project, Alaska

Oxidized drill cuttings with elevated copper and molybdenum: Potential for acid mine drainage and metal leaching



Article

Documentation of Acidic Mining Exploration Drill Cuttings at the Pebble Copper–Gold Mineral Prospect, Southwest Alaska

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Received: 1 June 2019; Accepted: 2 July 2019; Published: 4 July 2019



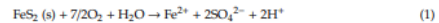
Abstract: During exploration drilling of the Pebble copper–gold–molybdenum (Cu–Au–Mo) deposit, drilling wastes were disposed of directly on the landscape or passed through unlined sumps prior to disposal. The ore and host rock are rich in sulfides, which weather to sulfuric acid with consequent metal leaching. Oxidized cuttings were visually evident, and confirmed with laboratory and field testing to have a pH of 2.7–4.3. At these sites, Cu and Mo exceeded or were at the high end of the natural background. With one exception, Cu was in the range of 545 mg/kg to 4865 mg/kg. Dead vegetation was observed at all sites with drill cuttings on the surface. Dead vegetation was also observed on sump soil covers, unrelated to drilling waste. Sites where vegetation had not re-established were from four to thirteen years old. The potential impact to surface and groundwater was not determined. Understanding the source and extent of damage from cuttings could lead to better site management.

Keywords: acid drainage; drill cuttings; mine exploration; reclamation; sulfide deposit

1. Introduction

1.1. Acid Mine Drainage

Mineral exploration frequently targets sulfide ore bodies. When this occurs, drill cuttings rich in sulfides are generated. Mineralized surface rock with sulfides naturally oxidize, forming sulfuric acid and releasing metals in the rock matrix; iron-rich red staining from this process is frequently seen (Equation (1)).



Disposal of sulfide-rich drill cuttings is expected to similarly allow them to oxidize and lead to the development of acid on cuttings surface with consequent metals release. However, documentation of this effect is absent in the literature. In the summer of 2016, we conducted an investigation of a mineralized area, the Pebble deposit in Southwest Alaska, that had seen intensive exploration drilling but no mining, and sampled drill cuttings that remained on the surface.

1.2. Site Location

The site is located 320 km by air from Anchorage, and 16 km from Nondalton village (Figure 1). Field crew were transported by helicopter daily from the nearby village of Nondalton from 1–5 August 2016. Sampling was conducted from 1–5 August 2016.

The deposit landscape consists of low rolling hills with lakes, small ponds, wetlands, and over 4000 documented springs [1]. The main deposit is on a high plateau at about 305 m asl (meters above



(a)



(b)



(a)



(b)



(c)



(d)



(a)



(b)

Risk Factors related to Uranium Exploration by CNEC

Risk is the product of the consequences of failure and the probability of failure

1. Aquifer contamination could result in the loss of valuable sources of drinking water for people and livestock.

U.S. Geological Survey:

“The major aquifers in the Black Hills area are the Deadwood, Madison, Minnelusa, Minnekahta, and Inyan Kara aquifers.”

U.S. Department of the Interior
U.S. Geological Survey

Hydrology of the Black Hills Area, South Dakota

By Daniel G. Driscoll, Janet M. Carter, Joyce E. Williamson, and Larry D. Putnam

Water-Resources Investigations Report 02-4094

Prepared in cooperation with the
South Dakota Department of Environment and Natural Resources
and the West Dakota Water Development District

2. The underlying Minnelusa Formation is a potential source of artesian water that could ascend to the surface through improperly plugged wells.

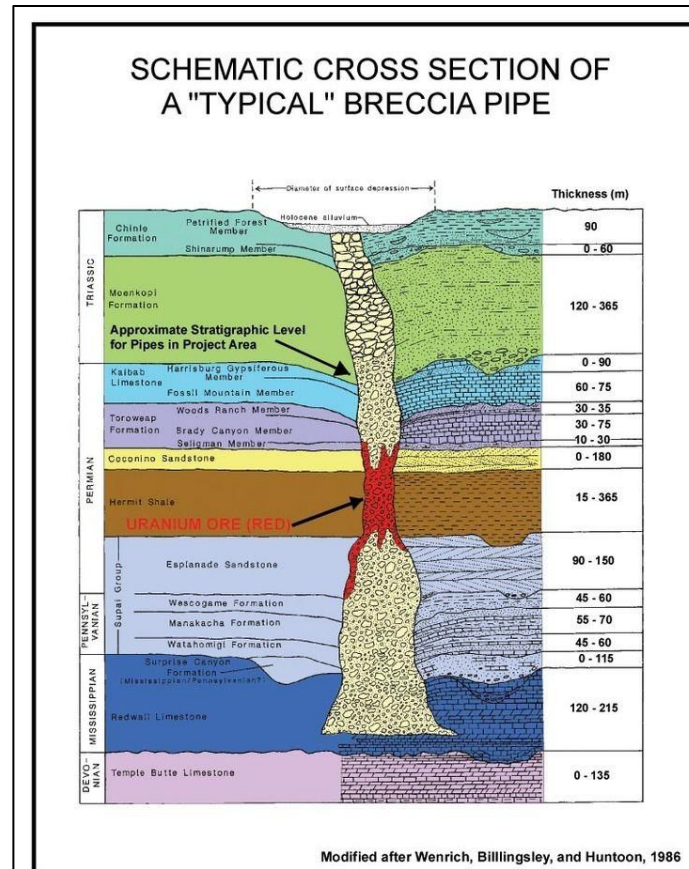
U.S. Geological Survey:

- The Minnelusa Formation is Pennsylvanian to early Permian in age and underlies the Inyan Kara Group.
- The Minnelusa Formation is the dominant source of recharge to the aquifers of the Inyan Kara Group.
- Breccia pipes (vertical chimneys of broken rock) extend upward from the Minnelusa Formation into the Inyan Kara Group and to the surface.

Stratigraphy of the Inyan Kara Group and Localization of Uranium Deposits, Southern Black Hills, South Dakota and Wyoming

GEOLOGICAL SURVEY PROFESSIONAL PAPER 763

Prepared on behalf of the
U.S. Atomic Energy Commission



3. The drill cuttings left on the surface will be potential sources of contamination.

- Uranium concentrations of drill cuttings are anticipated to be in the range of 1000 ppm (compare with EPA Residential Soil Level of 16 ppm).
- Drill cuttings are also likely to contain selenium, vanadium, and molybdenum (elements that follow similar chemical pathways as uranium).
- Drill cuttings from the Fall River Formation will include pyrite, which could be a source of acid mine drainage.

U.S. Geological Survey:

“The lower unit of the Fall River Formation is present throughout the southern Black Hills ... The unweathered rock contains pyrite nodules a few inches in longest dimension ... Fluvial unit 5 sandstone cuts through the highly carbonaceous and pyritiferous basal Fall River siltstone and sandstone ...”

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4. Drilling through highly fractured rocks increase the likelihood of the loss of circulation and introduction of drilling fluids and drill cuttings into aquifers.

Downloaded from <http://sp.lyellcollection.org/> at Pennsylvania State University on February 19, 2016

Regional tectonics and fracture patterns in the Fall River Formation (Lower Cretaceous) around the Black Hills foreland uplift, western South Dakota and northeastern Wyoming

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Abstract: The Fall River Formation around the Black Hills uplift is pervasively fractured by layer-perpendicular joints. Systematic joints in the formation maintain consistent orientations over large areas and are commonly abutted by later-formed fractures, resulting in an orthogonal pattern. There are two major systematic sets, trending northeast and northwest, and one minor set trending north-south. The first two sets define two major fracture domains in the study area. The northwest joint set occupies a southern domain where it is the sole systematic fracture set. The northeast joint set is pervasively established throughout the northern domain, where northwest and north-south fracture sets are also developed in well-defined sectors. There is no genetic or spatial relationship between joint sets and local Laramide monoclines or folds of the region. Instead, the stratigraphic record indicates that joint development originated early in the lithification history of Fall River sandstones. Jointing occurred in response to local and regional extensional stresses that pervaded the northern and southern domains as a result of recurrent movement on basement faults that parallel the regional lineament system and surface structural zones throughout the region. Major uplift of the Black Hills and local fold development during Laramide time merely resulted in passive rotation of the early formed systematic and non-systematic joints.

Statement of problem

Preliminary field work and aerial photograph reconnaissance revealed a pervasive network of joints throughout the Fall River Formation (Lower Cretaceous) outcrop belt around the Black Hills in northeastern Wyoming and western South Dakota. The major objectives of this study were to establish the joint patterns present in sandstones of this formation (Fig. 1) and to determine whether these joints are controlled by this Laramide uplift, its smaller associated folds or deep-seated basement fracture zones that are expressed by a regional lineament system. Systematic jointing in the Fall River Formation of the Black Hills was first documented by N. H. Darton (1904). He described the 'trade columnar appearance' of its massive sandstone cliffs near Newcastle, Wyoming (Fig. 1). Later, Gott *et al.* (1974) attributed changes in horizontal compressive stress directions for different joint trends in the southwestern part of the present investigated area. Other authors, including Bergendahl *et al.* (1961) and Brobst & Epstein (1963), have commented on the prominent fractures present in the Fall River but have no definite conclusions regarding their overall mode of origin and spatial

relationship to regional or local structure. Overall, the patterns and structural significance of Fall River Formation joints have not been extensively studied by previous workers. The Fall River Formation was chosen for this study because of its areal extent and the comprehensive stratigraphic study by Gott *et al.* (1974). More recent work by Willis *et al.* (1995) has further defined the architecture of this formation in the southwestern Black Hills.

Methods of investigation

The upper Fall River Formation was chosen for this study because it consists primarily of a 10–40-foot (3–12.2-m) thick massive sandstone unit, and caps many hogbacks and divides throughout the Black Hills region. Where this unit was absent or concealed, the middle Fall River Formation was used. One hundred and forty stations were established and 7214 joint attitudes were measured.

At each station joint strike was measured, or taken from aerial photographs in inaccessible areas (Fig. 2). All joints examined had an overall perpendicular relationship to bedding. In nearly all circumstances it was possible to distinguish

From: COSGROVE, J. W. & AMEIN, M. S. (eds), *Forced Folds and Fractures*. Geological Society, London, Special Publications, 169, 145–165. 1-86239-060-6/00/\$15.00 © The Geological Society of London 2000.

Wicks et al.:

“The Fall River Formation around the Black Hills uplift is pervasively fractured by layer-perpendicular joints.

Systematic joints in the formation maintain consistent orientations over large areas ...”

U.S. Geological Survey:

“Breccia pipes are likely to develop at the intersection of fractures, particularly in zones of intense fracturing and (or) faulting, such as the Dewey and Long Mountain structural zones.”

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5. Drilling through the Fuson Member (confining layer) could cause mixing of water between the Fall River and Lakota aquifers.

Materials that could pass between Fall River and Lakota aquifers:

- Groundwater
- Drilling fluids
- Drill cuttings
- Uranium
- Selenium
- Vanadium
- Molybdenum

Mixing of waters from different aquifers can result in unanticipated chemical reactions.

Summary of Risk Factors related to Uranium Exploration by CNEC

1. Aquifer contamination could result in the loss of valuable sources of drinking water for people and livestock.
2. The underlying Minnelusa Formation is a potential source of artesian water that could ascend to the surface through improperly plugged wells.
3. The drill cuttings left on the surface will be potential sources of contamination.
4. Drilling through highly fractured rocks increases the likelihood of the loss of circulation and introduction of drilling fluids and drill cuttings into aquifers.
5. Drilling through the Fuson Member (confining layer) could cause mixing of water between the Fall River and Lakota aquifers.

Conclusion

The risks of surface water and groundwater contamination resulting from uranium exploration by CNEC outweigh the benefits.

