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Contributions from the Coconino Plateau Technical Advisor Committee, Compiled by Donald Bills (U.S. Geological Survey, Emeritus), August 2021

Kanab North Mine, May 2009, still producing.
Photo by D.J. Bills, 2009.

Kanab North Mine reclaimed, September 2019.
Google Earth image, 2019.

Geology and uranium in the Grand Canyon region: In 1990, the U.S. Geological Survey estimated that a mean undiscovered uranium endowment of 1.3 million tons (2.6 billion pounds) U3O8 is present in breccia pipe deposits in northern Arizona. This estimate is almost 3 times the U.S. uranium reserves estimate of 445 thousand tons (890 million pounds) U3O8 for developed deposits elsewhere in the United States.

Uranium mobilizes in aerobic (with oxygen) environments and is precipitated in anoxic (without oxygen) environments. Uranium is also mobilized and dispersed by wind as dust and airborne particles. This results in a wide range of geologic environments where uranium can accumulate or be mobilized and dispersed. One of these environments unique to the Grand Canyon region are breccia pipes, non-volcanic collapse features that originate in caves forming in the Redwall and Muav Limestones. Over time the roofs of the caves collapse and continue to stoop upward to the surface. Not all breccia pipes reach the surface, but where they do, they are commonly associated with circular collapse features of a few hundred feet up to a half a mile. Since the Grand Canyon region is layered with limestone sedimentary rocks karst topography is also quite common. As a result, many collapse features are sinkholes and solution collapse not associated with breccia pipes. Not all breccia pipes are mineralized with uranium. Those that are formed under anoxic (without oxygen) conditions as groundwater rich in dissolved uranium and other dissolved minerals from areas that contained dispersed or concentrated uranium ores and migrated up, down, or through the breccia pipes.

Uranium has been naturally eroding from breccia pipes in the Grand Canyon region for 200 to 300 million years. Mining in the Grand Canyon region for copper and silver since the late 1800's and for uranium since about the 1950's has exposed more of the breccia pipe ore deposits to air and oxygenated water that can increase the local dispersal of uranium to the environment.

The natural background radiation at the surface in the Grand Canyon region is about 5 to 10 microrems, about the same as one cross country, round trip airline trip (5 microrems) or one chest x-ray (10 micro rems). The historical average concentration of dissolved uranium in the Colorado River (since the 1970's) is from 3 to 5 micrograms per liters (ppb), compared to the EPA limit for safe drinking water of 30 micrograms per liter.

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The U.S. Department of Energy (DOE) established the Office of Legacy Management (LM) to ensure the future protection of human health and the environment at more than 100 sites across the country. LM responsibilities include stakeholder relations; this involves public outreach to and input from those individuals, groups, host communities, and other entities in the

public and private sectors that are interested in or affected by any of DOE's activities and decisions. The purpose of this Communication and Outreach Plan is to describe how LM will (1) support stakeholder participation and community relations with the Navajo Nation, (2) support public awareness and understanding about the long-term management of the four Navajo Nation Uranium Mill Tailings Radiation Control Act (UMTRCA) site, and (3) foster communication with stakeholders.

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U.S. Department of Energy, 1986, Environmental Assessment Remedial Action at the Tuba City Uranium Mill Tailings Site Tuba City, Arizona: Albuquerque, NM,U.S. Department of Energy, November 1986.

The proposed remedial action for the Tuba City tailings is stabilization in place. All of the tailings and other contaminated materials would be consolidated with the existing tailings pile, and the resulting pile would be recontoured to have 20 percent side slopes (five horizontals to one vertical) and a gently sloping top. The pile would then be covered with 1.5 feet of compacted earth to inhibit radon emanation and water infiltration and to ensure compliance with a one-foot-thick layer of gravel sized rock to protect the pile against erosion, penetration by animals, and inadvertent human intrusion. The south side slope and the drainage ditches surrounding the pile would be covered with a two-foot-thick layer of large rock. The top of the stabilization pile would average approximately 33 feet above the surrounding terrain. A drainage ditch would divert surface runoff around and away from the pile. Areas disturbed by remedial action would be recontoured, revegetated as required, and released for unrestricted use.

U.S. Department of Energy, 1985, Environmental Assessment of Remedial Action at the Tuba City Uranium Mill Tailings Site Tuba City, Arizona: Albuquerque, NM, U.S. Department of Energy, December 1985.

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to one vertical) and a gently sloping top. The pile would then be covered with 1.5 feet of compacted earth to inhibit radon emanation and water infiltration and to ensure compliance with a one-foot-thick layer of gravel sized rock to protect the pile against erosion, penetration by animals, and inadvertent human intrusion. The south side slope and the drainage ditches surrounding the pile would be covered with a two-foot-thick layer of large rock. The top of the stabilization pile would average approximately 33 feet above the surrounding terrain. A drainage ditch would divert surface runoff around and away from the pile. Areas disturbed by remedial action would be recontoured, revegetated as required, and released for unrestricted use.

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The purpose of the Abandoned Uranium Mines Project was to identify the radiation sources, characterize the exposure, and recommend methods to reduce radiation exposure from abandoned uranium mines on the Navajo Nation. Providing education and outreach about radiation and working with individuals' communities living in proximity to the abandoned mines, was also an important component of the project. For the Abandoned Uranium Mines Project to be sued, it was necessary to involve the affected communities and to engage them as active community partners. An important objective of the project was to develop an outreach strategy that would result in a two-way sharing information. This involved educational efforts to increase understanding and awareness of the mines and their possible effects, as well as engaging the participation of Chapter Officials to assist in identifying water sources used for human consumption and homes that should be surveyed.

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This Phase I Ground Water Compliance Action Plan for the Tuba City, Arizona , Uranium Mill Tailing Remedial Action (UMTRA) Project site describes the first phase, Phase I, of ground- water remediation activities that will take place at the Tuba City site. Phase I is expected to last approximately 3 years. The second phase, Phase II, will include expansion of remediation capacity and monitoring to assure that the project aquifer restoration standards are met. A Phase II GCAP will prepared to document the additional remediation activities completed.

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remedy construction. Conduct appropriate cleanup actions at mine sites that pose an unacceptable risk to residents or the environment. Objective 5: Cleanup of the Tuba City Dump—Complete Remedial Investigation and Feasibility Study and select and begin implementing a remedy. Objective 6: Protection of Human Health and the Environment at Former Uranium Processing Sites—Update the groundwater compliance strategy at Shiprock, NM and evaluate different treatment options for the Tuba City, AZ site. Objective 7: Health Studies—Complete work on the Navajo Birth Cohort study in cooperation with the University of New Mexico, the Navajo Nation Community Health Representative Program, and Navajo Area IHS. Work with the Navajo Nation's Epidemiology Center and support their efforts to evaluate various cancer case rates by geographic location of cancer patient's Federal Actions to Address Impacts of Uranium Contamination in the Navajo Nation 2014 residence and known radiation exposure sources, and the health status of descendants of uranium miners/mill workers.

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The quality of ground water in the alluvial aquifer of the Puerco River basin, northeastern Arizona, was evaluated in order to assess potential contamination from uranium mining and milling operations in New Mexico. A total of 14 wells and 1 spring were sampled to determine if a contaminant plume of radionuclides or trance elements is present. The water is characterized by high dissolved solids with a median of 698 milligrams per liter and high concentrations of alkalinity, sodium, and sulfate. Except for iron, manganese, and strontium, the concentrations of trace elements generally are below the applicable U.S. Environmental Protection Agency and State of Arizona maximum contaminant levels. Gross alpha activity has a median of 27 pococuries per liter and ranges from 4 to 41 pococuries per liter. Uranium, which amounts for most of the gross alpha activity, has a median concentration of 19 micrograms per liter and ranges from 1 to 38 micrograms per liter. Twenty to 84 percent of the gross alpha activity was derived from other undetermined radionuclides. Other radionuclides, including radium-226 and radium-228, generally are not present in activities greater than 5 picocuries per liter in the water.

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The U.S. Geological Survey began a 5-year study of the occurrence and movement of radionuclides and other trace metals in ground water and surface water in the Puerco River in northeastern Arizona and northwestern New Mexico. Radionuclides and other trace metals our naturally in water, rock, and sediments in the region; however, mining operations have enhanced their release to the Puerco River through discharges of mine effluents. Additionally, in 1979, the failure of a tailing-pond dike resulted in the largest known single release of water contaminated by uranium tailings in the United States. This report presents selected historical water-quality data and a bibliography of selected references on the geology, hydrology, and water quality of the Puerco River basin. Historical water-quality data for surface water, ground water, and uranium-mine discharges for water years 1942 through 1988 were compiled from information from Federal, State, and local agencies.

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