# Ground water remediation at the Moab, Utah, USA, former uranium-ore processing site

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**Abstract.** Seepage from the Moab, Utah, USA, former uranium-ore processing site resulted in ammonia and uranium contamination of naturally occurring saline ground water in alluvium adjacent to the Colorado River. An interim ground water remediation system, operating since 2003, is currently being evaluated for design of a long-term remedy. Final design is to minimize ammonia discharge to critical habitat areas.

## Introduction

The Moab, Utah, USA, former uranium-ore processing (mill) site encompasses 178 hectares (439 acres), of which 52 hectares (130 acres) is covered by a 30-meter-high (90-feet-high), unlined mill tailings pile. Fig. 1 shows the site location, which is situated on the west bank of the Colorado River and is adjacent to Arches National Park. The processing mill operated from 1956 to 1984 under private ownership. The milling operations created process-related wastes and tailings, a sandlike material containing radioactive and other contaminants. Over time, seepage from the tailings pile resulted in ammonia and uranium contamination in the alluvial ground water beneath the site.

## Regulatory framework

Following bankruptcy of the mill owner in 1998, the U.S. Nuclear Regulatory Commission (NRC), which regulates the site, appointed a trustee. Through congressional legislation, title to the site and responsibility for cleanup were transferred to the U.S. Department of Energy (DOE) in 2001. Cleanup, including ground water, was required to be performed in accordance with Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978. The act was instituted to clean up former uranium-ore processing sites across the U.S.; these cleanups were largely completed in the 1980s and 1990s.

Contaminated soils and ground water at the Moab site must be cleaned up to U.S. Environmental Protection Agency (EPA) standards established in Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192).

DOE prepared an Environmental Impact Statement (EIS) to fulfill the National Environmental Policy Act requirement to assess the potential environmental effects of remediating the Moab site. DOE analyzed the potential impacts on surface

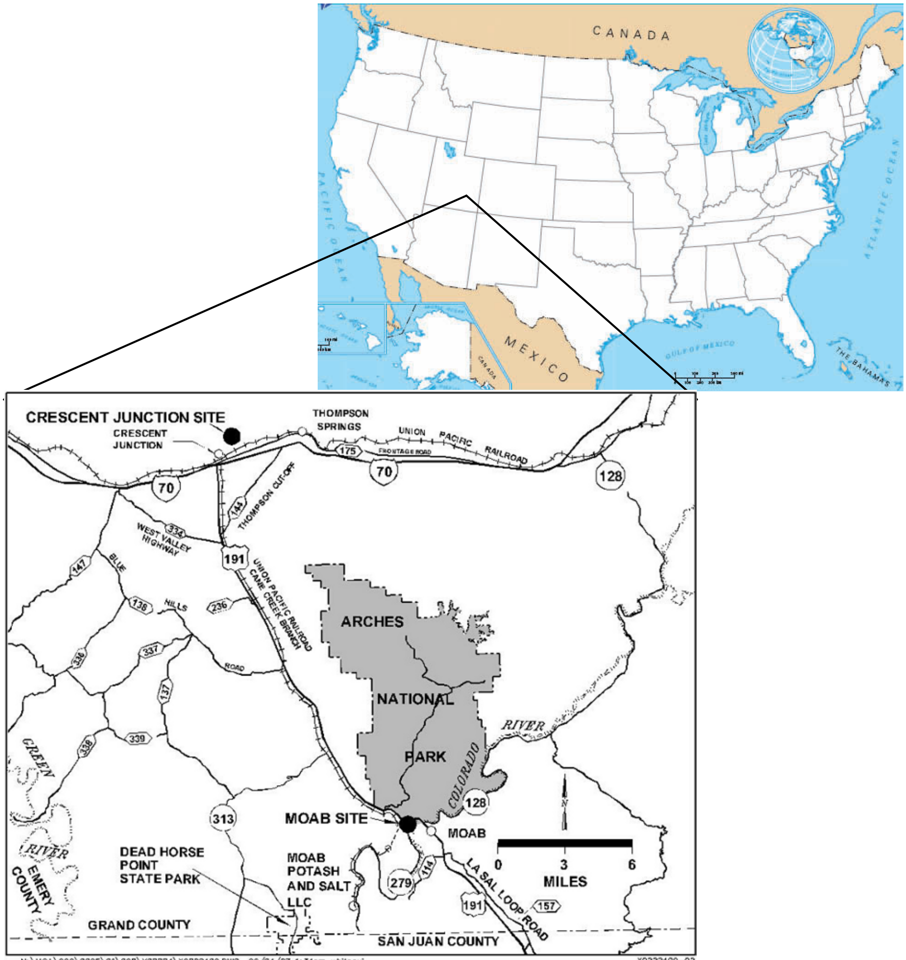


**Fig. 1**. Location of Moab site.

water and ground water of on-site and off-site remediation alternatives. Uncertainty of river migration and the long-term effects of contaminated ground water entering the Colorado River were expressed as concerns about leaving the contaminated materials on site. Although migration of the river into the tailings pile if left in place were unfounded (DOE 2003a), DOE decided in a 2005 Record of Decision (ROD) to relocate the tailings to a site at Crescent Junction, Utah 48 kilometers (30 miles) north of the Moab site and far away from the Colorado River. The ROD also included actively remediating contaminated ground water at the Moab site.

Final ground water cleanup will be described in a Ground Water Compliance Action Plan (GCAP) that will be submitted to the NRC in 2010 for concurrence. The long-term ground water remedial action must be in place by 2012.

## Ground water conditions

The former processing site is underlain by a high hydraulic conductivity alluvium that is connected to the Colorado River (Fig. 2). The alluvium has an anisotropic ratio of 10 to 100. A brine surface occurs beneath saline water. Ground water at the site occurs in alluvial sediments that extend 120 meters (400 feet) below the ground surface. Total dissolved solids (TDS) in ground water vary naturally from slightly saline (1,000 to 3,000 milligrams/liter [mg/L]) to briny (> 35,000 mg/L), usually increasing with depth. The primary source of the slightly saline water, which is found only in the shallowest parts of the saturated zone, appears to be ground water discharge from post-Paradox Salt Formation bedrock that subcrop near the northwest border of the site and north of the tailings pile as shown in Fig. 2. Brine waters dominate the deepest parts of the alluvium and are attributed to chemical dissolution of the underlying Paradox Salt Formation, a large evaporite unit that has deformed to create a salt-cored anticline aligned with and underlying the area.

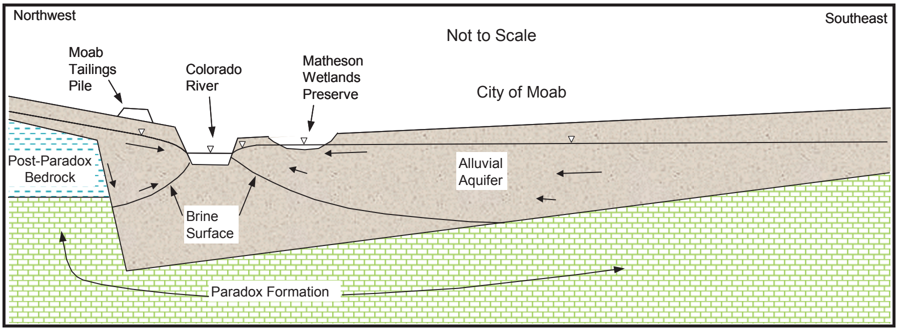


**Fig. 2.** The conceptual model shows density-dependent ground water flow in alluvium to the Colorado River.

## Ground water contamination

During milling operations, the tailings pond contained fluids with TDS concentrations ranging from 50,000 to 150,000 mg/L. In addition, the fluids contained ammonia with concentrations up to 1,500 mg/L and uranium with concentrations up to 10 mg/L (DOE 2007). These fluids had sufficient density to migrate vertically downward through less saline waters and into underlying briny water. This downward migration created a secondary zone of ammonia contamination that may be a long-term source of ammonia in ground water. However, its slow movement, presence within naturally occurring brine, and its likely discharge to the middle of the Colorado River make remediation unnecessary.

Although several other metals are present in alluvial ground water, ammonia and uranium are the primary contaminants of concern.

DOE identified one significant ammonia plume (see Fig. 3) associated with the site. The tailings pile is the source of ammonia seeping into the shallow alluvium, then migrating southwest and discharging into the Colorado River.

EPA has no cleanup standard for ammonia in 40 CFR 192 since it is so prevalent and is an essential part of the nitrogen cycle; however, ammonia is the constituent of greatest ecological concern when it discharges to the Colorado River at levels toxic to aquatic habitat.

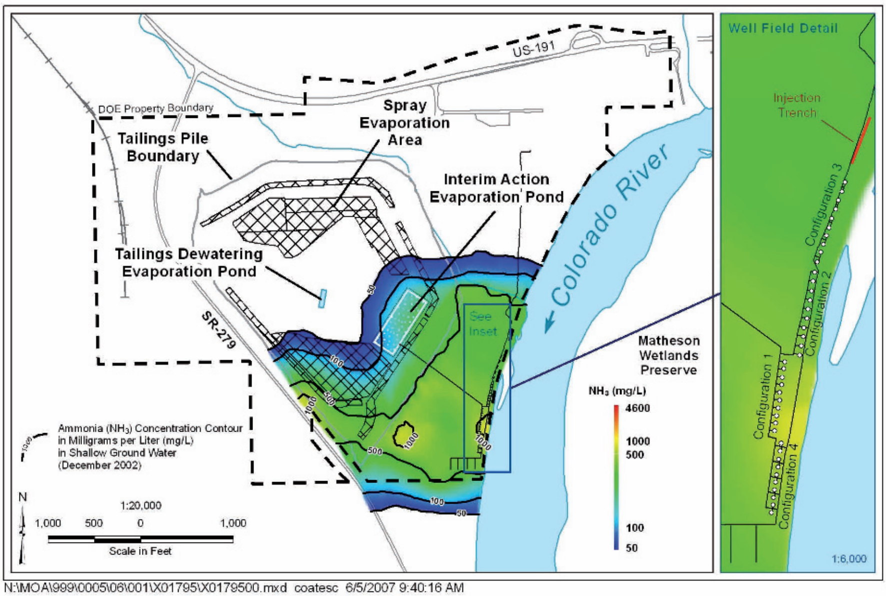


**Fig. 3**. The distribution of ammonia in shallow alluvial ground water is shown along with a backwater channel.

When DOE took over the Moab site and began sampling backwater channels of the Colorado River, ammonia was detected at concentrations that are toxic to certain endangered fish species that inhabit the river, including the Colorado pikeminnow, razorback sucker, bonytail, and humpback chub. Pikeminnow favor slow-moving backwater areas of the river as nursery habitat for young-of-the-year fish.

A plume of uranium in shallow alluvial ground water coincides with the ammonia plume (Fig. 3). A small secondary plume of uranium detected in ground water beneath the ore-processing portion of the site may have been caused by one or more of several sources including former ore storage, process areas, and disposal areas.

As tailings pile and off-pile remediation occur over the next several years, further information regarding the sources of the process area plume will be obtained. Over time, the two uranium plumes have comingled such that elevated concentrations exist within the shallow alluvium beneath a large portion of the site.

Because ground water at the Moab site is not potable, the drinking water standards established by EPA are not applicable. Even though more than 15 million people depend on water from the Colorado River, uranium from the Moab site is not discharged at a sufficient rate to be detectable in the river downstream of the site.

## Ground water interim action

In 2003, DOE implemented the first phase of ground water remediation at the Moab site to address concerns regarding elevated ammonia concentration while it evaluates a long-term solution. The ground water interim action system has since been expanded and currently consists of 41 extraction wells, a freshwater injection trench, and an evaporation pond and sprinkler system to evaporate water on top of the tailings pile (Fig. 3).

Four groups of 10 wells, termed configurations, each of which were constructed with similar design features, were installed, with improvements made with every configuration design. In addition, a separate deeper extraction well is often included in Configuration 1 (not shown). Ground water is extracted through the wells from the shallow alluvium and pumped via pipeline to a 1.6-hectare (4-acre) evaporation pond that was constructed outside the 100-year floodplain on top of the tailings pile.

Several extraction wells, particularly in Configuration 2, were screened at shallow depths to minimize drawing up underlying brine during pumping. As a result, these wells have insufficient available drawdown to pump at high enough rates to achieve hydraulic capture of all proximate ground water contamination. Such effectiveness-reducing deficiencies are being evaluated for the long-term ground water remedy.

A 49-meter-long (160-foot-long) infiltration trench was added to the system north of the Configuration 3 wells in fall 2006. This 3-meter-deep (10-foot-deep) trench is designed to inject filtered Colorado River water into the subsurface, thus creating a hydraulic barrier between the ammonia plume and the backwater areas of the river. The freshwater injection rate using the trench is comparable to the rate attained through a configuration of injection wells.

The impacts of freshwater injection and ground water extraction are based on samples collected from monitoring wells located in and around the well field including in backwater channels of the Colorado River (see Fig. 3). The effectiveness of the well field is evaluated by measuring the contaminant mass removed. Since the inception of well field operations, more than 375 million L (100 million gallons [g]) of ground water has been extracted. Approximately 45,000 kilograms (kg) (90,000 pounds [lbs]) of ammonia and 190 kg (400 lbs) of uranium are removed annually.

A sprinkler system that covers 16 hectares (38 acres) was installed on top of the pile to operate in conjunction with the evaporation pond to maximize the evaporative capacity of the interim action system. Ground water is sprayed at a rate such that it neither runs off nor percolates into the tailings pile cover soils. The site receives 230 millimeters (mm) (9 inches) of precipitation per year and has an annual pan evaporation of 140 mm (55 inches). The sprayed water also provides dust suppression. The extraction rate of the system averages 225 L/minute (60 gpm). Prior to the winter of 2007/2008, extraction was suspended during the colder months because of the reduced evaporation potential. However, to provide maximum protection of a habitat area downgradient of Configuration 1, several of the wells were operated through the majority of this past winter.

The existing interim action will likely be included in the final ground water remedial action. Current site operation and monitoring activities are, in part, designed to provide information for the final action.

## Surface water runoff and its effect on aquatic habitat

The Colorado River overflows its banks about every 10 years. The last severe flooding was in 1983 when the river reached the edge of the tailings pile. The winter of 2007/2008 brought above-normal snowfall in the Rocky Mountains that caused concern for high spring runoff. Although the river twice came up to the bank along the well field at the site, no flooding occurred in 2008. Well field operations were suspended during part of May and June as a precautionary measure since flooding of variable-frequency pump motor controllers would have represented a substantial loss of property.

High river flows are known to alter the channel that creates or eliminates backwater habitat. The Moab Wash is an ephemeral intermittent stream that transects the site. Water flow in the wash caused by intense summer storm events carries a high sediment load. The result is a buildup of sediment downstream of the confluence that can add to the backwater habitat area.

Backwater pools form at the edge of the Colorado River as the river rises during normal runoff years. These backwater areas, which serve as fish habitat, may expose endangered fish species to ammonia from the site. As part of the EIS process, DOE discussed with the U.S. Fish and Wildlife Service the discharge of contaminants to the Colorado River that could have a negative effect on these endangered species. DOE monitors the river water flow each year during spring runoff and is prepared to flush the backwater areas with diverted river water if ammonia concentrations reach an unacceptable level of 3 mg/L.

## Long-term ground water remediation strategy

The long-term ground water remediation strategy has to take into account the potential presence of ground water contamination beneath the tailings pile that may remain following pile removal, off-pile sources of contamination such as former process, storage, and disposal areas, and changing habitat areas along the Colorado River.

DOE intends to continue ground water remediation during removal of the tailings pile. Extraction rates and the position of wells will be optimized to more effectively remove ammonia and uranium.

The spray evaporation system will be affected as soon as excavation and conditioning activities on top of the pile begin. Initially, this impact can be addressed by adjusting the location of spray nozzles. Extraction rates will be adjusted to accommodate reduced capacity of the spray evaporation system. Within 10 years, the evaporation pond may have to be eliminated or moved.

If the long-term ground water remediaton system must operate without the benefit of an evaporation system, then an alternative treatment method will be required. Several treatment methods are being considered, including ammonia stripping, recirculation wells, alternating injection and extraction wells, and air sparging with soil vapor extraction.

## Conclusions

As the ground water interim action system is further evaluated, tailings removal begins, and the Colorado River channel is mapped following the runoff of 2008, a Final GCAP will be developed and submitted for NRC concurrence. Continued coordination with the U.S. Fish and Wildlife Service will take place to ensure protection of sensitive aquatic species.

## Acknowledgment

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