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TRANSURANIC WASTE DISPOSAL IN THE UNITED STATES OF AMERICA

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ABSTRACT

In the 1970s, the U.S. government selected a site near Carlsbad, New Mexico, known as the Waste Isolation Pilot Plant (WIPP), for investigation as a waste repository solely for transuranic (TRU) waste resulting from national defense processes. The site was selected for possible waste disposal into the Permian-age Salado Formation of evaporites, which is about 600 meters thick at this location. The region is also tectonically stable, so the Salado Formation is well-suited for geologic isolation of TRU waste. The 1992 Land Withdrawal Act (Public Law 102-579) transferred a block of land to the U.S. Department of Energy (DOE) for the purpose of developing the repository. Repository drifts were mined approximately 650 meters below the surface, near the middle of the Salado Formation. The first TRU waste was emplaced in 1999.

Waste emplacement continued until February 2014, when two unrelated incidents caused facility shut-down. First was a truck fire in the mine, which involved no radioactive material. Unrelated to this, nine days later an emplaced waste container experienced an exothermic reaction that breached the container and spread contamination through portions of the mine and its exhaust ventilation system. The latter event led to re-configuring mine ventilation, so all exhaust receives HEPA filtration. Ventilation capacity was significantly reduced, which has complicated mine operations and reduced the rate of waste emplacement. Capital improvements are now underway to greatly expand the HEPA filtration capacity and overall mine airflow. DOE is now looking to expand the mine's disposal capacity and extend the lifespan to meet the United States' TRU waste disposal needs for decades to come. Despite the 2014 incidents, all indications are that evaporite deposits function well for geologic disposal of radioactive waste.

INTRODUCTION

The USA regulatory framework separates nuclear waste into three categories: high-level waste (HLW), low-level waste (LLW), and TRU waste. Spent nuclear fuel is considered HLW. TRU waste is defined as materials contaminated with alpha emitters of atomic number greater than 92, with half-lives longer than 20 years, in concentrations greater than 100 nanocuries per gram. TRU waste is generated from US government facilities, largely defense-related activities such as weapons production and subsequent environmental remediation efforts. The waste is mostly workers' protective clothing, tools, debris, soil, and other items contaminated with small amounts of transuranic radioactive materials. In the 1950s, the USA National Academy of Sciences recommended deep geologic disposal as the best option for permanently disposing of TRU waste. In the 1960s, the US government began searching for an appropriate location for permanent disposal. The thick, Permian-age evaporite deposits of southeast New Mexico were identified as a promising disposal medium. Specifically, the Salado Formation, deposited approximately 250 million years ago, is about 600 meters thick in this region (see Figure 1). Thick evaporite layers like the Salado have extremely low permeability and fluid transmissivity, and this region has also demonstrated tectonic quiescence since the Salado was first deposited. The strata remain essentially flat-lying, and major seismic activity is rare in the region. In 1979, the US Congress established the WIPP at a site southeast of Carlsbad, New Mexico, for the purpose of exploring TRU waste disposal at depth (see Figure 2). Detailed site investigations began, and in 1981, the first exploratory shaft was drilled into the Salado Formation. Site exploration and development continued through the 1980s. In 1992, the US Congress authorized future TRU disposal at WIPP (subject to regulatory approvals) by passing the Land Withdrawal Act (LWA).

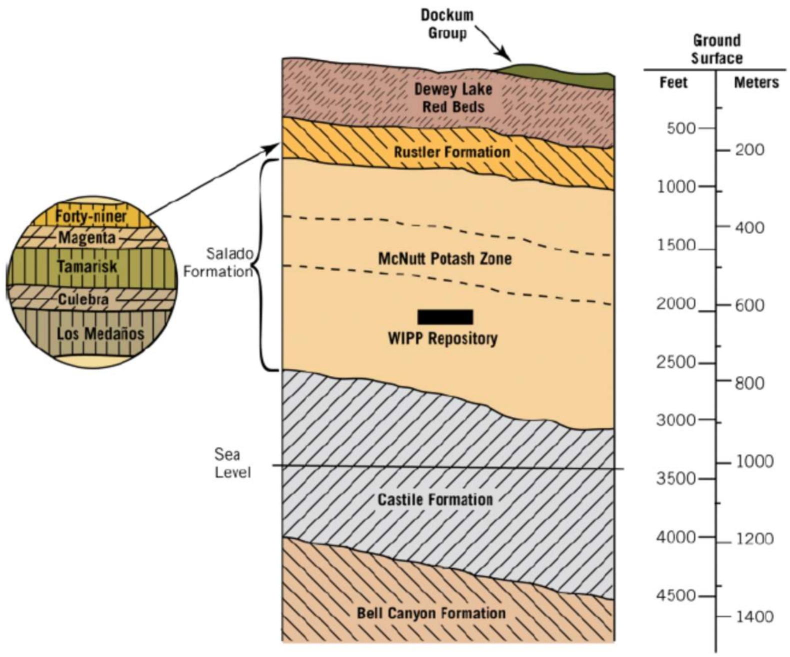

Figure 1: Geologic cross section of the WIPP vicinity, from EPA (2006).

Figure 2: Aerial view (looking east) of the WIPP site in southeast New Mexico.

The LWA transferred to DOE 16 square miles of land surface, and the volume beneath it, exclusively for the purpose of developing a TRU waste repository. The WIPP site lies within the productive petroleum region of the Permian Basin, and several oil-rich strata lie beneath the Salado Formation. With extensive oil and gas extraction ongoing today, further oil and gas exploration immediately surrounding the future waste repository had to be eliminated to protect its long-term integrity. The LWA also set limits on the type and quantity of waste that can be accepted at WIPP. Only TRU waste derived from the US government's defense nuclear facilities is allowed. HLW and LLW are specifically prohibited at WIPP. The LWA specified regulatory oversight roles for the US Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED), each of which had to grant approvals before WIPP could begin accepting waste for disposal. EPA certifies that the repository can meet its performance goals for the specified 10,000-year period, and NMED grants permits for hazardous waste disposal and other activities associated with repository operation. Final regulatory approvals were granted in 1998, and the first waste was emplaced in WIPP in March 1999. The facility is currently authorized to operate until 2035.

The network of drifts that compose the underground repository are constructed near the middle of the Salado Formation, about 650 meters below the ground surface. Four shafts extend from the surface to the repository depth (see Figure 3). One is exclusively for exhaust air with no means of conveying materials between the surface and the repository, one is for intake air with limited means of conveying materials, one is for removing mined salt that can also transport personnel and materials, and one is the primary shaft of entry for personnel and materials. The waste disposal areas are arranged into eight panels, each with seven rooms (approximately 100 m long, 10 m wide, and 4 m high) for placing waste containers. A network of drifts connects the disposal panels to the shafts and other portions of the mine used for administrative, maintenance, and research activities. Some waste with very high dose rates on the package exterior, known as remote-handled TRU waste, is placed inside cavities drilled into the walls of the rooms. This provides additional shielding and allows personnel to safely continue working in the rooms until they are permanently sealed. Once a panel is filled with waste, the drifts accessing that panel are backfilled. With no further maintenance of the walls and roof to prevent collapse, eventually the caverns collapse. Due to the plastic nature of the thick evaporite strata, over time the salt will deform to encompass the waste and prevent transport of the radionuclides for millennia.

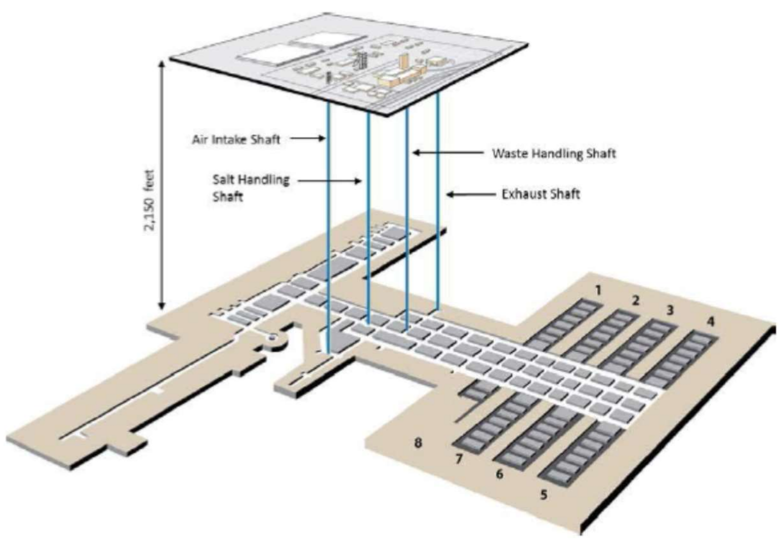

Figure 3: Layout of the repository drifts and shafts relative to the surface facilities.

2014 INCIDENTS

The WIPP received and emplaced TRU waste without major incidents between March 1999 and February 2014. The first six panels were filled, and waste emplacement had recently begun in panel seven when an underground vehicle used for hauling salt through the mine caught fire on 5 February 2014. Eighty-six workers were underground at the time and were safely evacuated, though several were treated for smoke inhalation (DOE, 2014a). The lack of serious injuries is a credit to the workers' emergency response training and actions. The accident investigation determined that the root cause was a lapse in the mine operator's vehicle maintenance program, allowing a build-up of combustible material that led to the fire.

Unrelated to this event, just nine days later, a release of radioactive material from a container recently emplaced in panel seven contaminated portions of the mine and ventilation equipment on the surface, and some contamination escaped to the environment. The event occurred at night and no personnel were in the mine at the time, though several were present on the surface. Many more personnel reported to the site the next morning before air samples were analyzed and the release of radioactive material was recognized. Bioassay results from those on site indicated a total of 21 personnel received small exposures (DOE, 2014b). Several surrounding environmental sampling stations indicated a release of material at levels well below regulatory limits, posing no hazard to offsite personnel or the environment. The release was eventually traced to a waste container that was emplaced on 31 January 2014. Further analysis revealed that the container was not packed in accordance with WIPP acceptance criteria, and an exothermic reaction of organic materials led to the breach and release of radioactive material (DOE, 2015).

After this incident spread contamination in the mine and up the exhaust shaft, exhausting mine air to the environment without HEPA filtration was deemed unacceptable. Limited filtration capacity reduced the airflow through the mine from 425,000 cubic feet per minute (CFM) before the event to approximately 60,000 CFM. Routine mine access was not restored for nearly nine months, as considerable decontamination and remediation efforts had to be completed. Numerous corrective actions stemming from the accident investigations had to be completed before resuming waste emplacement; it did not resume until January 2017. The reduced airflow has greatly limited the activities that can be performed simultaneously underground. Airflow is critical for mine worker safety, especially when using equipment that produces diesel exhaust. Furthermore, the permanent radioactive contamination in parts of the mine requires radiological controls and monitoring of personnel and equipment. This adds time and effort to the process of emplacing waste containers and moving equipment about the mine. As a result, WIPP accepts and emplaces TRU waste at a much lower rate than before February 2014, and DOE sites around the nation have had to adjust to this reduced shipping schedule. Interim upgrades to ventilation capabilities have been made, and the mine can normally flow 170,000 CFM today.

FUTURE OPERATIONS

In 2015, DOE developed plans to expand ventilation capacity in the mine to a level even higher than pre-2014. Two major projects were initiated that will eventually provide capability to flow 540,000 CFM through the mine, with that entire volume passing through HEPA filters before release to the environment. The first project, known as the safety-significant confinement ventilation system (SSCVS), is adding facilities, ducts, fans, filters, and ancillary equipment on the surface to manage this airflow. The second project, the utility shaft, is excavating a new, 7.9-meter diameter shaft to the repository level to serve as another air intake and potentially another access route for personnel and materials.

SSCVS construction is well underway. This project is building two new structures on the surface: one will host the salt reduction process to reduce exhaust air salt content before filtration, the other will host the HEPA filter banks and exhaust fans (see Figure 4). The salt reduction building will have de-dusters and water misters to remove most of the salt dust generated by mining or other activities in the mine. After the salt reduction, air will flow to the filter building which will contain 22 banks of HEPA filters and six 1000-horsepower fans to move the air. The SSCVS is currently expected to begin operating no later than early 2026.

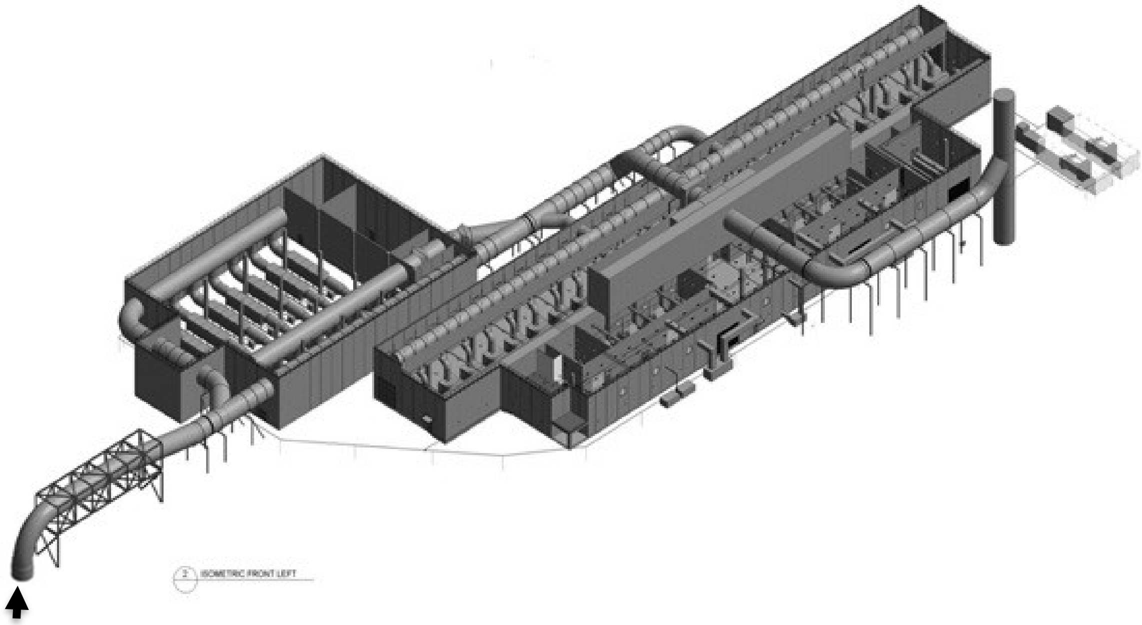

Figure 4: Layout of the Salt Reduction Building and Filter Building currently under construction.

The new utility shaft is also under construction. The shaft has been excavated to a depth of about 50 meters, and excavation should resume mid-2022. Both projects experienced significant schedule delays due to the pandemic and other factors, but the shaft project's delays were more severe. Fortunately, the shaft need not be completed for SSCVS to be commissioned and increase the airflow through the mine. Although the utility shaft will improve mine airflow, it will also prove very beneficial if the mine is expanded.

DOE is considering seeking authorization to extend the facility operating period, expand the repository, and increase the volume of TRU waste it is authorized to hold. The statutory limit of approximately 175,000 cubic meters of TRU waste will be reached in less than 20 years, before the entire inventory of US TRU waste is emplaced. Moreover, several drifts in the mine originally planned for waste emplacement were rendered unusable by the contamination event and have been permanently abandoned, so the mine will need to be expanded even to reach the current inventory limit. Abundant disposal space is available within the 16-square-mile WIPP boundary. If the facility is expanded, several new panels will be constructed in a western extension. Regulatory approvals for such expansion will be a lengthy process that is just beginning.

Finally, DOE and its operating contractor are working to improve mine operational efficiency by purchasing new equipment for use in the mine that is powered by electricity rather than diesel. Eliminating diesel exhaust has obvious benefits to worker safety, and it allows more activities to occur in the mine simultaneously. Each piece of operating diesel equipment requires a certain volume of airflow to ensure pollutants are carried away from workers, so in the current operating environment a limited number of work activities can occur at one time.

CONCLUSION

The WIPP facility has so far proven to be a successful location for geologic disposal of TRU waste. Thick evaporite units in a tectonically stable region are very well-suited for long-term isolation of hazardous materials from the biosphere. The WIPP salt haul truck fire in 2014 was an important reminder to keep highly disciplined conduct of operations and maintenance in any hazardous working environment. The radioactive material release reinforced the importance of procedure compliance, as well as maintaining a strong nuclear safety culture, both at the WIPP site and the DOE sites that package waste for disposal at WIPP. The event also had the unintended positive benefit of bringing new attention to the ageing facility infrastructure and the need for upgrades. The recognition that large volumes of air require HEPA filtration gave rise to the SSCVS project, which will greatly increase air filtration capacity and assist with safe, reliable operations through an extended facility life. The new utility shaft will further support safe operation, as well as improve operational efficiency if regulatory authorities allow mine expansion.

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