REMOVAL OF LONG-LIVED RADIOACTIVE WASTE DISPOSED AT THE WASTE ISOLATION PILOT PLANT

Mark L. Matthews* and Leif G. Eriksson**
*Department of Energy Carlsbad Field Office, P.O. Box 3090, Carlsbad, New Mexico 88221
**GRAM, Inc, 8500 Menaul Boulevard NE, Suite B-335, Albuquerque, New Mexico 87112

ABSTRACT

The Waste Isolation Pilot Plant (WIPP) deep geological repository for safe disposal of long-lived, transuranic radioactive wastes (TRUW)[a] in New Mexico, United States of America (USA) (Fig. 1), opened on March 26, 1999. Prior to opening WIPP, the United States (U.S.) Department of Energy (DOE) Carlsbad Field Office (CBFO) had to demonstrate compliance with very strict and prescriptive radioactive waste management and disposal regulations promulgated by the U.S. Environmental Protection Agency (EPA) (1,2). Specifically, the DOE had to demonstrate compliance with the following regulatory requirements for safe management and disposal of TRUW at the WIPP site:

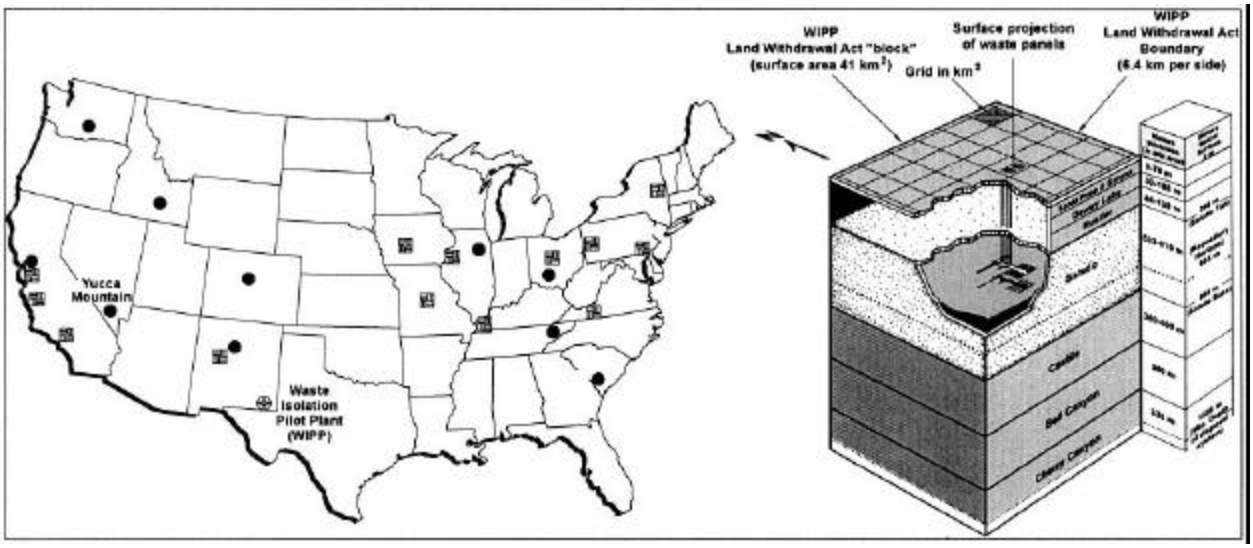

Fig. 1. The U.S. map (left) shows the locations of the WIPP site, and 10 large-quantity (filled circles) and 13 small-quantity (squares) TRUW generator and/or storage sites. The schematic WIPP Land Parcel (right) shows the 41.6 square kilometers (16 square miles), 1,828-meter (6,000-foot) deep, "controlled area" geosphere block.

1. Disposal systems shall be selected so that removal of most of the emplaced waste is not precluded for a reasonable period of time after disposal.
2. Any compliance certification shall include documentation, which demonstrates that removal of waste is feasible for a reasonable period of time after disposal.

3. This documentation shall include an analysis of the technological feasibility of mining the sealed disposal system, given technology levels at the time a compliance application is prepared.

Furthermore, the EPA states in the compliance application guidance document (3) that it expects the required analysis "to include:

- A sequence of procedures or steps which would need to be accomplished in order for the waste to be removed from the system after closure;
- A discussion of how this sequence could be implemented, including descriptions of how currently available equipment and technologies could be utilized; and
- An estimate of how long after disposal it would be technologically feasible to remove the waste, based on the disposal system design and closure, and using the system and equipment described in the application."

In October 1996, the CBFO submitted the WIPP Compliance Certification Application (CCA) (4) to the EPA. "Appendix WRAC" of the CCA describes a feasible system for waste removal using available mining technologies which demonstrates that post-closure removal of the emplaced TRUW is possible. In its May 1998 Certification Decision (5), the EPA stated that the DOE had demonstrated compliance with the applicable long-lived radioactive waste/materials (LLRM) disposal regulations for WIPP (1,2). In other words, the CBFO's feasibility study of post-closure removal of LLRM disposed in the WIPP repository met the regulatory requirements.

The transferable benefits of the CBFO's feasibility study on post-closure removal of LLRM disposed in a deep geological repository are to the global radioactive waste management community. In particular, its current primary value and benefit are to nations considering rock salt repositories, because the lasting scientific, engineering, and public-acceptance legacy of the WIPP removal feasibility study, is: *LLRM emplaced in a rock salt repository can be removed for a reasonably long time during the post-closure period with currently available technologies!*

INTRODUCTION

At the end of year 2000, WIPP is the world's only operating deep geologic repository for LLRMs (Figs. 1 and 2). The world's next deep geological repository for disposal of LLRMs is currently scheduled to open in year 2010 (6). In recent years, the term retrievability and various permutations of this term, such as recoverability, reversibility, and removability, have emerged around the world as a popular means to achieve and enhance public acceptance of deep-geological disposal of LLRMs. In the USA, retrieval of LLRM disposed in a deep geological repository has been considered since the late 1970s. For example, the October 1996 CCA (4) included a technical feasibility study on *removing* TRUW from the WIPP repository for a reasonable period after it has been closed. This study was subjected to a thorough public review process that culminated in May 1998 with the EPA Certification Decision (5) corroborating that post-closure removal of LLRM at WIPP is feasible.

The following discussion is a concise description and discussion of the DOE's feasibility study on removing the emplaced TRUW from the WIPP repository for a reasonable period after it has been closed, as presented in the CCA (4). The description and discussion section includes definitions of key terms used in this paper and applicable statutory and legal TRUW-retrieval and -removal requirements. The description and discussion section is followed by a summary of the authors' main conclusions.

DESCRIPTION AND DISCUSSION

Site-specific laws and regulations currently govern the siting, development, operation, decommissioning, and closure of any national deep geological repositories for safe disposal of LLRM in the USA. However, the definitions for the many terms associated with post-closure access to the disposed waste differ both among and within these documents. In this paper, the terms "retrieval", "removal", and "recover" depict the following three different concepts:

1) *Retrieval*, which is essentially the reverse of emplacement, refers to retrieving the waste prior to or soon after waste panel closure.
2) *Removal* refers to actions taken after the repository is closed and sealed.
3) *Recover* refers to the obligation to not preclude future generations' access to, and alternate use of, the LLRM emplaced in a repository by this generation.

The construction of the WIPP repository commenced in 1981. By the end of year 1988, an underground research laboratory, the North Experimental facility, and a portion (Panel 1) of the repository had been constructed at a depth of approximately 650 meters (m) (2,150 feet) below the surface in the lower half of a 250-million-year-old, 600-m-thick (200-foot-thick), seismically and tectonically undisturbed, laterally extensive, and virtually impermeable salt bed (Fig. 2).

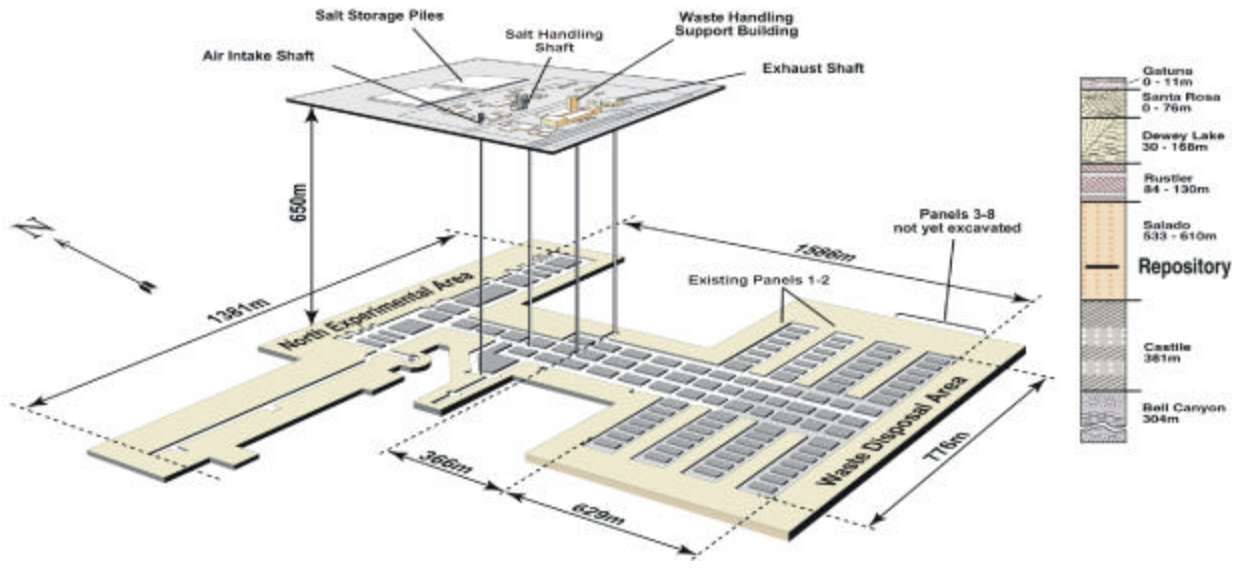

Fig. 2. Schematic illustration of surface and subsurface facilities, and main stratigraphic formations/units at the WIPP site.

As shown in Figure 2, the WIPP repository layout includes eight separate waste disposal panels. Each panel contains seven 4-m (13-foot) high, 10-m (33-foot) wide, and 91-m (300-foot) long disposal rooms. Contact-handled (CH) TRUW contained in standard 208-liter (55-gallon) drums or standard waste boxes (SWBs) will be stacked three high in the disposal rooms and surrounded by bagged magnesium oxide (MgO) backfill (4). Remote handled (RH) TRUW contained in shielded canisters measuring 0.66 m (26 inches) in diameter with a maximum length of 3.07 m (121 inches) and a maximum weight of 3.63 tons (8,000 pounds [lbs.]) will be emplaced in pre-drilled horizontal holes in the walls of the disposal rooms. The salt surrounding the disposal rooms will gradually encapsulate the emplaced waste within a few hundred years, thereby creating a virtually impermeable monolith (4). As illustrated in Figure 3, the WIPP repository will safely contain the emplaced. TRUW for at least 10,000 years, even if breached by multiple human intrusions.

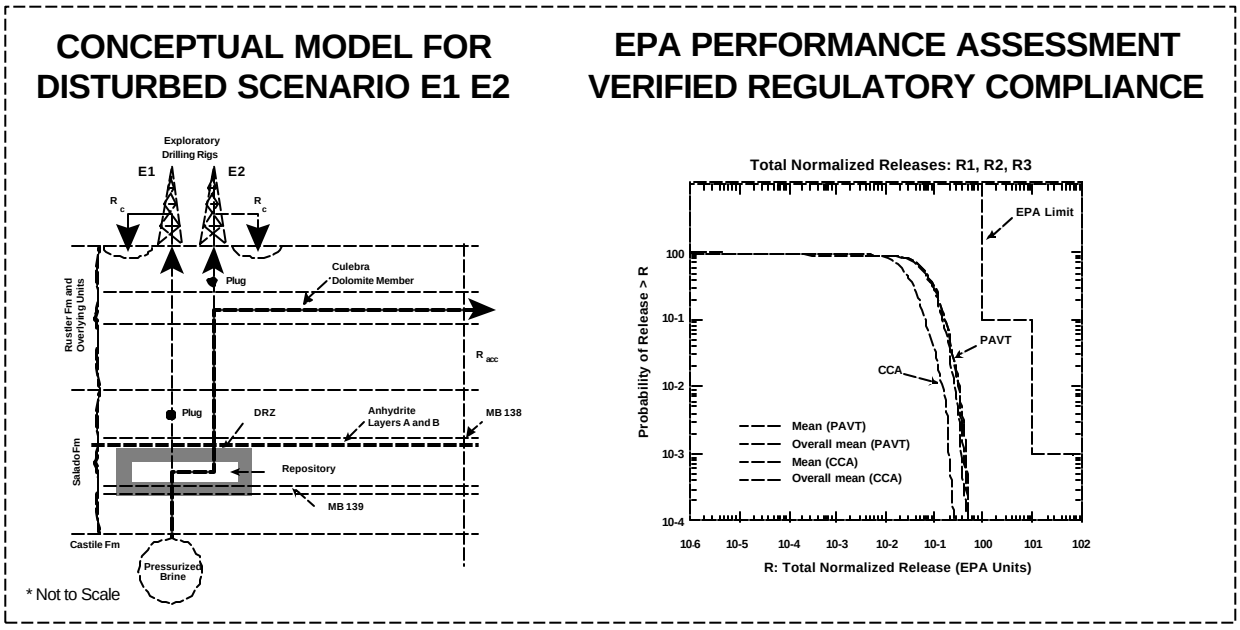

Fig. 3. Schematic illustration of the "highest-consequence" disturbed scenario (left) and the six mean (each mean curve represent 100 scenarios) complementary cumulative distribution functions (CCDFs) for radionuclide releases from all undisturbed and disturbed CCA and EPA-requested (PAVT) scenarios (right).

On March 26, 1999, the DOE opened the WIPP repository for safe disposal of up to 175,584 m^3 (6.2 million cubic feet [ft^3]) of TRUW (9), including 12 tons (26,455 lbs.) of plutonium with a half-life in excess of 24,000 years. The WIPP repository inventory will also include up to 7,080 m^3 (250,000 ft^3)[b] of RH-TRUW canisters with surface dose rates of up to 10 sieverts per hour (Sv/h) (1,000 rems/h).

The opening of the WIPP TRUW repository was preceded by a multi-year certification process, beginning in October 1996, with the DOE's submittal of the CCA (4) to the EPA. As required by the applicable EPA regulations (1,2), the CCA contained a feasibility study on post-closure removal of the emplaced waste. This was because the EPA believes that removal of the TRUW emplaced at WIPP, though not necessarily easy or inexpensive, would be prudent in the event

some future discovery or insight made it clear that the waste needed to be relocated. The process culminated with the EPA's favorable Certification Decision (5) in May 1998 and the DOE's and EPA's subsequent successful resolution of several legal challenges (7).

The 1992 WIPP Land Withdrawal Act of 1992 (LWA) (8) directed the EPA to develop final disposal regulations and related compliance criteria for the WIPP site. In December 1993, the EPA promulgated the final disposal regulations, also referred to as 40 CFR 191 (1). In February 1996, prior to the enactment of the WIPP Land Withdrawal Act of 1996 (LWAA) (9), the EPA promulgated "Criteria for Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance With the 40 CFR Part 191 Disposal Regulations; Final Rule", also referred to as 40 CFR 194 (2). Subpart 40 CFR 194.46 defines the following "Removal of waste" requirement for WIPP:

> "Any compliance application shall include documentation which demonstrates that removal of waste from the disposal system is feasible for a reasonable period of time after disposal. Such documentation shall include an analysis of the technological feasibility of mining the sealed disposal system, given technology levels at the time a compliance application is prepared."

The supplementary information to 40 CFR 194.46 provided by the EPA states:

> "In place of the requirement for a removal plan, EPA is including in the final rule a requirement that the DOE perform an evaluation to demonstrate that the removal of waste will remain feasible for a reasonable time period after disposal".

However, there is no regulatory guidance on "a reasonable time period after disposal". Thus, the responsibility to define a "reasonable time period" for the EPA's approval rests on the DOE. In the March 1996 "Compliance Application Guidance for 40 CFR 194" (3), the EPA states that it expects the required analysis "to include:

1. A sequence of procedures or steps, which would need to be accomplished in order for waste to be removed from the disposal system after closure.
2. A discussion of how the sequence described above could be implemented, including descriptions of how currently available equipment and technologies could be utilized.
3. An estimate of how long after disposal it would be technologically feasible to remove the waste, based on the disposal system design and closure, and using the system and equipment described in the application."

"Appendix WRAC" of the October 1996 CCA (4) defines the following five-phase approach to waste removal during the post-closure period:

1. Planning and permitting.
2. Initial, aboveground setup and shaft sinking.
3. Underground excavation and facility setup of underground ventilation, radiation control, packaging areas, decontamination areas, maintenance, remote control, and personnel support rooms.

4. Waste location and removal operations, including mining waste removal, packaging, package surveying and decontamination, transportation to surface, staging for off-site transportation, and off-site transportation.
5. Closure, decontamination, and decommissioning of the facility.

The DOE's feasibility study in "Appendix WRAC" of the CCA (4) discusses the techniques that could be applied in removing TRUW from WIPP after waste disposal. Two particularly significant concluding statements in the WIPP CCA are:

- "Removal of the waste after the repository is sealed is possible"; and
- "In no case, however, are the conditions expected to render removal impossible".

Following are the five main hazardous-waste removal conditions considered during this period:

1. Radioactivity.
2. Hazardous constituents.
3. Gas.
4. Brine.
5. Rock integrity.

The amount of radioactivity in the "disposal rooms" depends on the time at which removal is initiated. Within the first 300 years after closure, it may be necessary to consider treating the RH-TRUW differently than the CH-TRUW, because of its higher radioactivity. Beyond 300 years, all the emplaced waste can be managed in the same manner.

With regards to the hazardous constituents in the waste, the volatile organic compounds (VOCs) do not occur in sufficient quantities to pose a hazard as long as adequate ventilation is provided. Non-volatile hazardous constituents only pose threats if they are released during the removal process. Here, as with both the VOCs and the radioactive contaminants, proper ventilation will be needed to provide adequate protection to workers, the public, and the environment. If the environmental protection laws and regulations are the same at the time of removal as they are today, the planning for removal will require that the agency implementing removal provide detailed plans for controlling hazardous constituent contamination.

Post-closure gas pressures in the repository can range from 0.101 megapascals (MPa) to 13 MPa. This is due to the nature of disposal operations and the panel closure practices, and pressures could vary from panel to panel. As with gas, the quantity of brine can be different from one panel to the next. While brine and gas can maintain rather large pore volumes in a sealed panel, this condition is considered unlikely, because creep closure acts fairly rapidly and it is unlikely that sufficient brine and subsequent gas will be available to support large pore volumes without an external source. The repository is expected to reach its maximum closure before large quantities of brine are available.

The emplaced TRUW will not be well contained and will likely mix with other materials/constituents in the disposal rooms, thereby requiring specific caution to be exercised during a removal operation. The CCA states that "Radioactive contamination within the disposal

region can be removed at whatever rate is necessary to safely manage occupational and public exposure" (4). The excavated waste and materials would be placed in appropriately designed waste containers. The container surfaces would be decontaminated, if necessary, prior to being transported aboveground. Aboveground facilities would include a control center where any necessary remote waste handling and packaging operations are coordinated, and a decontamination area where waste containers would undergo any necessary decontamination. An underground control center would provide the interface between the aboveground control center and the underground operational activities. The waste containers would be staged aboveground for transportation.

As noted above, the waste removal plan proposed by the DOE for WIPP in the CCA addresses highly adverse conditions for workers' safety and waste removal. The mining and waste-removal operations would be designed to reduce the amount of contamination and exposure to allow limited human access for assessments, equipment retrieval, and equipment repairs. Operations would be designed to reduce human involvement to the extent possible. Mining techniques that were evaluated include the following:

- Continuous mining;
- Drill and blast;
- Solution mining;
- Small-scale mechanical mining, and
- Remote mining.

On April 2, 1992, a full-scale demonstration took place that successfully removed mock-up SWBs from a WIPP room (4). The demonstration simulated a cave-in or roof fall condition with salt and metal roof support piled on top of the SWBs. All removal operations were performed using remote-controlled equipment.

In May 1998, the EPA announced that WIPP complied with all applicable radioactive waste management and disposal regulations (5). This announcement was preceded by intense EPA and public scrutiny and oversight, which included successfully overcoming several legal challenges (7). Therefore, the feasibility of the waste removal plan, which was presented by the DOE in the CCA, has been successfully demonstrated to the satisfaction of the cognizant regulator and a diverse spectrum of stakeholders.

CONCLUSIONS

The DOE's pioneering benchmark study on the feasibility of post-closure removal of LLRM from a salt repository is the only regulator-reviewed and -approved study on the subject in the world. In this study, the DOE has convincingly demonstrated that the WIPP TRUW repository complies with both national requirements for safe disposal of LLRM as well as the current international obligation of this generation to not preclude future generations from recovering the emplaced LLRM (10,11,12). In summation, TRUW emplaced at WIPP will be safely encapsulated and isolated by the host rock in a few hundred years. The waste removal plan contained in the CCA indicated that it was feasible for TRUW to be accessed and removed, if

desired, after the closure of WIPP, which strongly supports the notion that LLRM can also be retrieved and recovered during the post-closure period.

However, the past statutory requirement for pre-closure removal of waste used in tests at WIPP was voided in the LWAA (9). Accordingly, presently the feasibility of removing LLRM emplaced in the WIPP deep geological repository for an extended period after it has been closed has greater global value than specific WIPP value. The most apparent global value of the WIPP feasibility study, beyond meeting a WIPP-specific regulatory requirement, is to nations pursuing rock salt as the host rock for a LLRM repository and, ultimately, to the development of confidence in and acceptance of the retrieval, removal, and recovery concepts. This favorable condition should also enhance confidence in and acceptance of deep geological disposal of LLRM.

REFERENCES

1. U.S. Environmental Protection Agency, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule", Code of Federal Regulations, Title 40, Part 191 (December 20, 1993).
2. U.S. Environmental Protection Agency, "Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations; Final Rule", Code of Federal Regulations, Title 40, Part 194 (February 9, 1996).
3. U.S. Environmental Protection Agency, "Compliance Application Guidance for 40 CFR Part 194", Office of Radiation and Indoor Air (EPA 402-R-95-014) (March 26, 1996)
4. U.S. Department of Energy, "Compliance Certification Application 40 CFR 191 Subpart B and C" (October 1996).
5. U.S. Environmental Protection Agency, "Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the Disposal Regulations: Certification Decision; Final Rule" (May 18, 1998).
6. U.S. Department of Energy Office of Civilian Radioactive Waste Management, "Viability Assessment of a Repository at Yucca Mountain", DOE/RW-0508 (December 1998).
7. U.S. Department of Energy Carlsbad Area Office, "The Waste Isolation Plant Pioneering Nuclear Waste Disposal", DOE/CBFO-00-3124 (February 2000).
8. Public Law 104-201, "*The Waste Isolation Pilot Plant Land Withdrawal Amendments Act of 1996"* (July 30, 1996).
9. Public Law 102-579, "*The Waste Isolation Pilot Plant Land Withdrawal Act of 1992"* (January 7, 1993).
10. International Atomic Energy Agency, "Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management", signed by the United States of America on 29 September 1997.
11. Organisation for Economic Co-operation and Development/Nuclear Energy Agency, "Geologic Disposal of Radioactive Waste" (in preparation).
12. European Commission/ EUROATOM, "Concerted Action on the Retrievability of Long-lived Radioactive Waste in Deep Underground Repositories", EUR 19145 EN (2000).

FOOTNOTES

a TRUW destined for WIPP must 1) be defense-related and 2) contain at least 3,700 becquerels (100 nanocuries) of alpha-emitting, transuranic (atomic weight/number greater than ^{92}uranium) isotopes with half-lives greater than 20 years, per gram of waste, but the canister surface dose rate may not exceed 10 sieverts per hour (Sv/h) (1,000 rems/h). There are two categories of TRUW: 1) contact handled (CH) that may have a maximum canister surface dose rate of 0.002 Sv/h (0.2 rem/h) and 2) remote handled (RH) that may have a canister surface dose rate between 0.002 Sv/h and 10 Sv/h.

b DOE and the State of New Mexico has agreed to limit 1) the depth of the controlled area (disposal system) to 1,828 m (6,000 ft) and 2) the amount of RH-TRUW to 7,080 m^3 (250,000 ft^3).