Planned EPA Regulatory Changes at the WIPP: 2010 and Beyond - 10595

Steve Kouba
URS Corporation, Washington Regulatory and Environmental Services
4021 National Parks Highway, Carlsbad, NM 88220

Russ Patterson
Department of Energy, Carlsbad Field Office
4021 National Parks Highway, Carlsbad, NM 88220

Michael Gross
MG Enterprises
415 Rivera Drive, San Rafael, CA 94901

ABSTRACT

The Waste Isolation Pilot Plant (WIPP) facility, in southeastern New Mexico, is operated by the U.S. Department of Energy (DOE) as the nation's only deep geologic repository for the disposal of defense-related transuranic nuclear waste. The WIPP Land Withdrawal Act (LWA) [1] vested compliance certification authority with the US Environmental Protection Agency (EPA) with regard to DOE disposal of radioactive constituents at the WIPP facility. The EPA certified DOE to begin disposal of transuranic waste in 1998 and the first waste shipment emplaced at the WIPP facility on March 26, 1999. During the first ten years of operational experience, the DOE has identified numerous operational changes to the EPA's regulatory baseline for the WIPP facility. These process improvements enhance the safety of the workforce, the public and the environment, and often generated savings for taxpayers.

The DOE prepares a Planned Change Request (PCR) for each proposed change that affects the regulatory baseline established for the WIPP Program. Each PCR must be approved by EPA before the change can be implemented by the DOE. Once the second recertification of the WIPP compliance to the disposal standards is completed, DOE is considering several changes to the operational and regulatory framework at the WIPP facility. This paper will discuss the potential changes that may be in the foreseeable future, the rationale for the potential changes, and a potential schedule for implementing those changes.

INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) facility, in southeastern New Mexico is operated by the U.S. Department of Energy (DOE) as the nation's only deep geologic repository for the disposal of defense-related transuranic (TRU) nuclear waste. The WIPP Land Withdrawal Act (LWA) [1] vested compliance certification authority with the U.S. Environmental Protection Agency (EPA) with regard to DOE disposal of TRU radioactive waste at the WIPP facility. EPA certified DOE to begin disposal of transuranic waste in 1998 and the first waste shipment was emplaced at the WIPP facility on March 26, 1999.

Over the first ten years of operational experience, the DOE has identified numerous operational changes to the regulatory baseline established for the WIPP Program. These process improvements enhance the safety of the workforce, the public and the environment, and many involved savings for the taxpayers. Starting in 2010, the DOE is considering several changes to the operational and regulatory framework, including the use of lead shielded containers for remote-handled transuranic (RH-TRU) waste, a revised panel closure system, the use of neutron shielded containers, chemistry model refinements, changes to the characterization of waste material parameters, and a revised passive institutional controls program.

LEAD SHIELDED CONTAINERS FOR REMOTE HANDLED TRANSURANIC WASTE

The Land Withdrawal Act limits the total amount of curies of RH-TRU waste that may be disposed of in the WIPP facility to 190 PBq (5.1 million curies). The Consultation and Cooperation Agreement [2] between the State of New Mexico and DOE also limits the disposal volume of RH-TRU waste in the WIPP facility to 7,080 m^3 (0.25 million cubic feet (ft^3)). A Class 3 modification to the Hazardous Waste Facility Permit (Permit) [3] with the New Mexico Environmental Department (NMED) limited the volume of RH-TRU waste disposed in panels 4-7 to 1,985 m^3 (70,100 ft^3), which is less than 30% of the regulatory limit. Future permit modification requests will be submitted to increase the permitted RH-TRU disposal volumes in Panels 8-10 to accommodate the RH-TRU inventory up to the statutory and agreed-to-limits.

The most recent *Annual TRU Waste Inventory Report – 2009*, DOE/TRU-09-3425 [4], indicates that RH-TRU waste volume has increased by approximately 60% since the 2008 inventory report. Current projections show the total volume of emplaced RH-TRU waste plus RH-TRU waste streams destined for shipment to the WIPP facility to be 4,724 m^3. Presently, RH-TRU waste is encapsulated in steel canisters that are emplaced in boreholes drilled in the wall of the waste disposal rooms. There is not enough wall space to dispose of the total projected volume of RH-TRU waste because no RH-TRU waste is emplaced in panels 1-3 and because of the limitation on disposal volume in panels 4-7.

Aside from the consideration of limited wall space for RH-TRU canisters, the use of shielded containers should improve the long-term performance of the repository through a number of processes [5]. The substantial amount of lead in the containers will add to the already reducing conditions in the long-term chemical evolution of the waste-rock matrix and thereby reduce the solubility of actinides, should brine ever be introduced via inadvertent human intrusion. In addition, the structurally robust nature of the shielded containers (over that of the horizontally emplaced remote-handled waste canisters in the disposal room walls) would add to the strength of the waste matrix, thereby reducing releases by the cuttings and cavings mechanisms in assumed human intrusion scenarios.

In addition to the consideration of storage space, there are additional programmatic benefits from using shielded containers. Remote-handled waste is currently shipped to the WIPP facility in RH-72B shipping casks, which can transport one facility disposal canister. The facility canister typically over-packs three 207-L drums or three 113 L drums. Using the proposed shielded container scheme, it may be possible to ship a total of nine shielded containers, each over-packing a 113-L drum. This represents a potential 3-to-1 efficiency gain over transport based on the RH-72B cask. Such efficiencies, in turn, represent a potential significant reduction in the overall number of shipments to the facility, thus reducing risks from transportation.

The cost of the shielded container assembly will be significant, but large-quantity pricing has not yet been developed. It is expected that the cost to ship and emplace remote-handled waste using the shielded containers will be significantly less than the cost of the baseline canister-in-wall scheme, and the use of recycled lead may make the cost of the shielded containers competitive with the baseline remote-handled canister cost.

The baseline disposal scheme requires more than 10 hours from initial receipt of the RH-72B cask until a single remote-handled waste canister is emplaced in the wall of an underground disposal room. WIPP is limited by operational constraints to a maximum of six baseline remote-handled waste shipments per week. In contrast, the contact-handled (CH) waste handling processes routinely allow four to five shipments (i.e., three HalfPACTs per shipment) per day to be received, unloaded, and emplaced. It follows that transportation and emplacement of RH-TRU waste in lead shielded containers will be much more efficient than the use of the RH-72B cask and canister-in-wall emplacement.

Another possible benefit from the use of shielded containers may be realized if the DOE is able to use its vast stockpiles of formerly used lead in the DOE inventory to manufacture the shielded containers. To keep costs low and to provide an environmentally prudent pathway for usefully managing some of that inventory, the DOE intends to use recycled lead to the maximum extent possible. Since the DOE's lead reuse program is designed to ensure that recycled lead meets supplemental limits approved for directed reuse, the lead is released from radiological control for such purposes (i.e., the lead is a safety element and not a waste product).

Significant infrastructure modifications at WIPP will not be needed to accommodate shielded containers. Use of shielded containers for shipping and emplacement of waste will meet all requirements of the WIPP waste acceptance criteria. Transportation will be by the existing licensed HalfPACT, and no modifications are required to the shipping cask. No changes to the waste handling processes for contact-handled waste will be required since each shielded container must meet the requirements for a contact handled waste container (which it actually is). The long-term repository performance will be unaffected and potentially even improved. There are no anticipated changes needed in the storage capacities already approved in the Hazardous Waste Facility Permit for WIPP.

The use of lead shielded containers will result in an improvement of repository performance and provide a more efficient way of transporting and emplacing remote-handled waste in the WIPP facility for permanent isolation and is expected to result in faster generator site cleanup.

The DOE submitted a PCR to the EPA in November 2007 for authorization to use lead shielded containers for emplacement of selected RH-TRU waste streams on the floor of the repository. The shielded container design has 2.5 cm thick lead shielding sandwiched between a double-walled steel shell with a 7.5 cm thick lid and 7.5 cm thick base (see Figure 1). The limiting activity for a shielded container with a 2.5 cm thick lead liner is 74 GBq of ^{137}Cs or 4.4 GBq of ^{60}Co per 114 L drum [6]. (Each shielded container contains a single 114 L drum of RH-TRU waste.) The candidate waste streams that are expected to contain less than 74 GBq Cs-137 or 4.4 GBq Co-60 per 114 L-gallon drum constitute about 1,900 m^3 of the total PABC RH-TRU waste inventory [6]. Some waste streams that exceed these limiting activities may also be considered for shipment to WIPP in lead shielded containers based on assay results on a per container basis. The shielded containers will be emplaced on the floor of the repository, side-by-side with contact-handled TRU waste containers, but the waste in shielded containers will continue to be designated as RH-TRU waste for regulatory tracking purposes.

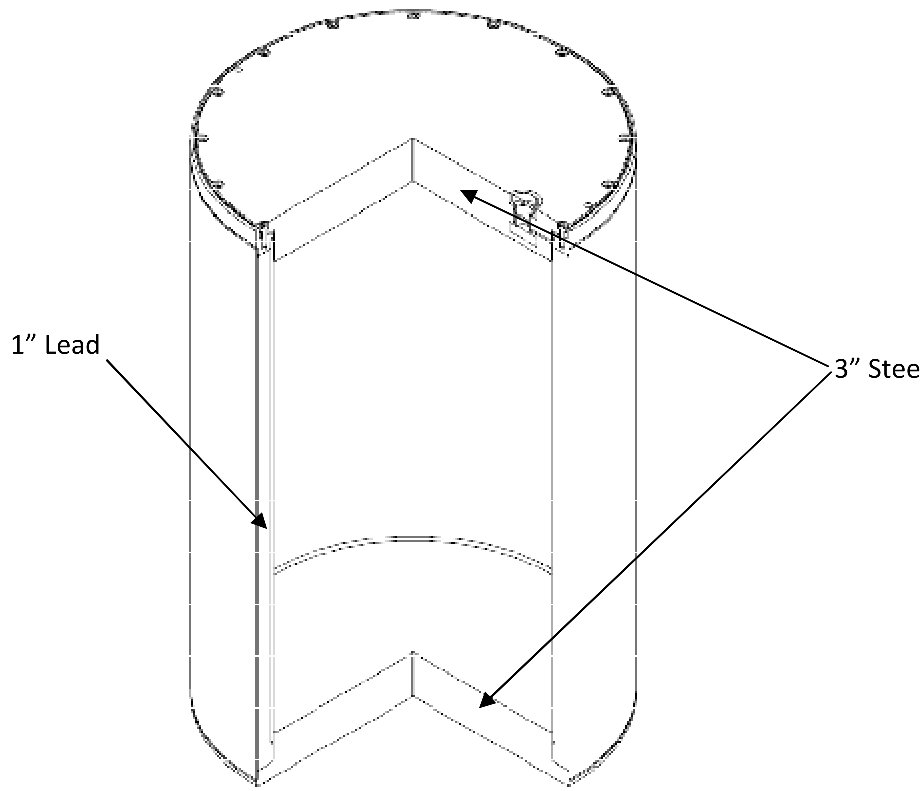

Fig. 1. Isometric Exposed View of the Lead Shielded Container

To date, the following activities have occurred on the Shielded Container PCR:

- DOE has self-certified the shielded container as meeting Department of Transportation (DOT) Type 7A specifications.
- The U.S. Nuclear Regulatory Commission (NRC) has approved the transport of the lead shielded container inside the Type B, HalfPACT package.
- EPA has completed its review of a large amount of documentation, including Performance Assessment (PA) calculations. EPA has also received nuclear safety documentation related to the use of lead shielded containers at the WIPP facility.

EPA’s review is currently suspended during its consideration of DOE’s 2009 Compliance Recertification Application [7]. Once the EPA completes its consideration of the recertification application, expected in the summer of 2010, EPA will reinitiate their review process for lead shielded containers. Finally, DOE will also prepare a Class 2 permit modification to the Permit and submit it to NMED.

Inter-site shipments between existing RH generator and storage sites using the lead shielded container are currently permissible, but have not started at this time. However, shipments to the WIPP facility are not expected to commence until late 2011.

PANEL CLOSURE SYSTEM

Panel closures systems are regulated by both the EPA and the NMED. The basis for the EPA regulatory authority is found in 40 Code of Federal Regulations (CFR) 194 [8]. EPA review of the panel closure system stated that the original purpose of the panel closure system was to reduce emissions of volatile organic compounds (VOC) from the repository during the operational period and control possible explosions (from gases such as hydrogen (H_2) and methane (CH_4)). However, the panel closures also have a long-term effect on repository performance by blocking the flow of brine and gas between panels.

Condition 1 of EPA's 1998 approval of DOE's Compliance Certification Application (CCA) [9] requires that DOE implement the Option D panel closure configuration. The Option D panel closure design is intended to restrict the migration of VOCs from a closed panel and to contain a postulated hydrogen explosion within the panel. Other performance specifications cover items such as constructability and materials. Since the closure components are present they must be taken into account in any other performance evaluations, but the parameters used in those evaluations are determined by others and are not part of the design performance specifications.

Option D consists of a 3.6 m thick explosion isolation wall and a 7.6 m thick concrete monolith, both of which are keyed into the panel entry drift. The explosion isolation wall is of mortared block construction and the monolith is of salt saturated concrete. Regulatory agencies specified specific concrete mixes rather a concrete performance specification. In field tests the specified salt-saturated concrete mix did not perform as expected in the design report. So in 2003, the DOE proposed a new design using high density concrete blocks and run-of-mine salt. Initial measurements of gases in closed portions of the repository indicated negligible concentrations of H_2 and CH_4 gas, the primary explosive gases. In 2007, with agreement from the EPA and NMED, the proposed design was withdrawn in favor of a long-term monitoring program for H_2 and CH_4 in the waste disposal rooms and in the exhaust side of the ventilation system. Any future changes to panel closures could be impacted by these monitoring results. To date, no levels of H_2 greater than action levels (4,000 parts per million by volume) have been detected. Furthermore, no CH_4 has been detected at or above the minimum level of detection.

In FY2010, a project has been initiated to revise the panel closure design and to submit a new planned change request to EPA and NMED in the 2010-2011 time frame.

NEUTRON SHIELDED CANISTERS FOR REMOTE HANDLED TRU WASTE

In addition to the gamma-emitting RH-TRU waste streams targeted for disposal in lead shielded containers, there are also a number of waste streams that have a high neutron dose rate. Because of the inherently high surface dose rates associated with the handling of RH-TRU waste, as low as reasonably achievable (ALARA) considerations dictate that such waste be handled remotely and/or using heavily shielded equipment, and be transported in shielded, NRC-certified, Type B shipping casks, such as the RH72-B or CNS10-160B. These shipping casks include significant amounts of lead shielding and are therefore well suited to minimize dose rates associated with gamma emitters. However, these transportation casks, payload containers, or the various pieces of waste handling equipment do not include neutron shielding. Thus, distance is the only means currently available to attenuate the dose associated with neutron emitters, and it is not currently possible to transport any significant quantities of neutron emitting radioisotopes within the 72-B shipping cask or its associated payload canister.

A significant quantity of RH-TRU waste at Oak Ridge National Laboratory (ORNL) yields approximately equal gamma and neutron dose. This waste is scheduled for relatively near term shipment, and one form of neutron shielding will be required to effectively transport this waste to WIPP. The neutron contributions from these ORNL waste streams are primarily from the radioisotope ^{252}Cf.

A project team was formed to develop a neutron shielded payload canister that retains the current external geometry of existing canisters that were developed for transport in the RH72-B shipping cask. The goal was to retain the existing canister designs and to provide neutron shielding by adopting cylindrical internal liners with top and bottom end caps. Initially, it was assumed that the RH-TRU waste containing significant neutron emitting radioisotopes and currently in 208 L drums or larger containers will be repackaged into 57 L or 114 L drums prior to shipment to the WIPP facility.

Waste streams with high neutron dose rates will continue to be shipped in 72-B canisters and disposed of in the WIPP underground walls like many other RH waste streams. The current design proposes placing extra-high molecular weight, high density polyethylene (HDPE) liners inside of the existing RH canister. Two different thicknesses of liners are proposed to shield the contents of 57 and 114 L containers in 72-B canisters.

When lined with neutron shielding and loaded with waste, the canister shall retain its U.S. DOT 7A Type A pedigree and be approved by the NRC as an acceptable payload configuration for transport in the Type B-certified, RH72-B package. This revision to the RH72-B cask is planned for submittal to the NRC in February 2010. NRC approval is expected to take nine to twelve months.

CHEMICAL MODEL REFINEMENTS

Assessment of the DOE ability to comply with containment requirements specified in 40 CFR § 191.13 [10] is based on PA calculations. The WIPP compliance PA calculations use linked computer models that calculate the probabilities of cumulative radionuclide releases from the disposal system during the 10,000 years following closure. These computer models and many of the input parameters for the models are based on conceptual models that describe the expected performance of the disposal system. Peer review of all conceptual models is required by 40 CFR § 194.27 [8], and the conceptual models used in the PA were originally peer reviewed at the time of the CCA [9] by the Conceptual Models Peer Review Panel [12]. This panel ultimately determined that all of the conceptual models related to repository chemistry were adequate. Since the initial reviews conducted in 1996 and 1997, additional peer review has not been performed on any of the conceptual models related to repository chemistry.

Although the current chemistry-related conceptual models remain adequate for the WIPP disposal system PA, questions related to water balance, degradation rate of plastics and rubbers, and organic ligands have been identified [13]. With regard to water balance, the current implementation only accounts for water consumed by anoxic corrosion of iron in the repository. However, other processes may affect the water balance in the repository: FeS precipitation in place of $Fe(OH)_2$, MgO hydration, magnesite formation, and cellulosic, plastic, and rubber (CPR) degradation. The potential importance of these other factors on the water balance in the repository should be evaluated.

Another question is the degradation rate of plastics and rubber materials in the waste. Currently, it is assumed that plastic and rubber degradation will occur at the same rate as cellulose degradation. This assumption is likely to overestimate plastic and rubber degradation rates. Additional evaluation of the potential effects of lower plastic and rubber degradation rates on PA would be required to determine if changes to these rates would be warranted.

One other area that may be included in chemistry model refinements is the assumption that all organic ligands present in the transuranic waste will be available to interact with the actinides and therefore increase solubility. The DOE is in the process of performing microbiology experiments on the relevant organic ligands in WIPP-like conditions with WIPP relevant microbes in order to determine the long-term response of ligands in the repository environment.

The experiments and investigations that will be required to prepare for the submittal of a PCR for new chemistry conceptual models will last for several more years. The plan is for all the work to be completed by 2013 with a peer review, if one is deemed necessary, to be completed the same year. The revised chemistry model would be used in PA calculations for the 2014 recertification

MATERIAL PARAMETER ESTIMATING REQUIREMENTS

Every waste container must be characterized at a generator site before it is transported to WIPP and emplaced in the underground facility. Characterization activities determine the activity of ten radioisotopes (^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{233}U, ^{234}U, ^{238}U, ^{90}Sr, and ^{137}Cs (CRA-2004 [11], Section TRU WASTE-3.1 and Table TRU WASTE-16)), the masses of CPR materials in the waste, and the mass of iron-based material in the waste. Characterization activities also determine the ^{239}Pu fissile gram equivalent for shipments in a TRUPACT-II container and the volume of residual liquids in the waste. The fissile gram equivalent is dependent on the abundances of ^{239}Pu, ^{235}U, and ^{233}U in the waste.

Characterization activities are time consuming, cost intensive, and have some amount of radiological risk associated with them. The DOE has therefore begun to consider changes to optimize characterization activities for the masses of CPR materials in the waste and the amount of residual liquid in the waste.

Masses of CPR Materials

The masses of CPR materials have major impacts on the WIPP facility operations and on WIPP PA:

- WIPP Facility Operations. Each room of the repository must contain enough magnesium oxide (MgO) to provide an excess factor of at least 1.2 relative to the moles of organic carbon in CPR materials and in waste emplacement materials (like plastic slipsheets). At the present time, a 1,400 kg supersack of MgO is emplaced on top of each stack of waste containers in the repository. This approach generally provides an adequate amount of MgO (i.e., above the threshold 1.2) unless the specific waste streams in a room have a high density of CPR materials. In rooms with large amounts of MgO, a 1,900 kg supersack is used. If the excess factor drops below 1.2, then additional supersacks of MgO must be added to the room to increase the excess factor so that it exceeds the threshold value of 1.2.

  The moles of organic carbon in a room are a direct function of the masses of CPR materials in each waste container. The masses of CPR materials are currently estimated during the waste characterization process for every waste container that is shipped to the WIPP facility. The WIPP facility operations then use this information to calculate the MgO excess factor based on the CPR in each drum in each room.

- WIPP PA. The biodegradation model in the WIPP disposal system PA is a source of gas generation and gas pressure after repository closure. The gas pressure generated by biodegradation is a direct function of the average densities of CPR materials in the repository. The inventory for the WIPP disposal system PA provides the average densities of CPR materials, based on the waste characterization process for each container of emplaced waste and on estimates for WIPP-bound waste streams which have yet to be characterized.

Preliminary PA sensitivity studies have indicated that repository performance is insensitive to a wide range of average densities of CPR materials because corrosion of iron is the dominant gas generation mechanism. More specifically, variations of average CPR densities from 10% to 200% of the current values produce negligible change in repository performance. Only when average CPR densities increase by a factor of five to ten is there a noticeable shift in repository performance. In this situation, future PA could be performed with average CPR densities that encompass the average CPR densities from recent inventories and maximize releases from the repository.

A similar approach cannot be used for the WIPP facility operations because the amount of MgO in each room is a direct function of the organic carbon in the waste in each room. However, a few CH-TRU waste streams provide the majority of the organic carbon in CPR materials based on an analysis of a recent inventory. For example, the top five waste streams (by CPR mass) provide 72% of the total organic carbon in CH-TRU waste and the top 10 waste streams (by CPR mass) provide 76% of the total organic carbon in CH-TRU waste. The remaining waste streams account for a very small fraction (0.5% or less per waste stream) of the total organic carbon in CPR materials. The obvious strategy here is to perform complete characterization on a few CH-TRU waste streams with significant amounts of organic carbon and “spot check” a few containers from other waste streams to confirm the estimated CPR densities in the inventory.

One possible approach is to characterize the five WIPP-bound CH-TRU waste streams with the highest levels of organic carbon. The top five waste streams (by CPR mass) are also those that may require additional MgO, beyond that included in each supersack. In other words, the MgO excess factor falls below 1.2 on a per stack basis for the top five waste streams. This is a conservative approach because additional MgO may not be required if the other waste containers in the room have low levels of CPR materials. This is consistent with the current planning for implementation of the MgO Excess Factor of 1.2.

Note that the spot check on the other waste streams does not have to be very accurate because the WIPP facility operations always emplaces a single supersack of MgO on top of each stack of waste containers. This approach provides ample leeway for error relative to the waste streams with minor amounts of organic carbon. RH-TRU waste contributes about 1% to the total organic carbon in CPR materials, and can also be characterized with a spot check.

Volume of Residual Liquids

The waste that is shipped to WIPP from the generator sites must be free of prohibited items and prohibited materials. Prohibited items include pressurized containers; Prohibited materials include liquids in excess of one percent of the container volume as well as specific contaminants, such as liquid poly-chlorinated biphenyls (PCBs). A TRU waste container found to contain these prohibited items must be remediated, involving risks to the workers.

The *Final Supplement Environmental Impact Statement (SEIS-II) for the Waste Isolation Plant* [14], issued in 1989, specified that the liquid content of waste is limited to one percent of the TRU waste container volume. However, the SEIS-II did not include a risk analysis of the possible exposure to workers during repackaging, nor did it discuss whether the application of the liquid limits and the resultant requirement to repackage or treat TRU waste was in conformance with the ALARA principle, by which there should be no radiation exposure to workers or the public without commensurate benefit. [15]

During FY2010, DOE will consider approaches to optimize characterization activities for the masses of CPR materials in the waste and for the residual liquid volume in the waste.

REVISED PASSIVE INSTITUTIONAL CONTROLS PROGRAM

Condition 4 of the EPA's certification for the WIPP disposal system [16] relates to passive institutional controls (PICs). The WIPP compliance criteria require DOE to use physical markers to warn future societies about the location and contents of the disposal system, and thus to deter inadvertent intrusion into the WIPP repository. In the CCA, DOE provided a design for a system of PICs, but stated that many aspects of the design would not be finalized for many years (even up to 100 years) after closure. However, the PICs constructed and emplaced in the future must be consistent with the basis for EPA's certification decision. Therefore, Condition 4 of the certification requires DOE to submit a revised schedule showing that markers and other measures will be implemented as soon as possible after closure of the WIPP facility. The DOE also must provide additional documentation showing that it is feasible to construct markers and place records in archives as described in the CCA.

For numerous reasons such as, significant postponements in completing environmental restoration activities at several large sites, DOE currently expects the life of the repository will extend beyond the initially planned lifetime of 35 years. In this situation, it no longer appears to be a priority to have a permanent marker design available by 2014. The present schedule, as agreed to by EPA in a March 7, 2008 Reyes to Moody letter [17], requires:

- suitable source materials for markers identified by 2014
- plans for the marker system to be available by 2016

- monitoring of berms and test markers start in 2019

DOE's current activities in support of PICs include:

- Develop new materials and/or processes which will ensure longevity of the permanent marker design and understanding of the message for future generations.
- Solicit international involvement in the enhancement of current record archive design and message systems.
- Develop marker materials that will endure future environmental and climate changes.
- Ensure the message will be understandable and believable to future generations.

DOE is no longer certain berms will be used to delineate the repository outline and would like to spend several years investigating alternate marker materials and alternative surface location indicators. A revised schedule will be proposed to the EPA in the near future and a PCR will be provided at a future date yet to be determined.

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CONCLUSION

Following almost two decades of planning and preparation, the DOE has been emplacing waste for more than 10 years. During this time, changes have taken place to improve operational efficiencies and/or save taxpayer funds. The authors have outlined the foreseeable changes that may be submitted to EPA in the form of PCR's in the near future, and the rationale behind each change. The WIPP Project staff continues to look for operational efficiencies and cost saving opportunities that will be beneficial to the operation of the WIPP facility in 2010 and beyond.

REFERENCES

1. U.S. Congress. 1996. Public Law 102-579. "Waste Isolation Pilot Plant Land Withdrawal Act of 1992", as amended by Public Law 104-201, 1996.

2. State of New Mexico and U.S. Department of Energy (DOE). 1984. "Agreement for Consultation and Cooperation on WIPP, First Modification," November 30, 1994. Carlsbad, NM: Department of Energy, Carlsbad Area Office.

3. NM4890139088-TSDF. 1999. Waste Isolation Pilot Plant Hazardous Waste Facility Permit. New Mexico Environment Department, Santa Fe, NM.

4. U.S. Department of Energy (DOE). 2009. "Annual TRU Waste Inventory Report – 2009", DOE/TRU-09-3425, Carlsbad, NM: Carlsbad Field Office.

5. Nelson, Roger and White, Sean. 2009. "Shielded Payload Containers for WIPP Remote-Handled Waste", Radwaste Solutions.

6. Crawford, Beverly A. and Daniel J. Taggart. 2007. "Analysis of RH-TRU Wastes for Containment in Lead Shielded Containers", INV-SAR-08, Revision 0, Los Alamos National Laboratory, Carlsbad Operations, Carlsbad, NM. August 30, 2007.

7. U.S. Department of Energy (DOE). 2009. "Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application 2009", DOE/WIPP 09-3424, Carlsbad, NM: Carlsbad Field Office.

8. U.S. Environmental Protection Agency (EPA). 1996. "40 CFR Part 194, Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations", Office of the Federal Register, National Archives and Records Administration, Washington, D.C.

9. U.S. Department of Energy (DOE). 1996. "Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant", DOE/CAO 1996-2184. Carlsbad, NM: Carlsbad Area Office.

10. U.S. Environmental Protection Agency (EPA). 40 CFR 191

11. U.S. Department of Energy (DOE). 2004. "Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application 2004", DOE/WIPP 04-3231, Carlsbad, NM: Carlsbad Field Office.

12. Wilson, C., D. Porter, J. Gibbons, E. Oswald, G. Sjoblom, and F. Caporuscio. 1996. "Conceptual Models Supplementary Peer Review Report" (December). Carlsbad, NM: Department of Energy, Carlsbad Area Office.

13. U. S. Environmental Protection Agency (EPA). 2008. "Verification of the Waste Isolation Pilot Plant Chemistry Conceptual Models" Washington DC.

14. U.S. Department of Energy (DOE). 1997. "Final Environmental Impact Statement for the Waste Isolation Pilot Plant." DOE/EIS-0026. Washington, DC: U.S. Department of Energy

15. PECOS Management Services, Inc. 2008. "An Evaluation of the Health and Safety Risks Resulting from Repackaging TRU Waste for Disposal at WIPP" Albuquerque, NM.

16. U.S. Environmental Protection Agency (EPA). 1998. “40 CFR Part 194: Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant’s Compliance with the Disposal Regulations: Certification Decision; Final Rule.” Federal Register.

17. Letter, Reyes to Moody, March 7, 2008, DOE’s Request for an Indefinite Extension in the Testing of Passive Institutional Controls.