Building a Credible and Updated WIPP Performance Assessment - New Knowledge Versus Conservative Assumptions and FEP Analysis, A Balancing Act

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ABSTRACT

Conservative assumptions are important components in conceptual model development where limited data is available. And, as appropriate, during the early 1990's Department of Energy (DOE) adopted many conservative assumptions in the development of the Waste Isolation Pilot Plant's (WIPP's) 24 Conceptual Models incorporated in DOE's 1996 Compliance Certification Application (CCA) performance assessment (PA). Many of these assumptions were formulated and documented in the WIPP relevant features, events and processes (FEPs) analyses; others were adopted when developing input parameter values and their distributions that were used as inputs to computer models.

The Agency accepted these conservative assumptions during their 1996 CCA assessment for several reasons; 1) at the time there was a scarcity of data related to long-term behavior of many parameters needed to be incorporated in the PA, 2) sensitivity studies performed during this time period determined that the affected 'conservative' assumptions adopted for some parameters had minimal to no impact on repository performance; and, 3) DOE could demonstrate compliance with EPA's radioactive waste disposal regulations while adopting conservative assumptions and data.

Since the initial 1996 CCA DOE has modified the repository panel closure design, and the repository footprint in the experimental areas has expanded. These modifications were incorporated into DOE's 2014 Compliance Recertification Application for WIPP. Additionally, there have been numerous investigations related to both the short- and long-term behavior of salt in a repository setting. As a result, the Agency is reassessing the use of these conservative assumptions and the continued applicability of the original FEP analyses, primarily developed during DOE's 1996 PA and carried forward to the current recertification. This paper examines some of these analyses.

Introduction

The Waste Isolation Pilot Plant (WIPP) facility is the nation's only deep geologic repository for the disposal of defense-related transuranic nuclear waste. The repository is located in southeastern New Mexico and excavated in a 280-million-year old bedded salt deposit of the Delaware Basin and (Figure 1).
The design includes ten waste panels; each panel has two access drifts.

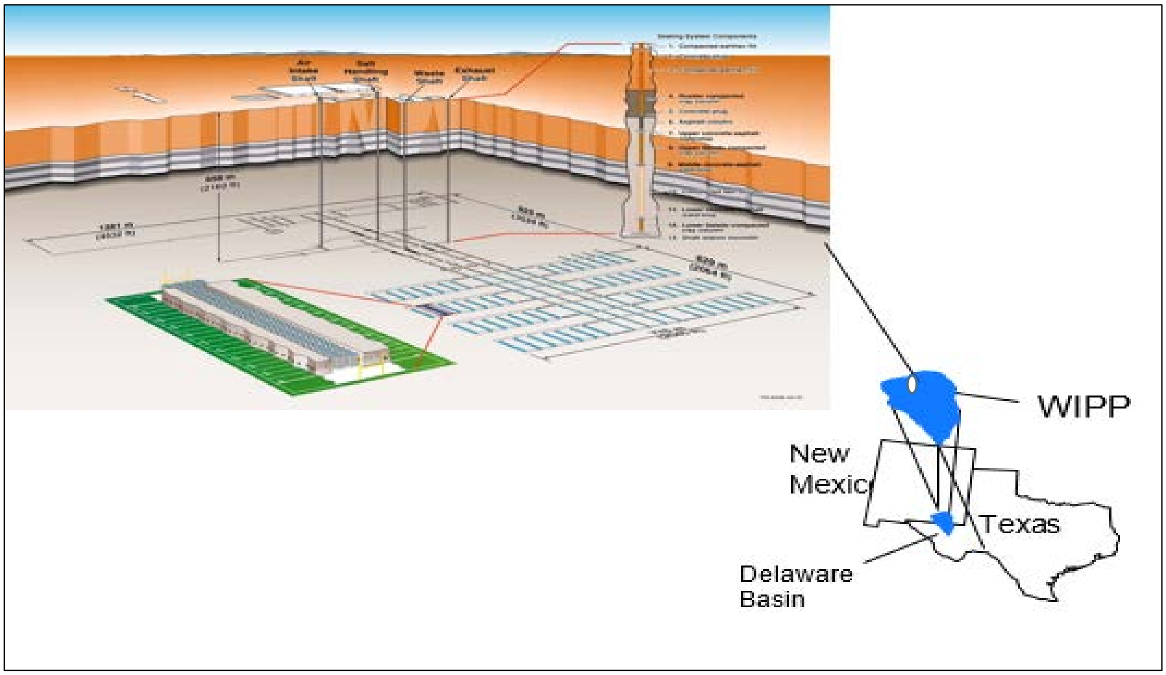

Fig. 1. Location of WIPP repository within the Delaware Basin in southeastern New Mexico

The Department of Energy (DOE) operates and manages the repository. The 1992 Land Withdrawal Act (LWA) gives the Environmental Protection Agency (EPA) the regulatory authority to assure the repository falls within regulatory limits over the 10,000-year regulatory period. The regulations require that a description of the time-varying components in the repository system, such as waste characteristics, geology, hydrology, and geochemistry be included in a set of Performance Assessment (PA) calculations. Future events acting on the system as a whole also need to be included. These features, events and processes are denoted as FEPs.

In 1996 the DOE submitted a Compliance Certification Application (CCA) PA to the EPA to operate the facility. The PA consisted of 24 Conceptual Models that were built on an extensive FEP screening process. Values for input parameter were sampled from probability distributions. These distributions were developed to capture uncertainties in parameter values over the modeled time frame.

The complexity of building these models required them to be first broken down into smaller units that, when combined together, build a scientifically defensible overarching PA model. These smaller units were developed using unique FEP screening calculations which can be considered as ‘micro’ conceptual models. The outcome of each FEP exercise was to determine whether a FEP was to be incorporated into one of the 24 primary ‘Conceptual Models’. The FEP ‘micro-models’ are like jig-saw puzzle pieces with notches and nobs on all sides that, when fit together, build the bigger conceptual model. The inputs to the CCA FEP calculations incorporated available data or/and observations. Of course, not everything about the repository system was known at the time of the submittal, or will ever be known for that matter. When data was limited assumptions were adopted to derive values and distributions. The outliers of these distributions were justified, in part, by promoting greater releases and thus deemed as conservative. If the outcome impacted the model results and promoted more releases, the FEP, including its underlying assumptions, was included in the PA model. If the outcome minimally impacted releases the FEP was excluded from the model.

The conceptual model development process started in the early 1980s and was a very intense and laborious effort within the geoscience community. The end-product micro-models were incorporated into the 24 Conceptual Models included in DOE’s first CCA PA submitted to EPA in 1996. After some modifications the EPA approved the 24 Conceptual Models in 1998. This approval included reviewing and assessing the ‘reasonableness’ and justifications of the conservative assumptions incorporated into each model given the available information. WIPP received its first waste in 1999.

The LWA requires WIPP to be recertified every five years after the first emplacement of waste. The Compliance Recertification Application (CRA) must incorporate any new and updated information related to the repository system that has occurred since the last recertification. There have been three WIPP CRA PAs submitted by DOE to EPA since 1998. The first two were submitted in 2004 and 2009 and incorporated relatively minor updates to the 1998 CCA PA. The most recent CRA PA was submitted by DOE in March of 2014. Of the three CRAs, the 2014 CRA PA has the most significant changes because two major features of the repository have been modified.

The most significant ‘feature’ modification was that made to the panel closure system (PCS) design used to close and separate the waste panels. The 1998 CCA panel closure design included a rigid ‘toed-in’ concrete monolith/explosion wall, denoted as the Option D Concrete Monolith design. The new 2014 CRA design did away with the rigid cement structures and use a closure system composed of initially loose run-of-mine (ROM) salt. Both designs are depicted in Figure 2.

The second major change in to the repository was an approximately 60% increase in the volume of the experimental and operational areas mined north of the waste panels. The increase footprint of the experimental area is depicted on the right of Figure 3.

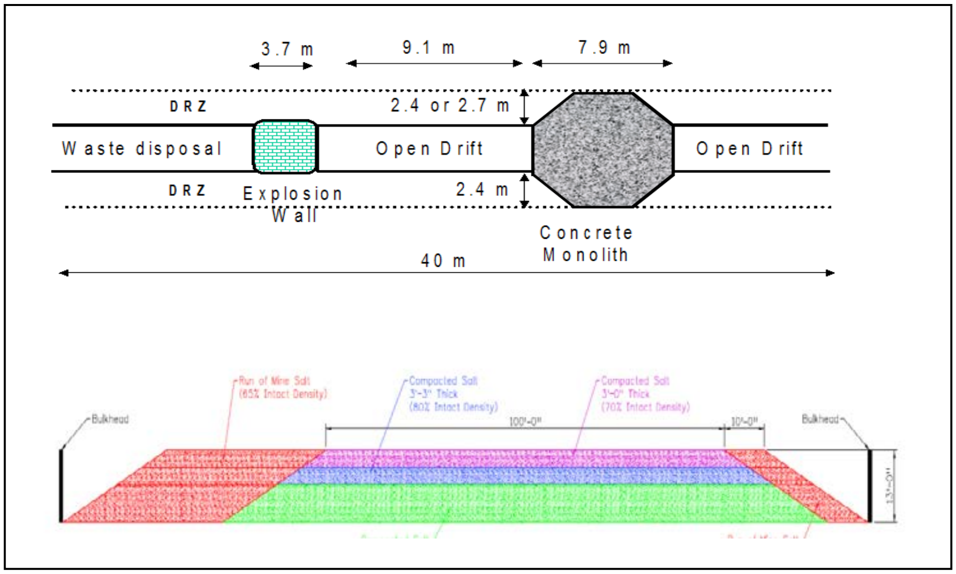

Fig. 2. Concrete Monolith/Explosion Wall (top) and ROM Salt (bottom) Panel Closure Designs.

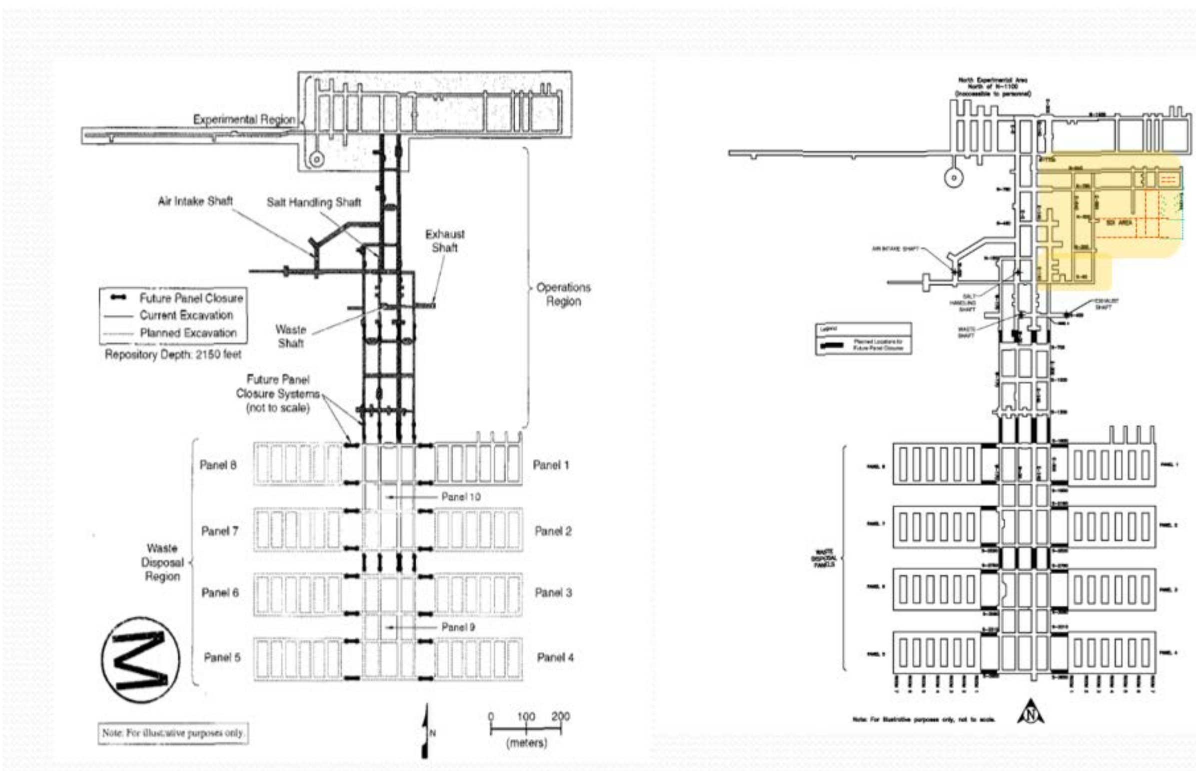

Fig. 3. WIPP repository footprint (left) as planned in 1996; expanded experimental area (in yellow) footprint added in 2014 PA.

DISCUSSION

The Agency is currently undergoing a review of DOE's 2014 CRA PA. The long-term behavior of the panel closures and experimental areas have inputs and assumptions adopted as far back as the mid-1990s and may not be aligned with updated empirical data and observations. For this reason, the Agency is reviewing their respective inputs, and whether 'conservative' assumptions developed in earlier PAs and are explicitly or implicitly adopted in this 2014 CRA PA, are appropriate given the changes to the repository design.

Reassessed Assumption 1 - The healed halite Disturbed Rock Zone (DRZ) permeability and porosity adjacent to the panel closures is modeled as if it was anhydrite that has higher permeability than the halite.

The WIPP is primarily excavated 655 m below the surface in a thick halite layer containing clay and thin interbedded anhydrite layers located approximately 12-m above 2.5-m below it [1]. Excavating an opening in the salt locally perturbs the *in-situ* equilibrium deviatoric stresses that cause fracturing in the rock surrounding the excavated opening. Once an opening is excavated, the process of creep closure acts on the open excavated faces, creating both micro and macro fractures that extend a few meters into the host rock. This fractured region is called the Disturbed Rock Zone (DRZ); in Europe it is often referred as the Excavated Disturbed Zone (EDZ). The fractures increase permeability and enlarge porosity adjacent to the excavated region. Soon after excavation lithostatic stresses are imposed on the excavated areas. This decreases deviatoric stresses and begins healing of the halite. This self-healing process in salt is an advantageous feature that promotes its use to store nuclear waste.

During the development of the CCA there was much uncertainty regarding the permeability and porosity values of the DRZ as it goes through the healing process. Consequently, a conservative assumption was adopted that the DRZ adjacent to excavated openings, including the panel closure drifts, would retain a relatively high permeability (10^{-15} m^2) for the entire modeled period. The assumption created an ongoing connected path between all the excavated areas via the DRZ enabling more brine to contact and dissolve waste and potentially produce more gas to be generated via corrosion and microbial activity. In 1996 this assumption adopting a constant high permeability was modified, per the Agency's direction, so that the DRZ permeability changed from a relatively high constant value to a distribution intended to capture a more realistic representation of the healed DRZ but still incorporated uncertainties in that distribution. The modified permeability ranged between $10^{-12.5}$ and $10^{-19.4}$ m^2 and was intended to capture uncertainties in what would be the permeability of a 'healed' DRZ. This distribution was intended to acknowledge both assumptions and uncertainties, these were: 1) the halite DRZ will heal, 2) the variability as to what healed end-point DRZ permeability would be, and 3) a healed DRZ may still include fractures, specifically in the anhydrite layers.

With the Option D Concrete monolith panel closure design, the halite DRZ was to be mined out above and below the closures to the adjacent anhydrite layers. Because the concrete monolith had a permeability and porosity that was similar to that of anhydrite layers, the DRZ permeability adjacent to the panel closures was assumed to be same as the concrete monolith, creating a situation where flow between the DRZ and the monolith would act as a unified seal 'system' unit [2].

Laboratory and field experiments conducted over the last 20 years indicate halite DRZ will readily heal due to multiple mechanisms. The most obvious is when compressive stresses act upon it, reducing porosity and closing fractures [3]. Other important processes are fluid assisted diffusion transfer and pressure dissolution and re-precipitation. Fluid assisted diffusion transfer occurs when the salt surface contains as little as 1 % wt. moisture or when the surface is exposed to small amounts of humidity. The process was initially observed by Speirs et al. [4] and has been subsequently observed and reported by others [5] [3].

Given this updated information, the both the Agency and DOE believe the halite DRZ adjacent to the ROM salt panel closures will heal within a few hundred years after closure [3] [5]. Within a few decades after closure the ROM PCS will act as a rigid body and produce backpressures on the adjacent DRZ surfaces and cause its fractures to close and heal. Concurrently, as the fractures close, small amounts of brine would be expected to promote additional healing due to fluid assisted diffusion transfer. Creep closure will continue to impose compressive stresses between the halite DRZ and ROM PCS. The DRZ endpoint permeability may be aligned with those of intact halite.

In the 2014 CRA the DRZ adjacent to the PCS has the same end-point permeability as was implemented in the both 2004 and 2009 CRA, and which are the same as anhydrite permeability. It appears the older conservative assumption has been implicitly adopted by assuming the healed halite DRZ end-point permeability will be the same used for anhydrite. Anhydrite is brittle, contains micro-fractures, and has a permeability that is several orders of magnitude higher than halite. The end-point permeability and porosity values assigned to the healed halite DRZ in the 2014 CRA PA may implicitly incorporate older conservative assumptions related to the healed halite DRZ. Current empirical data suggests that end-point values for a healed halite DRZ may be closer to *in-situ* halite than anhydrite. Therefore, the Agency has requested DOE carry out a set performance assessment sensitivity study calculations assuming the healed halite DRZ, adjacent to the panel closure system, is represented by permeability similar to halite. This study, in part, will incorporate information from updated empirical data that suggests halite DRZ will heal to porosity and permeability values representative of *in-situ* halite, and tests the effect of a healed PCS DRZ on the long-term performance of the repository.

Reassessed Assumption 2 – Modeling creep-closure of the non-waste areas will not impact repository performance.

There is no dispute that the non-waste rooms will close within a few hundred years. In 1995 the DOE conducted a FEP screening calculation to determine whether modeling creep closure of the repository non-waste rooms would impact repository performance. There were still many unknowns related to what repository features and processes would need to be included in the overall PA model. Conservative parameter values were incorporated in numerous FEP modeling exercises intended to promote greater releases. In this exercise the synergistic representation of a process, such as creep closure acting on the whole repository, was not modeled. The non-waste rooms were as modeled as creep closing over a 200-year period, with permeability a function of the gradually reduced room porosities. In this FEP exercise the effects of creep-closure reducing permeability and porosity was modeled in the non-waste area but not modeled in adjacent regions, such as the adjacent DRZ or panel closures. It was assumed that creep closure would not act on the adjacent DRZ or panel closures to reduce porosity and permeability. The end-point derived permeability, at 200 years, was 10^{-20} m^2, similar to that of intact halite; intact halite permeability ranges between 10^{-21} m^2 and -24 m^2. Permeability for the DRZ was assigned a constant value of 10^{-15} m^2, the value for panel closures permeability was 10^{-12} m^2. These values were considered conservative because they promoted brine and gas flow between all regions of the repository, yet impeded flow in the non-waste panels, and tested whether modeling the non-waste areas as ‘creep-closed’ would affect repository performance.

In the 1995 time-frame there was several uncertainties in the repository design, 1) the panel closure design hand not been finalized and 2) it was unknown how the non-waste rooms would be closed once the underground experiments were completed. These two uncertainties were incorporated into the FEP screening calculations, and were considered acceptable and reasonable by EPA. Now, approximately 20 years later, there are multiple differences in the repository design, the panel closures system design has been finalized, the non-waste area is approximately 60% greater, and there are differences in the computational grid. The Agency has reviewed the inputs used in the 1995 FEP screening to determine whether they reasonably represent current repository conditions and would they still be considered reasonably conservative. As a result of this review the Agency has requested DOE carry out a set of calculations modeling creep-closure of the now bigger non-waste rooms. The results will be used to determine whether the assumption that creep-closing the non-waste areas has minimal to no impact on the overall WIPP PA.

CONCLUSIONS

In performance assessments for WIPP, DOE has used conservative assumptions and EPA accepted them because 1) there was little data available to be used as inputs, 2) the outcome made little difference in the results, or 3) adopting the outcome overestimated releases but the results were still is within a ‘safety envelope’. Examples of conservative assumptions that were adopted in the mid-1990s related to the long-term permeability and porosity of the non-waste rooms, and the DRZ adjacent to the panel drifts and closure system. Many of these conservative assumptions were part of an early FEP screening process used to determine some of the specific components that should be incorporated into the 1996 WIPP CCA. Since the mid-1990s there has been new data collected at WIPP and elsewhere that is relevant to the repository.

As part of the EPA review of the 2014 CRA, the EPA is requesting DOE to perform sensitivity studies using updated parameter values related to creep-closure of the experimental area, flow properties of the ROM panel closure system, and the adjacent DRZ. The exercise will help EPA determine whether and how these older conservative assumptions, and affiliated FEP screening results, should be updated to reflect more current information.

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