WIPP PERFORMANCE ASSESSMENT: EFFECTS OF AN OPERATIONAL INCIDENT ON LONG-TERM REPOSITORY PERFORMANCE

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Summary

An APCS (Abandonment of Panel Closures in the South) assessment was developed to quantify the impacts of an operational policy change to not emplace panel closures and waste in specific areas of the Waste Isolation Pilot Plant (WIPP) repository. The long-term repository performance assessment (PA) was performed within the currently approved PA framework in which the southernmost panel closure area (between the waste panel (WP) and south rest-of-repository (SROR)) was effectively removed as a barrier. Because of limitations in the current conceptual model and code framework, explicit modeling of an open Panel 9 without waste was not performed; instead, a quantitative argument for the conservatism (with respect to releases) of including waste in Panel 9 was provided. A reassignment of panel neighbor relationships was also implemented when evaluating the probabilistic future events for consistency with the modified repository configuration. Increased releases are shown for most release mechanisms. The increased communication between the WP and SROR areas allows for greater brine pressures and saturations in the SROR following borehole intrusions that intersect the Castile brine reservoir, as there is no longer a significant barrier to equilibration with the WP. The increased pressures and saturations lead to increases in calculated direct brine releases (DBRs) and releases to/from the Culebra and increased pressures lead to increased spallings releases. Overall, total high-probability (P[Release>R] = 0.1) predicted mean releases from the repository were increased by about 72%. Total low-probability (P[Release>R] = 0.001) predicted mean releases were increased by about 152%. It is concluded that the operational safety considerations resulting in the abandonment of the southern half of the repository result in increases to the predicted total releases from the repository that remain below regulatory limits.

Introduction

The Waste Isolation Pilot Plant (WIPP) located east of Carlsbad, New Mexico, USA, is a U.S. Department of Energy transuranic waste repository that consists of 10 waste panels. The waste panels have historically been designed to be isolated from one other by panel closure systems, with the current design primarily consisting of a 100 ft length of run-of-mine-salt (ROMPCS). Due to events that occurred in February of 2014, operational constraints were placed on the repository that delayed and ultimately prevented the ability to employ the requisite amount of ground control processes necessary to ensure personnel safety in the affected areas. Because of subsequent roof fall events in the affected areas of the repository, an operational safety determination was made to abandon the south end of the repository, not emplace waste in Panel 9, and not emplace ROMPCS between waste Panels 3, 4, 5, 6 and 9.
WIPP performance assessments (PAs) provide estimated cumulative releases from the repository over the 10,000-year regulatory period based on the anticipated repository features at the time of closure. Because the performance of the repository is assessed for only the time period following the termination of repository operations, operational changes typically do not impact WIPP PA. However, the operational change to the panel closure implementation does potentially impact repository performance.

Approach

The Abandonment of Panel Closures in the South (APCS) analysis assesses the impact of not using run-of-mine-salt panel closures (ROMPCS) in Panels 3, 4, 5, 6 and not emplacing waste in Panel 9 (Zeitler et al., 2017). The approach consists of working within the currently approved PA framework; therefore, no consideration is given to conceptual model changes, major code changes, or novel parameter values. The approach consists of three parts: (1) selection of an appropriate baseline calculation for comparison, (2) assessment and appropriate modification of the current representation of panel closure areas and waste in Panel 9 in the model, and (3) assessment of the impact of the southern area’s abandonment on repository performance and comparison with limits set for regulatory compliance.

Baseline Calculation Comparison

The CRA-2014 was submitted to the EPA in March 2014 (USDOE, 2014) and WIPP was recertified in July 2017 (EPA 2017) such that the CRA-2014 PA is the certification baseline. During the EPA’s completeness review of the CRA-2014, the EPA requested that the DOE perform multiple sensitivity studies of repository performance based on EPA-specified parameter changes. The final sensitivity study, CRA14_SEN4, included parameter changes that resulted in increased releases compared to the CRA-2014 results (Zeitler and Day, 2016). To address the anticipated changes and consider the impact of larger potential releases, the APCS analysis uses the CRA14_SEN4 analysis as a comparative reference point.

Abandonment of Panel Closures in South End of Repository

Following a federal rulemaking that supported the use of the run-of-mine salt panel closures (ROMPCS) (USEPA, 2014), panel closures were represented by ROMPCS in the CRA-2014 PA. The operational policy change to not emplace ROMPCS in Panels 3, 4, 5, 6 and not emplace waste in Panel 9 significantly impacts the repository PA.

Representation of Panel Closures in the BRAGFLO AND BRAGFLO_DBR Grids

Panel closures are represented in PA calculations in the computational grids used by the BRAGFLO code. BRAGFLO calculates subsurface brine/gas flow in the repository and the surrounding area over a 10,000-year period using a two-dimensional, “flared” vertical cross section representation of the repository and surrounding area. This grid representation (Figure 1), there are three waste areas: (1) the “waste panel” (WP) represents waste emplaced in Panel 5; (2) the “south rest-of-repository” (SROR) represents waste emplaced in Panels 3, 4, 6, and 9; and (3) the “north rest-of-repository” (NROR) represents waste emplaced in Panels 1, 2, 7, 8, and 10. There are also three panel closure areas (PCS): the “southernmost” PCS representation is between the WP and SROR, the “middle” PCS representation is between the SROR and NROR, and the “northernmost” PCS representation is between the NROR and operations (OPS) area.

Panel 5 has been conservatively selected to represent a single waste panel as the WP in WIPP PA due to its location at the lowest repository elevation from a modeled 1 degree dip in the Salado formation that maximizes brine pressures and saturations. Another consequence of this lumping is that individual panel closures within the SROR and NROR areas (e.g., between Panels 3 and 9 or between Panels 1 and 10) are not explicitly represented in the BRAGFLO grid. Instead, the panel closure for Panel 5 (i.e., the
southernmost panel closure) is a proxy for panel closures between any two adjacent panels in the SROR and NROR areas.

A different grid (Figure 2), the DBR grid, is used for BRAGFLO direct brine release (DBR) calculations. The DBR grid represents, in a two-dimensional planar view, the individual waste panels and their immediate surroundings, including individual panel closures for each waste panel. BRAGFLO_DB calculates flow between the repository and the surface over a 4.5-day period within the 10,000-year regulatory period. The saturation and pressure values for each panel are initialized to averaged saturation and pressure values taken from the BRAGFLO grid; the averaged WP values are mapped to Panel 5, the averaged SROR values are mapped to Panels 3, 4, 6, and 9, and the averaged NROR values are mapped to Panels 1, 2, 7, 8, and 10.

For the planned changes to the configuration of panel closures, both the BRAGFLO "flared" grid and the DBR grid are impacted. Abandonment of the Panel 5 panel closure in the BRAGFLO grid entails representing the southernmost panel closure with material properties that are more permeable than the ROMPCS. In the DBR grid, each abandoned panel closure (i.e., for Panels 3, 4, 5, and 6) is similarly treated with an alternate material specification. However, due to lumping in the BRAGFLO grid, these changes have broader implications. Removing the southernmost panel closure conceptually represents removing the panel closures between any two adjacent panels in the SROR. The pressure and saturation values mapped to the panels in the SROR will be calculated assuming no adjacent panel closures. Removal of adjacent panel closures will allow faster pressure equilibration between panels (i.e., less isolation of panels), which is shown to result in increased calculated releases. This is considered to be a change that is conservative with respect to releases. In this analysis, the southernmost panel closure in the BRAGFLO grid and panel closures for Panels 3, 4, 5, and 6 in the DBR grid are effectively assumed not to exist.

Properties of Open Panel Closures

Because the abandoned panel closures areas will lack backfill or run-of-mine salt, the modeling of the material properties applied to these areas was re-examined. In current PA calculations, there are two areas in the BRAGFLO grid that are modeled as "open," the OPS and EXP areas. They are assumed to close "naturally" following closure of the WIPP, although in PA calculations, constant porosity and permeability over 10,000 years have been assumed (SNL, 1996). In the APCS analysis, material properties for abandoned panel closure areas were changed to be those used for the OPS/EXP areas and given a new material name, PCS_NO.

Use of DBR Scenarios in CCDFGF

The CCDFGF code calculates releases for hypothetical futures that are populated with drilling intrusion events. A typical PA analysis consists of 300 realizations, each of which has 10,000 hypothetical futures. In these futures, drilling intrusions may intersect any waste panel at any time and multiple times. CCDFGF calculates DBR releases from each intrusion event from DBR volumes calculated at a few points in time. Thus, panel lumping and abstraction also enter the CCDFGF calculations, but in terms of the combinatorial problem of what panel was intruded and to which panel(s) it is adjacent.

In BRAGFLO_DB cases, the intruded panel is labeled as lower (L), middle (M), or upper (U) (or same, adjacent, and nonadjacent) and corresponds to first intrusions in Panels 5, 3, and 10, respectively. The BRAGFLO_DB L case is then used by CCDFGF to represent a drilling intrusion event in a future in which the same panel has been previously intruded (the “Same” case in CCDFGF). The BRAGFLO_DB M case is used by CCDFGF to represent a drilling intrusion event in a future in which the most recently intruded panel was adjacent to the panel currently being intruded (the “Adjacent” case in CCDFGF). The BRAGFLO_DB U case is used by CCDFGF to represent a drilling intrusion event in a future in which the
most recently intruded panel was non-adjacent to the panel currently being intruded (the “Nonadjacent” case in CCDFGF).

**Redefinition of Panel Adjacency in CCDFGF**

Panel neighbor relationships were modified for APCS to correspond to degree of separation by panel closures instead of merely spatial proximity. The modification is consistent with the definition that panels having one or fewer panel closures between them are considered neighbors (“Adjacent”). The approach is consistent with the use of panel closures in both the BRAGFLO and BRAGFLO DBR grids and the definitions of SROR and NROR. There is only a single set of panel closures between any of the WP or SROR panels and Panel 10; as a result, all other panels are neighbors of Panel 10. The neighbor relationship update results in an increased number of neighbors for panels in WP and SROR due to the reduced use of panel closures (and thus increased transmissivity between panels).

In the APCS CCDFGF calculations, any selected “Adjacent” case uses DBR results that include the effects of no panel closures between the prior and current intrusions. Furthermore, regardless of whether there are zero or one set of panel closures between neighboring panels, CCDFGF uses the same DBR results that include the effects of a lack of panel closures. Therefore, CCDFGF calculates DBR releases that are conservative with respect to the proposed change in panel closure configurations.

**Figure 1: BRAGFLO “flared” grid for APCS.**
Removal of Waste from Panel 9

The current conceptual model and PA code base is incapable of handling the complexity introduced by removing waste from Panel 9 and relocating the waste to a new panel in the north. However, it is appropriately conservative with respect to releases to continue to model waste within the existing Panel 9 in lieu of adding new waste panel(s) due to the 1-degree (south) dip in the Salado formation, which results in increased brine accumulation due to gravity drainage, increased hydrostatic pressure, and increased gas generation. This conservatism is greatly enhanced due to the abandonment of panel closures, which effectively equilibrates the brine pressures and saturations in the WP and SROR because BRAGFLO_DBG simulates DBR releases for sequential intrusions of adjacent panels only in the south of the repository, but CCDFGF uses those same BRAGFLO_DBG results regardless of whether the adjacent panels are in the south (with no panel closures) or north (with panel closures) section of the repository. This treatment under APCS is exceedingly conservative because the panel closure between Panels 10 and 9 and the panel closures between Panel 10 and Panels 1, 2, 7, and 8 retard flow to subsequently intruded adjacent panels.

Results

Results that illustrate the primary impact of the operational changes regarding abandoned panel closure and waste emplacement are presented. The S2 scenario, which is for an early-time (350 yr) borehole intrusion that intersect a hypothetical Castile brine reservoir, has the primary impact due to increased brine saturations and pressures in the SROR (Panel 3, 5, 6, and 9) which are equilibrated with the WP (Panel 5) due to the lack of panel closures separating the panels. The resultant impact of increased brine saturations and pressures determined from the BRAGFLO Salado flow calculations under S2 drives an increase in the volume of brine released up the intrusion borehole as determined by the BRAGFLO_DBG calculations. The most impacted release mechanisms (direct brine releases, spallings releases) resulting from the increased brine pressures and saturations in the
SROR are presented along with the Total Releases for both APCS and CRA14_SEN4 in comparison with the regulatory release limits.

**Salado Flow (BRAGFLO)**

S2 mean transient responses of brine pressure and saturation are presented in Figure 3 from the three waste regions. In WIPP PA, a replicate consists of 100 calculated realizations. Three replicates were used to generate results for CRA14_SEN4 and APCS.

Brine pressure and saturation increases in the WP are modest but brine pressure and saturation increases in the SROR are substantial due to the pressure-limited flow of brine from the Castile and the enhanced communication between the WP and SROR that leads to pressure equilibration between these areas. Brine saturations in the NROR are reduced because the remaining panel closures effectively restrict brine flow from the SROR to NROR; however, the higher effective permeability of gas allows it to continue to flow north and increase the NROR pressures.

**Direct Brine Release (BRAGFLO_DBR)**

The average volume of direct brine flow up the intrusion borehole under the S2 scenario for CRA14_SEN4 and APCS is summarized in Figure 4. Increased brine saturation due to the abandoned panel closures allows the intruded WP pressures and saturations to equilibrate with the SROR such that later times the lower (L) and all middle (M) intrusions produce greatly increased cumulative flow of brine up the borehole. Upper (U) intrusions result in minimal brine flow due to the lower brine saturation in Panels 1, 2, 7, 8, and 10 that is maintained by the intact panel closures in the north.

**Releases (CCDFGF)**

The impacts of the modifications to APCS results include changes to all of the primary release components, except for cuttings and cavings, including: spallings, direct brine releases, and releases from the Culebra. Plots of APCS releases for the individual release mechanisms are shown in Figure 5. A comparison of the Total releases in Figure 5 illustrate that the planned operational changes under APCS increase both low and high probability releases as compared to CRA14_SEN4.

**Conclusion**

The APCS analysis incorporates a conservative representation of the repository that addresses an operational decision to not emplace panel closures in Panels 3, 4, 5, and 6 and not emplace waste in Panel 9 (that could be located in a new panel to the north). The increased communication between the WP and SROR areas allows for greater brine pressures and saturations in the SROR following borehole intrusions that intersect the hypothetical Castile brine reservoir, as there is no longer a significant barrier to equilibration with the WP. The increased pressures and saturations lead to increases in calculated direct brine releases (DBRs) and releases to/from the Culebra and increased pressures lead to increased spallings releases. Overall, total high-probability (P[Release>R] = 0.1) predicted mean releases from the repository increase by about 72%. Total low-probability (P[Release>R] = 0.001) predicted mean releases increase by about 152%. It is concluded that the operational safety considerations resulting in the abandonment of the southern half of the repository results in a) increases to the predicted total releases from the repository that remain below regulatory limits and b) a modified design of the repository would continue to comply with all regulatory release limits.
Figure 3: Scenario 2 Salado Flow – Brine Pressure and Saturation for Waste Panel, South Rest-of-Repository, and North Rest-of-Repository for APCS and CRA14_SEN4.
Figure 4: Scenario 2 Direct Brine – Average Volume of Brine Release by Intrusion Time and Intrusion Location for APCS and CRA14_SEN4.

Figure 5: Releases – Individual Release Components for APCS (left) and Total Release Comparison for APCS and CRA14_SEN4 (right).

References


