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SANDIA NATIONAL LABORATORIES
WASTE ISOLATION PILOT PLANT

Assessment of Abandoned Panel Closures in South End of Repository and Lack of Waste Emplacement in Panel 9

Revision 0

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Executive Summary

The DOE has requested that SNL undertake calculations and analyses to determine the impacts of proposed changes to the repository configuration, including abandonment of run-of-mine panel closures in Panels 3, 4, 5, and 6 and abandonment of waste emplacement in the area designated as Panel 9, on the long-term performance of the facility. This report provides the analysis approach and presents results of an analysis (**A**bandonment of **P**anel **C**losures in the **S**outh—APCS) that quantifies the impacts of the operational policy change on the long-term repository performance. 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 CRA14_SEN4 analysis is used as a basis for comparison. In the BRAGFLO grid, the southernmost panel closure area (between the waste panel (WP) and south rest-of-repository (SROR)) is effectively removed as a barrier by assigning looser "open area" parameters. In the DBR grid, panel closure areas for Panels 3, 4, 5, and 6 are similarly assigned "open area" parameters. Because of limitations in the current conceptual model and code framework, explicit modeling of an open Panel 9 is not done; instead, a quantitative argument for the conservatism (with respect to releases) of including waste in Panel 9 is provided. For the CCDFGF code, a reassignment of panel neighboring is done for consistency with the modified repository configuration. While cuttings and cavings releases are not impacted by the changes implemented in APCS, increased releases are shown for all other release mechanisms. The increased communication between the WP and SROR areas allows for greater brine pressures and saturations in the SROR following Castile intrusions, 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 approach taken to address the DOE-proposed changes results in increases to the predicted total releases from the repository. However, potential releases calculated in the APCS analysis are below regulatory limits.

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1 Introduction

The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, has been developed by the U.S. Department of Energy (DOE) for the geologic (deep underground) disposal of transuranic (TRU) waste. Containment of TRU waste at the WIPP is regulated by the U.S. Environmental Protection Agency (EPA) according to the regulations set forth in Title 40 of the Code of Federal Regulations (CFR), Part 191. The DOE demonstrates compliance with the containment requirements according to the Certification Criteria in Title 40 CFR Part 194 by means of performance assessment (PA) calculations performed by Sandia National Laboratories (SNL). WIPP PA calculations estimate the probability and consequence of potential radionuclide releases from the repository to the accessible environment for a regulatory period of 10,000 years after facility closure. The models used in PA are maintained and updated with new information as part of an ongoing process. Improved information regarding important WIPP features, events, and processes typically results in refinements and modifications to PA models and the parameters used in them. Planned changes to the repository and/or the components therein also result in updates to WIPP PA models. WIPP PA models are used to support the repository recertification process that occurs at five-year intervals following the receipt of the first waste shipment at the site in 1999.

In February 2014, WIPP was closed and later reopened on a limited basis, which resulted in maintenance delays in the repository. The DOE has proposed an operational policy change at WIPP as a result of the severe ground control issues caused by the maintenance delays. The policy change prohibits personnel access to (with the ultimate goal of withdrawal from) the area in the WIPP underground designated as equivalent Panel 9 (USDOE, 2016). With that change, the planned implementation of run-of-mine salt panel closures (ROMPCS) in Panels 3, 4, 5, and 6 would no longer be possible. Also, waste emplacement in the area designated as Panel 9 would no longer be possible.

At the time of writing the analysis plan for the analysis described here, the DOE was considering a planned change notice (PCN) to the EPA that justifies the decisions to not implement panel closures in Panels 3, 4, 5, and 6 and to not emplace waste in Panel 9 (Zeitler and Day 2017). It is anticipated that a PCN would not require PA results as part of the justification; however, the DOE requested that SNL undertake calculations and analyses to determine the impacts of the proposed changes to the repository configuration on the long-term performance of the facility (USDOE, 2017). This report provides the analysis approach and presents results that quantify the impacts of the operational policy change on the long-term repository performance.

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2 Approach

This analysis assesses the impact of not using ROMPCS in Panels 3, 4, 5, 6 and not emplacing waste in Panel 9. 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. The following sections describe the approaches taken.

2.1 Baseline Calculation Comparison

The CRA-2014 was submitted to the EPA in March 2014 (USDOE, 2014). As part of the recertification application, a PA calculation was performed that included a number of parameter value and computational model changes from the PABC-2009 baseline.[1] 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). At the time of the writing of the analysis plan for the analysis documented here, the EPA had determined that the CRA-2014 was complete and no formal request had been made by the EPA for the DOE to provide a new PA baseline (i.e., through a PABC - Performance Assessment Baseline Calculation - like those performed following CRA-2004 and CRA-2009). In July 2017, the WIPP was recertified following acceptance of the CRA-2014 (based on CRA-2014 calculations) by the EPA as documented in a Federal Register Notice (EPA 2017). Thus, the CRA-2014 PA has become the new baseline. However, it is anticipated that some of the parameter changes investigated in CRA14_SEN4 will become part of the next recertification application performance assessment. To address the anticipated changes and consider the impact of larger potential releases, the current analysis will primarily use the CRA14_SEN4 analysis (but also the CRA-2014 where appropriate) for comparison - all changes discussed in this document will be made with CRA14_SEN4 as a reference point.

2.2 Abandonment of Panel Closures in South End of Repository

Prior to submittal of the CRA-2014, the PCS-2012 analysis investigated the replacement of the plan for "Option D" panel closures with a plan for run-of-mine salt panel closures (ROMPCS) (Camphouse, 2012). Following a federal rulemaking that supported the use of the ROMPCS

[1] In 2012, the PCS-2012 PA investigated changes to the panel closure properties associated with replacing Option D closures with run-of-mine salt closures (Camphouse, 2012). Because that PA was approved by the EPA in a federal rulemaking, it could be considered to be the PA baseline immediately prior to submission of the CRA-2014. However, the CRA-2014 made comparisons to the PABC-2009 as a baseline.

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(USEPA, 2014), panel closures were represented by ROMPCS in the CRA-2014 PA. The proposed plan change, that considers not emplacing ROMPCS in Panels 3, 4, 5, 6 and not emplacing waste in Panel 9, is evaluated in an **A**bandonment of **P**anel **C**losures in the **S**outh (APCS) analysis.

2.2.1 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. In this grid representation (Figure 2-1), 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.

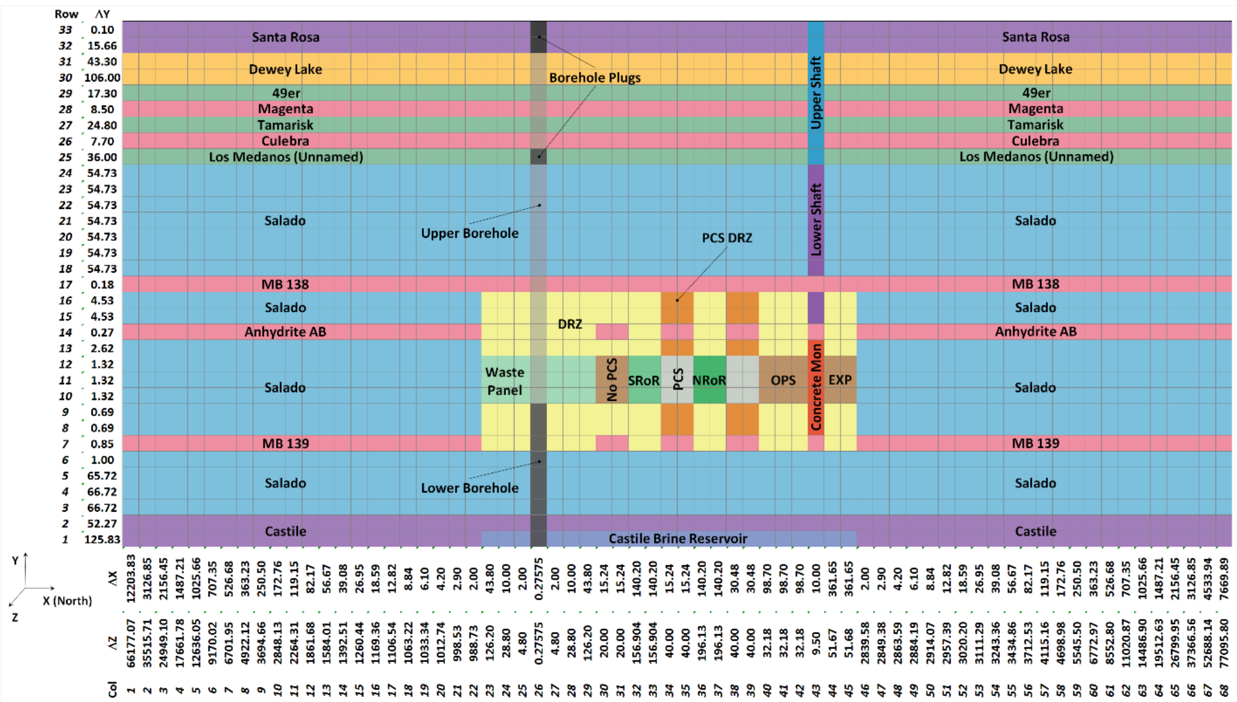

Figure 2-1: BRAGFLO "flared" grid to be used for APCS.

The southernmost panel closure represents a single set of two panel closures (one for each panel entrance) for Panel 5, with a caveat described below. The middle panel closure represents the four closures in the drifts between Panels 9 and 10. The northernmost panel closure represents the four

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closures in the drifts between Panel 10 and the OPS area as well as the four closures in the drifts between the OPS and experimental (EXP) areas.[2]

This lumping of panels and panel closures essentially distills the lateral flow paths available to any individual panel in the repository down to two - the path between a panel and the surrounding formation, and the path between a panel and the "rest-of-repository." Panel 5 has been conservatively selected to represent a single waste panel as the WP in WIPP PA. 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. Finally, this lumping also applies to modeling wellbore intrusion scenarios where initial intrusions into Panel 5 are explicitly modeled and conservatively used to represent initial intrusions into other panels.

A different grid (Figure 2-2), the DBR grid, is used for BRAGFLO direct brine release (DBR) calculations. The DBR grid represents a smaller portion of the repository than the BRAGFLO grid - it represents, in a two-dimensional planar view, the individual waste panels and their immediate surroundings, including individual panel closures for each waste panel. BRAGFLO_DBR calculates flow between the repository and the surface over a 3.5-day period, with different simulations starting at different specified times within the 10,000-year regulatory period. While the ten waste panels are represented individually in the DBR grid, 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.

[2] For CRA-2014, the northernmost panel closure was incorrectly represented as 30.48 m long, which is equivalent to the length of a single drift closure. In CRA14_SEN4, the representation was corrected to 60.96 m in order to represent the length of two drift closures.

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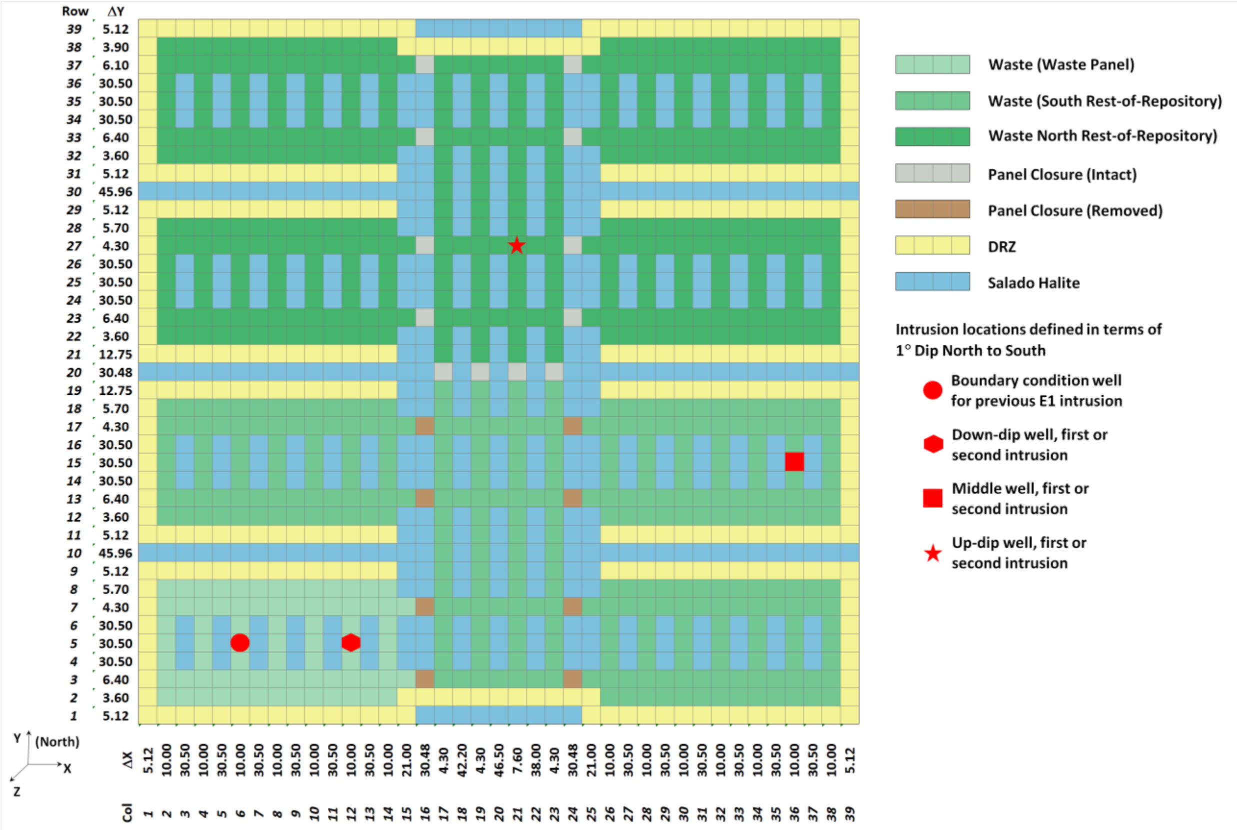

Figure 2-2: BRAGFLO_DBR grid to be used for APCS.

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. Also, since values from the BRAGFLO "flared" grid are mapped onto the DBR grid as initial conditions, 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 (see Section 6.5 below). 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 assumed not to exist.

2.2.2 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 those 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. There

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is no plan to backfill those areas, so they are assumed to close "naturally" following closure of the WIPP. Although the closure of the OPS/EXP areas is expected to occur gradually over time, 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 (i.e., panel closures for Panels 3-6 in the DBR grid and the southernmost panel closure in the BRAGFLO grid) were changed to be those used for the OPS/EXP areas and given a new material name, PCS_NO (Table 2-1). This change is justified in that it is shown to be conservative with respect to releases, and that the properties used for the OPS/EXP areas are the only analogues for open areas used in WIPP PA.[3] Additionally, the DRZ above and below the abandoned panel closure areas retain the properties applied to the DRZ above and below the waste areas and operations and experimental areas (i.e., DRZ_PCS is not invoked at 200 years) (Table 2-2). For the ROMPCS panel closure areas, the same properties used in the CRA14_SEN4 analysis are applied.

[3] An SNL computational study of the change in porosity with time for an empty room subject to creep closure was performed, which resulted in a set of porosity surfaces. However, permeability for such a system was not determined and the porosity surfaces have not been used in PA calculations (Butcher, 1997).

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Table 2-1: Open Panel Closure Properties

Material	Property	Description	Value
PCS_NO	CAP_MOD	Model number, capillary pressure model	1
PCS_NO	COMP_RCK	Bulk Compressibility	0
PCS_NO	KPT	Flag for Permeability Determined Threshold	0
PCS_NO	PCT_A	Threshold Pressure Linear Parameter	0
PCS_NO	PCT_EXP	Threshold pressure exponential parameter	0
PCS_NO	PC_MAX	Maximum allowable capillary pressure	1.0E8
PCS_NO	PORE_DIS	Brooks-Corey pore distribution parameter	0.7
PCS_NO	POROSITY	Effective porosity	0.18
PCS_NO	PO_MIN	Minimum brine pressure for capillary model KPC=3	101325
PCS_NO	PRESSURE	Brine far-field pore pressure	101325
PCS_NO	PRMX_LOG	Log of intrinsic permeability, X-direction	-11
PCS_NO	PRMY_LOG	Log of intrinsic permeability, Y-direction	-11
PCS_NO	PRMZ_LOG	Log of intrinsic permeability, Z-direction	-11
PCS_NO	RELP_MOD	Model number, relative permeability model	11
PCS_NO	SAT_IBRN	Initial Brine Saturation	0
PCS_NO	SAT_RBRN	Residual Brine Saturation	0
PCS_NO	SAT_RGAS	Residual Gas Saturation	0

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Table 2-2: Materials Used for Southernmost Panel Closure Area and Associated DRZ from 0 to 10,000 yr in CRA14, CRA14_SEN4, and APCS[1]

Model Area	CRA14	CRA14_SEN4	APCS
Southernmost Panel Closure Area	PCS_T1 (0-100 yr) PCS_T2 (100-200 yr) PCS_T3 (200-10,000 yr)	PCS_T1 (0-100 yr) PCS_T2 (100-200 yr) PCS_T3 (200-10,000 yr)	PCS_NO
DRZ Above and Below Southernmost Panel Closure Area	DRZ_1 (0-200 yr) DRZ_PCS (200-10,000 yr)	DRZ_PC_1 (0-200 yr)[2] DRZ_PCS (200-10,000 yr)	DRZ_1

Notes:
1 Material properties for a given material are identical across the three analyses
2 Material properties for DRZ_1 and DRZ_PC_1 are identical

2.2.3 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 vectors, 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 by translating and interpolating DBR volumes calculated at a few points in time for a much smaller set of scenarios (Table 2-4). For instance, while CCDFGF models intrusions into any of the ten panels, BRAGFLO_DBR simulations model intrusion events in only three of the ten panels (Panels 3, 5, or 10), and furthermore the BRAGFLO_DBR simulations select their initial conditions from a set of BRAGFLO scenarios (Table 2-3) in which only a single panel (Panel 5, the WP in the BRAGFLO grid)[4] is intruded (or is undisturbed). 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) is it adjacent.

Each BRAGFLO_DBR scenario described in Table 2-4 consists of three pieces of information about the BRAGFLO_DBR simulation: (1) the initial conditions of the BRAGFLO_DBR simulation, (2) which panel is intruded during the simulation, and (3) the time of the intrusion. The initial conditions are taken from BRAGFLO simulation output from different BRAGFLO scenarios - S1-DBR selects its initial conditions from the BRAGFLO S1-BF (E0 undisturbed) scenario, while scenarios S2-DBR through S5-DBR select their initial conditions from BRAGFLO scenarios S2-BF through S5-BF (in which the WP has been previously intruded - this is the “initial” intrusion that is referred to in Table 2-4). The panel intruded in the BRAGFLO_DBR simulation is labeled as lower, middle, and upper, or same, adjacent, and nonadjacent, and in both cases corresponds to Panels 5, 3, and 10, respectively. The terms same, adjacent, and nonadjacent refer

[4] Panel 5 is chosen as the intruded panel because the down dip of the repository presumably will lead to the highest brine concentrations there, which would lead to greater gas generation and potentially maximize releases.

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to the position of the intruded panel with respect to Panel 5, the WP.[5] Lastly, the time of the intrusion specifies the time at which the initial conditions are selected from the corresponding BRAGLO scenario simulation. Thus, for BRAGFLO_DBR scenarios S2-DBR through S5-DBR (Table 2-4), three cases are run at each of the five intrusion times: Lower (L), Middle (M), and Upper (U). The L case corresponds to a first intrusion in Panel 5 followed by a subsequent intrusion in Panel 5. The M case corresponds to a first intrusion in Panel 5 followed by a subsequent intrusion in Panel 3. The U case corresponds to a first intrusion in Panel 5 followed by a subsequent intrusion in Panel 10.

Table 2-3: BRAGFLO Scenarios

Fundamental Scenario	Specific Scenario	Time of Drilling Intrusion(s)
E0: no drilling intrusions	S1-BF	N/A
E1: single intrusion through an excavated area of the repository that penetrates pressurized brine in the Castile.	S2-BF	350 years
	S3-BF	1,000 years
E2: single intrusion through an excavated area of the repository that does not penetrate pressurized brine in the Castile.	S4-BF	350 years
	S5-BF	1,000 years
E1E2: two intrusions into the same waste panel, the first being an E2 intrusion and the second being an E1 intrusion.	S6-BF	1,000 years for E2 intrusion 2,000 years for E1 intrusion

[5] Same, adjacent, and nonadjacent are primarily terminologies utilized in CCDFGF, but introduced in the DBR discussion to illustrate the correlation between lower, middle, and upper panel references.

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Table 2-4: BRAGFLO-DBR Scenarios

Scenario	Description
S1-DBR	*Initially undisturbed repository (i.e., E0 conditions).* Intrusion into lower, middle, or upper waste panel at 100; 350; 1,000; 3,000; 5,000; or 10,000 years: 18 combinations.
S2-DBR	Initial E1 intrusion at 350 years followed by a second intrusion into the same, adjacent, or nonadjacent waste panel at 550; 750; 2,000; 4,000; or 10,000 years: 15 combinations.
S3-DBR	Initial E1 intrusion at 1,000 years followed by a second intrusion into the same, adjacent, or nonadjacent waste panel at 1,200; 1,400; 3,000; 5,000; or 10,000 years: 15 combinations.
S4-DBR	Initial E2 intrusion at 350 years followed by a second intrusion into the same, adjacent, or nonadjacent waste panel at 550; 750; 2,000; 4,000; or 10,000 years: 15 combinations.
S5-DBR	Initial E2 intrusion at 1,000 years followed by a second intrusion into the same, adjacent, or nonadjacent waste panel at 1,200; 1,400; 3,000; 5,000; or 10,000 years: 15 combinations.

The BRAGFLO_DBR 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). For example, if an intrusion in Panel 10 followed a previous intrusion into Panel 10, then results from the L case (which were actually calculated for the more conservative case in which Panel 5 is intruded twice) would be used.

The BRAGFLO_DBR 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). For example, if an intrusion in Panel 10 followed a previous intrusion into Panel 8 (which is adjacent to Panel 10; see Section 2.2.4 below), then the M case results (which were actually calculated for the more conservative case in which Panel 3 is intruded after Panel 5) would be used.

The BRAGFLO_DBR 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). For example, if an intrusion in Panel 10 followed a previous intrusion into Panel 3 (which is not adjacent to Panel 10; see Section 2.2.4 below), then the U case results (which were actually calculated for the more conservative case in which Panel 10 is intruded after Panel 5) would be used.

2.2.4 Redefinition of Panel Adjacency in CCDFGF

Version 6.02 (and previous versions) of the CCDFGF code specified 144 model node locations for drilling intrusions, which corresponded to 14 locations per panel for Panels 1-8 and 16 locations each for Panels 9 and 10 (Figure PA-11 in Appendix PA, 2014). For a given intrusion into the repository, a node was chosen at random with equal probability. Node-to-Panel correlations and "panel adjacency" (the adjacent or non-adjacent relationship between panels) were specified explicitly in the CCDFGF code (i.e., were "hard-coded"). As explained above, panel adjacency is

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relevant to the calculation of DBRs. The CCDFGF code version 6.0 was used in CRA-2014 calculations.

Table 2-5: Listing of adjacent panel ("neighbor") relationships for CRA14_SEN4 and APCS

Panel	CRA14_SEN4	APCS
1	2, 10	10
2	1, 3, 10	10
3	2, 4, 9	4, 5, 6, 9, 10
4	3, 9	3, 5, 6, 9, 10
5	6, 9	3, 4, 6, 9, 10
6	5, 7, 9	3, 4, 5, 9, 10
7	6, 8, 10	10
8	7, 10	10
9	3, 4, 5, 6, 10	3, 4, 5, 6, 10
10	1, 2, 7, 8, 9	1, 2, 3, 4, 5, 6, 7, 8, 9

Beginning with CCDFGF v. 7.00, the use of node locations for intrusions was replaced with the use of panel locations, with panel probabilities specified at run-time via relative panel areas in the CCDFGF control file (WIPP PA, 2010).[6] Panel adjacency is handled by specifying immediate (i.e., adjacent) neighbors for each panel in the CCDFGF control file. The definition of panel adjacency used in CRA14_SEN4 (which used CCDFGF v. 7.02) is the same as that used in the CRA-2014 described in (Table 2-5).[7] For example, Panel 1 had Panels 2 and 10 as neighbors and Panel 5 has Panels 6 and 9 as neighbors.

In the current analysis, panel neighbor relationships were modified to correspond to degree of separation by panel closures (Table 2-5) 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. 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 (see Section 2.2 above).

The neighbor relationship updates (Table 2-5) manifest themselves in two ways: (1) decreased number of neighbors for Panels 1-8 due to no longer counting adjacencies across pure halite; and (2) increased number of neighbors for panels in WP and SROR due to the reduced use of panel closures (and thus increased transmissivity between panels). Panels that are separated from each

[6] As part of the process for migrating WIPP PA codes from the Alpha/VMS system to the Solaris system, the use of CCDFGF v. 7.02 was regression tested against CRA-2014 calculations with panel probabilities given as 14/144=0.09722222 for Panels 1-8 and 16/144=0.11111111 for each of Panels 9 and 10. Panel adjacency was specified in input control files to correspond exactly to that which had been "hard-coded" in v. 6.02 (and previous versions) of CCDFGF.

[7] For CRA14_SEN4, actual panel areas (rather than fraction of node locations) were used to calculate panel probabilities (Schreiber, 1991).

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other by a single set of panel closures are considered neighbors ("Adjacent"). As an example of the first type of update, Panel 1 now only has one neighbor, Panel 10 (but not Panel 2). As an example of the second type of update, Panel 5 is now neighbors with Panels 3, 4, 6, 9, and 10. 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.

As a logical extension of the updated panel neighbor relationships, the question may arise as to whether the WP and SROR areas should be modeled as a single, combined panel. That would entail, for CCDFGF calculations, treating successive intrusion into any two of Panels 3, 4, 5, 6 and 9 as the "Same" instead of "Adjacent." For this analysis, panels were not combined in order to preserve flexibility in the model because there exists uncertainty in the evolution of the "open areas" where panel closures were previously planned to be inserted. On one hand, if the open areas close relatively quickly and compact tightly (such that they behave as run-of-mine salt panel closures), then the true neighbor adjacency of those panels will have properly been preserved.[8] If, on the other hand, the open areas close slowly and compact loosely (such that they provide little barrier to brine and gas flow), then results from the "Same" and "Adjacent" BRAGFLO_DBR cases will be similar because, in the BRAGFLO_DBR simulations, Panels 3, 4, 5, 6 and 9 will behave as a single, large panel. Thus, in the CCDFGF calculations, any selected "Adjacent" case uses DBR results that include the effects of a lack of panel closures. Furthermore, regardless of whether there is 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.

2.3 Removal of Waste from Panel 9

Removal of waste from Panel 9 and relocation of waste to a new panel somewhere north of Panel 8 in the repository is expected to increase overall DBR releases by an amount equal to DBR releases from similar panels in the NROR. The expected increase is anticipated due to an increase in the probability of intersecting a panel (i.e., on the order of a 10% increase). This estimation assumes that radioactively contaminated brine could migrate to and accumulate in panels without waste. Cuttings and cavings releases are expected to be unaffected by removal of waste from Panel 9 and relocation to the north as both are directly related to the presence of solid waste material within the area in question. Due to a reduction in brine saturation and associated gas generation-driven pressures in the NROR as compared to the SROR and WP, spallings are expected to be reduced by removal of waste from Panel 9 and relocation to the north.

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. Firstly, CCDFGF does not allow individual release mechanisms to separately be turned on/off

[8] In this case, some of the neighbor designations (e.g., Panels 5 and 9) would no longer be consistent with the updated definition of panel adjacency. However, the result can be considered conservative with respect to releases, since "Adjacent" DBR results would be used in place of "Non-Adjacent" DBR results.

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within a panel. Additionally, the BRAGFLO grid and CCDFGF codes are currently limited to conceptually representing all waste panels as a grouping of lower, middle, and upper panels. With radially concentric flow being a central tenet of the Salado Flow conceptual model, inclusion of a fourth grouping of panels to represent a new panel that is not symmetrically configured with respect to the existing panels is not possible.

Even with the above discussed conceptual model and code limitations, 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) to the north. The conservatism is attributed 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 due to corrosion (enabled by the increased availability of brine) at the deeper/south portion of the repository. Previous PA analyses consistently show increasing brine saturations and pressures in the repository when moving from the north to the south. Thus, continuing to model the same mass of waste as if it is located in Panel 9 results in somewhat larger DBR and spallings releases compared to if the same mass was relocated to an arbitrary location further north.

In the APCS analysis, this conservatism is greatly enhanced due to the abandonment of panel closures between Panels 3, 4, 5, 6, and 9, which effectively equilibrates the brine pressures and saturations in Panels 3, 4, 5, 6, and 9. This result is appropriate when modeling DBR releases from panels in the south due to the lack of separating panel closures. However, it represents a major source of conservatism when modeling DBR releases from panels in the north that have intact panel closures. This is because BRAGFLO_DBR simulates DBR releases for sequential intrusions of adjacent panels only in the south of the repository, but CCDFGF uses those same BRAGFLO_DBR results regardless of whether the adjacent panels are in the south (with no panel closures) or north (with panel closures) section of the repository. For example, a CCDFGF future that encounters an initial brine intrusion into Panel 10 followed by a subsequent intrusion in Panel 1, 2, 7, 8, or 9 uses DBR releases from an "Adjacent" release case due to the modification of Panel 10 neighbor relationships. 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 do not allow brine pressures and saturations in the initially intruded panel to readily equilibrate with that of the subsequently intruded panel. Additional discussion of the conservatism in DBRs can be found in Appendix A.

An important product of the analyses is that the conservatism associated with representing adjacent intrusions in the north is shown to more than compensate for the non-conservatism associated with not addressing the probability of DBR release from a new Panel 9 replacement in the north rest-of-repository (see Section 5 and Appendix A).

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3 Code Execution

Run control documentation of codes executed in the APCS analysis is provided in Section 11 of this report. This documentation contains:

1. A description of the hardware platform and operating system used to perform the calculations.
2. A listing of the codes and versions used to perform the calculations.
3. A listing of the scripts used to run each calculation.
4. A listing of the input and output files for each calculation.
5. A listing of the library where each file is stored.
6. File naming conventions.

Results obtained in this analysis are compared to those acquired in the CRA-2014 PA and the CRA14_SEN4 sensitivity study. Documentation of run control for results calculated in the CRA-2014 PA is provided in Long (2013). Similarly, documentation of run control for results calculated in the CRA14_SEN4 sensitivity study is provided in Zeitler and Day (2016). Documentation of run control for the STEPWISE sensitivity analysis performed as part of the CRA14_SEN4 sensitivity study is provided in Zeitler and Sarathi (2017a).

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4 BRAGFLO Calculations

This section describes the changes between the APCS and CRA14_SEN4 analyses that are relevant to the flow of brine and gas in the vicinity of the WIPP repository over a 10,000 year regulatory compliance period. The results of these calculations are used by other codes to calculate potential radionuclide releases to the accessible environment. For a more complete description of the Salado flow computational procedures, refer to the CRA-2014 Salado flow analysis package document (Camphouse 2013).

4.1 Introduction

The Salado flow analysis approach implemented for APCS deviates slightly from the CRA14_SEN4 through the use of modified material parameters in the abandoned panel closure areas (PCS_NO) and associated DRZ areas above and below the PCS_NO areas, as provided in Section 2.

4.2 Results

Salado flow results obtained after replacement of the PCS_T1, PCS_T2, and PCS_T3 material with the PCS_NO material in the southernmost panel closure area of the BRAGFLO grid are now presented and compared to those obtained in the CRA14_SEN4 sensitivity study. Results are discussed in terms of overall means. Overall means are obtained by forming the average of all realizations obtained for a given quantity and scenario. In WIPP PA, a replicate consists of 100 calculated realizations. Three replicates were used to generate results for CRA14_SEN4 and APCS. Means and statistics presented for the analyses are also calculated over all three replicates.

Results are presented for the undisturbed scenario S1-BF. Results associated with intrusions are presented for scenarios S2-BF and S4-BF, as these are representative of the intrusions considered in scenarios S3-BF and S5-BF, respectively, with the only differences being the timing of drilling intrusions. Results from BRAGFLO scenario S6-BF are also discussed. In the results that follow, summary statistics and plots were generated with Python, an open-source software package.

4.2.1 Pressure

The utilization of the PCS_NO material, with relatively high porosity and permeability values to represent the abandoned panel closures in Panels 3, 4, 5, and 6, facilitates an increase in brine and gas flow between the waste panel and the south rest-of-repository. In addition, for intruded scenarios, it facilitates communication between the borehole and connected waste regions (waste panel and south rest-of-repository).

Plots of mean brine pressure for the experimental area, operations area, and north rest-of-repository are shown in Figure 4-1 to Figure 4-12. When compared to CRA14_SEN4, the abandoned panel closures introduce only a small change in OPS/EXP and NROR pressures for the undisturbed (S1-BF) and E2 (S4-BF) intrusion scenarios because these areas are more isolated from the southern repository areas by the middle and northernmost panel closures. However, due to the substantial increase in brine saturation in the waste panel and south rest-of-repository (see Section 4.2.2) and the associated increase in gas generation under the reported scenarios with an E1 or E1E2 intrusion

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(S2-BF and S6-BF), pressures in the OPS/EXP and NROR are substantially increased in comparison to CRA14_SEN4.

The lack of ROMPCS panel closures between the south rest-of-repository (Panels 3, 4, 6, and 9) and the waste panel (Panel 5) facilitates pressure equilibration between these areas under each scenario as shown in Figure 4-13 to Figure 4-20. In the S1-BF scenario, the pressure in the SROR is very slightly increased and the pressure in the smaller (by volume) WP is decreased to accommodate the pressure equilibration. Without the intact southernmost panel closure, the 1-degree Salado dip results in brine migration from the SROR southwards which accumulates in the WP and results in increased brine saturation and associated gas generation that is then communicated back to the SROR. A similar process occurs under the S4-BF scenario, but the increased communication of the WP and SROR with the intruded borehole facilitates additional flow of brine and gas up the borehole to the marker beds and contributes to a small decrease in pressure for both WP and SROR waste areas in comparison to CRA14_SEN4. Scenarios with a Castile brine intrusion (S2-BF and S6-BF) produce substantial increases in equilibrated pressure within the WP and SROR due to both the brine influx from the Castile and the resulting increase in gas generation due primarily to the large increase in brine saturation within the SROR in comparison to CRA14_SEN4.

Pressure statistics for CRA14_SEN4 and APCS are summarized in Table 4-1 and Table 4-2. Table 4-1 provides the 3-replicate mean (integrated over time) and 3-replicate maximum (over all time) pressure values. Table 4-2 provides the maximum pressure (over all time) for all individual vectors. The use of PCS_NO results in increased 3-replicate mean and maximum pressures as compared to the CRA14_SEN4 for all reported areas over all scenarios except S4-BF as discussed above. The individual vector maximum pressure values for APCS are minimally changed for all reported areas and scenarios.

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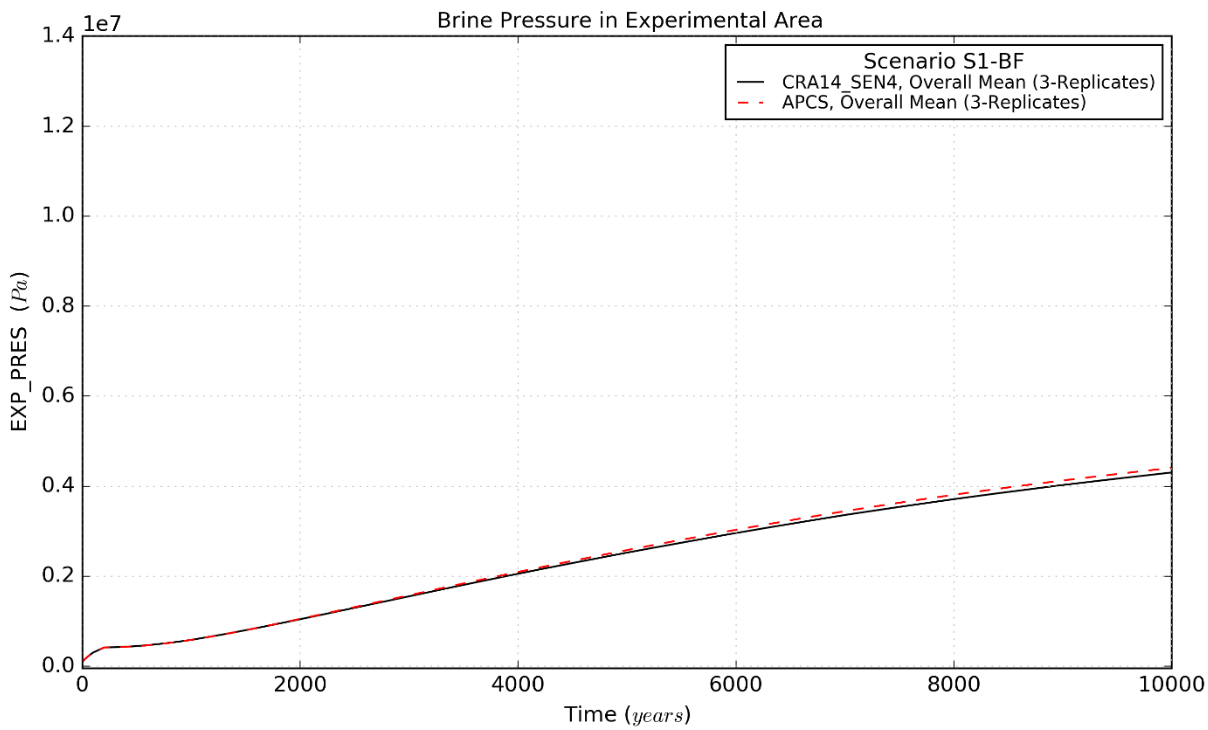

Figure 4-1: Pressure Means for the Experimental Area, Scenario S1-BF

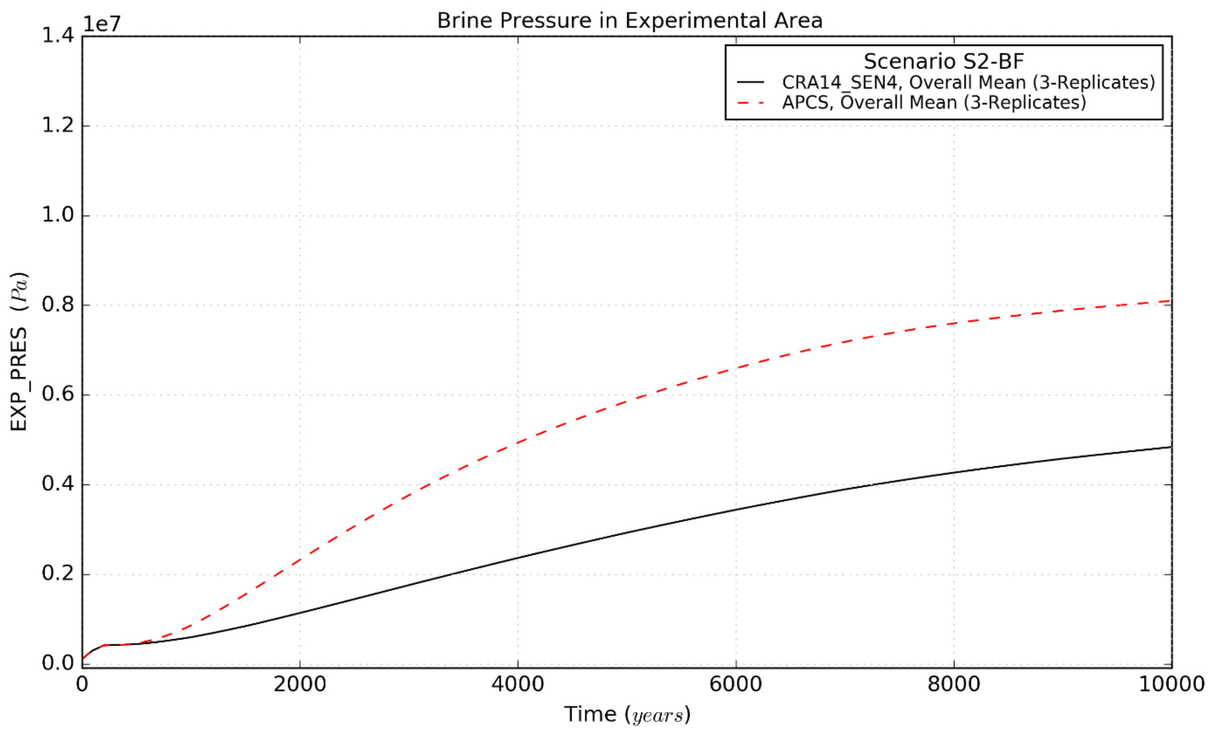

Figure 4-2: Pressure Means for the Experimental Area, Scenario S2-BF

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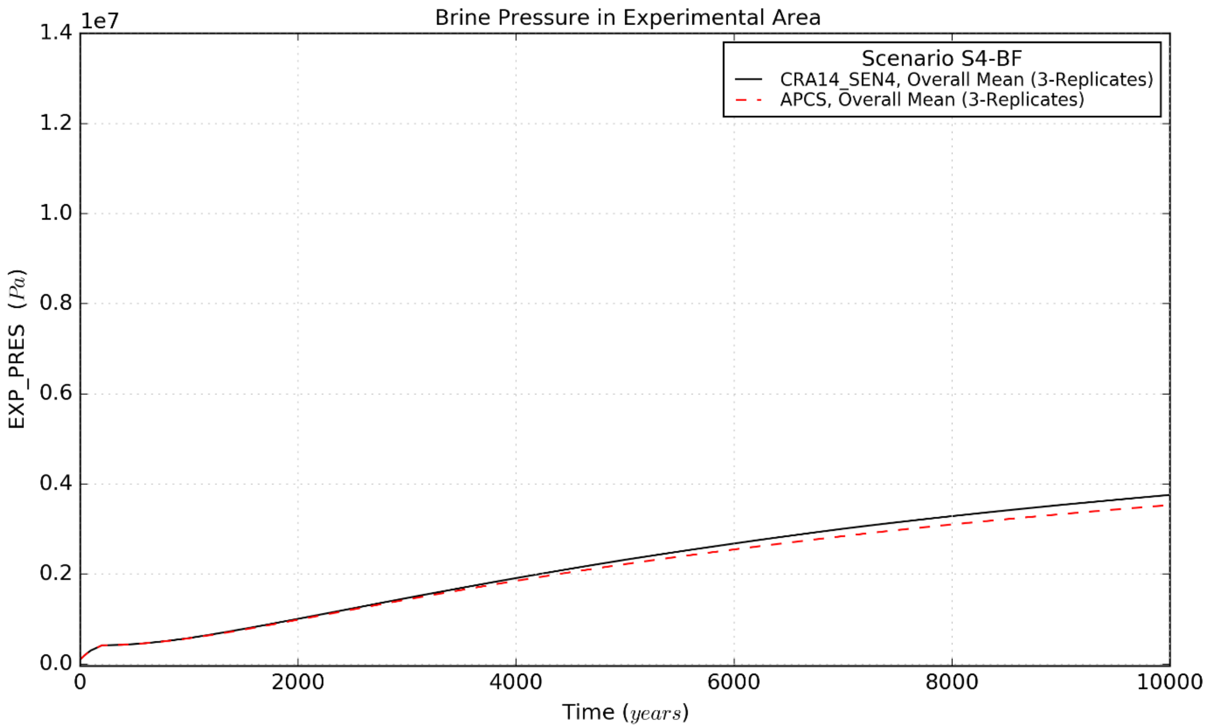

Figure 4-3: Pressure Means for the Experimental Area, Scenario S4-BF

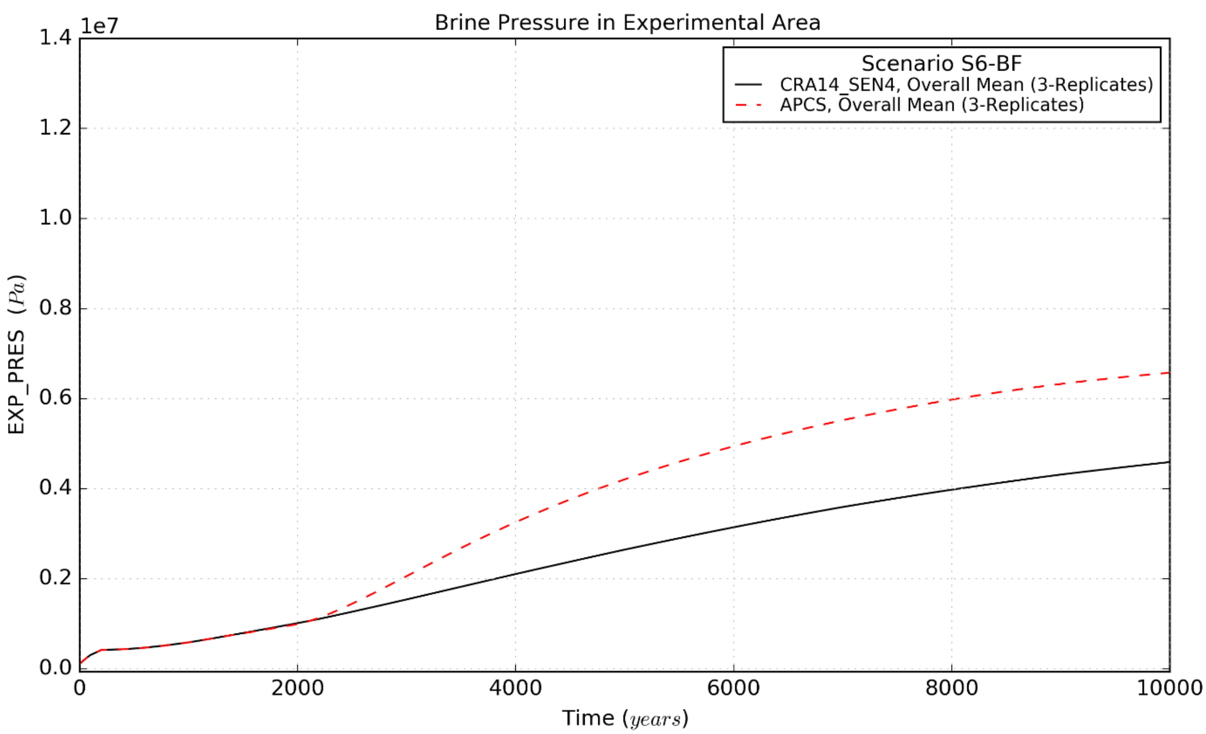

Figure 4-4: Pressure Means for the Experimental Area, Scenario S6-BF

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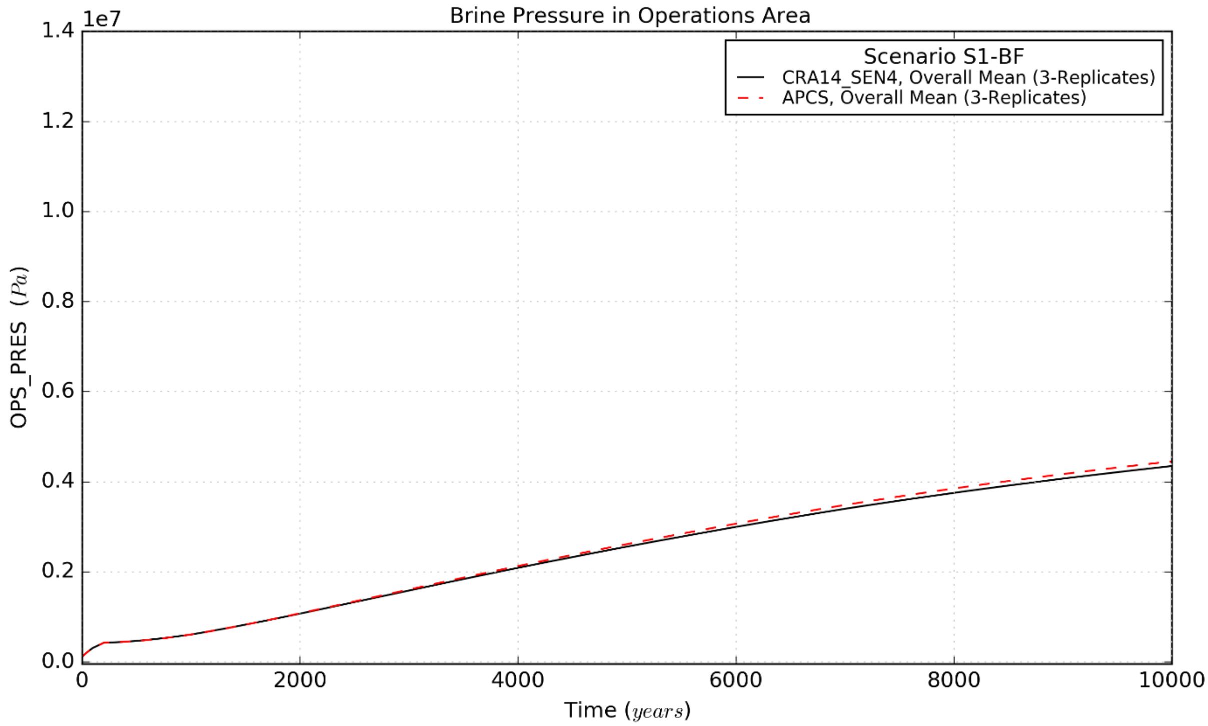

Figure 4-5: Pressure Means for the Operations Area, Scenario S1-BF

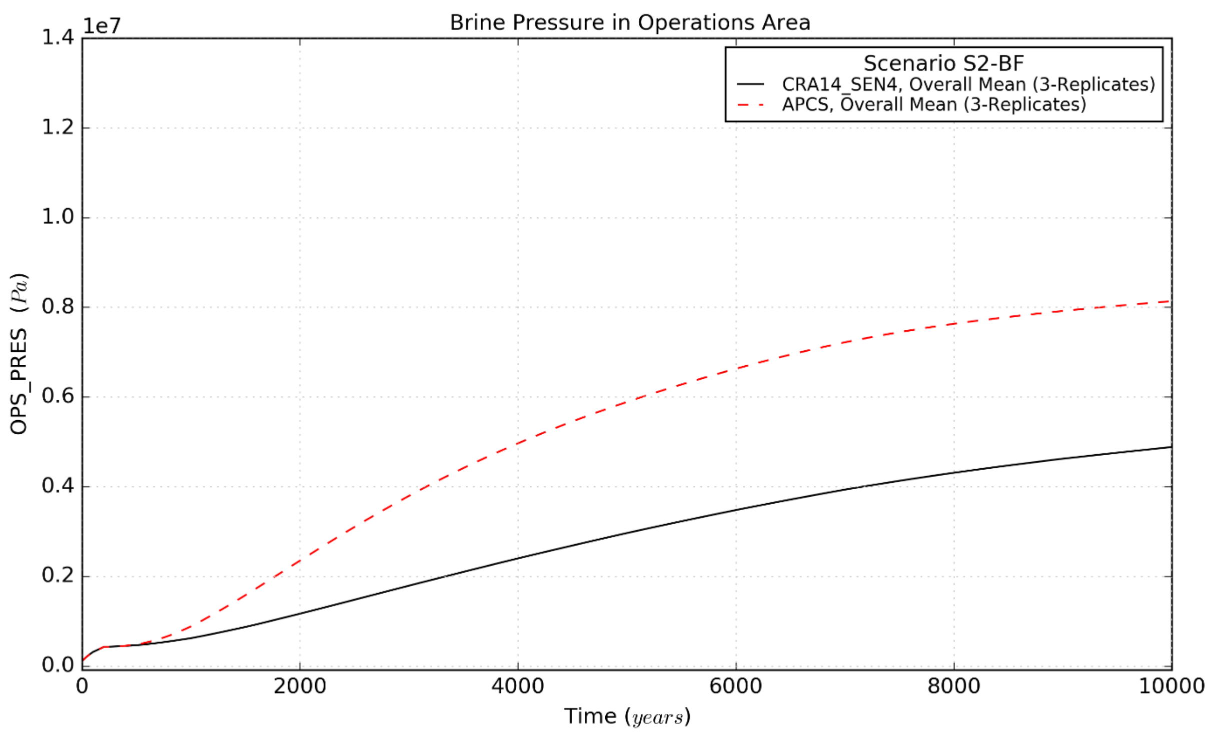

Figure 4-6: Pressure Means for the Operations Area, Scenario S2-BF

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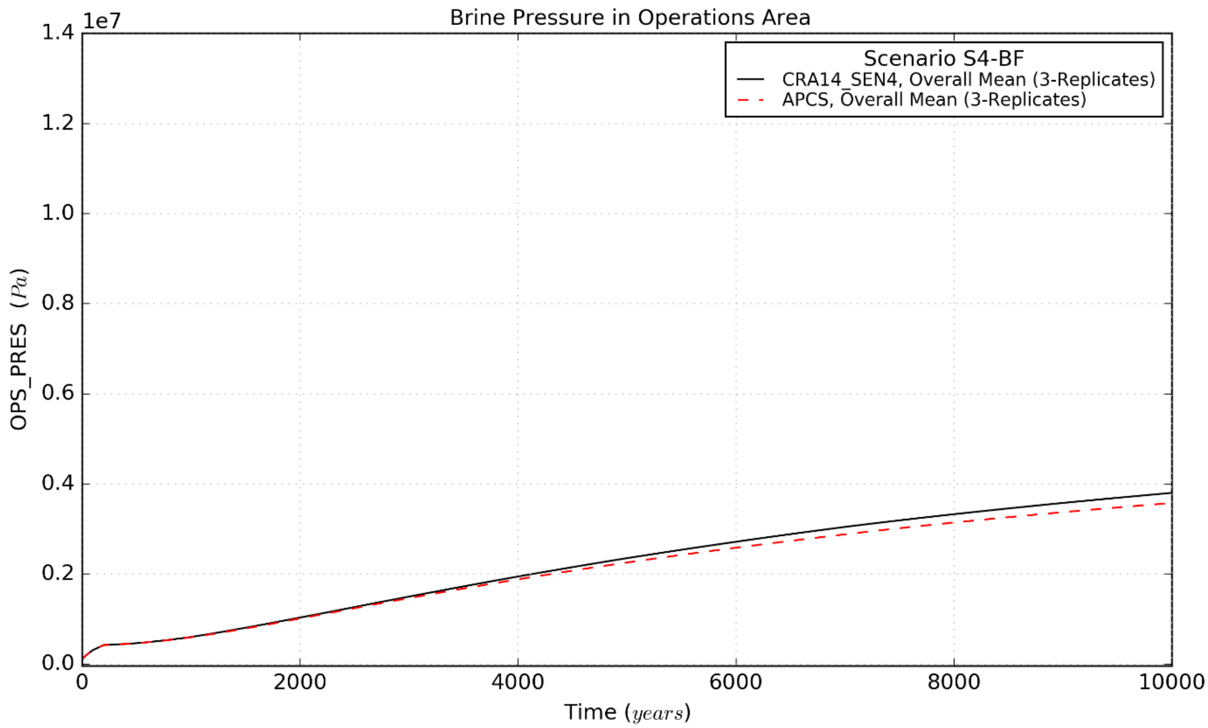

Figure 4-7: Pressure Means for the Operations Area, Scenario S4-BF

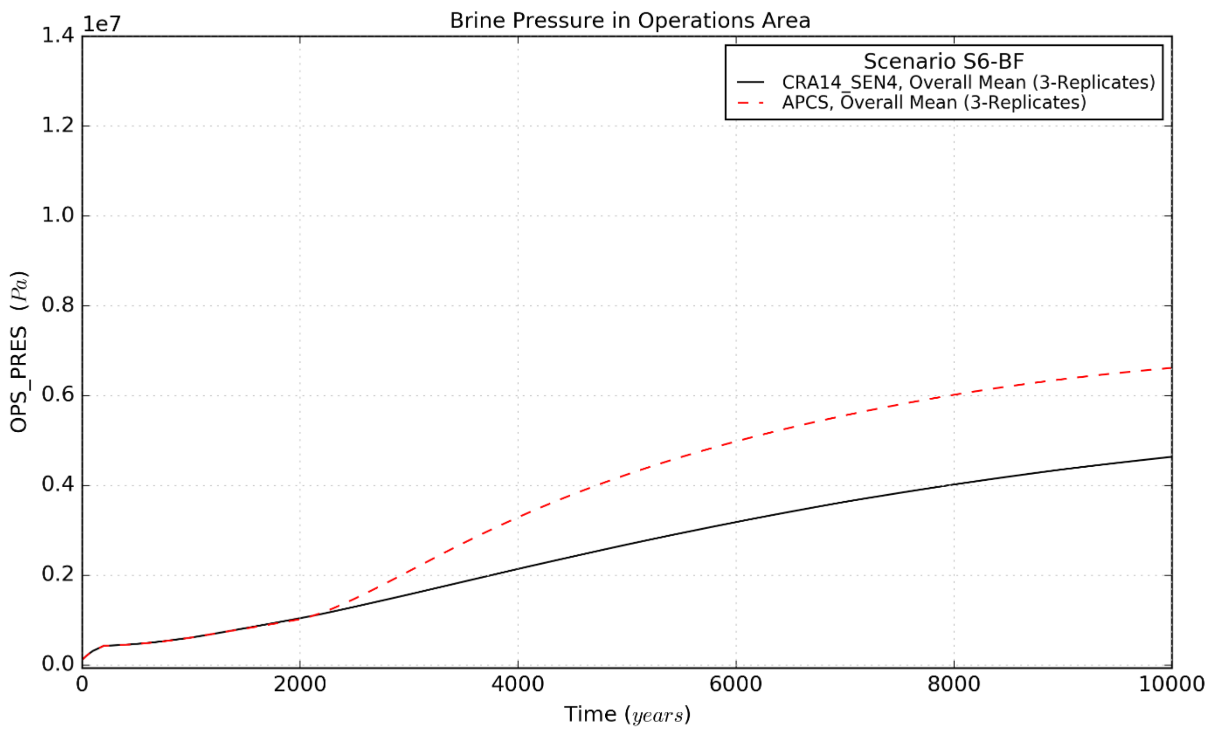

Figure 4-8: Pressure Means for the Operations Area, Scenario S6-BF

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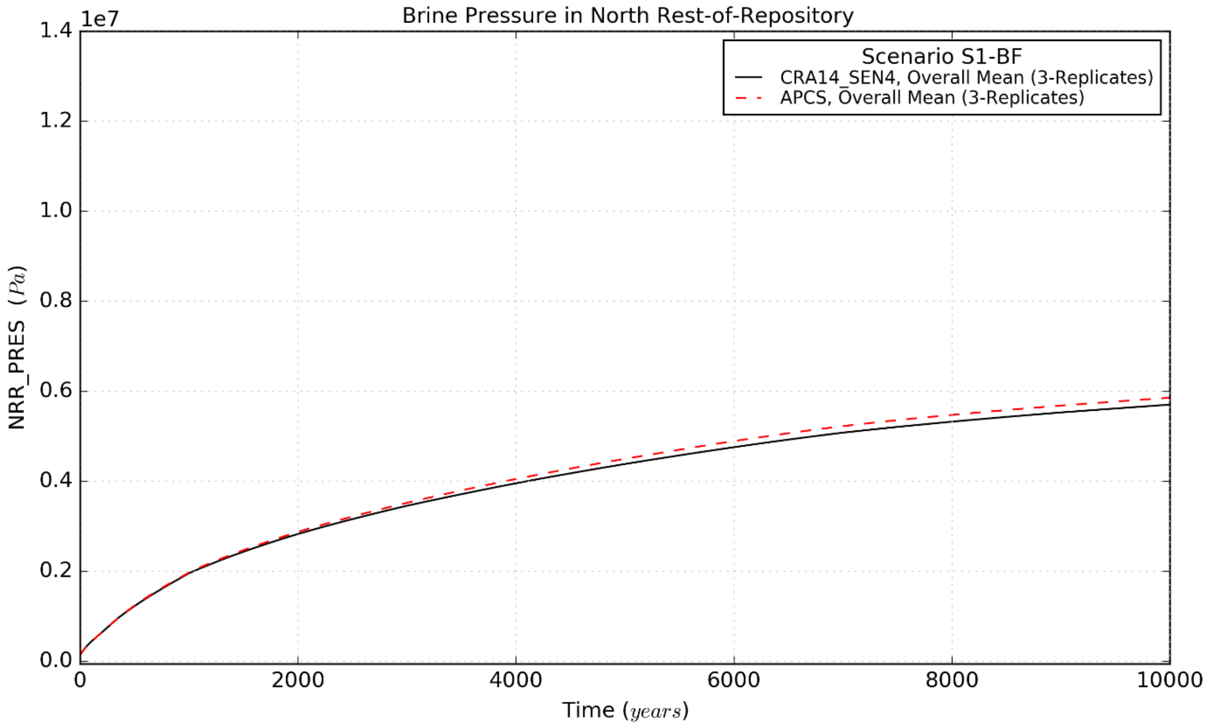

Figure 4-9: Pressure Means for the North Rest-of-Repository, Scenario S1-BF

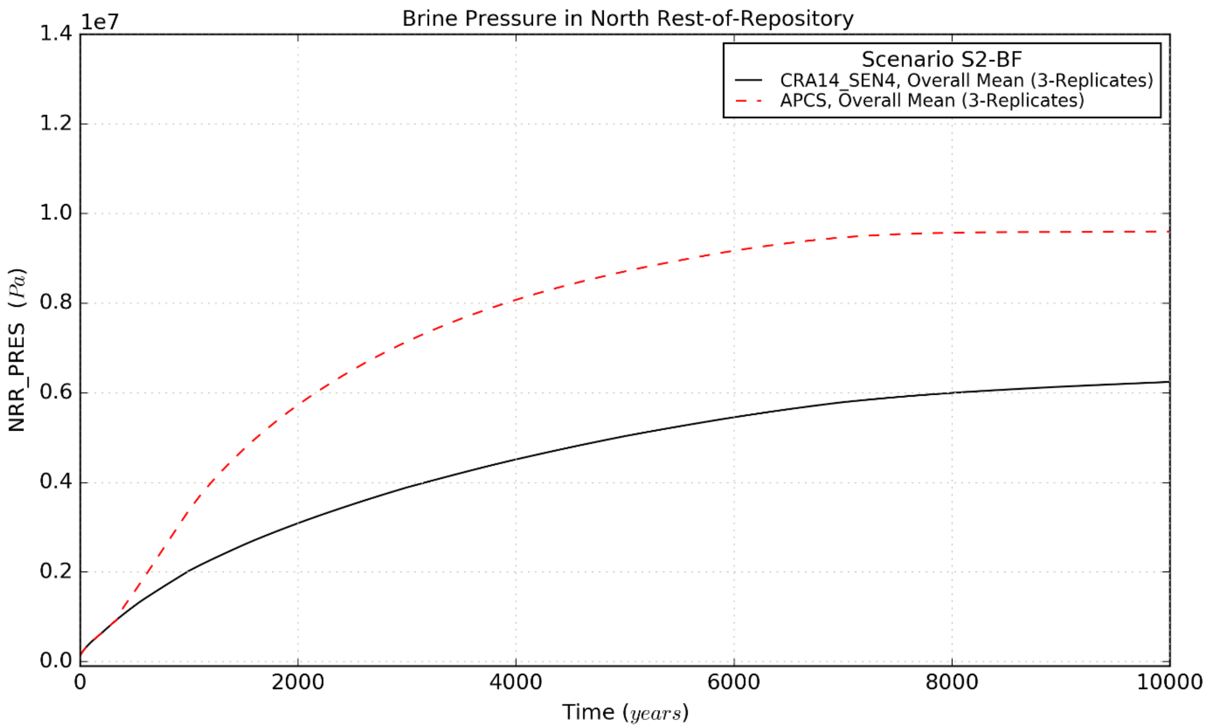

Figure 4-10: Pressure Means for the North Rest-of-Repository, Scenario S2-BF

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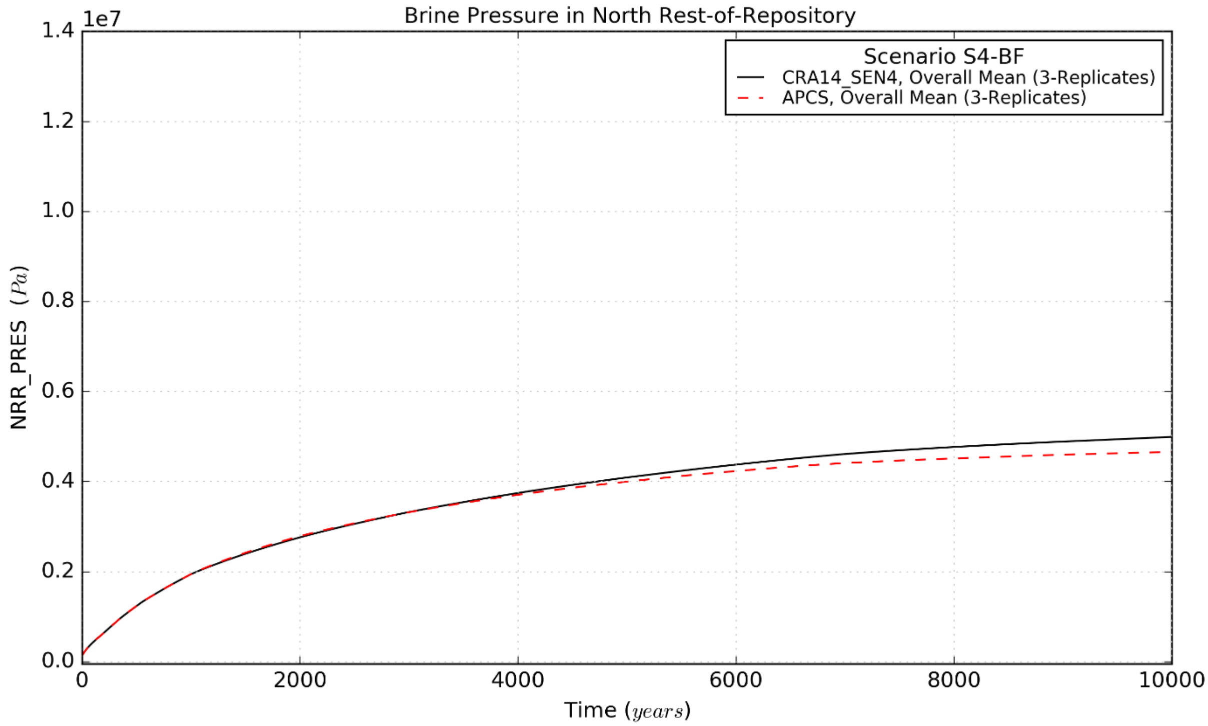

Figure 4-11: Pressure Means for the North Rest-of-Repository, Scenario S4-BF

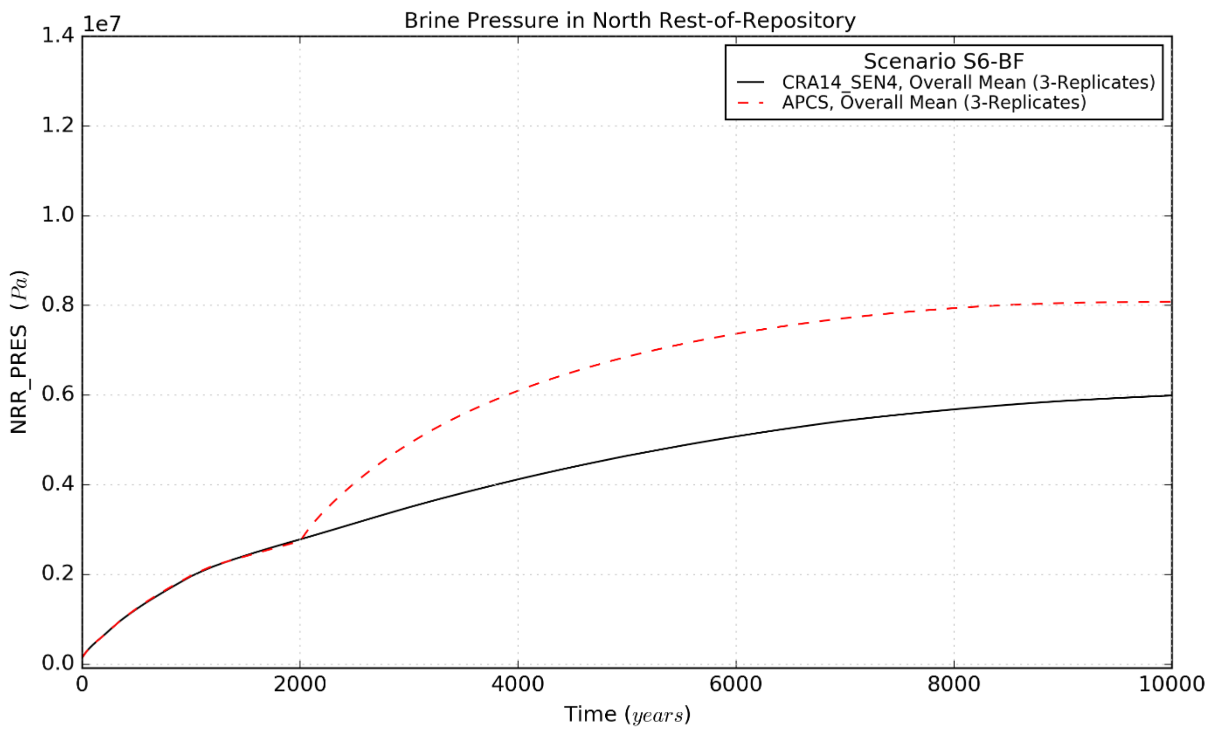

Figure 4-12: Pressure Means for the North Rest-of-Repository, Scenario S6-BF

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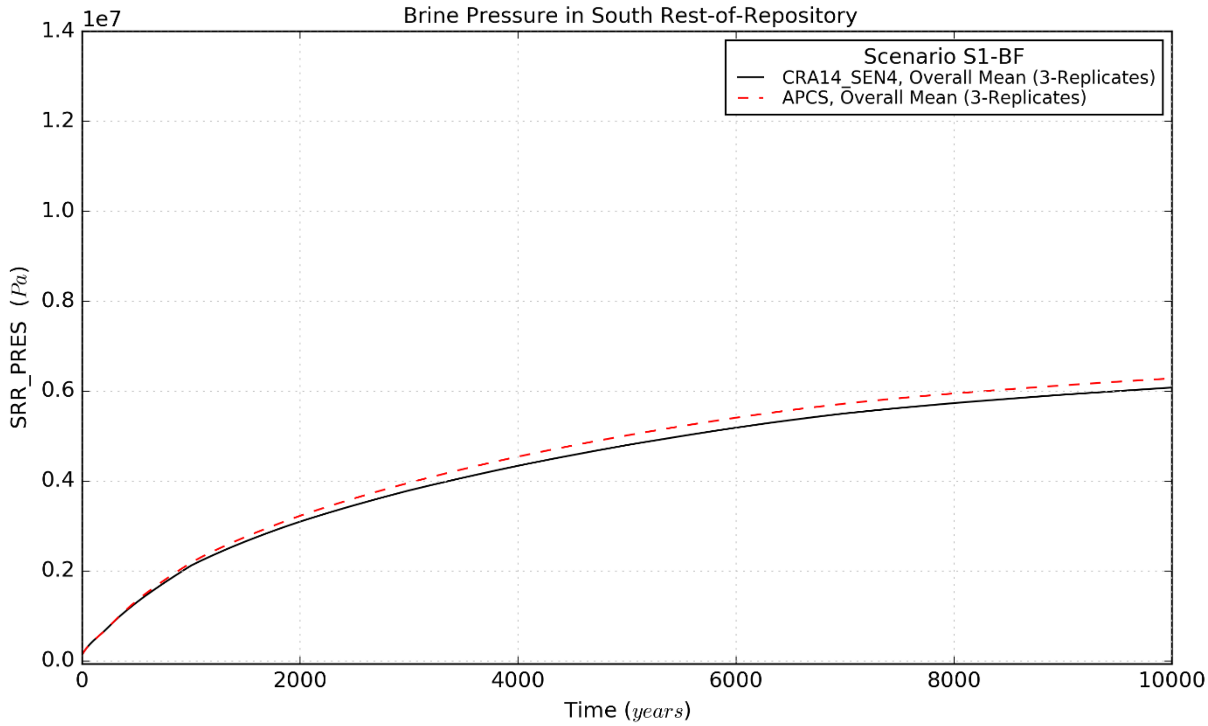

Figure 4-13: Pressure Means for the South Rest-of-Repository, Scenario S1-BF

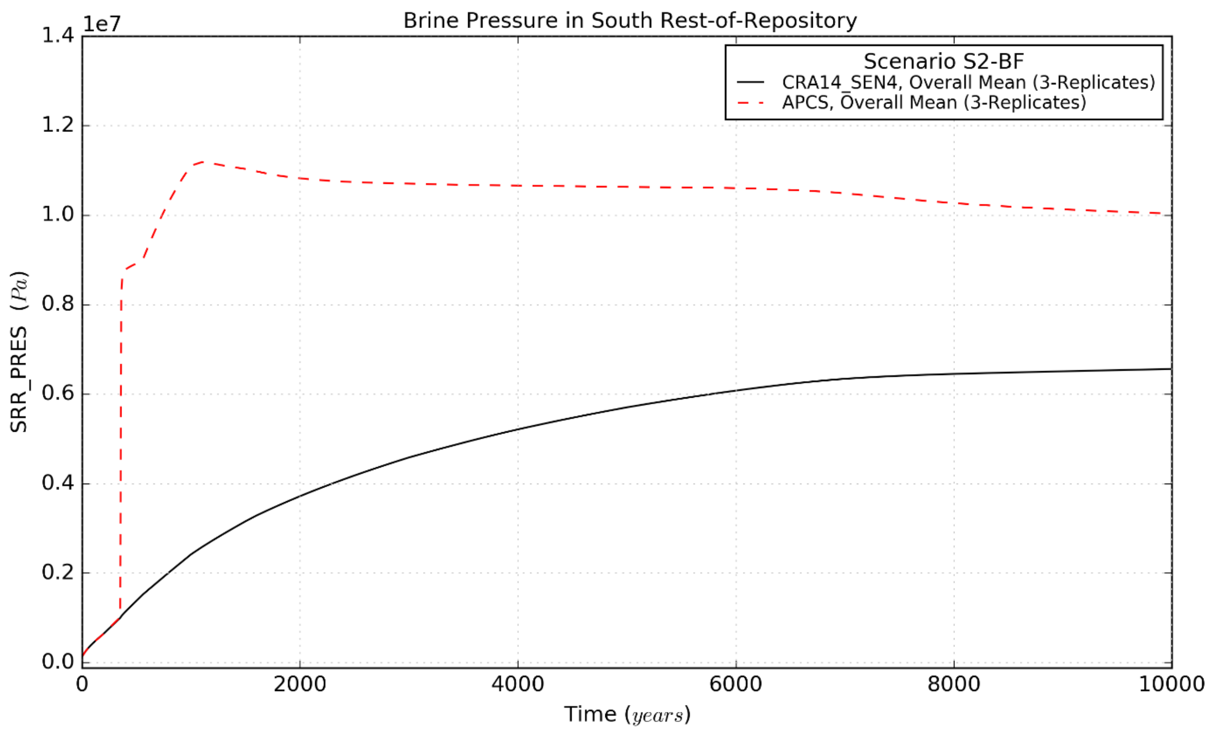

Figure 4-14: Pressure Means for the South Rest-of-Repository, Scenario S2-BF

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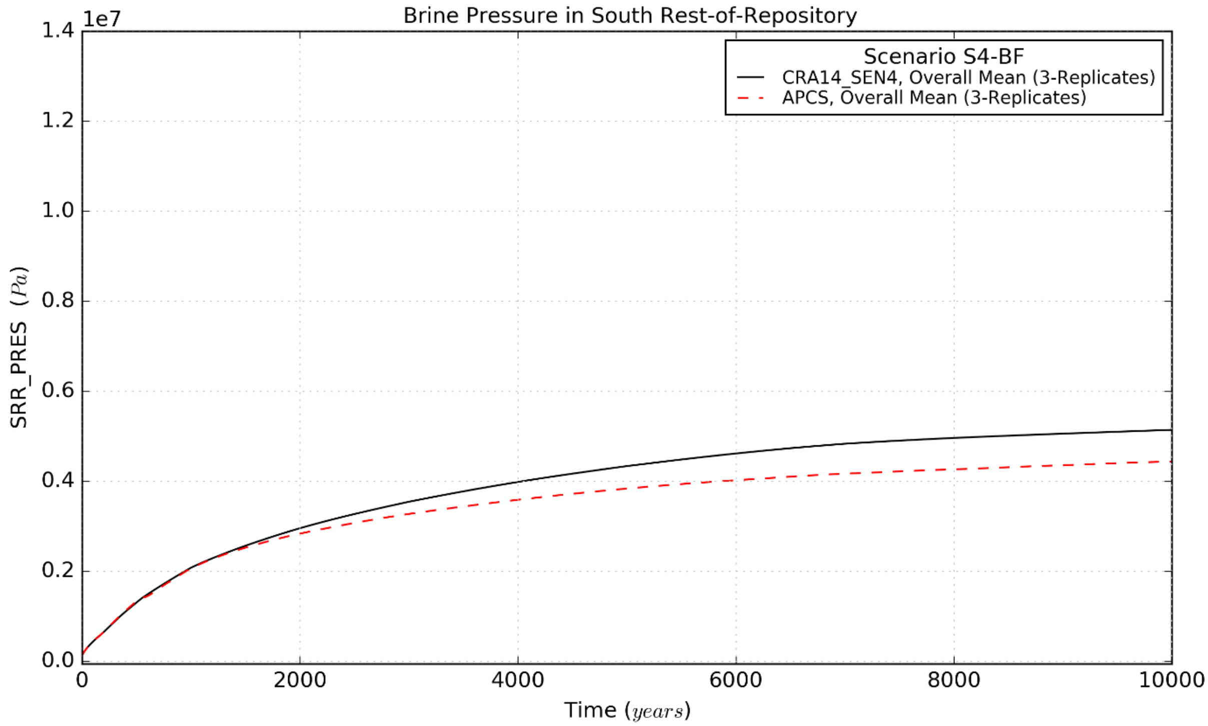

Figure 4-15: Pressure Means for the South Rest-of-Repository, Scenario S4-BF

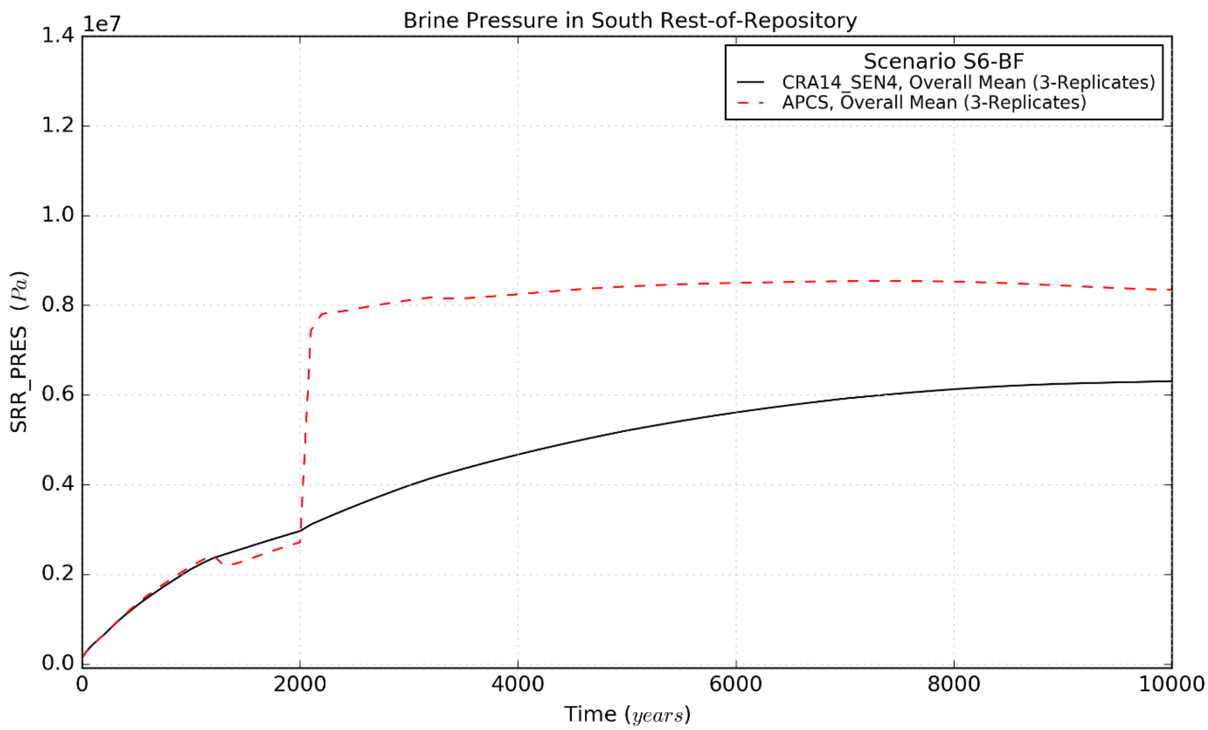

Figure 4-16: Pressure Means for the South Rest-of-Repository, Scenario S6-BF

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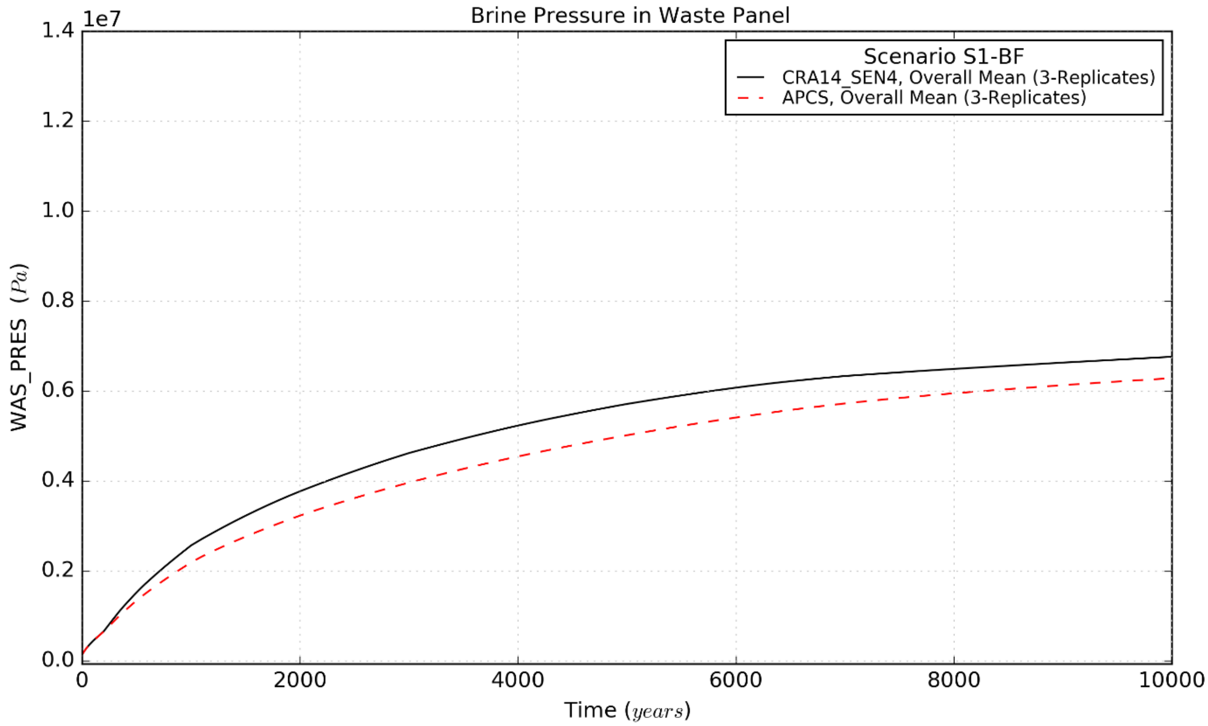

Figure 4-17: Pressure Means for the Waste Panel, Scenario S1-BF

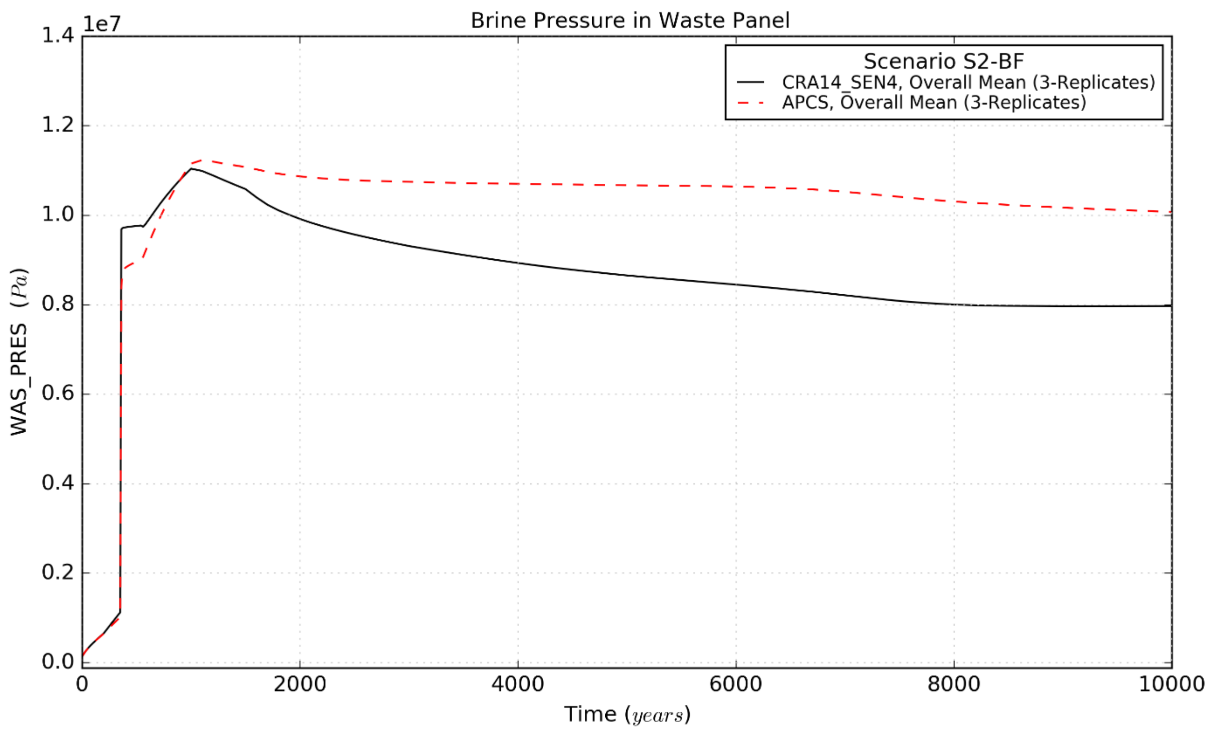

Figure 4-18: Pressure Means for the Waste Panel, Scenario S2-BF

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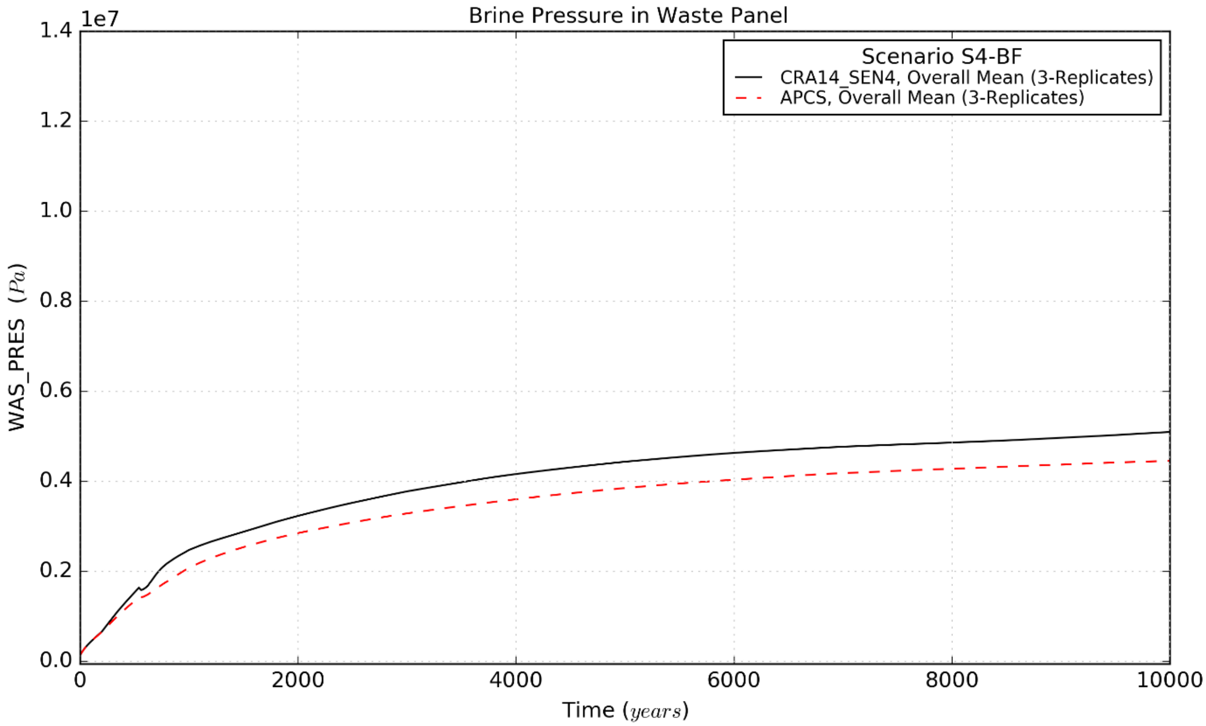

Figure 4-19: Pressure Means for the Waste Panel, Scenario S4-BF

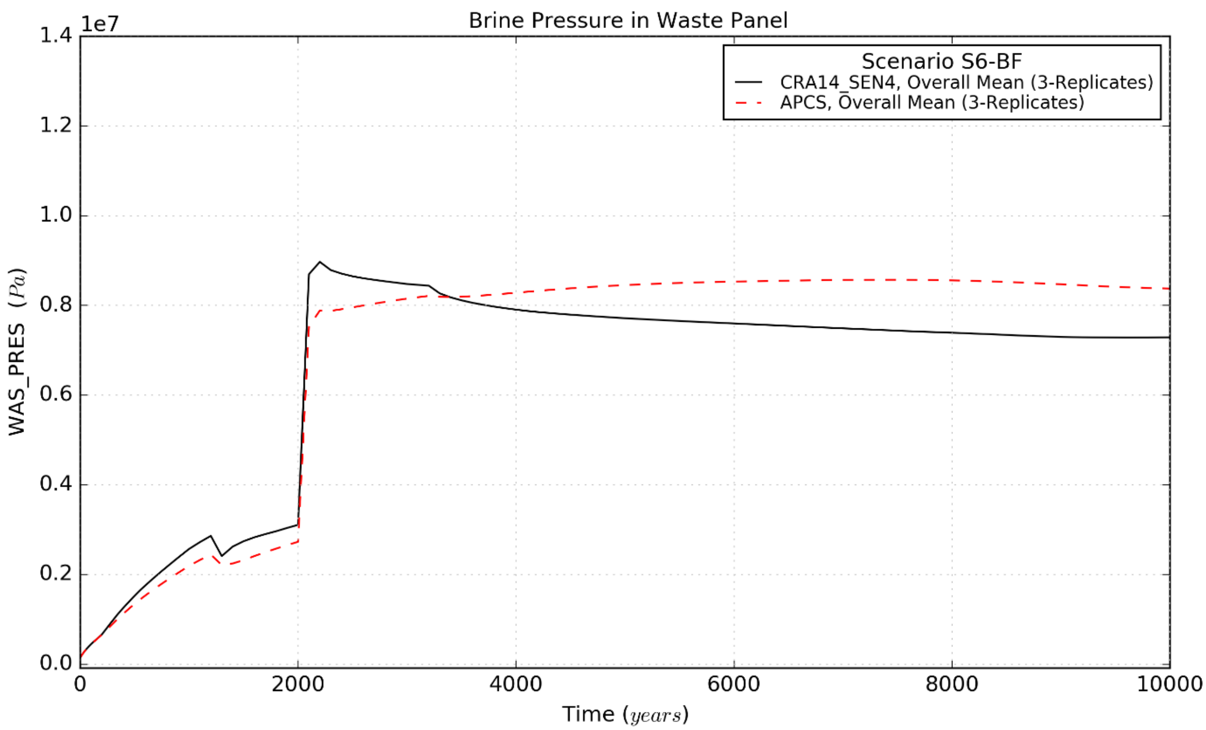

Figure 4-20: Pressure Means for the Waste Panel, Scenario S6-BF

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Table 4-1: Pressure Statistics on Overall Means for CRA14_SEN4 and APCS

Quantity (units)	Description	Scenario	Mean Value[1]		Maximum Value[2]	
			CRA14_SEN4	APCS	CRA14_SEN4	APCS
EXP_PRES (Pa)	Brine Pressure in Experimental Area	S1-BF	2.41E+06	2.47E+06	4.31E+06	4.41E+06
		S2-BF	2.76E+06	5.12E+06	4.84E+06	8.10E+06
		S4-BF	2.18E+06	2.08E+06	3.76E+06	3.53E+06
		S6-BF	2.54E+06	3.73E+06	4.59E+06	6.58E+06
OPS_PRES (Pa)	Brine Pressure in Operations Area	S1-BF	2.45E+06	2.50E+06	4.35E+06	4.45E+06
		S2-BF	2.79E+06	5.15E+06	4.89E+06	8.14E+06
		S4-BF	2.22E+06	2.12E+06	3.80E+06	3.58E+06
		S6-BF	2.57E+06	3.77E+06	4.64E+06	6.62E+06
NRR_PRES (Pa)	Brine Pressure in North Rest-of-Repository	S1-BF	4.04E+06	4.14E+06	5.71E+06	5.86E+06
		S2-BF	4.53E+06	7.58E+06	6.24E+06	9.60E+06
		S4-BF	3.73E+06	3.61E+06	4.99E+06	4.66E+06
		S6-BF	4.23E+06	5.82E+06	5.99E+06	8.08E+06
SRR_PRES (Pa)	Brine Pressure in South Rest-of-Repository	S1-BF	4.38E+06	4.56E+06	6.08E+06	6.28E+06
		S2-BF	5.06E+06	1.01E+07	6.57E+06	1.12E+07
		S4-BF	3.92E+06	3.49E+06	5.15E+06	4.44E+06
		S6-BF	4.63E+06	7.02E+06	6.31E+06	8.54E+06
WAS_PRES (Pa)	Brine Pressure in Waste Panel	S1-BF	5.11E+06	4.56E+06	6.76E+06	6.29E+06
		S2-BF	8.58E+06	1.02E+07	1.10E+07	1.12E+07
		S4-BF	4.01E+06	3.51E+06	5.10E+06	4.46E+06
		S6-BF	6.58E+06	7.05E+06	8.97E+06	8.57E+06

Notes:
1 Calculated as the function average (integrated) over the time interval (0-10,000 yr) for the overall means (3 replicates)
2 Calculated as the function maximum over the time interval (0-10,000 yr) for the overall means (3 replicates)

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Table 4-2: Pressure Statistics on Individual Vectors for CRA14_SEN4 and APCS

Quantity (units)	Description	Scenario	Maximum Value[3]	
			CRA14_SEN4	APCS
EXP_PRES (Pa)	Brine Pressure in Experimental Area	S1-BF	1.47E+07	1.46E+07
		S2-BF	1.46E+07	1.52E+07
		S4-BF	1.45E+07	1.44E+07
		S6-BF	1.45E+07	1.49E+07
OPS_PRES (Pa)	Brine Pressure in Operations Area	S1-BF	1.47E+07	1.47E+07
		S2-BF	1.47E+07	1.53E+07
		S4-BF	1.46E+07	1.45E+07
		S6-BF	1.46E+07	1.49E+07
NRR_PRES (Pa)	Brine Pressure in North Rest-of-Repository	S1-BF	1.67E+07	1.67E+07
		S2-BF	1.68E+07	1.66E+07
		S4-BF	1.68E+07	1.64E+07
		S6-BF	1.68E+07	1.65E+07
SRR_PRES (Pa)	Brine Pressure in South Rest-of-Repository	S1-BF	1.67E+07	1.67E+07
		S2-BF	1.68E+07	1.72E+07
		S4-BF	1.68E+07	1.50E+07
		S6-BF	1.68E+07	1.64E+07
WAS_PRES (Pa)	Brine Pressure in Waste Panel	S1-BF	1.67E+07	1.67E+07
		S2-BF	1.63E+07	1.72E+07
		S4-BF	1.46E+07	1.50E+07
		S6-BF	1.45E+07	1.64E+07

Notes:
3 Calculated as the function maximum over the time interval (0-10,000 yr) for all replicates (300 vectors)

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4.2.2 Brine Saturation

Brine pressure and saturation changes in the OPS/EXP, NROR, SROR and WP are historically inversely proportional to one another due to pressure-driven flow with brine saturations also generally increasing toward the south in the repository due to the 1-degree Salado dip and the associated gravity-driven flow of brine. This trend is maintained for repository areas that are isolated from the SROR and WP by ROMPCS panel closures as shown in Figure 4-21 to Figure 4-32 for the EXP, OPS, and NROR over all reported scenarios.

As a result of the abandonment of panel closures in the south, as discussed in Section 4.2.1, brine saturation changes for the SROR and WP also follow the historical trend for inverse relationship with brine pressure for all scenarios (S1-BF and S4-BF) that do not involve a Castile intrusion. For scenarios involving a Castile intrusion (S2-BF and S6-BF), brine saturation increases in the WP are modest but brine 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. Figure 4-33 to Figure 4-40 illustrate the effects on brine saturation for APCS in comparison to CRA14_SEN4.

Brine saturation statistics for CRA14_SEN4 and APCS are summarized in Table 4-3 and Table 4-4. Table 4-3 provides the 3-replicate mean (integrated over time) and 3-replicate maximum (over all time) pressure values. Table 4-4 provides the maximum brine saturation (over all time) for all individual vectors. The abandonment of panel closures in the south, accomplished through the use of the PCS_NO material in the southernmost panel closure area of the BRAGFLO grid, result in minimal changes to 3-replicate mean and maximum brine saturations in all reported repository areas under all scenarios with the exception of intruded scenarios (S2-BF, S4-BF, and S6-BF) and the SROR as compared to the CRA14_SEN4. The overall trend for individual vector maximum brine saturation values for APCS is minimal change for all areas and scenarios as compared to CRA14_SEN4.

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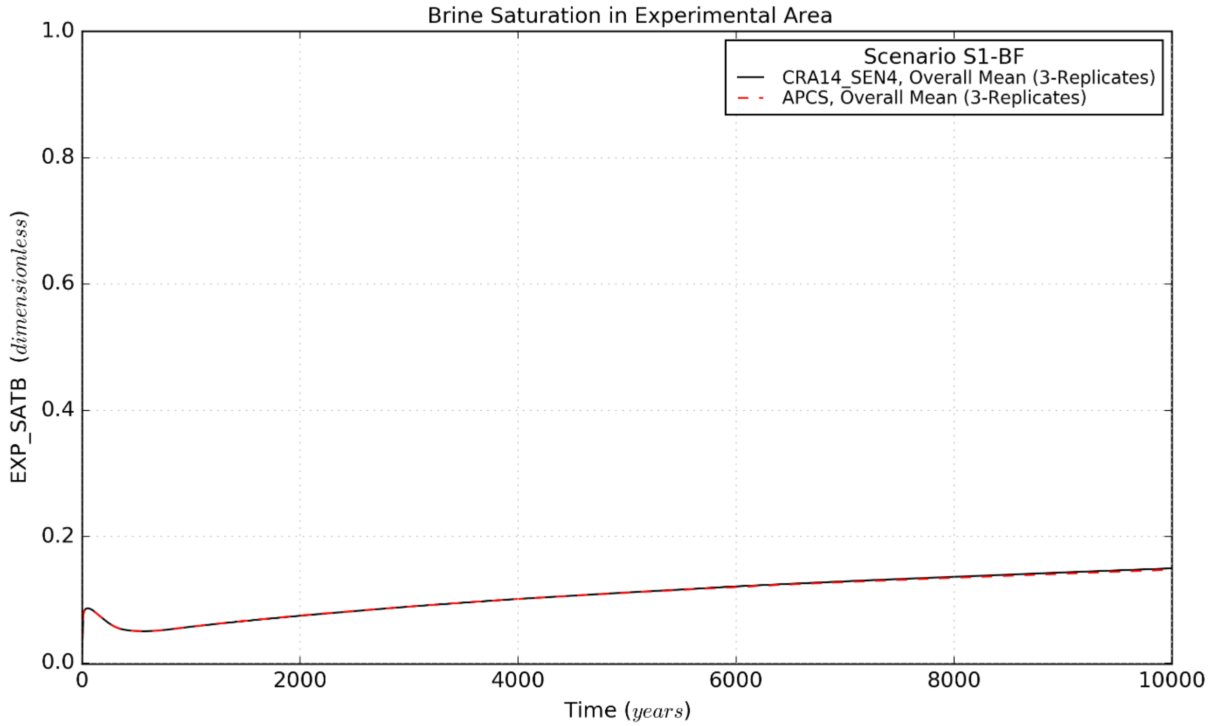

Figure 4-21: Brine Saturation Means for the Experimental Area, Scenario S1-BF

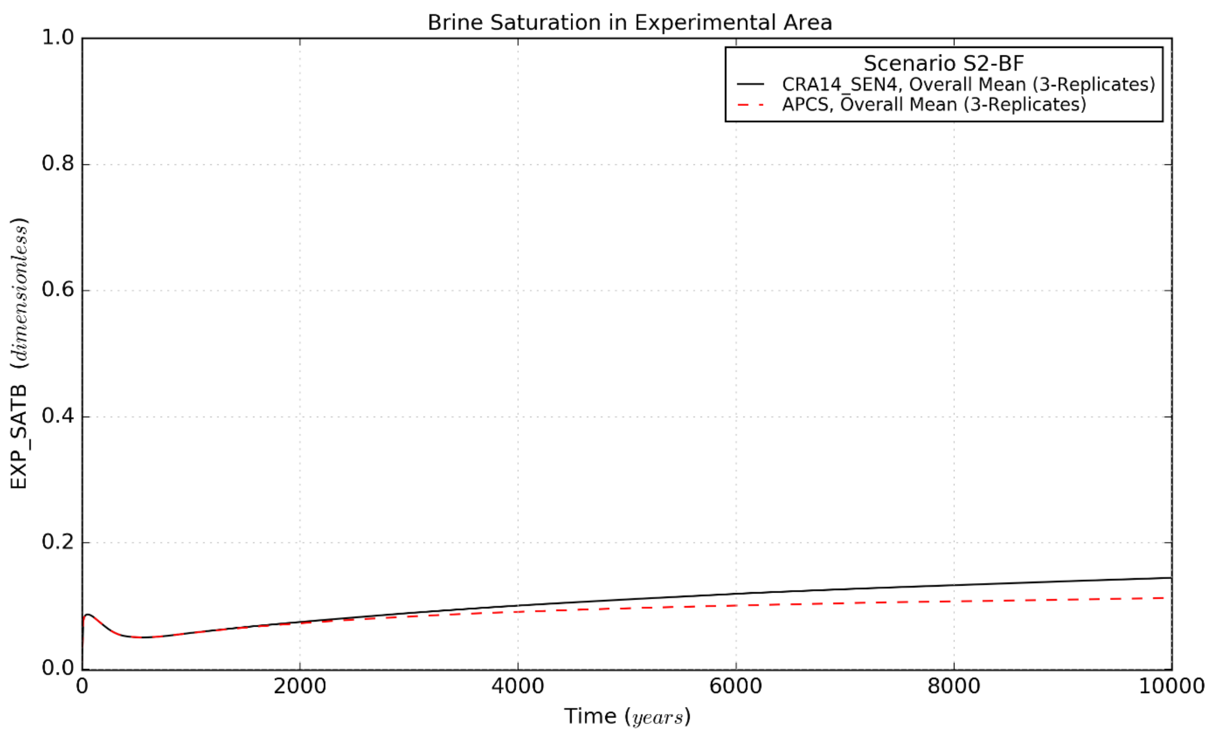

Figure 4-22: Brine Saturation Means for the Experimental Area, Scenario S2-BF

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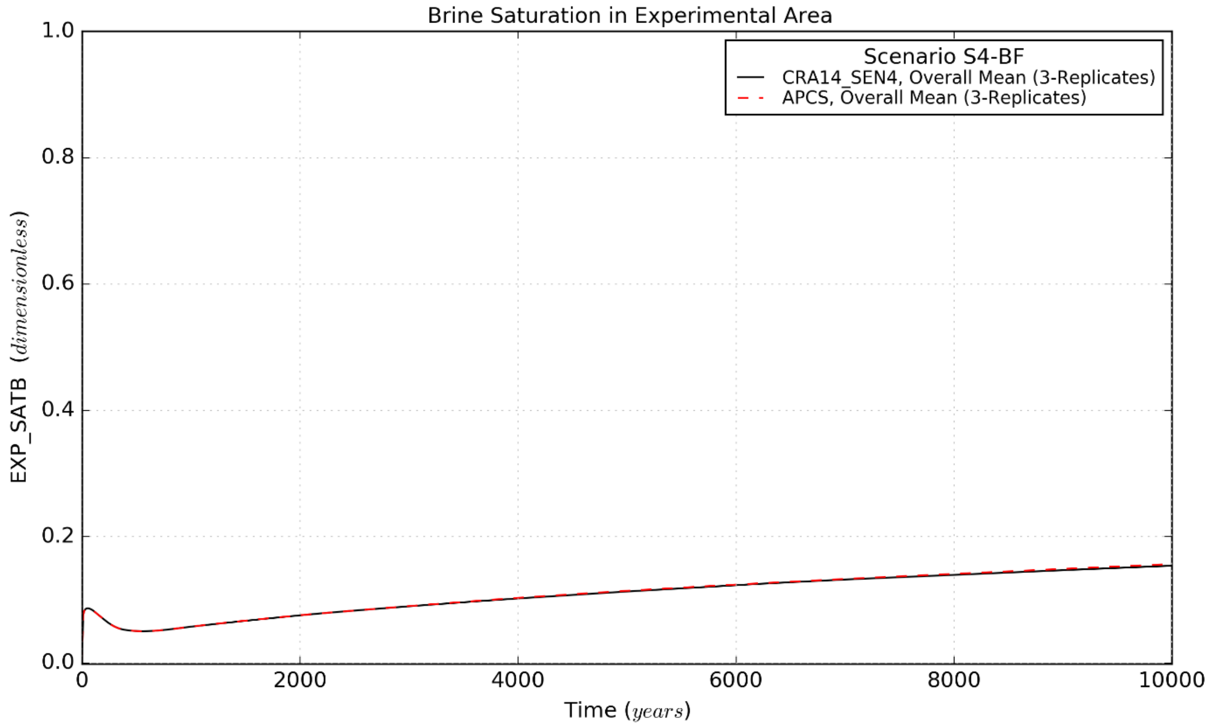

Figure 4-23: Brine Saturation Means for the Experimental Area, Scenario S4-BF

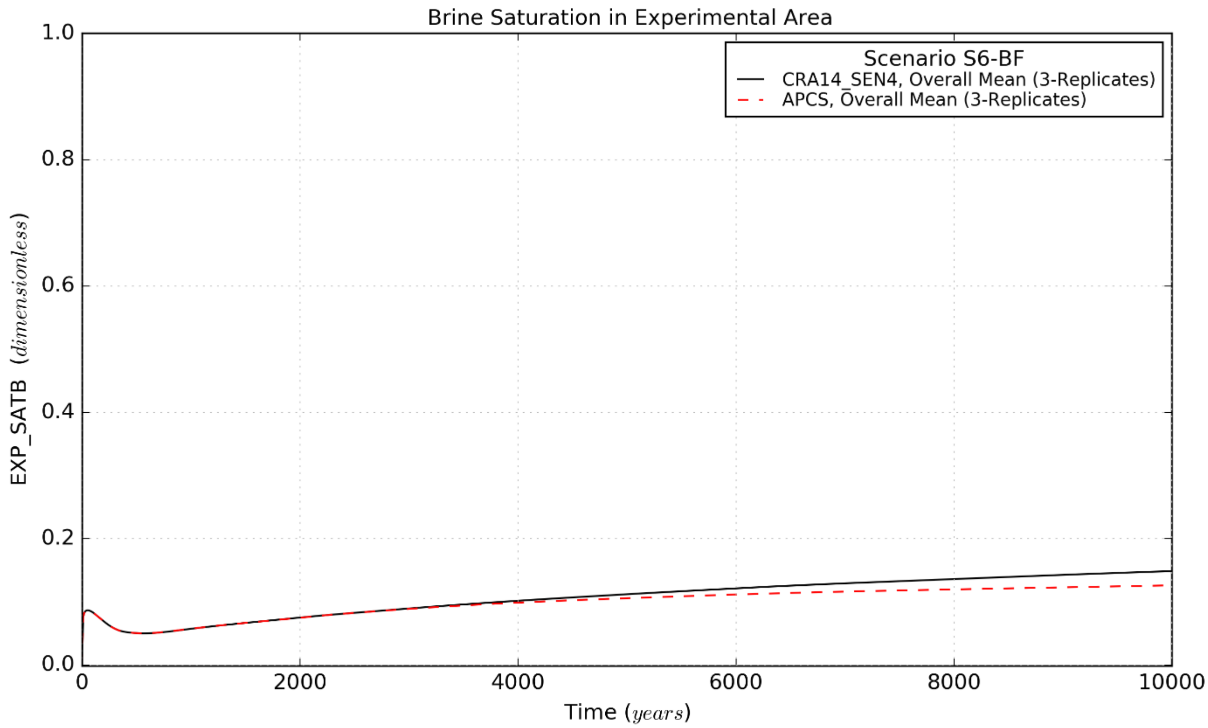

Figure 4-24: Brine Saturation Means for the Experimental Area, Scenario S6-BF

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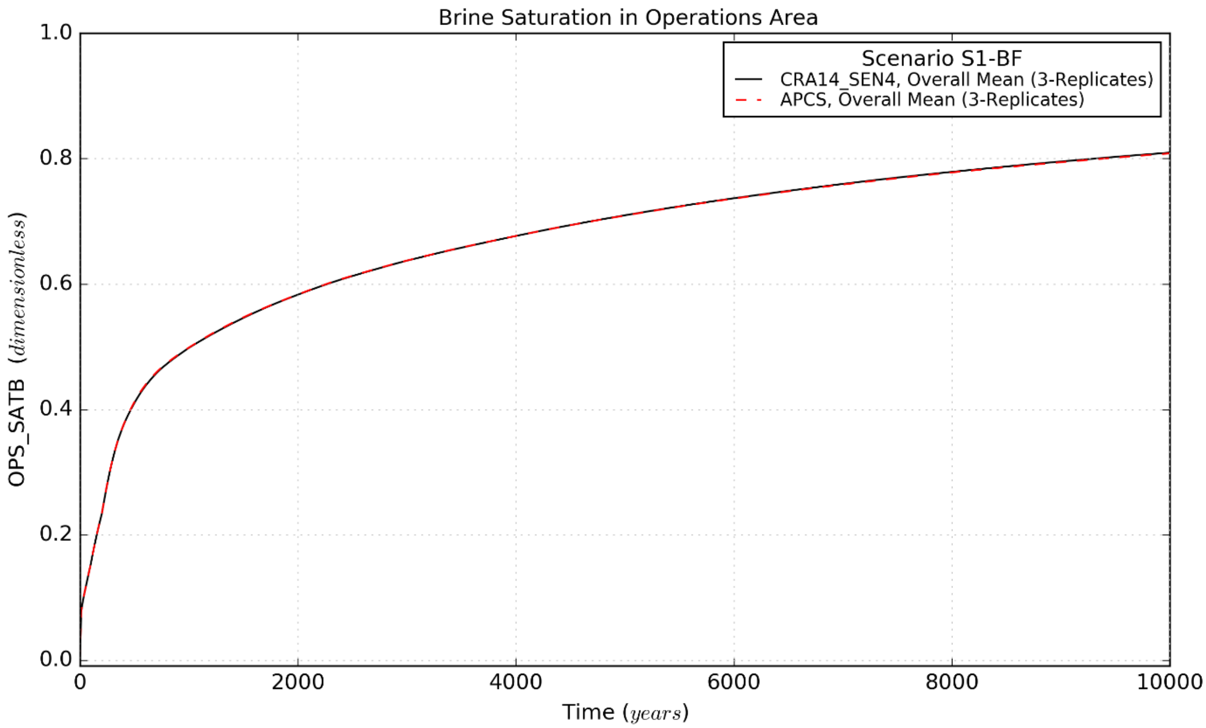

Figure 4-25: Brine Saturation Means for the Operations Area, Scenario S1-BF

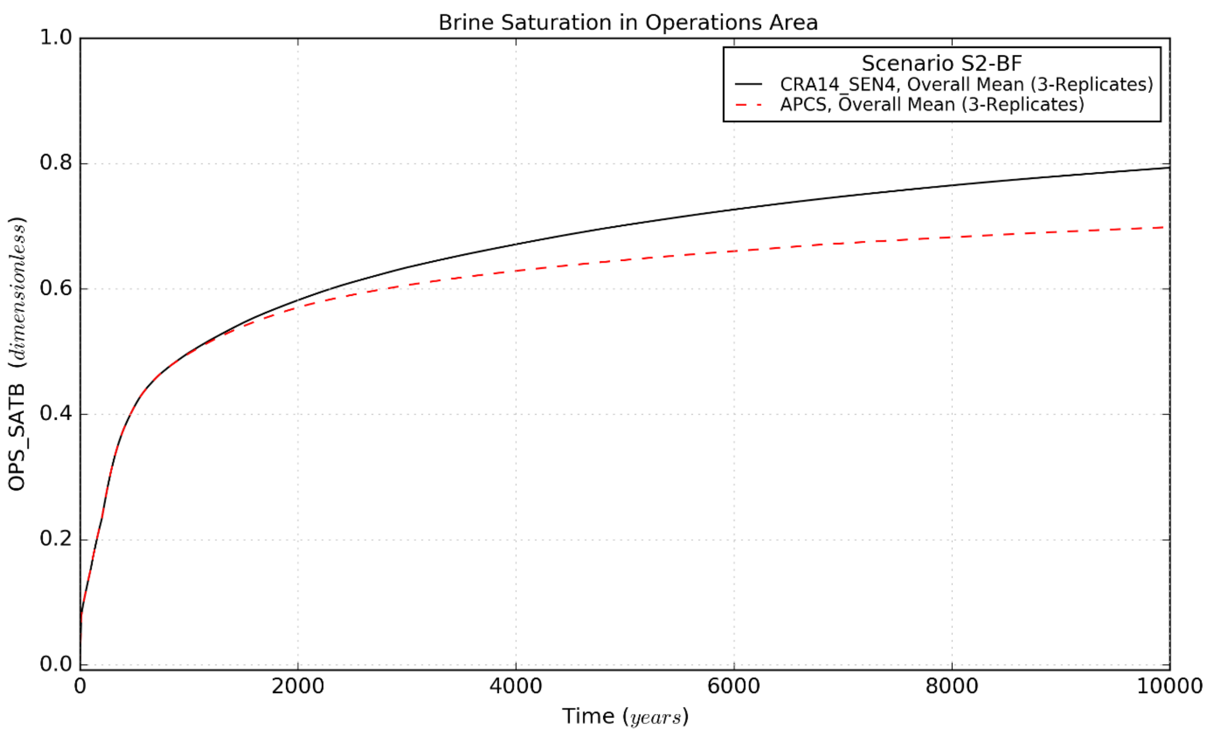

Figure 4-26: Brine Saturation Means for the Operations Area, Scenario S2-BF

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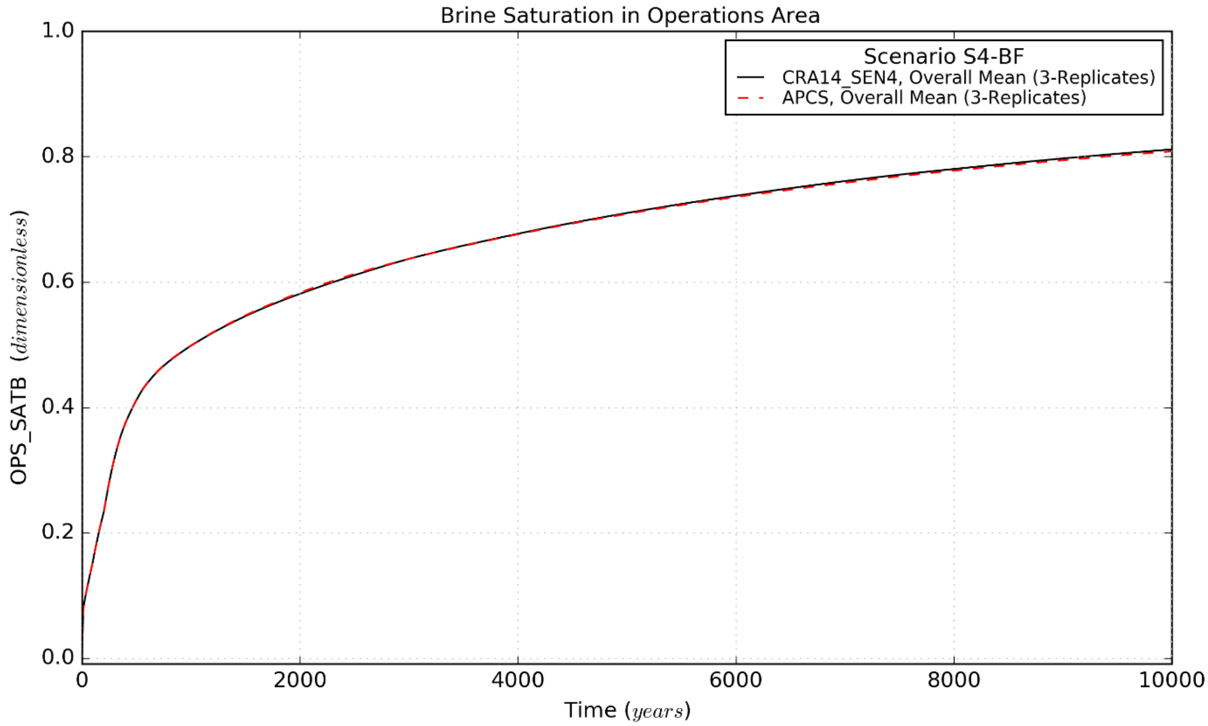

Figure 4-27: Brine Saturation Means for the Operations Area, Scenario S4-BF

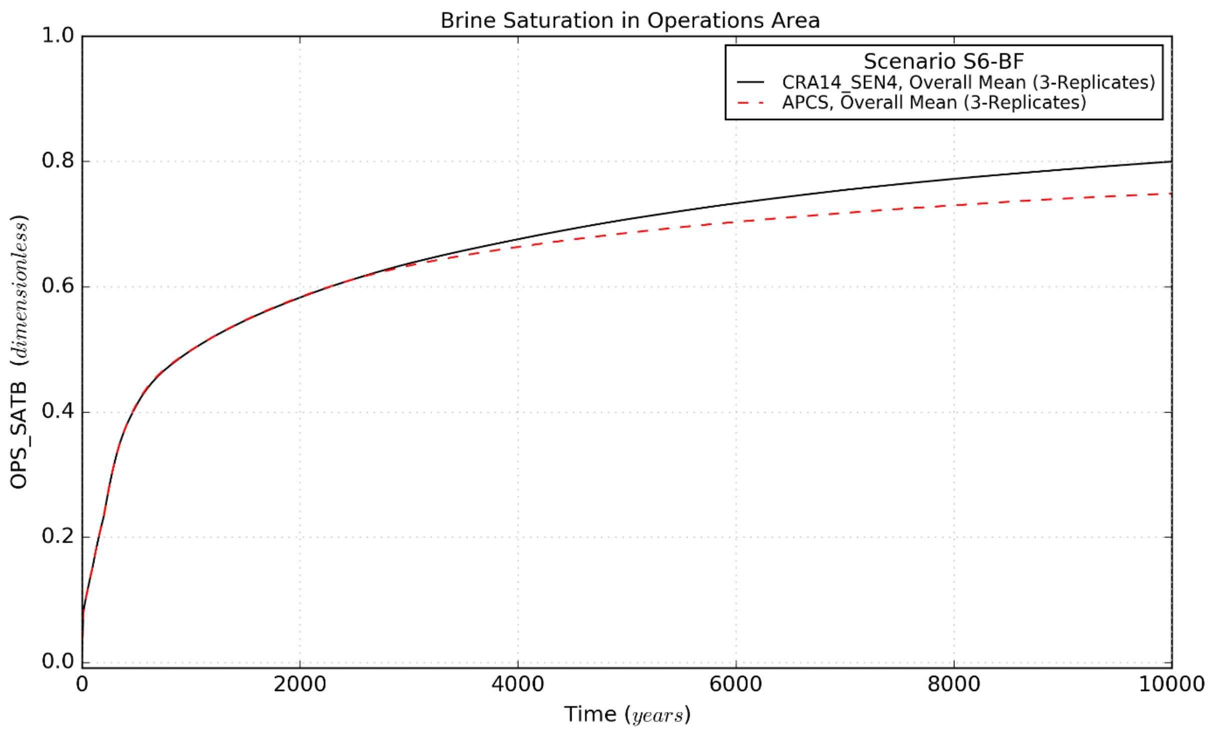

Figure 4-28: Brine Saturation Means for the Operations Area, Scenario S6-BF

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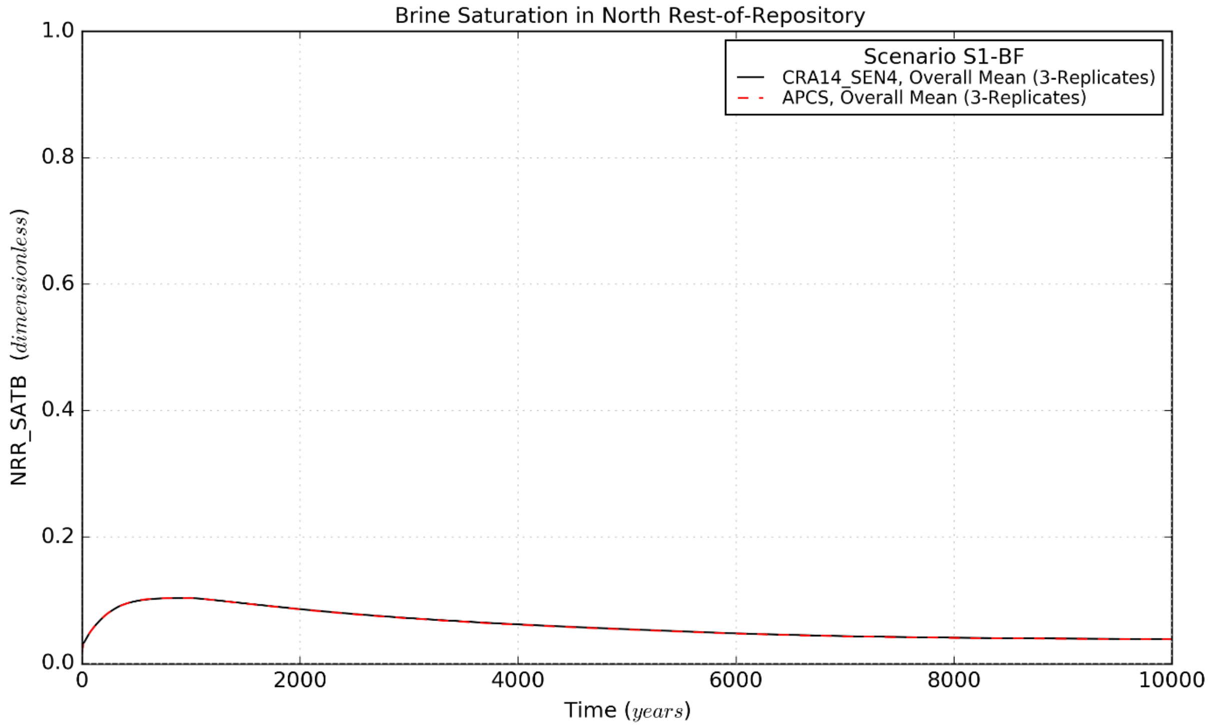

Figure 4-29: Brine Saturation Means for the North Rest-of-Repository, Scenario S1-BF

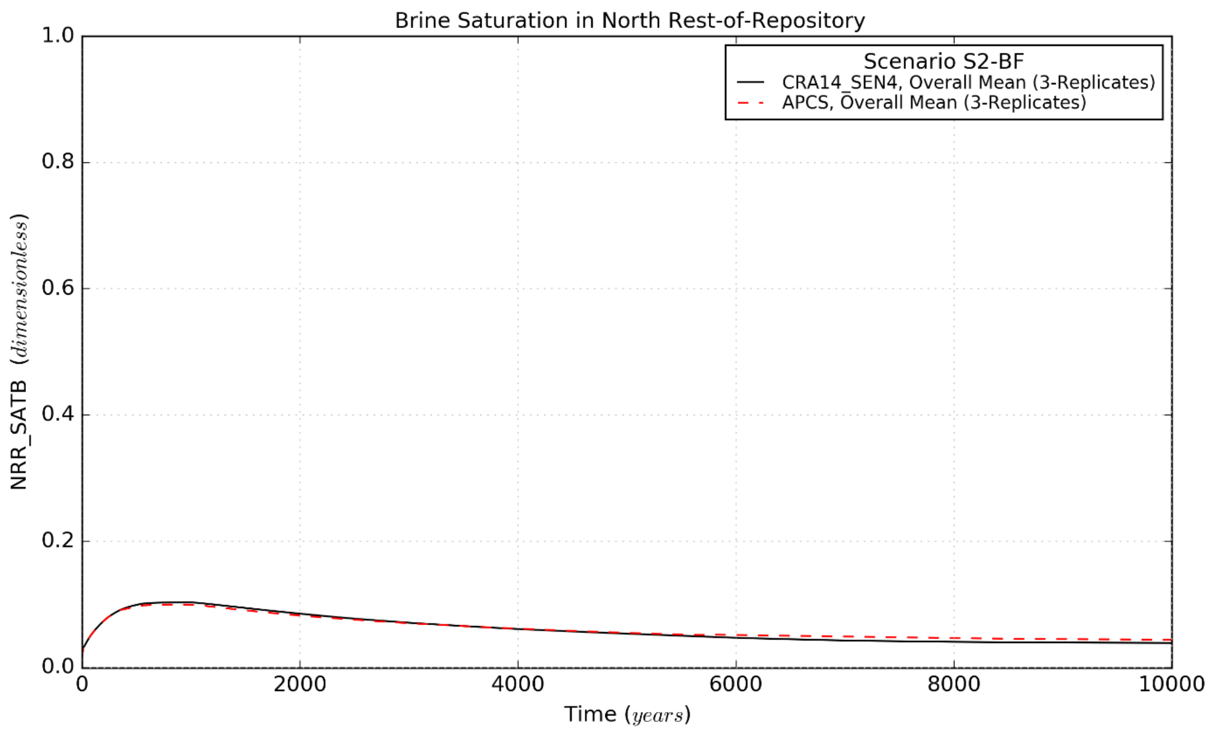

Figure 4-30: Brine Saturation Means for the North Rest-of-Repository, Scenario S2-BF

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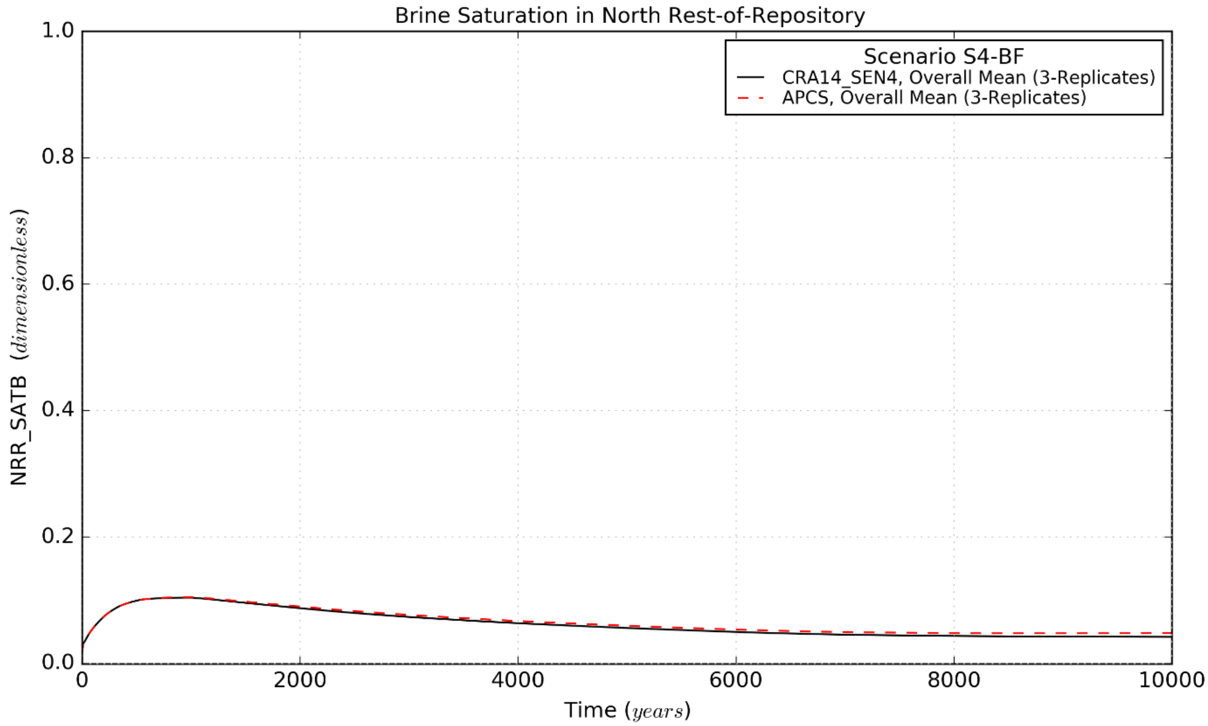

Figure 4-31: Brine Saturation Means for the North Rest-of-Repository, Scenario S4-BF

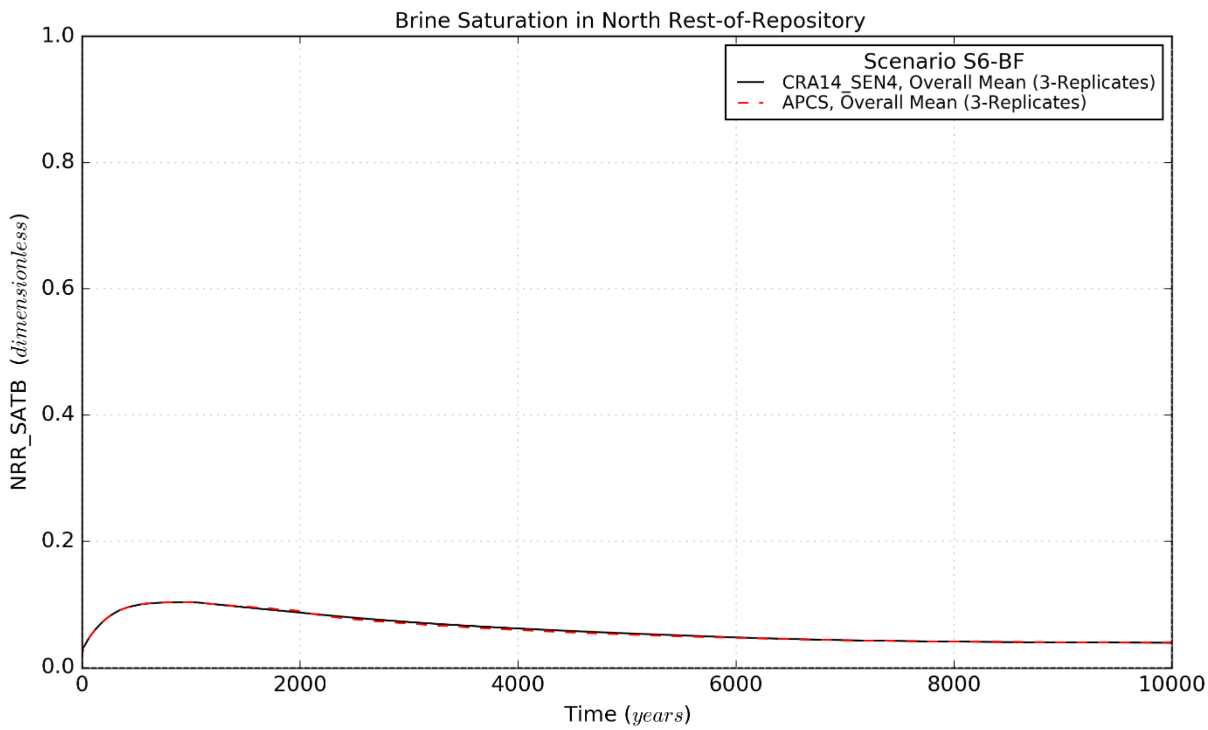

Figure 4-32: Brine Saturation Means for the North Rest-of-Repository, Scenario S6-BF

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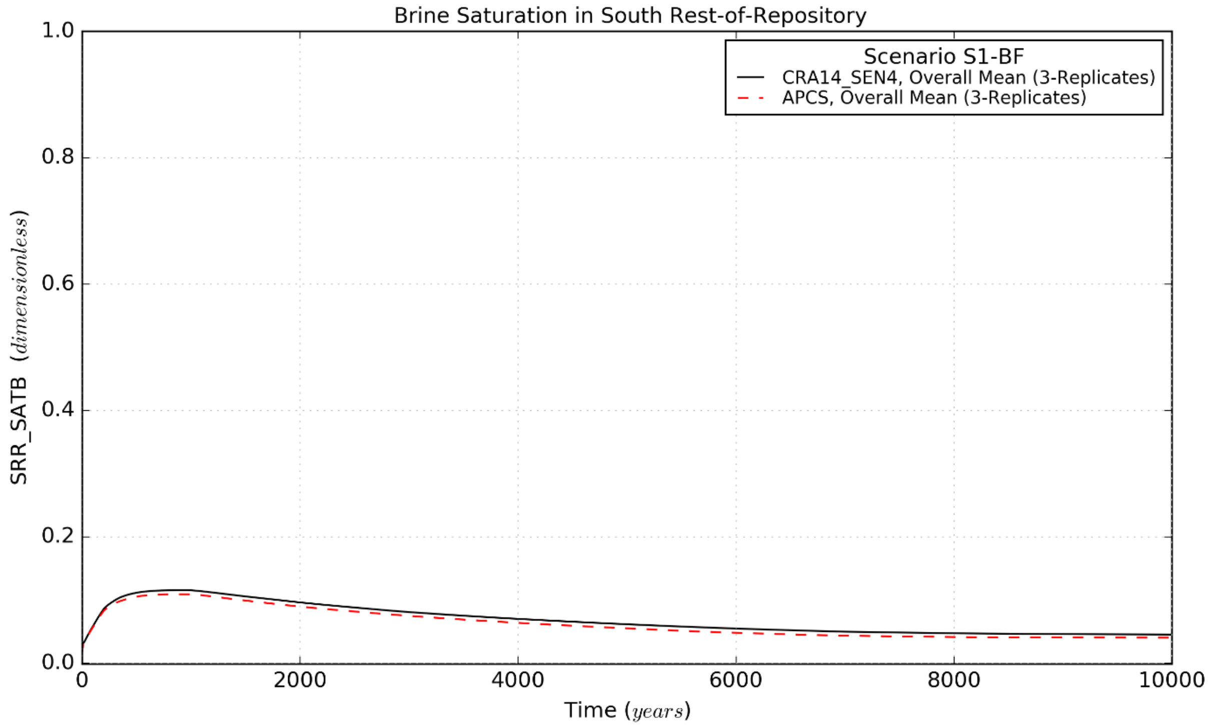

Figure 4-33: Brine Saturation Means for the South Rest-of-Repository, Scenario S1-BF

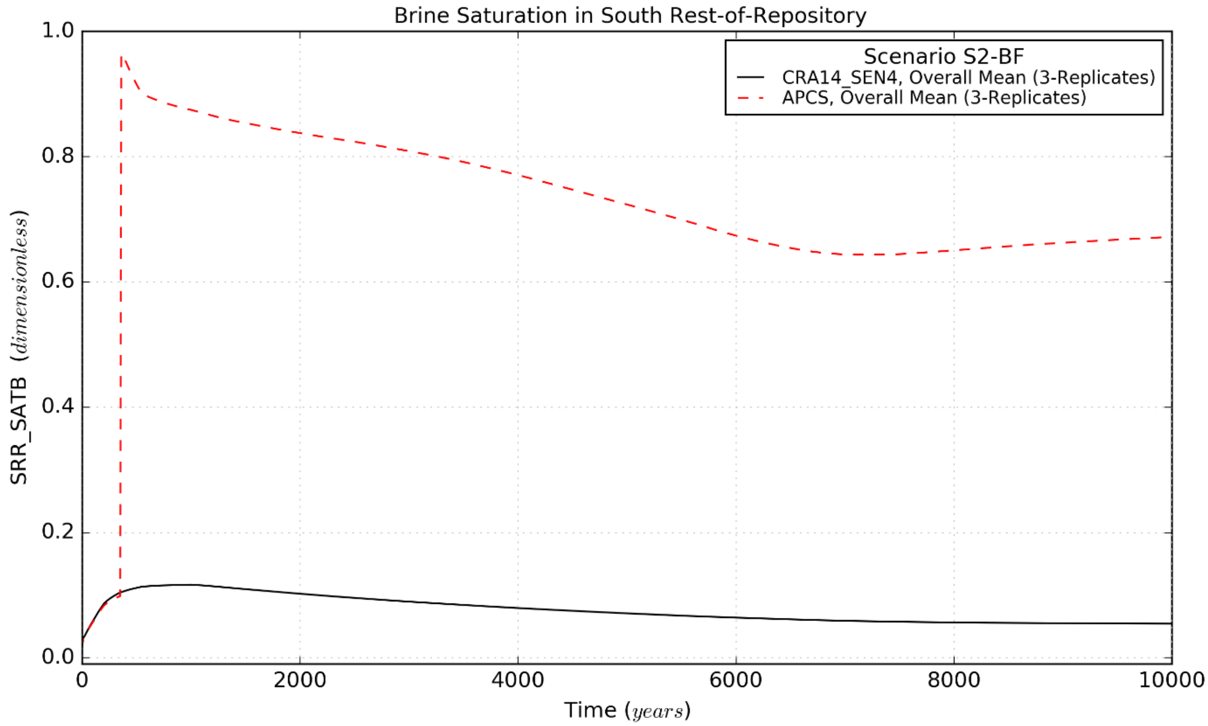

Figure 4-34: Brine Saturation Means for the South Rest-of-Repository, Scenario S2-BF

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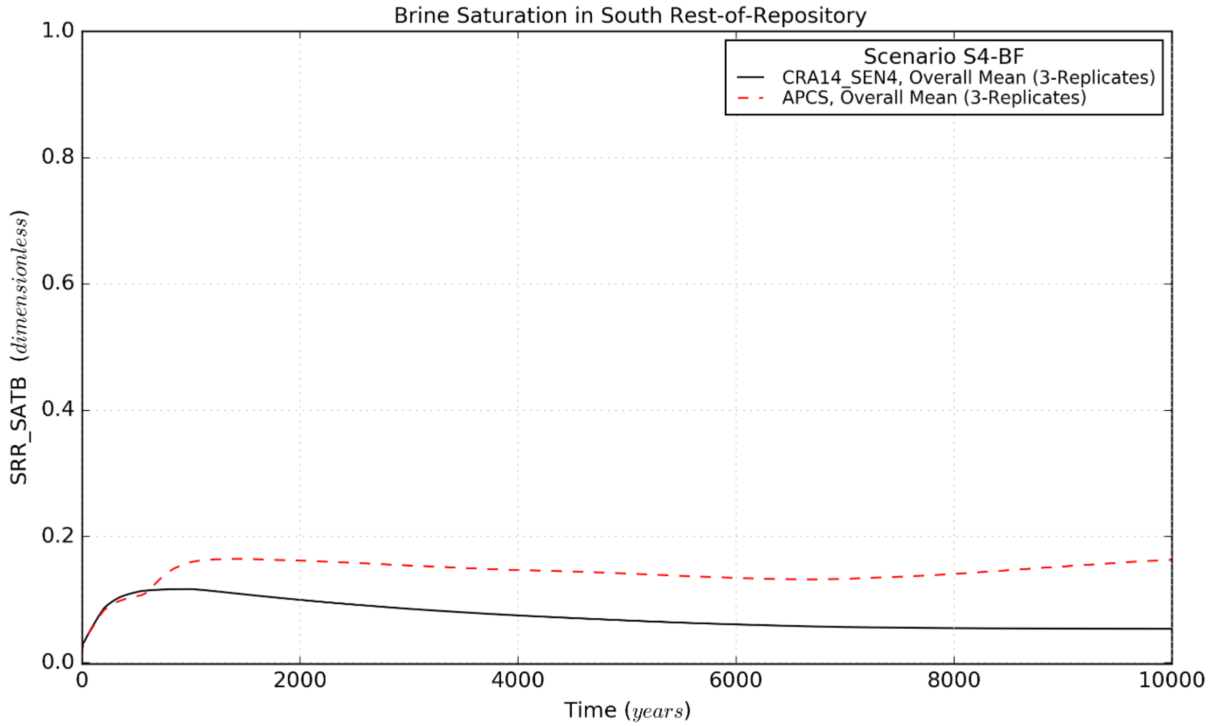

Figure 4-35: Brine Saturation Means for the South Rest-of-Repository, Scenario S4-BF

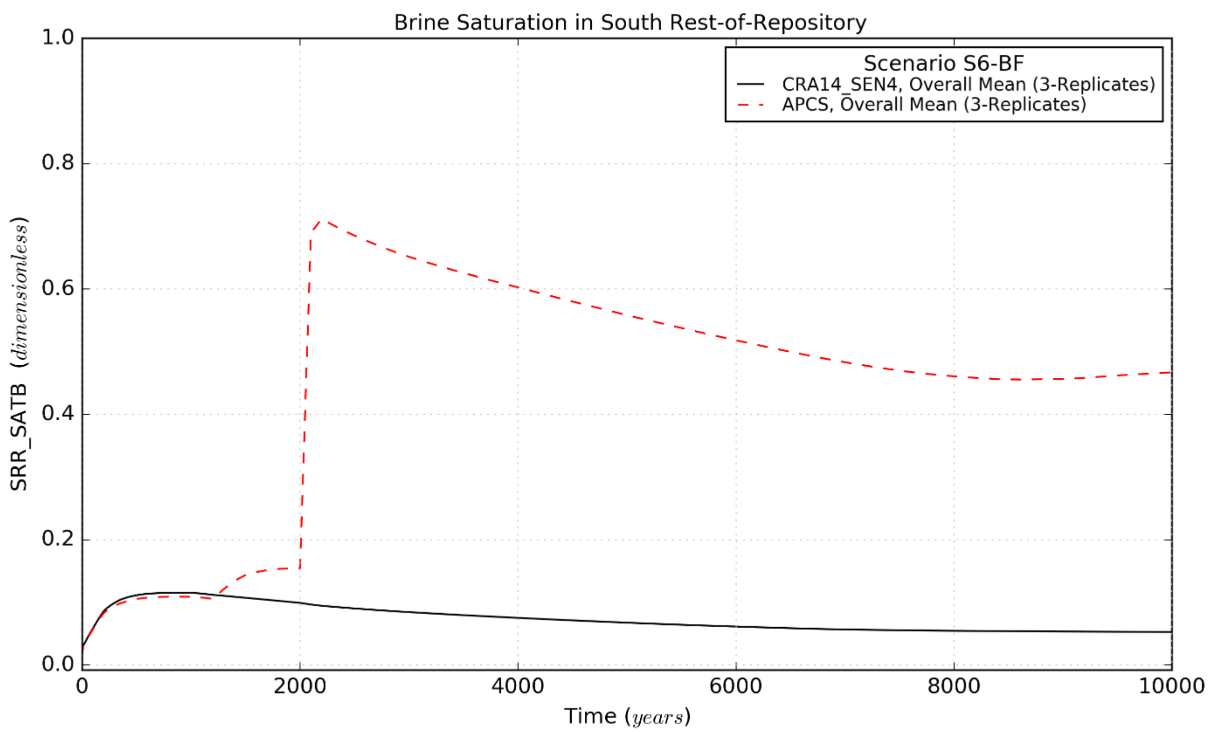

Figure 4-36: Brine Saturation Means for the South Rest-of-Repository, Scenario S6-BF

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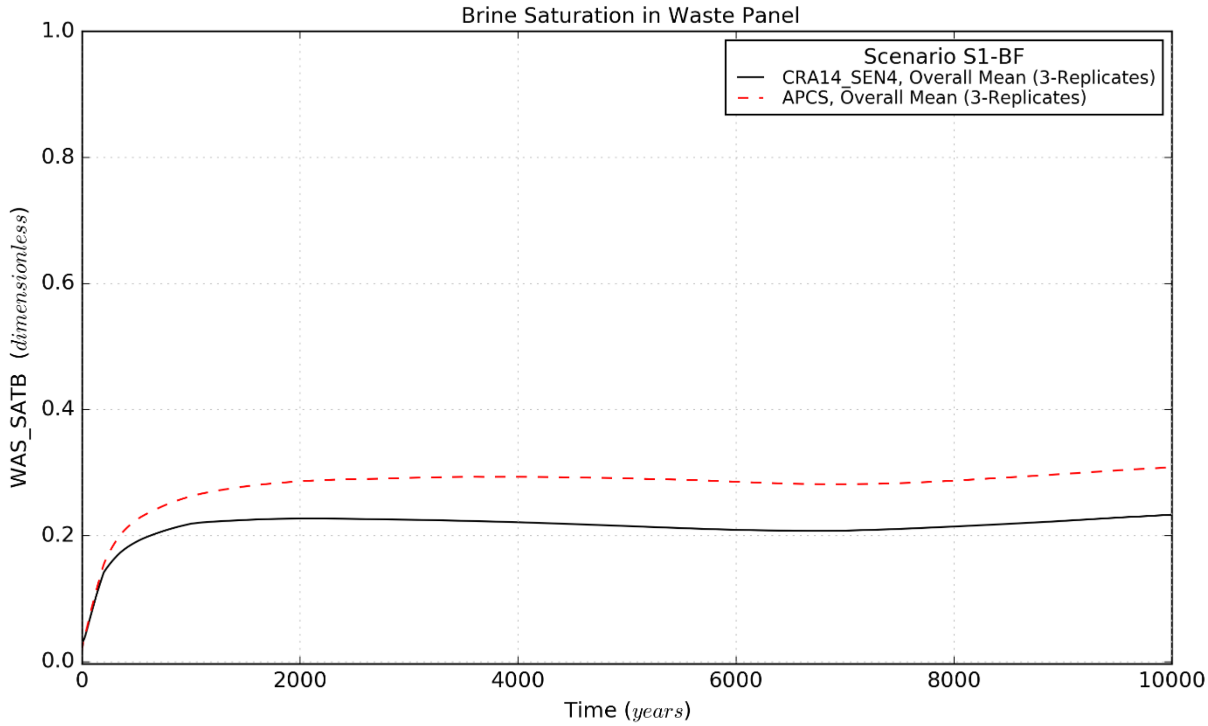

Figure 4-37: Brine Saturation Means for the Waste Panel, Scenario S1-BF

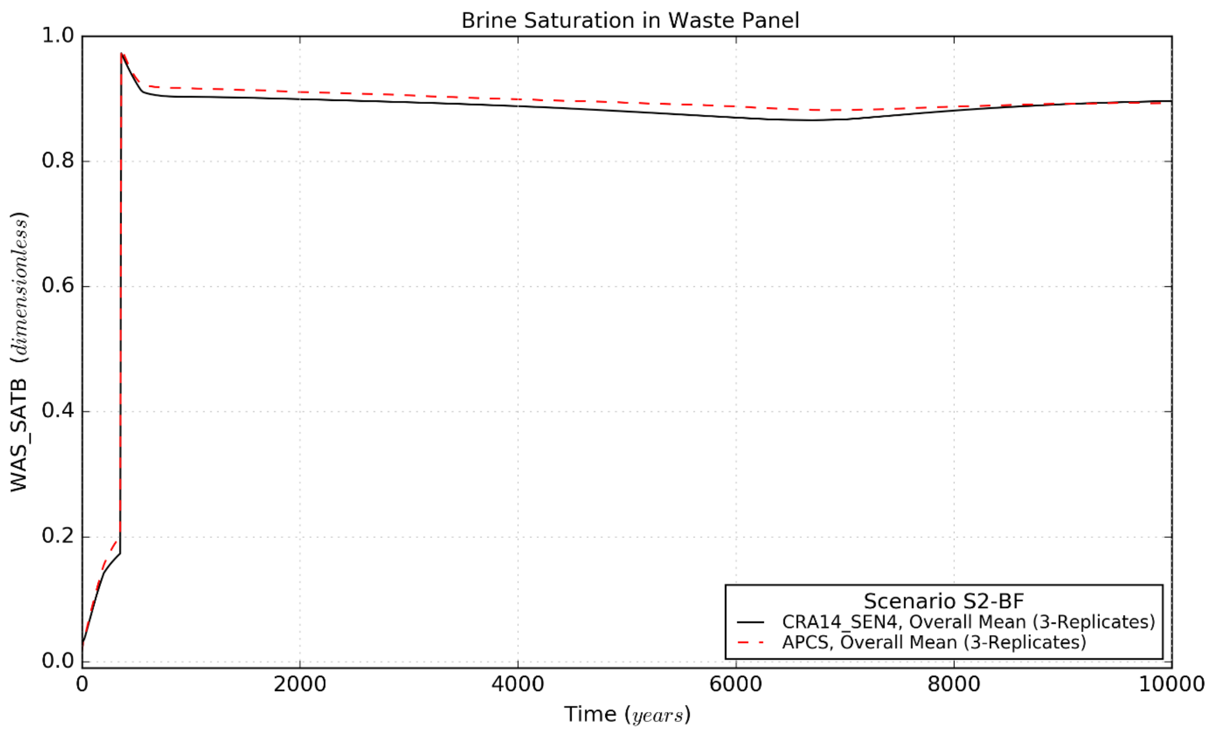

Figure 4-38: Brine Saturation Means for the Waste Panel, Scenario S2-BF

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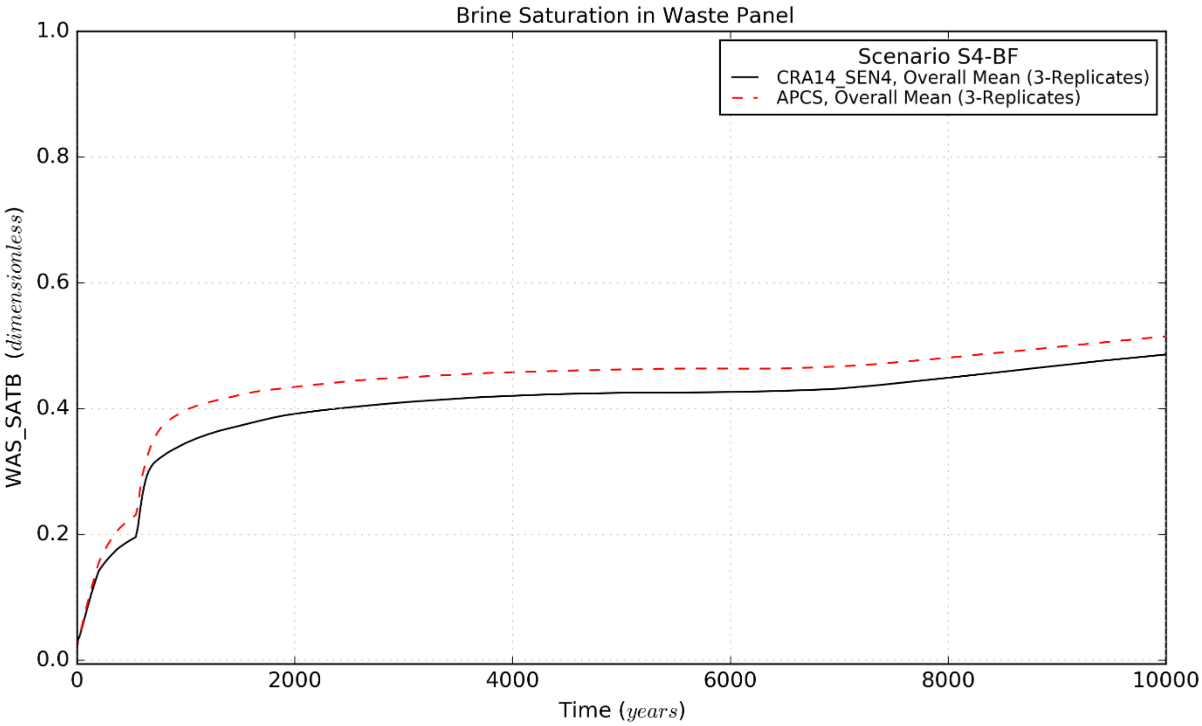

Figure 4-39: Brine Saturation Means for the Waste Panel, Scenario S4-BF

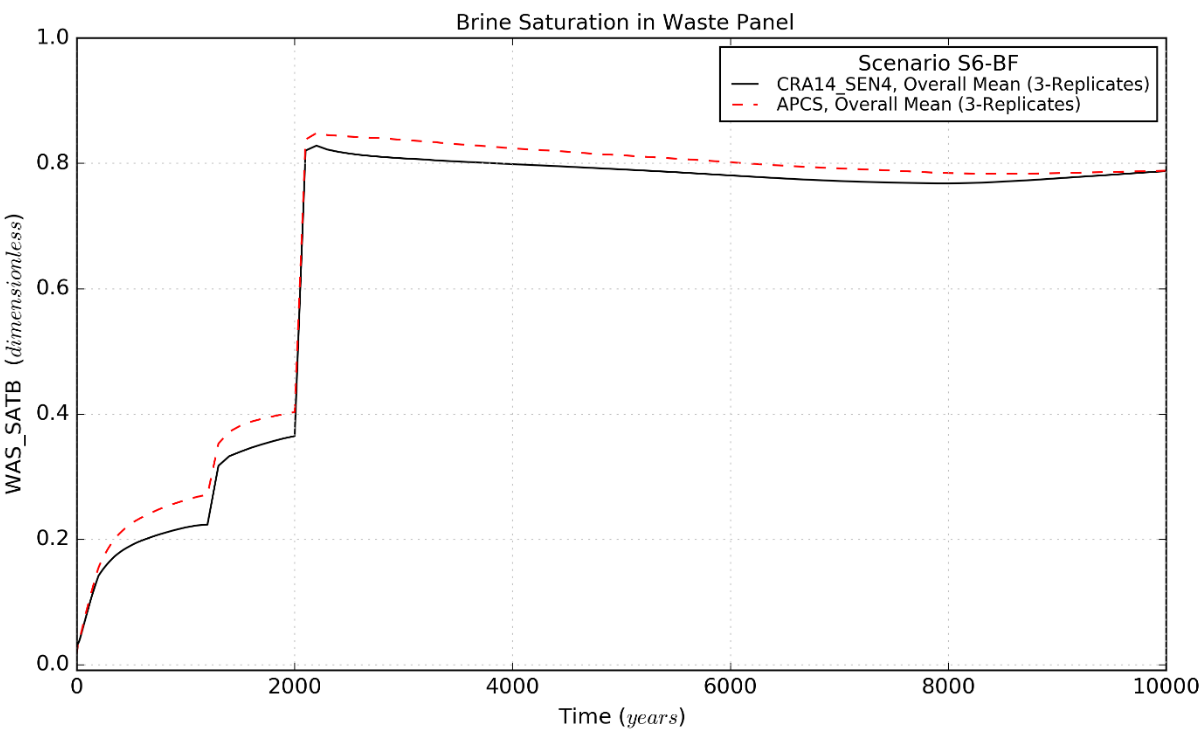

Figure 4-40: Brine Saturation Means for the Waste Panel, Scenario S6-BF

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Table 4-3: Brine Saturation Statistics on Overall Means for CRA14_SEN4 and APCS

Quantity (units)	Description	Scenario	Mean Value		Maximum Value	
			CRA14_SEN4	APCS	CRA14_SEN4	APCS
EXP_SATB (dimensionless)	Brine Saturation in Experimental Area	S1-BF	1.07E-01	1.06E-01	1.50E-01	1.48E-01
		S2-BF	1.05E-01	9.11E-02	1.45E-01	1.13E-01
		S4-BF	1.09E-01	1.10E-01	1.54E-01	1.57E-01
		S6-BF	1.07E-01	9.91E-02	1.49E-01	1.26E-01
OPS_SATB (dimensionless)	Brine Saturation in Operations Area	S1-BF	6.71E-01	6.70E-01	8.10E-01	8.09E-01
		S2-BF	6.63E-01	6.13E-01	7.94E-01	6.99E-01
		S4-BF	6.71E-01	6.70E-01	8.12E-01	8.09E-01
		S6-BF	6.67E-01	6.46E-01	8.00E-01	7.49E-01
NRR_SATB (dimensionless)	Brine Saturation in North Rest-of-Repository	S1-BF	6.03E-02	6.00E-02	1.04E-01	1.04E-01
		S2-BF	6.00E-02	6.18E-02	1.03E-01	9.97E-02
		S4-BF	6.23E-02	6.57E-02	1.04E-01	1.05E-01
		S6-BF	6.05E-02	5.99E-02	1.04E-01	1.03E-01
SRR_SATB (dimensionless)	Brine Saturation in South Rest-of-Repository	S1-BF	6.87E-02	6.26E-02	1.16E-01	1.09E-01
		S2-BF	7.61E-02	7.15E-01	1.17E-01	9.64E-01
		S4-BF	7.39E-02	1.44E-01	1.17E-01	1.65E-01
		S6-BF	7.36E-02	4.52E-01	1.16E-01	7.12E-01
WAS_SATB (dimensionless)	Brine Saturation in Waste Panel	S1-BF	2.14E-01	2.80E-01	2.33E-01	3.09E-01
		S2-BF	8.61E-01	8.71E-01	9.73E-01	9.80E-01
		S4-BF	4.06E-01	4.43E-01	4.86E-01	5.15E-01
		S6-BF	6.76E-01	6.99E-01	8.28E-01	8.48E-01

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Table 4-4: Brine Saturation Statistics on Individual Vectors for CRA14_SEN4 and APCS

Quantity (units)	Description	Scenario	Maximum Value	
			CRA14_SEN4	APCS
EXP_SATB (dimensionless)	Brine Saturation in Experimental Area	S1-BF	8.79E-01	8.49E-01
		S2-BF	9.11E-01	8.33E-01
		S4-BF	9.20E-01	9.11E-01
		S6-BF	9.12E-01	8.33E-01
OPS_SATB (dimensionless)	Brine Saturation in Operations Area	S1-BF	1.00E+00	1.00E+00
		S2-BF	1.00E+00	1.00E+00
		S4-BF	1.00E+00	1.00E+00
		S6-BF	1.00E+00	1.00E+00
NRR_SATB (dimensionless)	Brine Saturation in North Rest-of-Repository	S1-BF	6.87E-01	6.86E-01
		S2-BF	6.86E-01	6.77E-01
		S4-BF	6.87E-01	7.18E-01
		S6-BF	6.87E-01	6.86E-01
SRR_SATB (dimensionless)	Brine Saturation in South Rest-of-Repository	S1-BF	9.35E-01	9.35E-01
		S2-BF	9.35E-01	9.99E-01
		S4-BF	9.35E-01	9.85E-01
		S6-BF	9.35E-01	9.95E-01
WAS_SATB (dimensionless)	Brine Saturation in Waste Panel	S1-BF	9.83E-01	9.94E-01
		S2-BF	9.99E-01	9.99E-01
		S4-BF	9.95E-01	9.94E-01
		S6-BF	9.99E-01	9.99E-01

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4.2.3 Gas Saturation

Gas saturation results are not explicitly provided herein, but are inferred from the brine saturation results presented in Section 4.2.2, with gas saturation equal to one minus the brine saturation.

4.2.4 Brine Flow and Gas Generation

The greater communication between the WP and SROR facilitated by the abandonment of panel closures between Panels 3, 4, 5, 6, and 9 results in a net increase in brine inflow to the repository as reflected by the previously discussed pressure and saturation results. The inflow increases associated with undisturbed (S1-BF) and non-Castile intrusions (S4-BF) are rather modest when compared to the inflow increases for intrusion that are associated with the Castile (S2-BF and S6-BF) which are essentially doubled in comparison with CRA14_SEN4. Figure 4-41 to Figure 4-44 show the magnitude of brine influx to the repository for all reported scenarios. As a result of the increased influx of brine, gas generation in total waste areas is increased in proportion to the increased availability of brine as shown in Figure 4-45 to Figure 4-48.

Mean brine flows up the intrusion borehole under APCS are effectively the same as those predicted under CRA14_SEN4 and, therefore, not appreciably influenced by the abandoned panel closures for scenarios involving a Castile intrusion (S2-BF and S6-BF). An increase in mean brine flows up the intrusion borehole are observed for E2 intrusions (S4-BF), partly due to the more-direct communication between the SROR with the borehole. The comparative flows up the intrusion borehole are provided in Figure 4-49 to Figure 4-51.

Brine flow and gas generation statistics for CRA14_SEN4 and APCS are summarized in Table 4-5 and Table 4-6. Table 4-5 provides the 3-replicate mean (integrated over time) and 3-replicate maximum (over all time) brine inflow and total waste area volumetric gas generation values. Table 4-6 provides the maximum brine inflow and gas generation (over all time) for all individual vectors.

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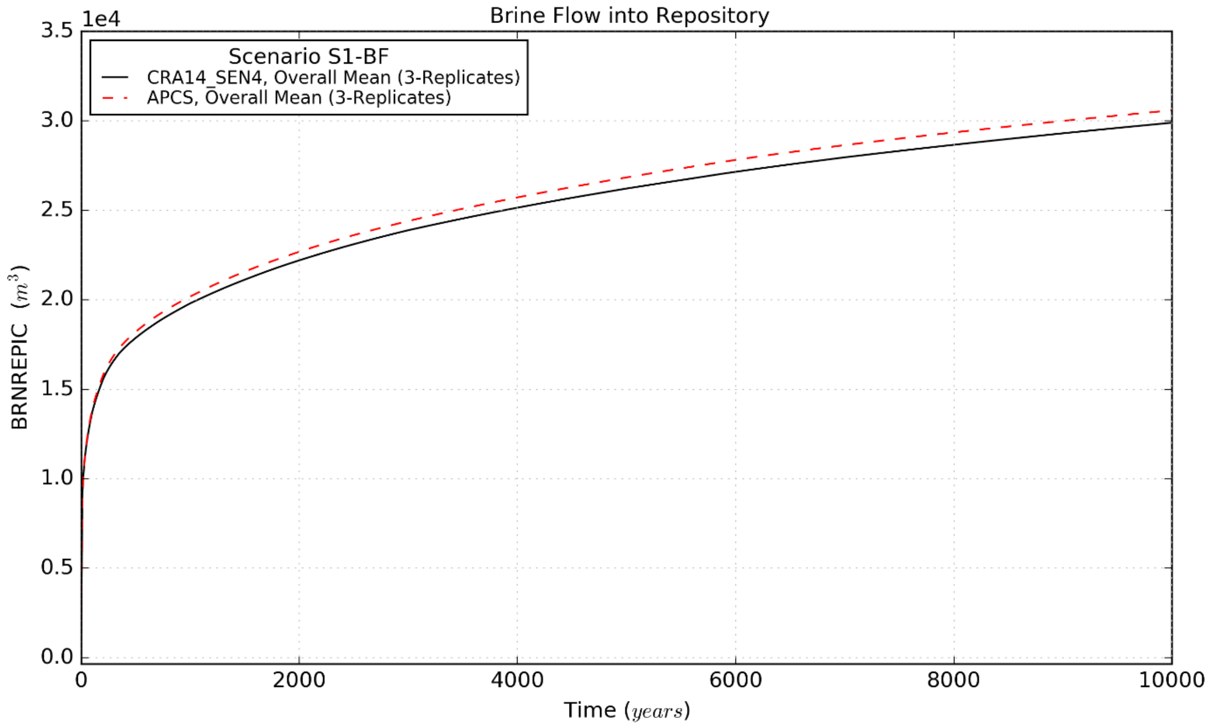

Figure 4-41: Brine Flow into the Repository, Scenario S1-BF

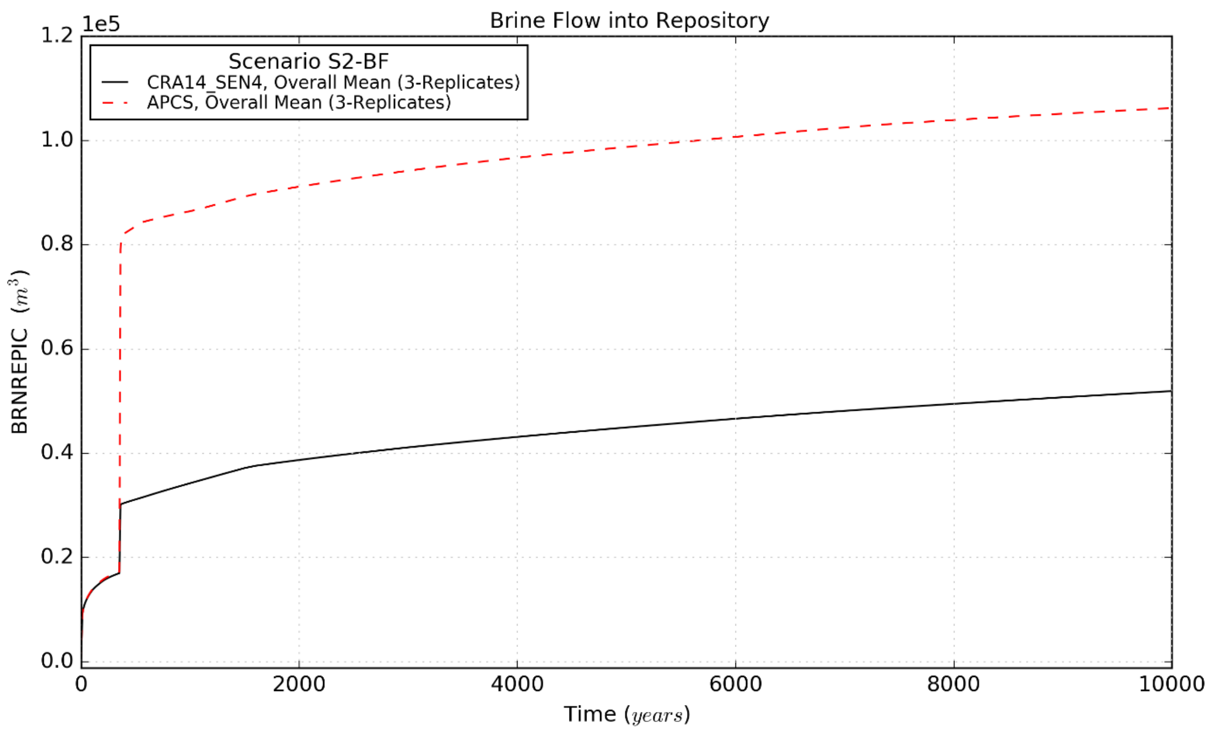

Figure 4-42: Brine Flow into the Repository, Scenario S2-BF

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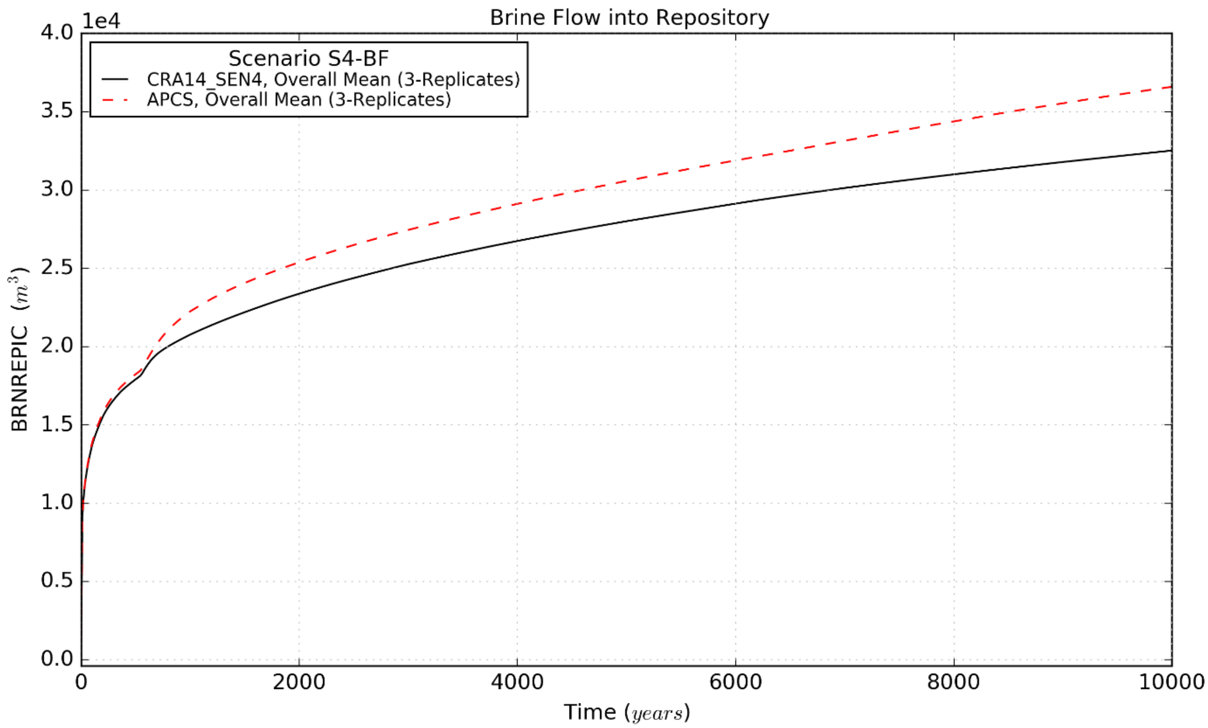

Figure 4-43: Brine Flow into the Repository, Scenario S4-BF

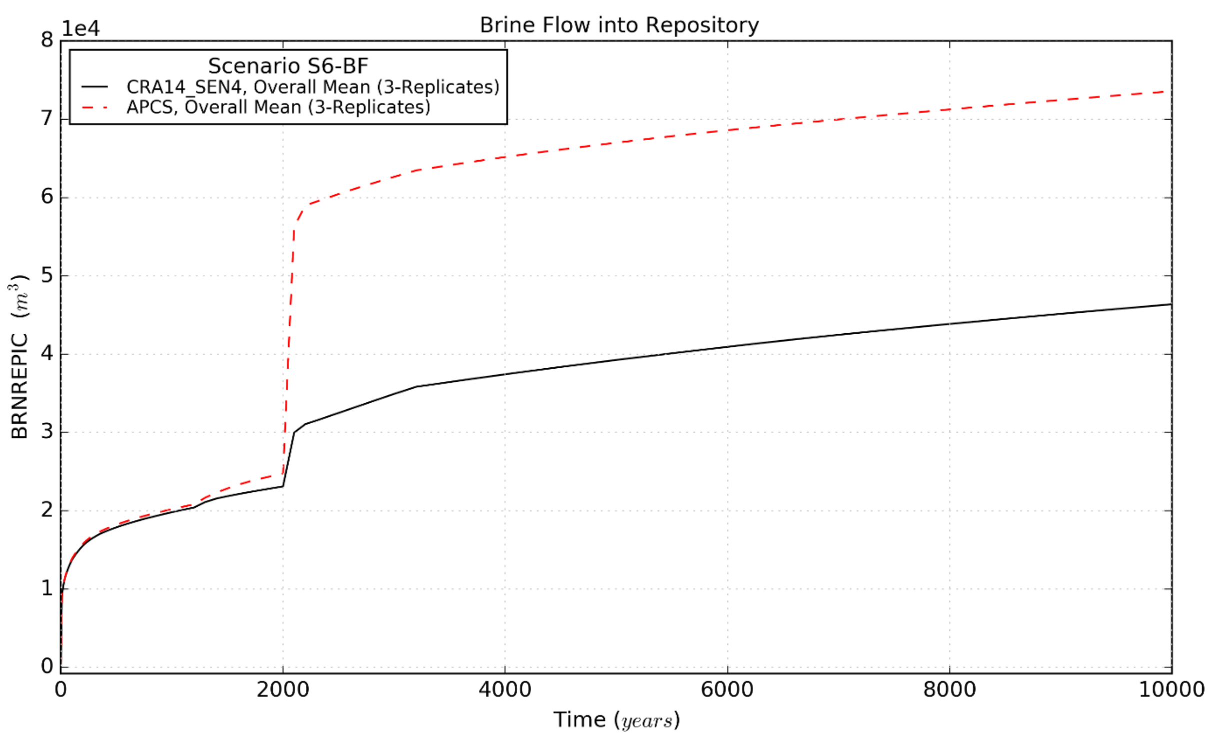

Figure 4-44: Brine Flow into the Repository, Scenario S6-BF

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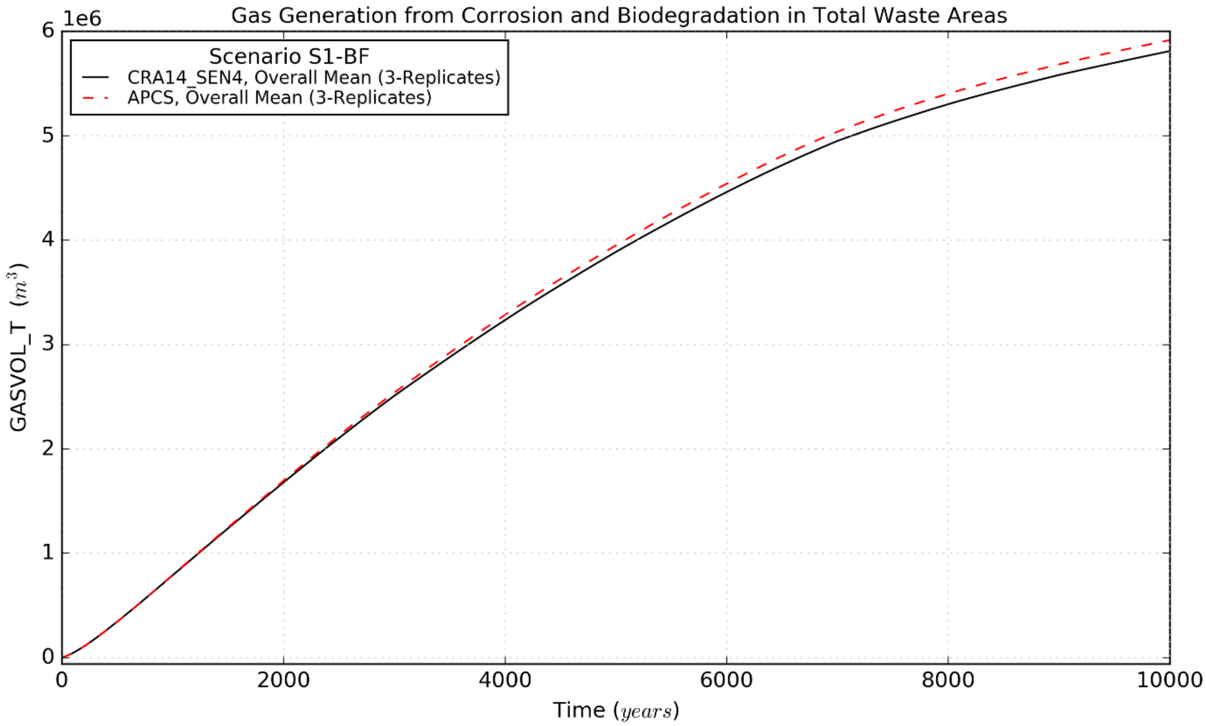

Figure 4-45: Total Volumetric Gas Generation in Waste Areas, Scenario S1-BF

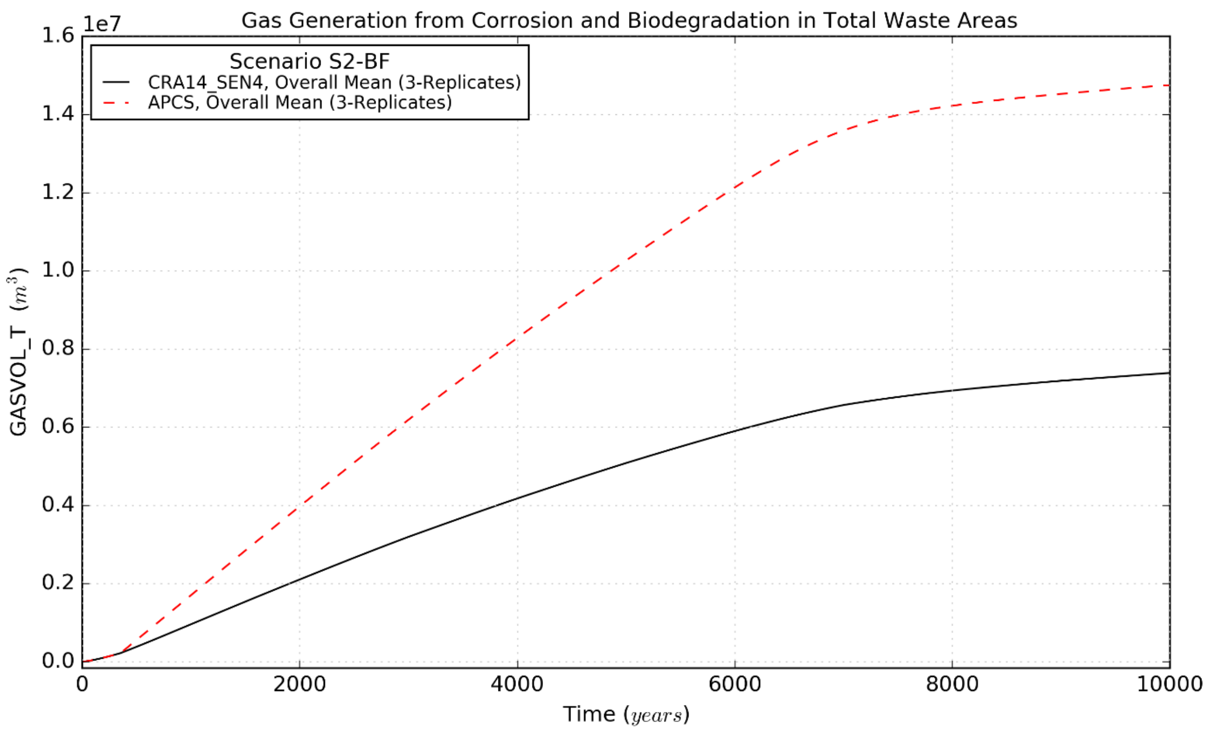

Figure 4-46: Total Volumetric Gas Generation in Waste Areas, Scenario S2-BF

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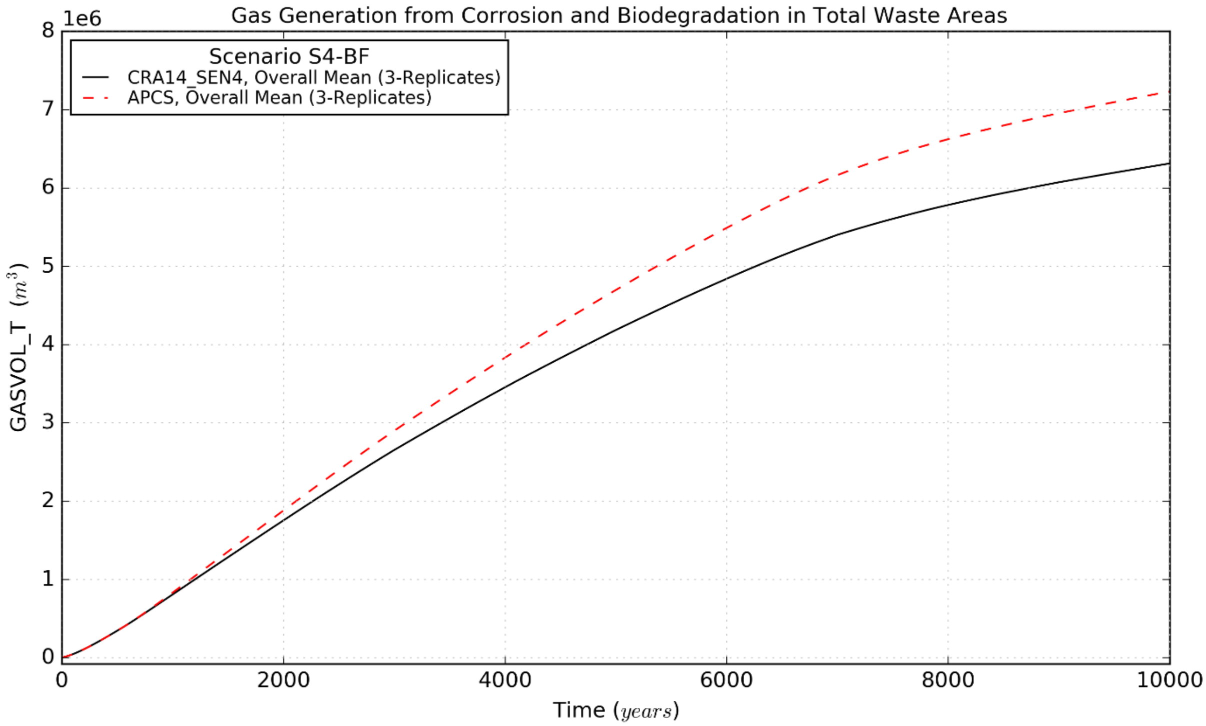

Figure 4-47: Total Volumetric Gas Generation in Waste Areas, Scenario S4-BF

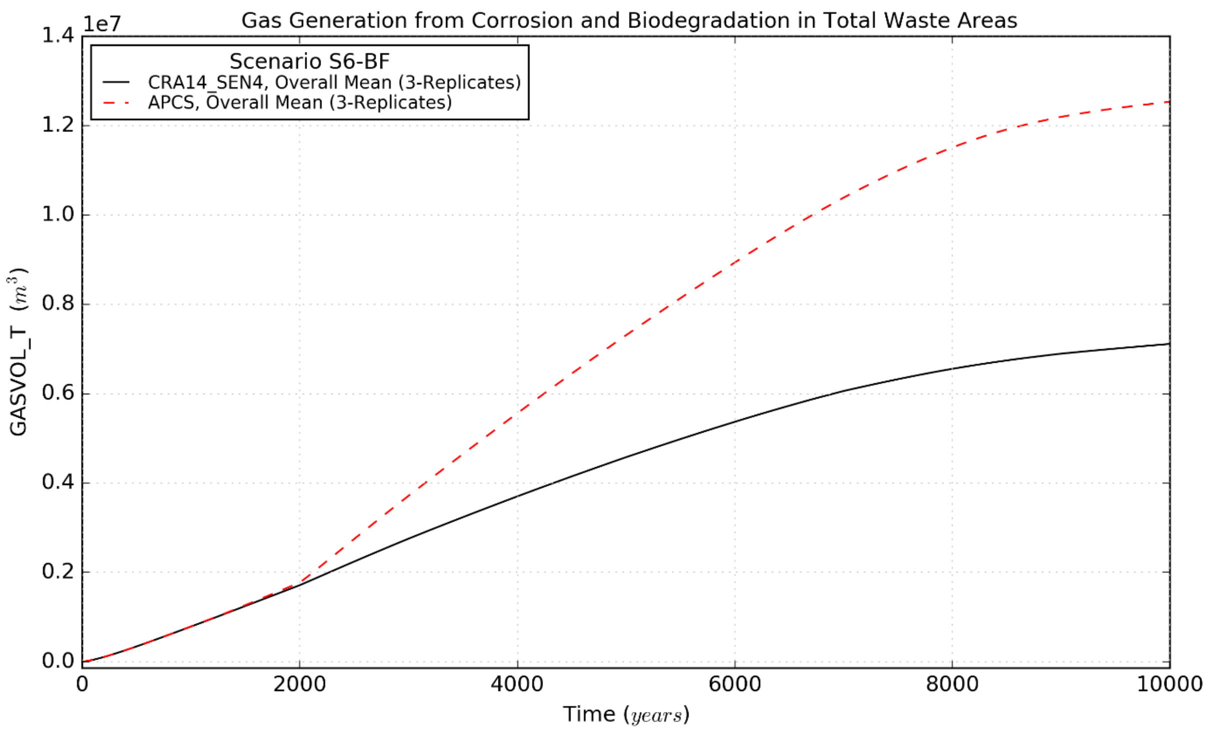

Figure 4-48: Total Volumetric Gas Generation in Waste Areas, Scenario S6-BF

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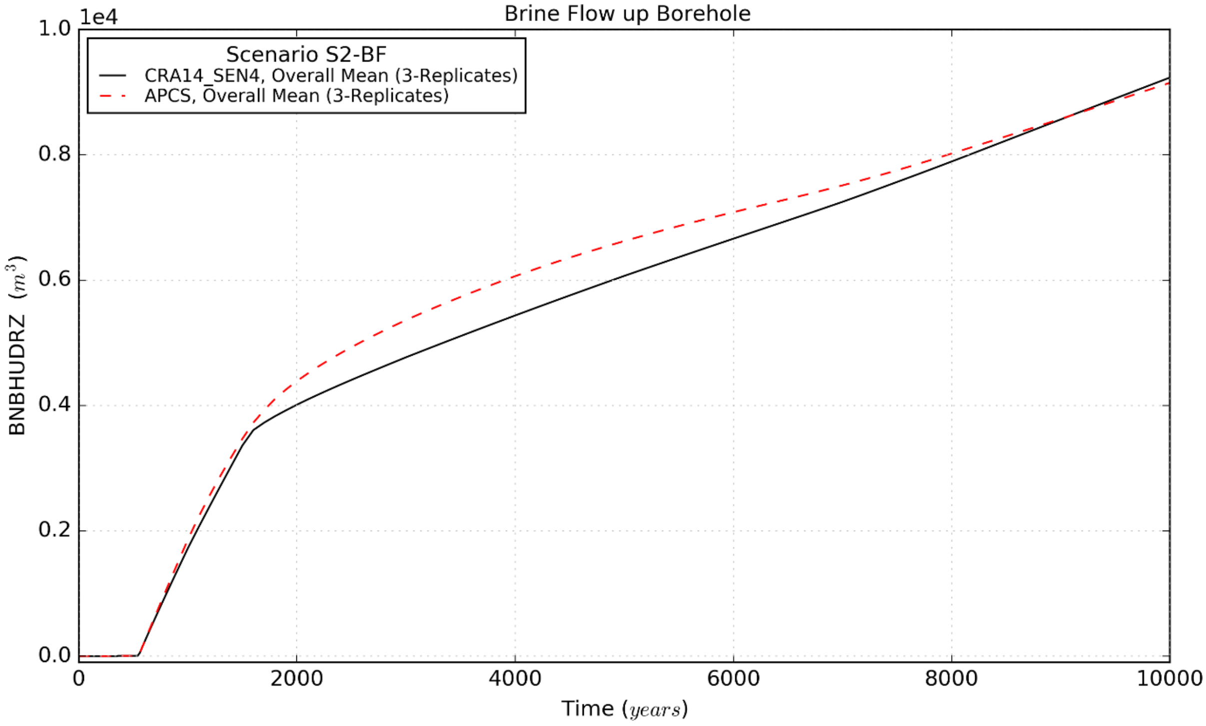

Figure 4-49: Brine Flow Means up the Borehole, Scenario S2-BF

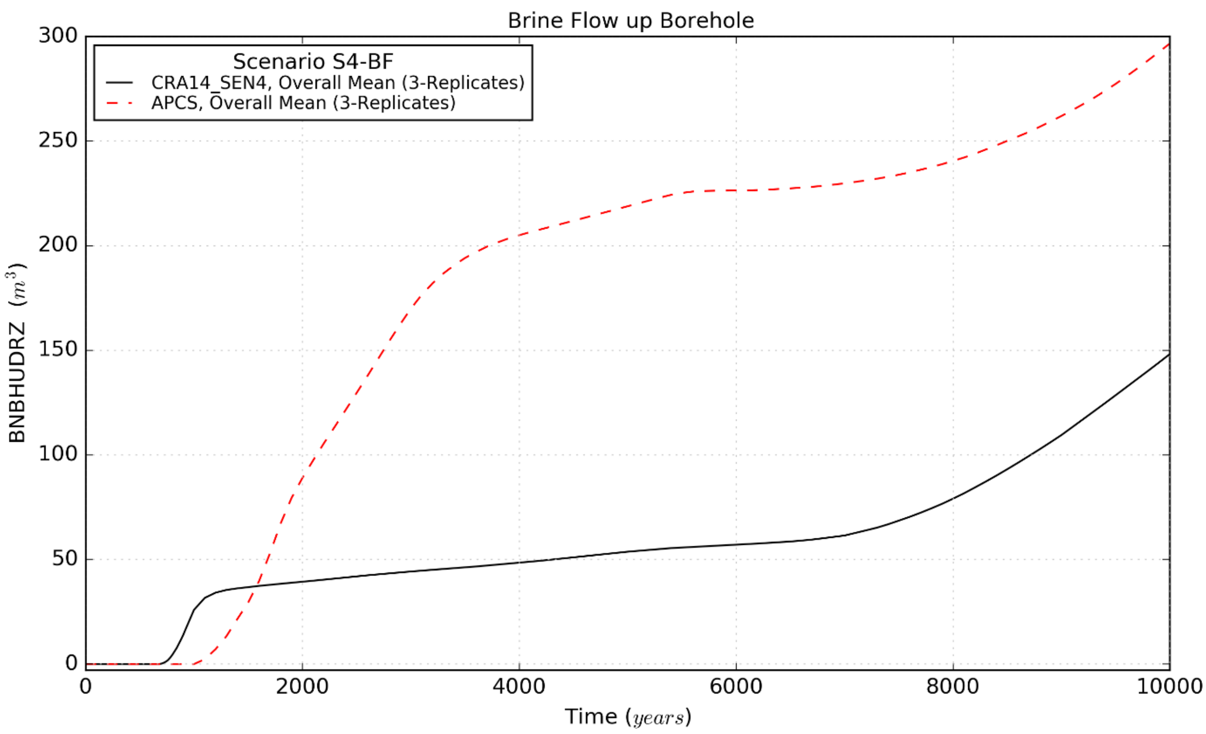

Figure 4-50: Brine Flow Means up the Borehole, Scenario S4-BF

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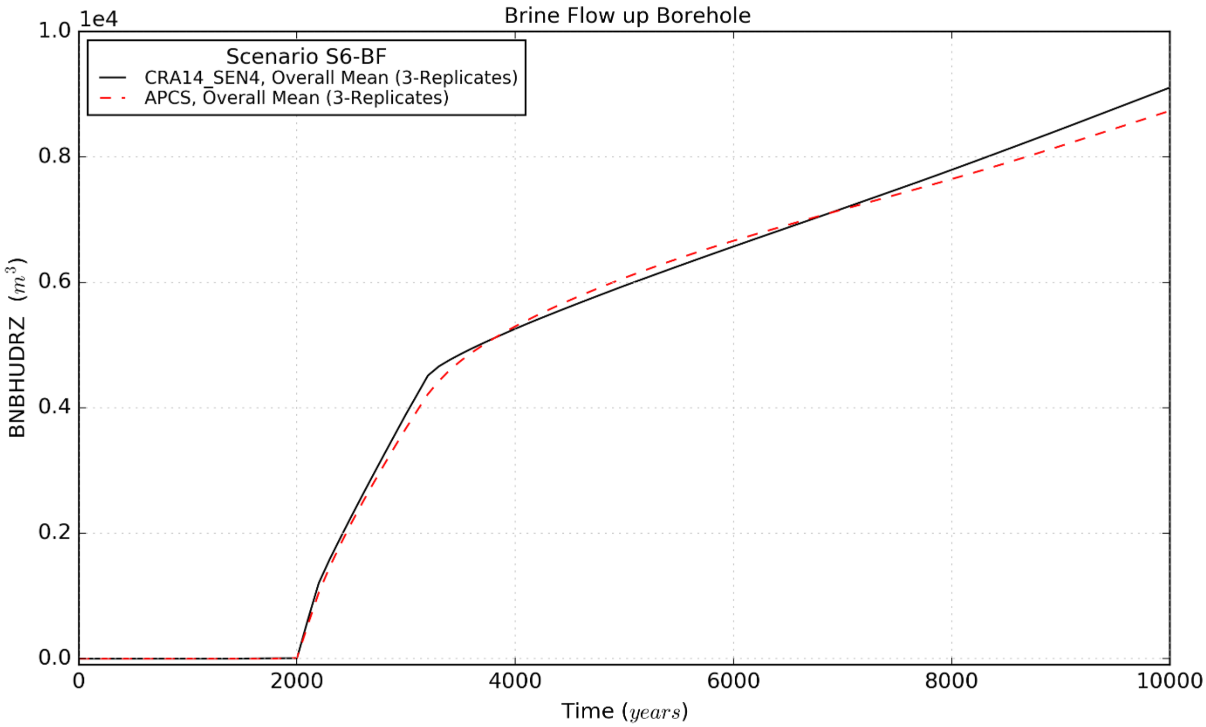

Figure 4-51: Brine Flow Means up the Borehole, Scenario S6-BF

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Table 4-5: Brine Flow and Gas Generation Statistics on Overall Means for CRA14_SEN4 and APCS

Quantity (units)	Description	Scenario	Mean Value[1]		Maximum Value[2]	
			CRA14_SEN4	APCS	CRA14_SEN4	APCS
BRNREPIC (m^3)	Brine Flow into Repository	S1-BF	2.53E+04	2.59E+04	2.99E+04	3.06E+04
		S2-BF	4.33E+04	9.50E+04	5.19E+04	1.06E+05
		S4-BF	2.70E+04	2.95E+04	3.25E+04	3.66E+04
		S6-BF	3.61E+04	5.81E+04	4.64E+04	7.36E+04
GASVOL_T (m^3)	Gas Generation from Corrosion and Biodegradation in Total Waste Areas	S1-BF	3.53E+06	3.59E+06	5.81E+06	5.92E+06
		S2-BF	4.58E+06	9.23E+06	7.39E+06	1.48E+07
		S4-BF	3.81E+06	4.30E+06	6.31E+06	7.23E+06
		S6-BF	4.20E+06	6.86E+06	7.12E+06	1.25E+07
BNBHUDRZ (m^3)	Brine Flow up Borehole	S1-BF	-	-	-	-
		S2-BF	5.68E+03	5.98E+03	9.23E+03	9.15E+03
		S4-BF	5.84E+01	1.78E+02	1.48E+02	2.97E+02
		S6-BF	5.01E+03	4.95E+03	9.11E+03	8.74E+03

Notes:
1 Calculated as the function average (integrated) over the time interval (0-10,000 yr) for the overall means (3 replicates)
2 Calculated as the function maximum over the time interval (0-10,000 yr) for the overall means (3 replicates)

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Table 4-6: Brine Flow and Gas Generation Statistics on Individual Vectors for CRA14_SEN4 and APCS

Quantity (units)	Description	Scenario	Maximum Value[3]	
			CRA14_SEN4	**APCS**
BRNREPIC (m^3)	Brine Flow into Repository	S1-BF	1.41E+05	1.49E+05
		S2-BF	2.15E+05	2.59E+05
		S4-BF	1.41E+05	1.52E+05
		S6-BF	2.12E+05	2.47E+05
GASVOL_T (m^3)	Gas Generation from Corrosion and Biodegradation in Total Waste Areas	S1-BF	3.16E+07	3.16E+07
		S2-BF	3.16E+07	3.16E+07
		S4-BF	3.16E+07	3.16E+07
		S6-BF	3.16E+07	3.16E+07
BNBHUDRZ (m^3)	Brine Flow up Borehole	S1-BF	1.74E+05	1.57E+05
		S2-BF	3.87E+03	1.48E+04
		S4-BF	1.74E+05	1.66E+05
		S6-BF	1.74E+05	1.57E+05

Notes:
3 Calculated as the function maximum over the time interval (0-10,000 yr) for all replicates (300 vectors)

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4.3 Conclusions

The primary impacts to the Salado flow solution resulting from the abandonment of panel closures in the south (ROMPCS between Panels 3, 4, 5, 6, and 9) using the PCS_NO material in the BRAGFLO grid were as follows when compared to CRA14_SEN4:

- EXP, OPS, and NROR – increase brine pressure in scenarios with Castile intrusions (S2-BF and S6-BF); brine saturations minimally impacted
- SROR – substantially increase brine pressure AND saturations in scenarios with Castile intrusions; brine pressures equilibrate with the WP under all scenarios with brine saturations less than the WP due to the Salado dip
- WP – brine pressures decrease and saturations increase for all scenarios not involving a Castile intrusion (S1-BF and S4-BF); brine pressure increase AND saturations increase for all scenarios with an associated Castile intrusion (S2-BF and S6-BF); thus, saturations are increased under all scenarios due to the additional communication with the SROR and brine flow due to the Salado dip
- Brine flow into the repository and associated total gas generation in the waste areas is substantially increased for all scenarios, essentially doubling the total gas generation due to corrosion and biodegradation for scenarios involving Castile brine intrusions (S2-BF and S6-BF)

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5 BRAGFLO_DBR Calculations

This section describes the changes between the APCS and CRA14_SEN4 analyses that are relevant to direct brine release volume calculations and summarizes the differences between the results of those two analyses. For a more complete description of the direct brine release computational procedures, refer to the CRA-2014 direct brine release analysis package document (Malama 2013).

5.1 Introduction

If the WIPP repository were to be penetrated by a borehole while under conditions of sufficient repository brine pressure and saturation, brine could migrate up through the intruding borehole to reach the land surface. Such an event is defined as a direct brine release (DBR). The BRAGFLO DBR analysis uses the BRAGFLO code to numerically evaluate DBR volumes under a suite of 23,400 reference conditions, including permutations of initial repository pressures and saturations produced by the BRAGFLO scenarios (Table 2-3), and the intrusion locations and times evaluated in the DBR scenarios (Table 2-4).

BRAGFLO calculates DBR volumes by integrating the volumetric flux of brine over the duration of the release, as follows:

$$DBR\ volume = \int_0^{t_e} q_b(t)dt = \int_0^{t_e} J_b[p_b(t) - p_{wf}]dt$$

In which:

t_e is the duration of the DBR event;
q_b(t) is the volumetric flux of brine to the intrusion as a function of time, t;
J_b is a well productivity index (Mattax and Dalton 1990; Chappelear and Williamson 1981);
p_b(t) is the volume-averaged brine pressure of the repository in the vicinity of the intrusion; and
p_{wf} is the flowing bottom-hole pressure.

The results of this calculation are ultimately multiplied by the repository radionuclide concentrations to calculate DBR radionuclide releases in the CCDFGF package (Section 6.4).

Certain pressure and saturation conditions must exist within the waste in order for brine to flow to the surface during an intrusion and produce a DBR. Pressure in the intruded waste must be great enough to overcome the static pressure exerted by a column of drilling fluid at the repository depth, assumed to be equal to 8 megapascals (MPa). Brine saturation in the intruded waste must be above the residual brine saturation of the waste, i.e., the brine must be mobile. In both CRA14_SEN4 and APCS, residual brine saturation of the waste is a sampled parameter (WAS_AREA:SAT_RBRN) that varies between 0 and 0.552 for each model vector.

The modifications made in the APCS analysis impact the DBR calculations in two ways:

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1. The modified panel closure properties in the Salado flow model produce different initial conditions for the DBR analysis; and
2. The modified panel closure properties in the DBR grid impact flow toward an intrusion during a DBR event.

Both of these changes are the result of the different parameter values in the abandoned panel closure material, PCS_NO, relative to the existing panel closure materials in CRA14_SEN4. Additional changes made to the APCS model impact the use of DBR results in final release estimates calculated by the CCDFGF code (Section 6.4).

5.2 Results

DBR calculation results obtained with the PCS_NO material in the southern panel closures are presented and compared to those from the CRA14_SEN4 analysis. The summary statistics and plots presented below were generated with Python, an open-source software package, and Microsoft Excel.

Summary statistics were calculated by scenario and panel intrusion location across all three model replicates and all 100 realizations within each replicate, such that each entry in Row 1 of Table 5-1, for example, was evaluated over the results of 5,400 modeled intrusion events (the 6 intrusion times for each of 3 intrusion locations of S1-DBR, times the 100 model vectors and 3 model replicates).

Results show that the APCS analysis produces increased average DBR volumes in all scenarios, with the most pronounced differences in the scenarios with prior E1-type intrusions, S2-DBR and S3-DBR (Table 5-1; refer to Table 2-4 for a description of scenarios). As a result, although E1 scenarios already had the highest average releases in CRA14_SEN4, the difference between scenarios becomes even larger in APCS. The probability of a nonzero DBR increased significantly in E1-type scenarios, but decreased slightly in the undisturbed and E2-type scenarios.

Table 5-1: Summary statistics of DBR volume by scenario and intrusion location

Scenario	**Nonzero release rate (%)**		**Maximum release volume (m^3)**		**Mean nonzero release volume (m^3)**		**Mean release volume (m^3)**	
	SEN4	APCS	SEN4	APCS	SEN4	APCS	SEN4	APCS
S1-DBR	3.57	3.35	98.30	98.40	4.24	10.11	0.15	0.34
S2-DBR	24.62	52.11	61.70	104.00	13.18	19.08	3.24	9.94
S3-DBR	21.29	47.04	57.50	75.00	9.74	14.02	2.07	6.60
S4-DBR	1.93	1.56	51.40	46.40	5.32	7.21	0.10	0.11
S5-DBR	2.67	1.93	38.90	59.30	3.68	8.08	0.10	0.16
Lower	24.39	31.31	13.30	20.90	3.20	5.92	97.27	59.68
Middle	2.65	28.19	0.23	17.90	0.09	4.00	2.66	40.30
Upper	1.91	2.04	0.01	0.01	2.0E-3	2.0E-3	0.07	0.02
OVERALL	10.54	20.51	98.30	104.00	10.40	16.14	1.10	3.31

Lower panel intrusions account for 97% of the total DBR volumes in CRA14_SEN4, but only 60% in APCS (Table 5-1). The situation is reversed in the middle panel, where intrusions account for

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only 3% of the DBR volumes in CRA14_SEN4, but 40% in APCS. Further, although the lower panel accounts for a lesser proportion of total DBR release in APCS, intrusions into the lower panel produce larger and more frequent DBR events than in CRA14_SEN4. Releases from intrusions in the upper panel did not significantly change between CRA14_SEN4 to APCS, and as a result represent a lower proportion of the total release in APCS.

Given the repository conditions documented in the BRAGFLO results (Section 4.2), many of the DBR results are relatively straightforward to interpret. For example, the increased pressures and saturations in the south rest-of-repository (SROR) of E1 intrusion scenarios (Figure 4-14 and Figure 4-34) produce the expected increase in DBR volumes. However, in other scenarios and intrusion locations, a mechanistic interpretation of the results is more complicated. For example, decreasing pressures and increasing saturations in the waste panel in S1-BF (Figure 4-17 and Figure 4-37, respectively), produce fewer yet larger DBR volumes in S1-DBR.

To further investigate roles of repository conditions in producing the DBR volumes, release volumes are presented in more detail below alongside plots of panel pressure and saturation conditions. Results are grouped by scenario intrusion type. For the disturbed scenarios, pressure and saturation data are presented only for S2-DBR and S4-DBR, because these are representative of the intrusions considered in scenarios S3-DBR and S5-DBR, respectively, with the only differences being the timing of prior and modeled drilling intrusions. Plots contain results compiled from all three replicates and all 100 vectors for the specified scenarios and intrusion times and locations.

5.2.1.1 S1-DBR: No Prior Intrusion (Initially Undisturbed Repository)

Scenario S1-DBR release volumes increased in the APCS analysis in the lower panel intrusions, particularly for later modeled times (Figure 5-1). Releases from the middle and upper panels are low and essentially unchanged between analyses. Time series output from the BRAGFLO calculations show increased brine saturation and decreased pressure in the lower panel (Figure 4-17 and Figure 4-37, respectively), which independently should have opposite effects on DBR volume. To help illustrate how these conditions lead to increased release volumes, plots of pressure and mobile brine saturations encountered by all intrusions in the lower panel are shown below (Figure 5-2).

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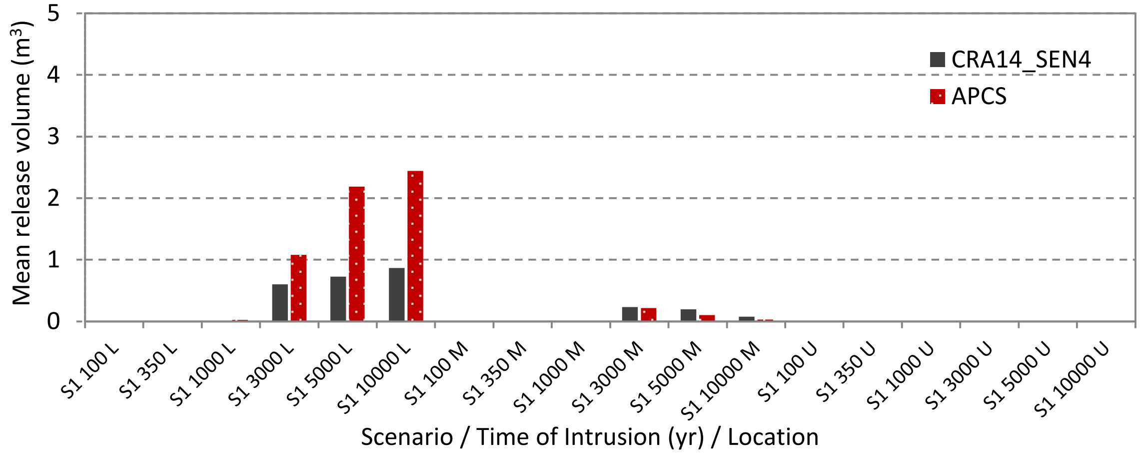

Figure 5-1: S1-DBR average release volumes

Mobile brine saturation levels in the lower panel show substantial scattering, likely due in part to the sampled nature and wide range of the residual brine saturation parameter, but in general are higher in APCS than CRA14_SEN4 throughout the modeled time period. Pressures are slightly lower in the APCS analysis, but tend to converge with the CRA14_SEN4 analysis pressures at later times and higher pressures. It appears that the increased average releases are due to broadly higher mobile brine saturations, while the decreased nonzero DBR frequency is caused by more pressure values below the minimum DBR threshold of 8 MPa.

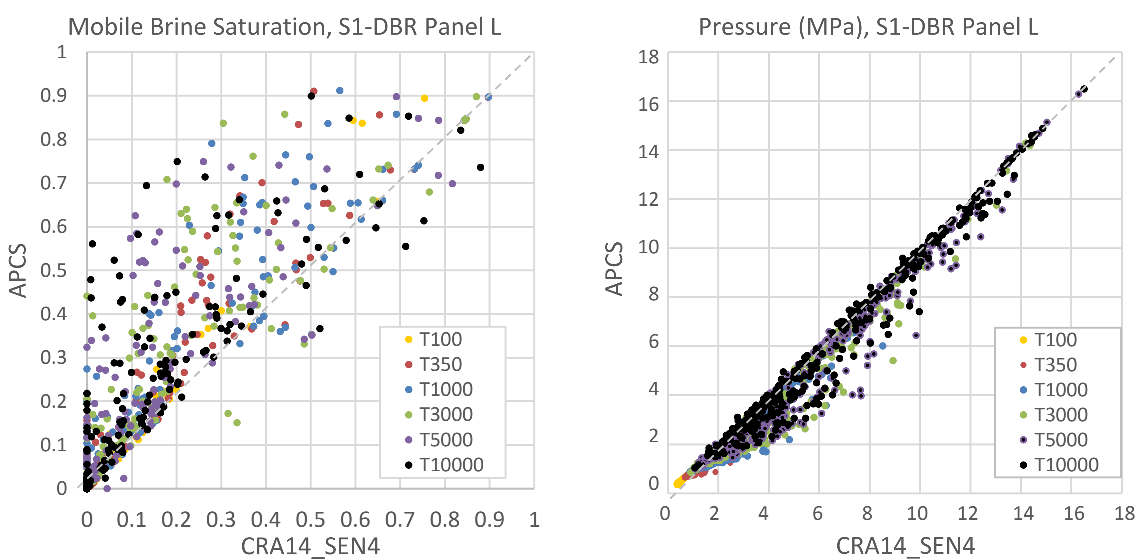

Figure 5-2: S1-DBR APCS and CRA14_SEN4 mobile brine saturations and pressures in lower intrusion location at time of intrusion

5.2.1.2 S2-DBR and S3-DBR: Prior E1 Intrusion

Results from scenarios with a prior E1 intrusion show DBR release volumes increased in the APCS analysis lower and middle panel intrusions, but not in the upper panel intrusions, where release volumes remained low (Figure 5-3). Note that the axis of Figure 5-3 has been scaled to the range

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of the data. The time series of pressure and saturation shown in the BRAGFLO output for both the waste panel (Figure 4-18 and Figure 4-38) and SROR (Figure 4-14 and Figure 4-34) of S2-BF are higher in APCS, consistent with the increased DBR volumes. In particular, the increased saturations and pressures in the SROR are a significant result of the APCS analysis that clearly leads to greater DBR releases from the middle panel (Section 6.4). Pressure and saturation values from individual intrusions of the scenario S2-DBR are plotted for the lower and middle panels (Figure 5-4 and Figure 5-5, respectively).

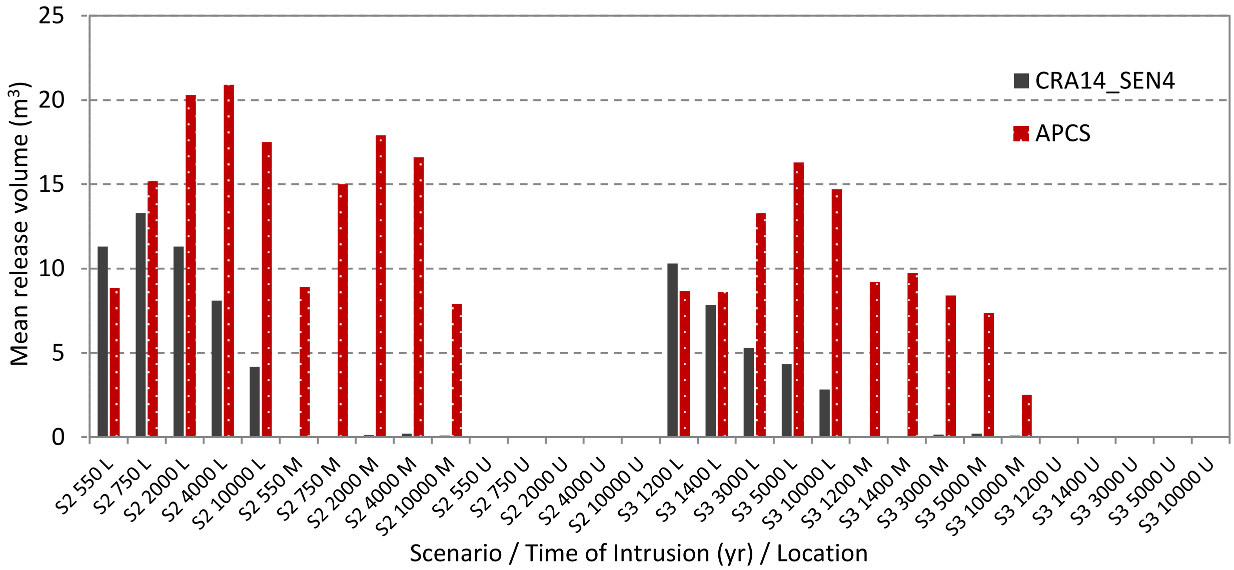

Figure 5-3: S2-DBR and S3-DBR average release volumes

Lower panel intrusions encounter slightly increased mobile brine saturation in APCS, though as with scenario S1-DBR there is enough scatter in the values to mask any temporal trend in either analysis (Figure 5-4). The pressures of the lower panel are initially slightly lower in APCS, but increase through time to overtake and become significantly higher than those of CRA14_SEN4 by the end of the simulation time. It is unclear how to apportion the increase in average DBR volume between the increased saturation and increased pressure, but the pressure increase was relatively larger and more consistent.

Middle panel intrusions for the S2-DBR scenario occur under increased mobile brine saturation in APCS (Figure 4-34), though again any temporal evolution is masked by the scatter in the data (Figure 5-5). While there is often no mobile brine present in the middle panel of CRA14_SEN4, mobile brine is nearly always present in the middle panel of APCS. Pressure differences between APCS and CRA14_SEN4 in the middle panel are much greater at early times, and then remain steady (Figure 4-14) as pressures in CRA14_SEN4 increase to approach and even surpass them in a few instances. The increases in pressure and saturation resulted in the APCS intrusions encountering DBR-producing conditions much more frequently than in CRA14_SEN4.

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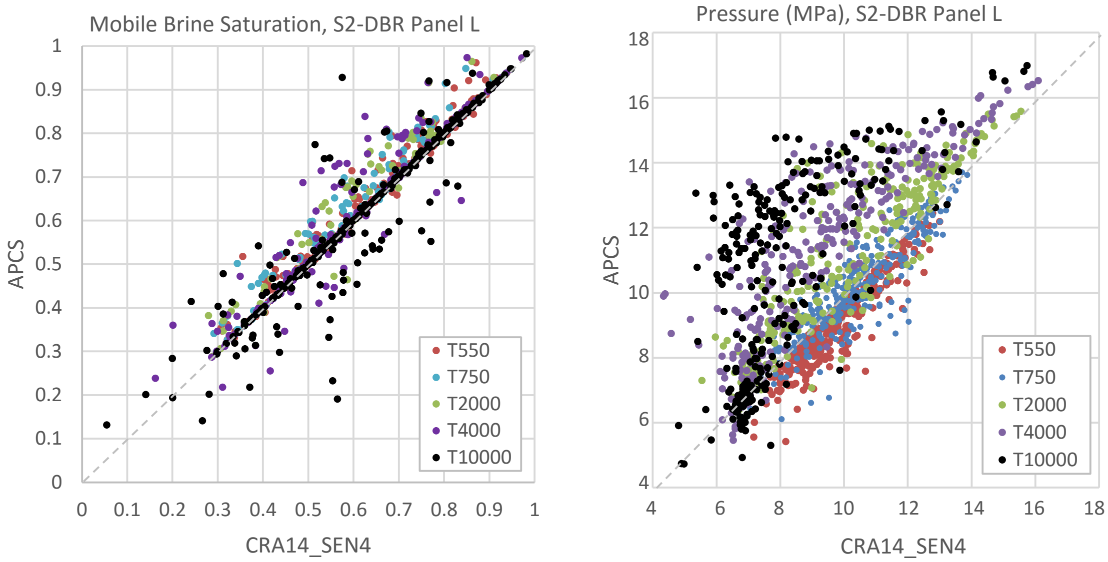

Figure 5-4: S2-DBR and S3-DBR APCS and CRA14_SEN4 mobile brine saturations and pressures in middle intrusion location at time of intrusion

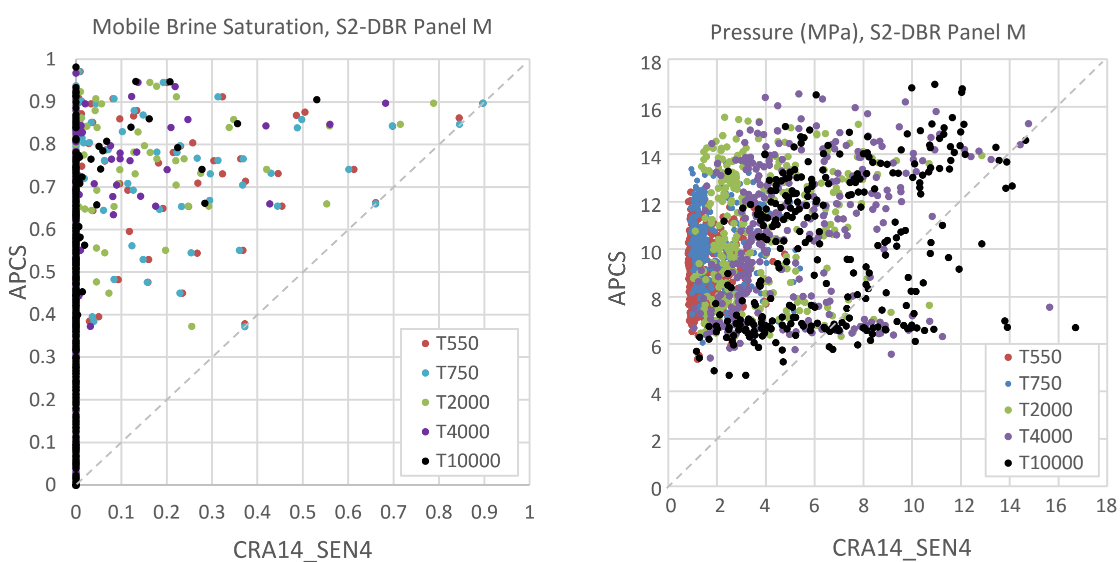

Figure 5-5: S2-DBR and S3-DBR APCS and CRA14_SEN4 mobile brine saturations and pressures in middle intrusion location at time of intrusion

5.2.1.3 S4-DBR and S5-DBR: Prior E2 Intrusion

Results from scenarios with E2-type intrusions show increased DBR volumes in APCS from the lower panel, decreased volumes in the middle panel, and negligible releases from upper panels (Figure 5-6). The BRAGFLO output time-series are equally conflicting, showing increased saturation and decreased pressure in both the waste panel (and Figure 4-19 Figure 4-39), and the SROR (Figure 4-35 and Figure 4-15), which independently should have opposite effects on DBR volume. Once again, plots of pressure and mobile brine saturations encountered by all intrusions

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in the lower and middle panels are shown to illustrate the mechanisms at play (Figure 5-7 and Figure 5-8, respectively).

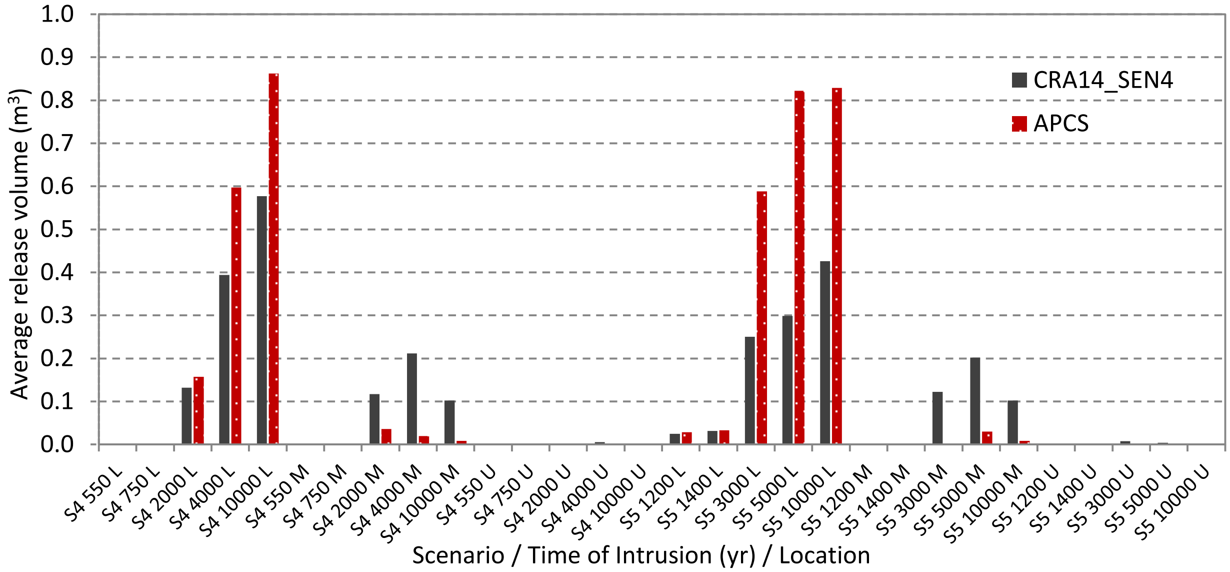

Figure 5-6: S4-DBR and S5-DBR average release volumes

Although mobile brine saturations are higher in the lower panel, as with the other scenarios, there is substantial scattering in both analyses. Pressures are broadly lower in the APCS than in CRA14_SEN4, though, as in S1-DBR, pressures begin to converge at later times and higher pressures. It appears that the lower pressures seen in the BRAGFLO time series did not affect the DBR volumes, because they mostly affected pressures that were already below 8 MPa in CRA14_SEN4, the pressure required to produce a DBR. Instead, it appears that the DBR release volumes are higher because of the higher mobile brine saturations encountered.

In the middle panel, mobile brine saturations are higher in the APCS analysis, whereas there was often no mobile brine present in the CRA14_SEN4 analysis. This should result in a greater number of nonzero DBR release volumes, but this result appears to be offset by most intrusions encountering significantly lower pressures, including many that had been high enough to produce a nonzero DBR volume in CRA14_SEN4.

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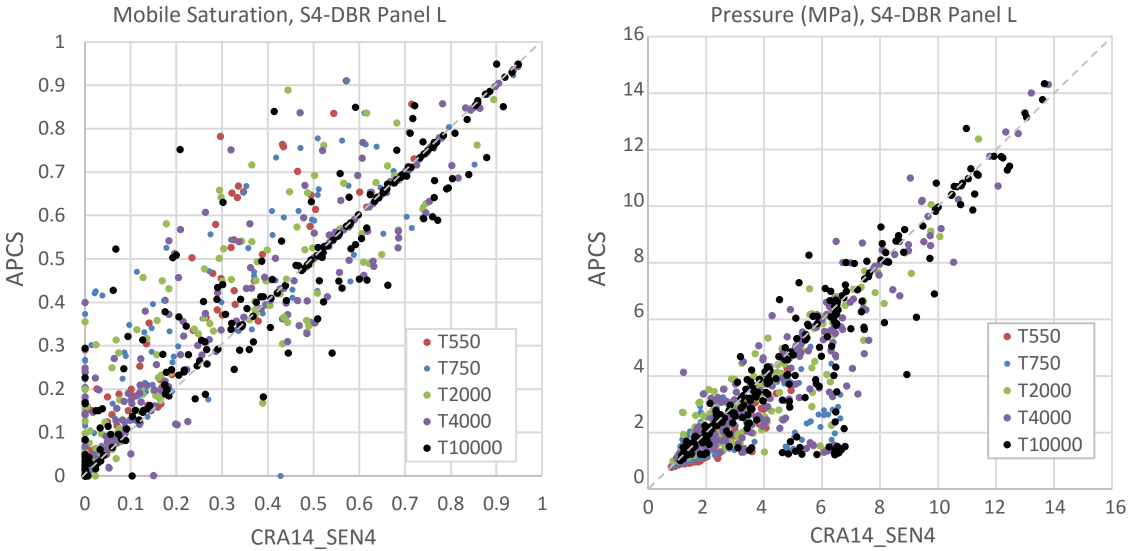

Figure 5-7: S4-DBR and S5-DBR APCS and CRA14_SEN4 mobile brine saturations and pressures in lower intrusion location at time of intrusion

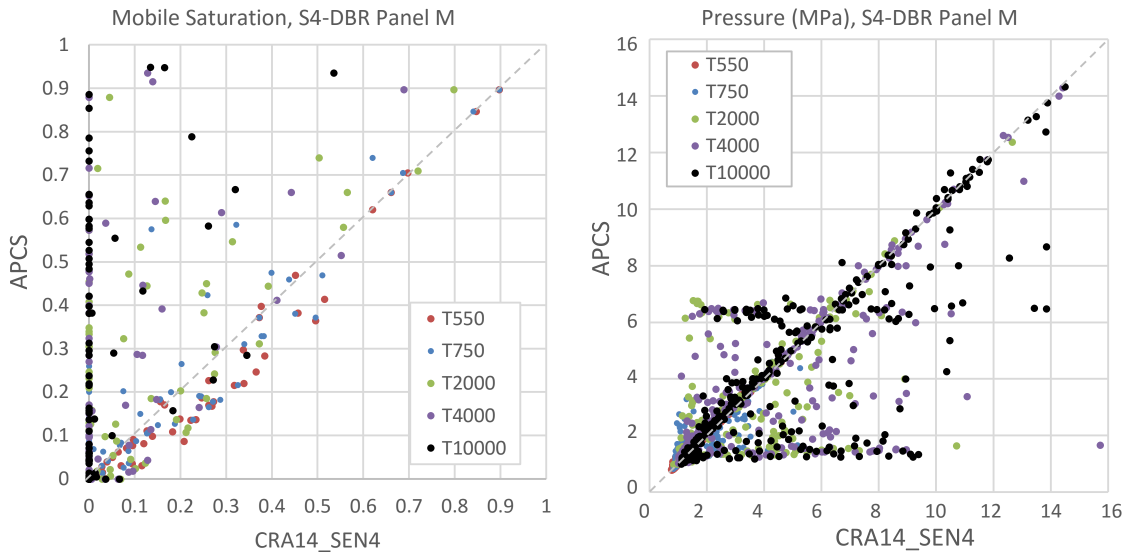

Figure 5-8: S4-DBR APCS and CRA14_SEN4 mobile brine saturations and pressures in middle intrusion location at time of intrusion

5.3 Conclusions

BRAGFLO DBR results from the abandonment of panel closures in the south show increased average DBR volumes in all scenarios when compared to CRA14_SEN4. The increased average is largely attributable to increases in two sets of model permutations, described below:

- Average lower intrusion location DBR volumes increased from 3.20 to 5.92 m^3, representing an increase by a factor of 1.85. This effect was seen in all scenarios and was

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particularly prominent at later model times. This effect appears to be primarily driven by higher mobile brine saturations in the lower panel. Although lower panel pressures decreased overall in scenarios S1-DBR, S4-DBR, and S5-DBR, the difference was more pronounced at pressures that were already below the threshold for a DBR release in CRA14_SEN4. Intrusions that encountered sufficient pressure for a DBR in CRA14_SEN4, tended to do so again in APCS.

- Average middle panel intrusion location DBR volumes increased from 0.09 to 4.00 m^3, representing a factor of 44.4 increase. E1-type scenarios, S2-DBR and S3-DBR, account for the nearly all of this increase. Both pressures and saturations encountered by middle panel intrusions were substantially higher in E1 scenarios for the entire modeled time period.

The BRAGFLO DBR calculations show the average DBR volume[9] to be three times higher in APCS than in CRA14_SEN4, increasing from 1.10 to 3.31. Because of their larger magnitudes, releases from scenarios S2-DBR and S3-DBR account for the majority of the absolute increase, but releases from scenario S1-DBR also increased by a similar proportion.

[9] The average DBR volume in this case is strictly an average for all of the individual cases run under BRAGFLO DBR, which subsequently provide the basis for the DBR volumes calculated by CCDFGF for individual futures.

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6 Overall Results

Results for all release mechanisms[10] are now presented and compared to those obtained in the CRA-2014 PA (CRA14) and CRA14_SEN4. Results are discussed in terms of overall means. Overall means are obtained by forming the average of all realizations. In WIPP PA, a replicate consists of 100 calculated realizations. Three replicates are used to generate results for APCS, CRA14, and CRA14_SEN4. Means and statistics presented for the analyses are also calculated over all three replicates. The impacts of the modifications to APCS results include changes to all of the primary release mechanisms, except for cuttings and cavings: spallings, direct brine releases, and releases from the Culebra. Plots of releases for individual release mechanisms include comparisons of means results with mean results from CRA14 and CRA14_SEN4. A summary table of means and lower and upper confidence limits for total releases at probabilities of 0.1 and 0.001 is presented in Section 6.5.

6.1 Cuttings and Cavings Releases

Cuttings and cavings releases under APCS are identical to those from CRA14_SEN4 (Figure 6-1). No model changes made for the APCS analysis had any impact on the cuttings and cavings calculations.

[10] In APCS, one of the NUTS screening vectors (replicate 1, vector 53) registered a maximum cumulative release of 1.1×10^{-8} EPA Units to marker beds at the land withdrawal boundary (LWB) for an undisturbed repository (scenario 1). However, this same vector also showed a "nonzero" level of release (2.6×10^{-10} EPA Units for CRA-2009 and 1.8×10^{-9} for CRA14_SEN4) that was determined to be "indicative of numerical dispersion resulting from the coarse grid spacing between the repository and the LWB, rather than from actual transport of radionuclides" (DOE 2009, Appendix PA). That same analysis concluded that "regardless of the significance attached to the numerical values reported above, the releases from the undisturbed scenario are insignificant compared to releases from drilling intrusions. Consequently, releases in the undisturbed (S1) scenario are omitted from the calculation of total releases from the repository." Because the level of release to the LWB from an undisturbed repository in APCS is similar to that seen in the CRA-2009 PA and CRA14_SEN4, and many orders of magnitude smaller than average releases for disturbed scenarios, we also conclude that the undisturbed release is insignificant and can be omitted when considering the total releases from the repository. In CRA14, no vectors registered nonzero releases for the undisturbed case.

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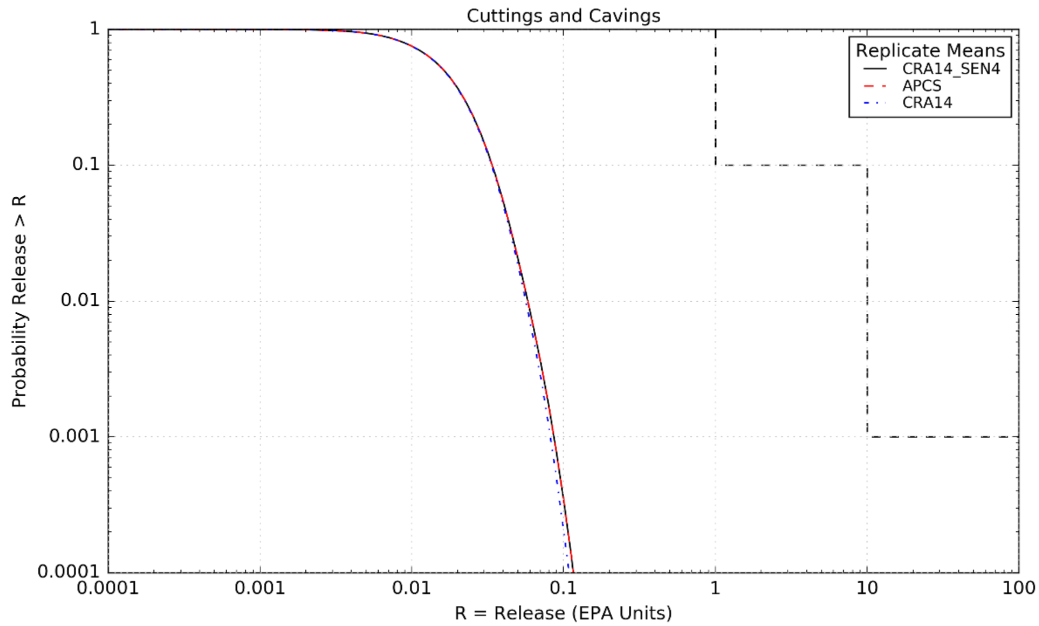

Figure 6-1: Overall Mean CCDFs for Cuttings and Cavings Releases: CRA14_SEN4, APCS, and CRA14

6.2 Spallings Releases

Spallings releases are a function of repository pressure at the time of intrusion. Increases in pressure necessarily translate to increased spallings release volumes. The model changes made for APCS have led to increased average waste panel pressures for all waste panel areas and most BRAGFLO scenarios. For E2 intrusions, small average pressure decreases are seen (Figure 4-11, Figure 4-15, Figure 4-19), but for E1 intrusions, large average pressure increases are seen (Figure 4-10, Figure 4-14, Figure 4-18). The impact on pressure due to the changes introduced in APCS is especially pronounced in the SROR due to the increased communication between the WP and SROR areas. Effectively, the higher pressures that previously existed only in the WP (in CRA14 and CRA14_SEN4) are now “equilibrated” across the SROR as well, drastically driving up average pressures in the SROR while only slightly decreasing pressure in the WP. The net effect is increased pressures (Table 4-1), which lead to increased spallings. Overall, spallings releases are increased with the application of the model changes in APCS, as compared to CRA14 and CRA14_SEN4 results (Figure 6-2).

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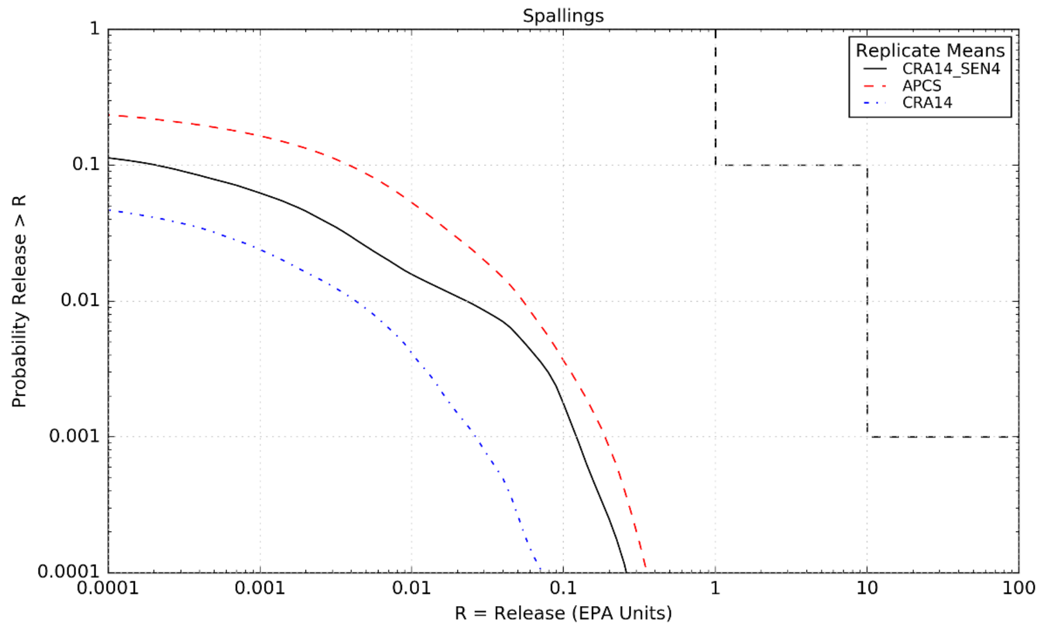

Figure 6-2: Overall Mean CCDFs for Spallings Releases: CRA14_SEN4, APCS, and CRA14

6.3 Releases from the Culebra

Transport releases through the Culebra and across the land withdrawal boundary are impacted by the amount of brine released to the Culebra. Brine flows up the intrusion borehole obtained in APCS are increased for E2 intrusions compared to those obtained in CRA14_SEN4 (Section 4.2.4). Consequently, volumes of brine flowing up to the Culebra are increased. The changes introduced in APCS lead to increased waste panel pressures following intrusion into pressurized brine below the repository (as discussed above for spallings releases), which also tend to increase releases to the Culebra. Overall, transport releases through the Culebra and across the land withdrawal boundary are slightly increased compared to results calculated for CRA14 and CRA14_SEN4 (Figure 6-3).

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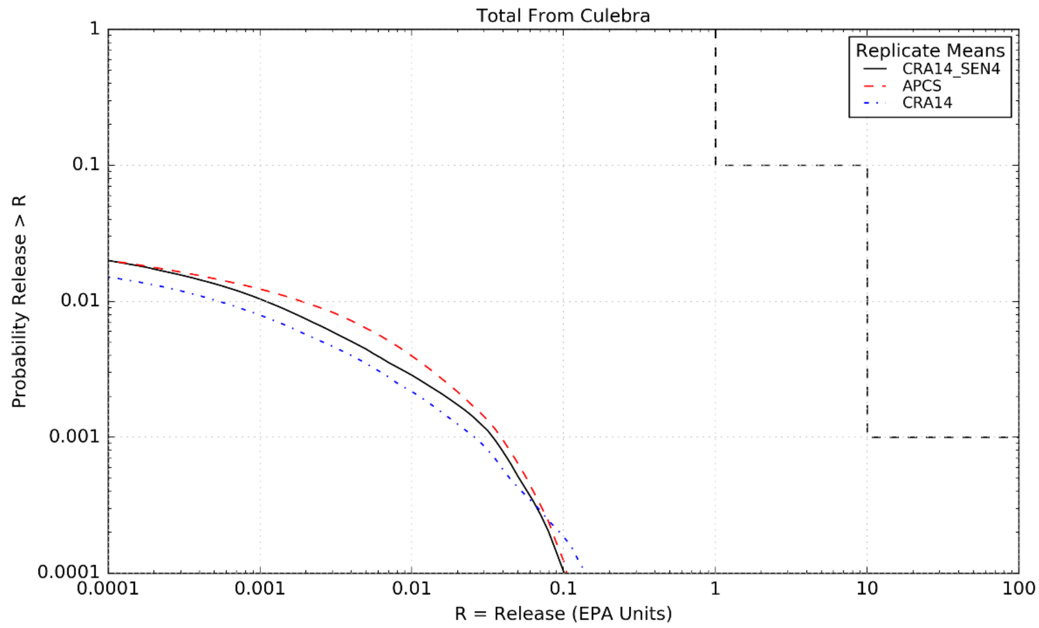

Figure 6-3: Overall Mean CCDFs for Releases from the Culebra: CRA14_SEN4, APCS, and CRA14

6.4 Direct Brine Releases

Direct brine releases (DBRs) require sufficient waste panel pressure and brine saturation in order to occur. The repository pressure near the drilling location must exceed the hydrostatic pressure of the drilling fluid, which is specified to be 8 MPa in WIPP PA. The brine saturation in the intruded panel must exceed the residual brine saturation of the waste, a sampled parameter in WIPP PA. The changes to the CRA14_SEN4 analysis that have been implemented for APCS result in increased waste region pressures and largely increased or similar waste region brine saturations (Section 4). The impact of the overall increased pressures and saturations at the times of intrusion lead to increased DBR volume, particularly for E1 intrusions (Section 5). Because DBR releases are the product of DBR volumes and repository-averaged radionuclide concentrations (which are not impacted by the changes in APCS), increased DBR releases are expected and indeed observed for APCS (Figure 6-4). The net result of the changes introduced in APCS is a large increase in DBRs over those for CRA14 and CRA14_SEN4 at all probabilities. Additional discussion of the conservatism in DBRs can be found in Appendix A.

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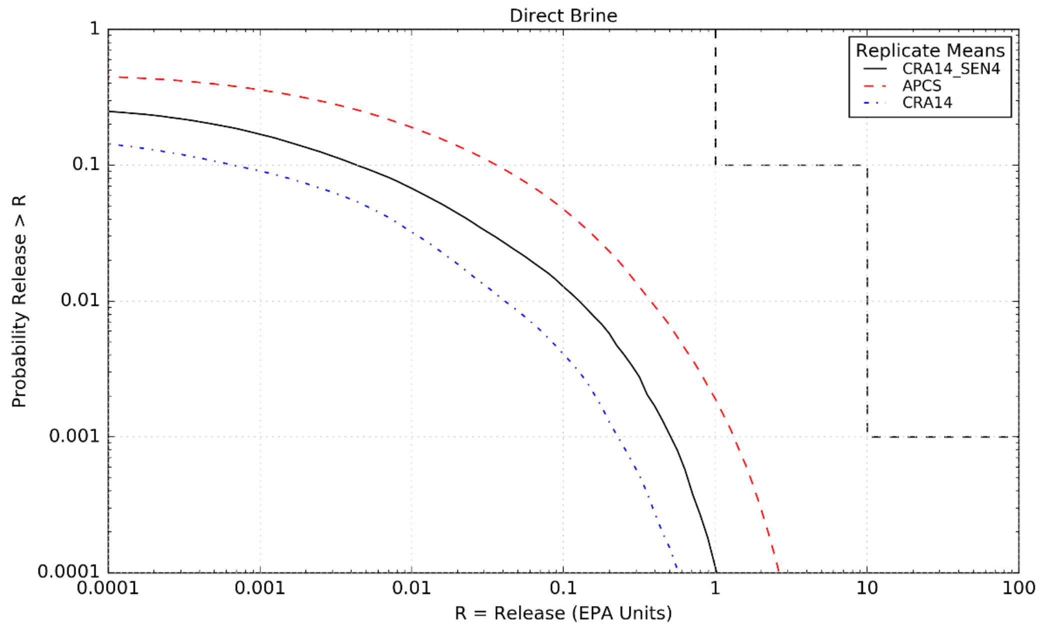

Figure 6-4: Overall Mean CCDFs for Direct Brine Releases: CRA14_SEN4, APCS, and CRA14

6.5 Total Releases

Total releases are calculated by totaling the releases from each release pathway: cuttings and cavings releases, spallings releases, DBRs, and transport releases (there were no undisturbed releases to contribute to total release—see Footnote 10 above). APCS CCDFs for total releases obtained in replicates 1, 2, and 3 are plotted together in Figure 6-5.[11] The overall mean CCDF is computed as the arithmetic mean of the mean CCDFs from each replicate. A confidence interval is computed about the overall mean CCDF using the Student's t-distribution and the mean CCDFs from each replicate. Figure 6-6 shows 95% confidence intervals about the overall mean for APCS.

Mean CCDFs of the individual release mechanisms that comprise total normalized releases are plotted together in Figure 6-7, as well as the APCS total release overall mean. As seen in that figure, total normalized releases obtained for APCS are dominated by cuttings and cavings releases and DBRs. Contributions to total releases from spallings and Culebra transport are not dominant, although spallings and Culebra transport releases have been increased in comparison to CRA14_SEN4.

Overall means for total normalized releases obtained for APCS, CRA14, and CRA14_SEN4 are plotted together in Figure 6-8. Overall, total normalized releases increase from CRA14_SEN4 to APCS due to increases in all contributing release components (except for cuttings and cavings,

[11] Total releases CCDFs for two vectors shown in Figure 6-5 exceed the EPA release limit of 1 EPA Unit at 0.1 probability. However, compliance with EPA release limits is based on the mean release (Figure 6-6).

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which did not change). Total normalized releases increase at low probabilities (below 0.1) from CRA14_SEN4 to APCS principally due to increased DBRs. A comparison of the statistics on the overall mean for total normalized releases obtained for APCS, CRA14, and CRA14_SEN4 can be seen in Table 6-1. At a probability of 0.1, values obtained for the mean total release and upper 95% confidence interval for APCS are increased in comparison to CRA14_SEN4 (72 and 84%, respectively). At a probability of 0.001, the mean total release and upper 95% confidence level are higher for APCS in comparison to CRA14_SEN4 (152 and 172%, respectively).

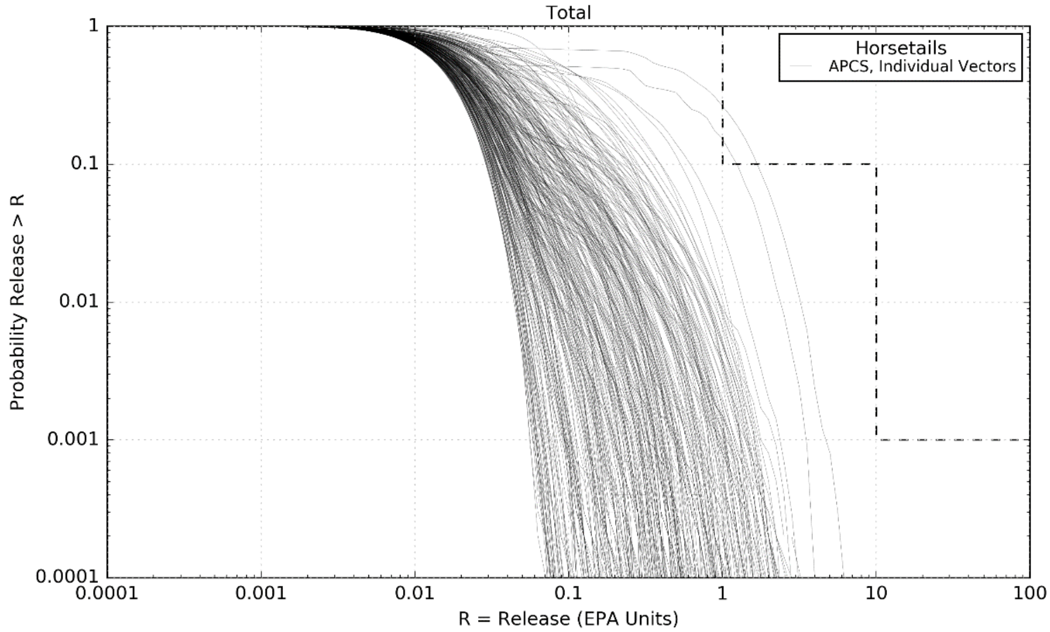

Figure 6-5: Total Normalized Releases, Replicates R1, R2, and R3, APCS

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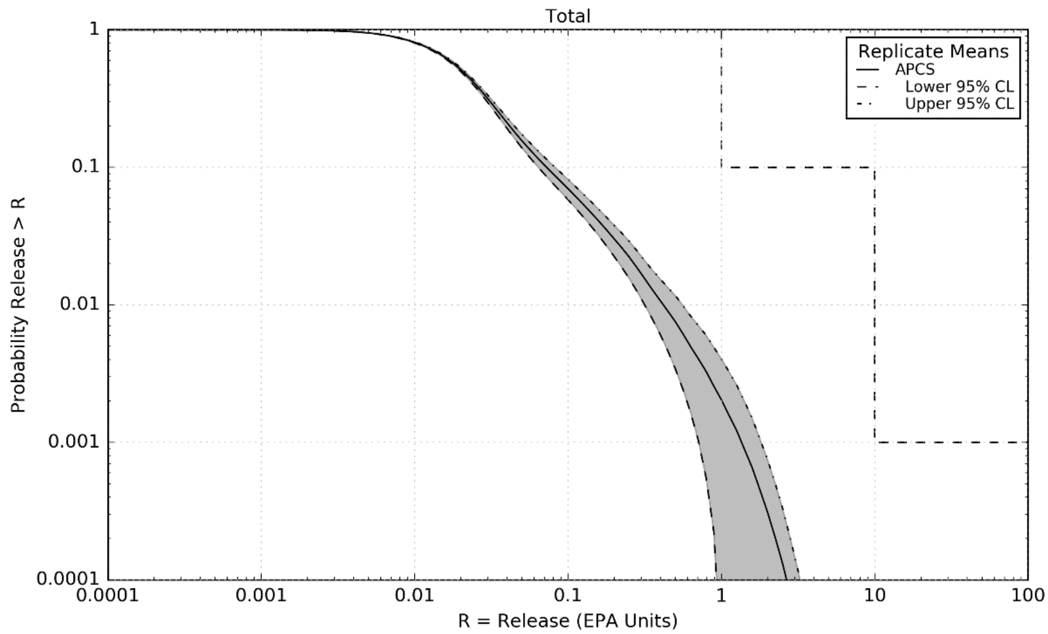

Figure 6-6: Confidence Interval on Overall Mean CCDF for Total Normalized Releases, APCS

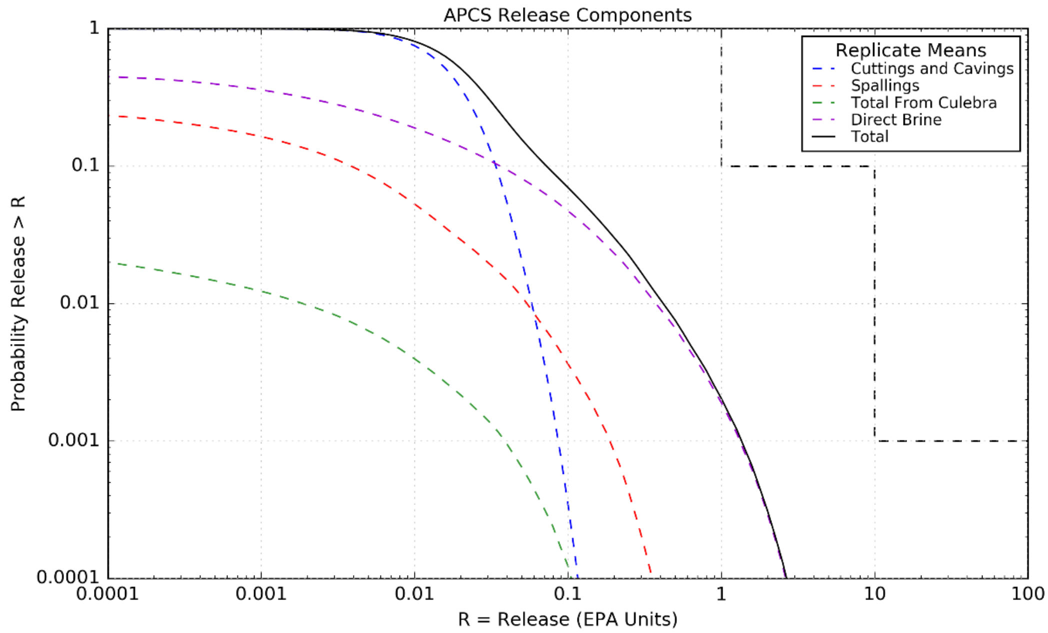

Figure 6-7: Comparison of Overall Means for Release Components of APCS

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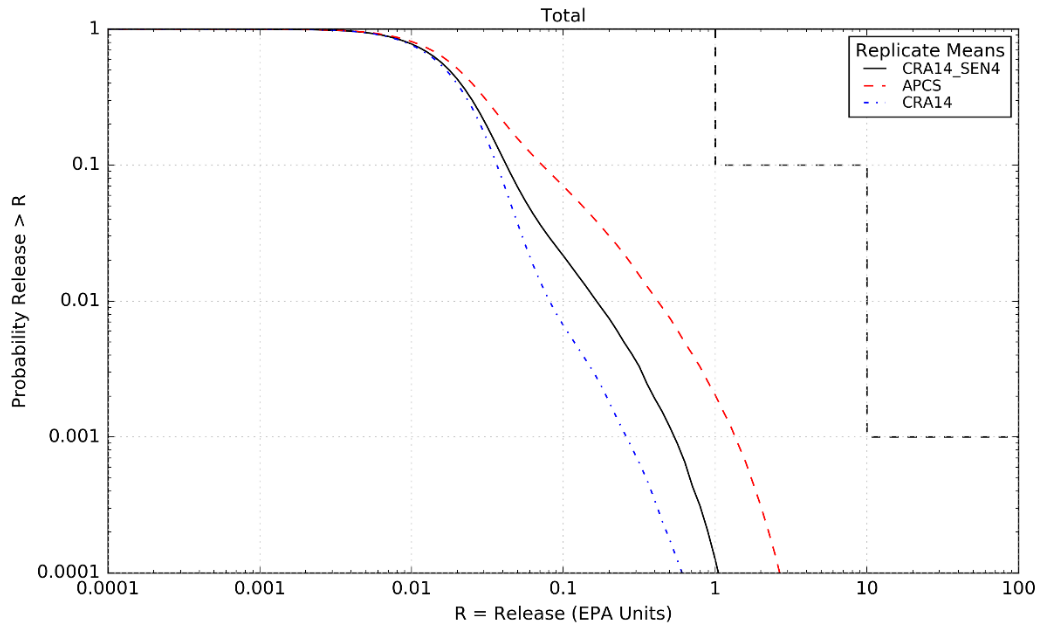

Figure 6-8: CRA14_SEN4, APCS, and CRA14 Overall Mean CCDFs for Total Normalized Releases

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Table 6-1: CRA14_SEN4, APCS, and CRA14 Statistics on the Overall Mean for Total Normalized Releases in EPA Units at Probabilities of 0.1 and 0.001

Probability	Analysis	Mean Total Release	Lower 95% CL	Upper 95% CL	Release Limit
0.1	CRA14_SEN4	0.0423	0.0397	0.0449	1
	APCS	0.0727	0.0641	0.0826	
	CRA14	0.0367	0.0353	0.0381	
0.001	CRA14_SEN4	0.5413	0.3431	0.6725	10
	APCS	1.3618	0.7130	1.8264	
	CRA14	0.2613	0.2020	0.3077	

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7 FEPs Re-assessment

The FEPs review (Kirkes 2017) concludes that the current FEPs baseline is suitable to support the analysis described in AP-177. No screening decision conflicts were identified, and no changes to screening arguments or descriptions are necessary in support of this analysis.

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8 Sensitivity Analysis

This section discusses the STEPWISE regression analysis results for the APCS analysis and compares them to the results from the CRA14_SEN4 analysis.

Ranked, stepwise multiple regression analysis was used to assess the relative importance of the 63 epistemic variables (i.e. sampled parameters) included in the APCS calculations with respect to the variability in the mean normalized release values. A similar analysis was performed for CRA14_SEN4 (Zeitler and Sarathi 2017b).

The APCS analysis contains no changes with respect to the epistemic variables and distributions, and identical sampled values were used in both the CRA14_SEN4 and the APCS analysis. Thus for this sensitivity analysis comparison, the regression model independent variables and values are the same. However, the material property changes in the BRAGFLO and BRAGFLO_DBR grids and the changes in panel adjacencies in CCDFGF alter the dependent variable (the mean normalized releases), and this change in the dependent variable is what drives the change in the assessed model sensitivity.

8.1 STEPWISE Method

In this procedure, for each epistemic variable, the sampled values are ordered according to their magnitude and then replaced by their ordering index, or “rank.” For example, across one replicate, the 100 sampled values for the parameter BOREHOLE:TAUFAIL are replaced with integers 1 to 100. This rank transformation serves to normalize the input values and to reduce the effects of nonlinearities. Next, a sequence of multivariate linear regression models is created that relate the rank values to the calculated mean release value for each vector (where the mean is taken across the 10,000 simulated futures for each vector). The first regression model contains the independent variable with the strongest correlation to the output. Each subsequent regression model adds one independent variable – the variable with the next largest partial correlation (i.e. independent of the previously included independent variables). The regression models are constructed in a stepwise fashion until adding a variable no longer improves the regression correlation by a statistically significant amount. The regression model typically includes only a few of the 63 epistemic variables. Further details of the method are presented in Kirchner (2013).

8.2 STEPWISE Regression Analysis Results

Because the regression analysis is performed on the mean release values, the number of vectors with nonzero mean release values can influence the sensitivity analysis results. Mean release values less than 0.0001 EPA units are considered to be dominated by numerical error and unreliable (Kirchner 2013). Consequently, the STEPWISE regression models constructed with release pathway subsets with few vectors above this 0.0001 threshold are less reliable than those constructed with subsets where the majority of vectors are above the threshold. Table 8-1 lists the number of vectors in each replicate, for each release pathway subset, that have mean release values greater than 0.0001 EPA units. Releases from the Culebra have very few vectors above the threshold, and hence the sensitivity analysis results are not meaningful. Spallings releases similarly have a small fraction of vectors above the noise threshold, although the number increases in the APCS analysis.

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Table 8-1 – Number of vectors with mean release values >0.0001 EPA units. Each replicate contains 100 vectors.

Release	Replicate 1		Replicate 2		Replicate 3	
	CRA14_SEN4	APCS	CRA14_SEN4	APCS	CRA14_SEN4	APCS
Cuttings and Cavings	100	100	100	100	100	100
Spallings	23	45	22	44	21	40
Direct Brine	94	95	96	98	96	95
From the Culebra	5	5	8	9	6	6
To the Culebra	74	78	74	79	71	78
Total Releases	100	100	100	100	100	100

In the STEPWISE results tables presented in the following sections, three sets of values are presented for each relevant parameter – the step, the cumulative coefficient of determination (R^2), and the standardized rank regression coefficient (SRRC). The step refers to the order in which the variable entered the stepwise linear regression model and is an indication of the relative importance of the variable. The cumulative coefficient of determination R^2 refers to the fraction of the total variability in the dependent (output) variable that is accounted for by all of the independent variables included up to the current step. The difference between R^2 values in each step is an indication of the fraction of variability in the dependent variable apportioned to the independent variable added at that step. The standardized rank regression coefficient SRRC refers to the partial (i.e. independent of the other variables), standardized linear regression coefficient that correlates the variable's rank-transformed values with the mean release values. The term standardized indicates that the independent variable was normalized by subtracting its mean and dividing by its standard deviation, and the regression coefficient is defined with respect to the standardized independent variable.

To aid in interpretation and discussion of the results, parameters with ΔR^2 values (the difference in R^2 between the current step and the previous step) greater than 0.05 are highlighted in the tables below. While this threshold is somewhat arbitrary, those highlighted parameters are clearly influential and tend to have a more distinct ordering.

8.2.1 Cuttings and Cavings Releases

The CRA14_SEN4 and APCS sensitivity results are identical for cuttings and cavings mean releases – BOREHOLE:TAUFAIL, the shear strength of waste, and BOREHOLE:DOMEGA, the drill string angular velocity, are the most influential parameters. Since cuttings and cavings volumes are calculated in PA without regard to the conditions in the repository at the time of the simulated intrusion, the results are independent of BRAGFLO and BRAGFLO_DBR results. Thus, the changes to the BRAGFLO and BRAGFLO_DBR grids in the APCS analysis do not impact the cuttings and cavings results.

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Table 8-2 – Ranked regression analysis for mean cuttings and cavings releases, replicate 1

	Expected Normalized Release					
	CRA14_SEN4 Replicate 1			**APCS Replicate 1**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	BOREHOLE:TAUFAIL	0.66	-0.82	BOREHOLE:TAUFAIL	0.66	-0.82
2	BOREHOLE:DOMEGA	0.72	0.25	BOREHOLE:DOMEGA	0.72	0.25
3	(Composite):MKD_U	0.74	-0.16	(Composite):MKD_U	0.74	-0.16
4	SHFTU:SAT_RBRN	0.75	0.11	SHFTU:SAT_RBRN	0.75	0.11

a Steps in stepwise regression analysis
b Variables listed in order of selection
c Cumulative R^2 value with entry of each variable into regression model
d Standardized Rank Regression Coefficient

Table 8-3 – Ranked regression analysis for mean cuttings and cavings releases, replicate 2

	Expected Normalized Release					
	CRA14_SEN4 Replicate 2			**APCS Replicate 2**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	BOREHOLE:TAUFAIL	0.72	-0.84	BOREHOLE:TAUFAIL	0.72	-0.84
2	BOREHOLE:DOMEGA	0.79	0.26	BOREHOLE:DOMEGA	0.79	0.26
3	PCS_T2:POR2PERM	0.82	0.18	PCS_T2:POR2PERM	0.82	0.18
4	PHUMOX3:PHUMCIM	0.82	-0.10	PHUMOX3:PHUMCIM	0.82	-0.10
5	CASTILER:PRMX_LOG	0.83	0.08	CASTILER:PRMX_LOG	0.83	0.08
6	S_HALITE:PRMX_LOG	0.84	0.08	S_HALITE:PRMX_LOG	0.84	0.08

Table 8-4 – Ranked regression analysis for mean cuttings and cavings releases, replicate 3

	Expected Normalized Release					
	CRA14_SEN4 Replicate 3			**APCS Replicate 3**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	BOREHOLE:TAUFAIL	0.66	-0.80	BOREHOLE:TAUFAIL	0.66	-0.80
2	BOREHOLE:DOMEGA	0.74	0.30	BOREHOLE:DOMEGA	0.74	0.30
3	CULEBRA:APOROS	0.76	0.13	CULEBRA:APOROS	0.76	0.13
4	S_HALITE:POROSITY	0.78	0.11	S_HALITE:POROSITY	0.78	0.11
5	(Composite):OXSTAT	0.79	0.10	(Composite):OXSTAT	0.79	0.10
6	SHFTU:SAT_RBRN	0.80	-0.11	SHFTU:SAT_RBRN	0.80	-0.11
7	WAS_AREA:BRUCITEH	0.81	0.10	WAS_AREA:BRUCITEH	0.81	0.10
8	SPALLMOD:REPIPERM	0.82	0.10	SPALLMOD:REPIPERM	0.82	0.10
9	PCS_T1:POROSITY	0.83	0.09	PCS_T1:POROSITY	0.83	0.09
10	S_MB139:SAT_RBRN	0.84	-0.09	S_MB139:SAT_RBRN	0.84	-0.09

8.2.2 Spallings Releases

For spallings mean releases, the CRA14_SEN4 and APCS sensitivity analysis results show moderate differences. Both STEPWISE analysis results suffer from datasets with a small fraction mean releases greater than 0.0001 EPA units (Table 8-1). A side effect of this can be seen in the regression results – several variables have similar ΔR^2 values, suggesting that the ranked linear

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regression model cannot clearly distinguish the relative influence of different variables. However, the APCS analysis has more vectors with mean releases greater than 0.0001 EPA units (45 compared to 23 for replicate 1) overall, and this increase alone can impact the sensitivity results since the APCS results are somewhat less dominated by noise.

Despite these shortcomings, the APCS results indicate a stronger and more consistent influence of BH_SAND:PRMX_LOG, the (logarithm of the) permeability of the silty-sand-filled borehole, in all three replicates. A scatterplot of BH_SAND:PRMX_LOG versus spallings mean release values is shown in Figure 8-1, for both the CRA14_SEN4 and APCS analyses, and illustrates the increased response in the APCS analysis. The negative SRRC values indicate that lower borehole permeability values correlate with larger mean release values. This is because lower sand-filled borehole permeability values allow for larger pressure buildup in the waste areas after a primary intrusion, and larger pressure values can propel more spallings (waste solids) into and up a wellbore during a secondary intrusion. In addition, a more consistent influence of SPALLMOD:REPIPERM and SPALLMOD:PARTDIAM, the waste permeability and particle diameter of disaggregated waste, respectively, used in the DRSPALL code, is seen across all three replicates (Figure 8-2).

Table 8-5 – Ranked regression analysis for mean spallings releases, replicate 1

	Expected Normalized Release					
	CRA14_SEN4 Replicate 1			**APCS Replicate 1**		
Step [a]	**Variable** [b]	**R^2** [c]	**SRRC** [d]	**Variable** [b]	**R^2** [c]	**SRRC** [d]
1	SPALLMOD:PARTDIAM	0.13	-0.36	BH_SAND:PRMX_LOG	0.19	-0.49
2	CASTILER:PRESSURE	0.25	0.36	SPALLMOD:REPIPERM	0.34	0.38
3	SPALLMOD:REPIPERM	0.36	0.33	SPALLMOD:PARTDIAM	0.46	-0.34
4	S_HALITE:POROSITY	0.41	0.21	WAS_AREA:PROBDEG	0.50	0.20
5	BH_SAND:PRMX_LOG	0.46	-0.23	CASTILER:PRESSURE	0.54	0.20
6	SPALLMOD:REPIPOR	0.50	-0.22	TH+4:MKD_TH	0.57	0.17
7	DRZ_PCS:PRMX_LOG	0.53	-0.17	S_HALITE:POROSITY	0.60	0.18
8	WAS_AREA:PROBDEG	0.55	0.16	SOLMOD3:SOLVAR	0.62	0.15
9	(Composite):OXSTAT	0.57	-0.15	SHFTU:SAT_RGAS	0.64	0.13

a Steps in stepwise regression analysis
b Variables listed in order of selection
c Cumulative R^2 value with entry of each variable into regression model
d Standardized Rank Regression Coefficient

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Table 8-6 – Ranked regression analysis for mean spallings releases, replicate 2

	Expected Normalized Release					
	CRA14_SEN4 Replicate 2			APCS Replicate 2		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	BH_SAND:PRMX_LOG	0.14	-0.39	BH_SAND:PRMX_LOG	0.19	-0.46
2	SPALLMOD:REPIPERM	0.29	0.36	SPALLMOD:REPIPERM	0.33	0.35
3	CASTILER:PRESSURE	0.40	0.35	S_HALITE:POROSITY	0.39	0.24
4	S_HALITE:POROSITY	0.48	0.29	SPALLMOD:PARTDIAM	0.45	-0.24
5	WAS_AREA:SAT_WICK	0.52	0.17	WAS_AREA:SAT_WICK	0.50	0.23
6	GLOBAL:PBRINE	0.55	0.18	CASTILER:PRESSURE	0.55	0.22
7	WAS_AREA:BIOGENFC	0.57	0.16	GLOBAL:PBRINE	0.59	0.21
8	SPALLMOD:PARTDIAM	0.59	-0.16	SPALLMOD:REPIPOR	0.62	-0.16
9	WAS_AREA:BRUCITES	0.61	0.13			

Table 8-7 – Ranked regression analysis for mean spallings releases, replicate 3

	Expected Normalized Release					
	CRA14_SEN4 Replicate 3			APCS Replicate 3		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	CASTILER:PRESSURE	0.20	0.44	SPALLMOD:PARTDIAM	0.18	-0.38
2	SPALLMOD:REPIPERM	0.32	0.33	BH_SAND:PRMX_LOG	0.32	-0.41
3	SPALLMOD:PARTDIAM	0.43	-0.31	SPALLMOD:REPIPERM	0.45	0.35
4	S_HALITE:POROSITY	0.50	0.26	S_HALITE:POROSITY	0.49	0.18
5	DRZ_PCS:PRMX_LOG	0.54	-0.19	SPALLMOD:REPIPOR	0.54	-0.23
6	GLOBAL:PBRINE	0.56	0.14	DRZ_1:PRMX_LOG	0.57	-0.17
7	SPALLMOD:TENSLSTR	0.58	-0.14	GLOBAL:CLIMTIDX	0.59	0.15
8	PCS_T1:SAT_RBRN	0.60	-0.14	CASTILER:PRESSURE	0.62	0.17
9	BH_SAND:PRMX_LOG	0.62	-0.14	WAS_AREA:PROBDEG	0.65	0.15
10	GLOBAL:CLIMTIDX	0.64	0.13	SHFTL_T2:PRMX_LOG	0.67	0.15
11				GLOBAL:PBRINE	0.68	0.13
12				PCS_T2:POR2PERM	0.70	-0.13
13				S_HALITE:PRESSURE	0.71	-0.12
14				SPALLMOD:TENSLSTR	0.73	-0.11

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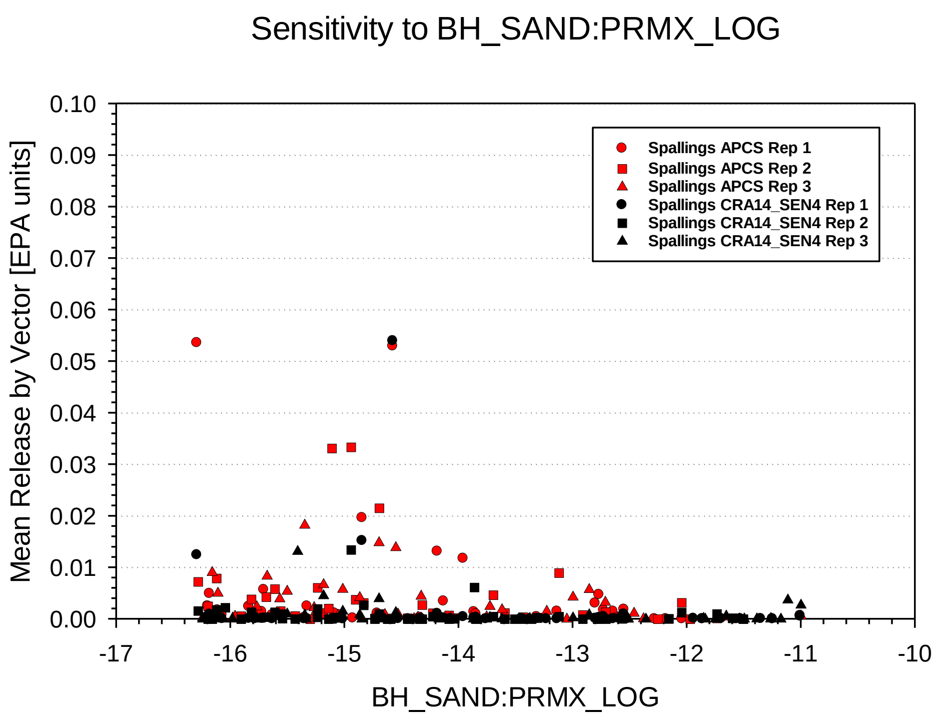

Figure 8-1 – Scatterplot of (the logarithm of) borehole permeability versus mean spallings releases

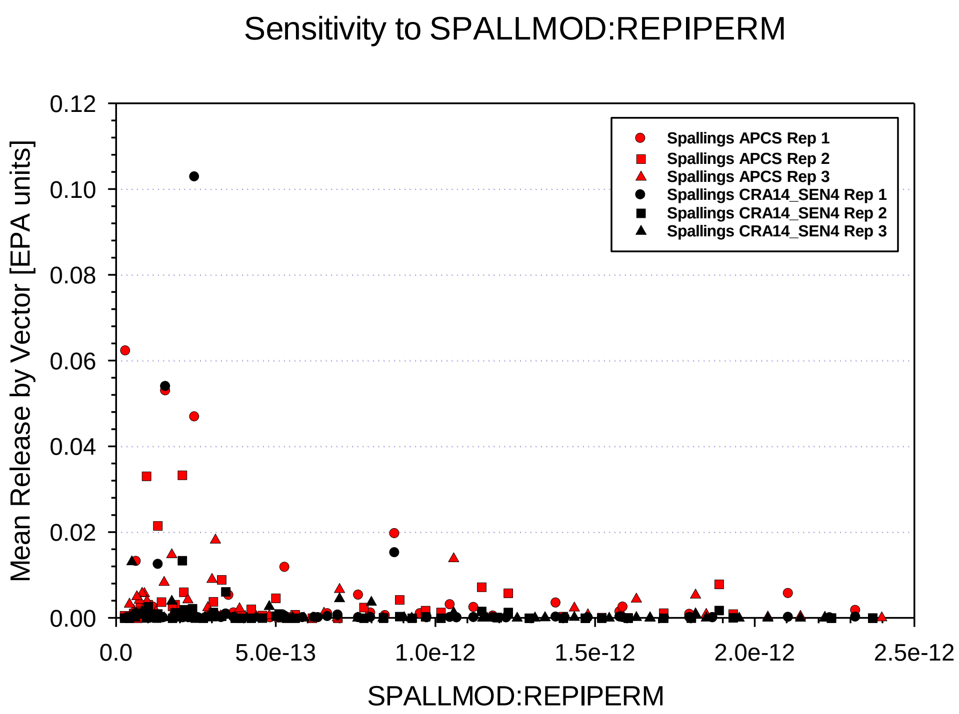

Figure 8-2— Scatterplot of waste permeability (used in CUTTINGS) versus mean spallings releases

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8.2.3 Direct Brine Releases

For direct brine mean releases, CASTILER:PRESSURE (the initial brine pressure in the Castile brine reservoir), SOLMOD3:SOLVAR (solubility multiplier for III oxidation states), and GLOBAL:PBRINE (probability that a drilling intrusion penetrates the pressurized brine in the Castile) remain the most influential parameters in both the CRA14_SEN4 and APCS analyses. BH_SAND:PRMX_LOG is more influential in the APCS analyses (Figure 8-3), having ΔR^2 values of 0.07, 0.07, and 0.13 for the three replicates, compared to 0.03, 0.07, and 0.06 in the CRA14_SEN4 analysis. CASTILER:PRESSURE has slightly decreased in relative influence in the APCS analysis (Figure 8-4) in all three replicates, as seen by the decreased ΔR^2 and SRRC values. These two observations together suggest that the pressure buildup in the waste area (which is a phenomenon, not a sampled parameter) has an increased influence on the DBR releases. Both changes made in the APCS analysis – the lack of panel closures in the South end of the repository and the redefinition of panel adjacencies – lead to this increased influence. The lack of panel closures allow Panels 3, 4, 5, 6 and 9 to act as a single, combined pressure reservoir during DBR events, which allows brine to flow up the wellbore at higher and more sustained rates. This is even more pronounced during E1E2 intrusion scenarios in which the Castile has been penetrated because (1) there is more accessible brine in the repository for a DBR, and (2) the increased brine in the repository increases gas generation rates, which further increases pressure in the repository. The redefinition of panel adjacencies effectively increases the probability of adjacent intrusions (in which there are no panel closures between adjacent panels) and decreases the probability of non-adjacent intrusions, which further increases the importance of the pressure buildup in the effectively-connected south end of repository. These relative changes are consistent with those seen in the spallings results.

Table 8-8 – Ranked regression analysis for mean direct brine releases, replicate 1

	Expected Normalized Release					
	CRA14_SEN4 Replicate 1			**APCS Replicate 1**		
Step [a]	**Variable** [b]	**R^2** [c]	**SRRC** [d]	**Variable** [b]	**R^2** [c]	**SRRC** [d]
1	CASTILER:PRESSURE	0.34	0.54	CASTILER:PRESSURE	0.30	0.50
2	SOLMOD3:SOLVAR	0.52	0.46	SOLMOD3:SOLVAR	0.53	0.51
3	GLOBAL:PBRINE	0.63	0.32	GLOBAL:PBRINE	0.63	0.31
4	WAS_AREA:BIOGENFC	0.67	0.18	BH_SAND:PRMX_LOG	0.70	-0.26
5	BH_SAND:PRMX_LOG	0.70	-0.17	CASTILER:COMP_RCK	0.72	0.18
6	S_MB139:RELP_MOD	0.72	-0.16	WAS_AREA:BIOGENFC	0.75	0.17
7	WAS_AREA:PROBDEG	0.74	0.12	DRZ_1:PRMX_LOG	0.78	-0.16
8	GLOBAL:CLIMTIDX	0.75	-0.11	S_HALITE:POROSITY	0.80	0.12
9	S_HALITE:POROSITY	0.77	0.13	WAS_AREA:PROBDEG	0.81	0.10
10	WAS_AREA:SAT_RBRN	0.78	-0.12	WAS_AREA:SAT_RBRN	0.82	-0.10
11	SHFTU:PRMX_LOG	0.79	-0.11	WAS_AREA:GRATMICI	0.83	0.10
12	CASTILER:COMP_RCK	0.80	0.10			
13	PCS_T1:POROSITY	0.81	-0.10			
14	GLOBAL:OXSTAT	0.82	-0.10			
15	DRZ_PCS:PRMX_LOG	0.83	-0.10			

a Steps in stepwise regression analysis
b Variables listed in order of selection
c Cumulative R^2 value with entry of each variable into regression model
d Standardized Rank Regression Coefficient

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Table 8-9 – Ranked regression analysis for mean direct brine releases, replicate 2

	Expected Normalized Release					
	CRA14_SEN4 Replicate 2			APCS Replicate 2		
Step [a]	**Variable** [b]	**R^2** [c]	**SRRC** [d]	**Variable** [b]	**R^2** [c]	**SRRC** [d]
1	SOLMOD3:SOLVAR	0.37	0.63	SOLMOD3:SOLVAR	0.32	0.58
2	GLOBAL:PBRINE	0.53	0.42	CASTILER:PRESSURE	0.44	0.34
3	CASTILER:PRESSURE	0.66	0.36	GLOBAL:PBRINE	0.53	0.35
4	BH_SAND:PRMX_LOG	0.73	-0.24	BH_SAND:PRMX_LOG	0.60	-0.25
5	GLOBAL:OXSTAT	0.77	-0.19	CASTILER:COMP_RCK	0.66	0.26
6	CULEBRA:DPOROS	0.78	0.12	(Composite):OXSTAT	0.70	-0.19
7	SPALLMOD:REPIPOR	0.80	0.12	S_HALITE:POROSITY	0.72	0.15
8	CASTILER:COMP_RCK	0.81	0.10	SHFTU:SAT_RGAS	0.74	-0.14
9	SHFTU:SAT_RGAS	0.82	-0.10	CULEBRA:DPOROS	0.76	0.12
10	S_HALITE:POROSITY	0.83	0.10	DRZ_1:PRMX_LOG	0.77	-0.10
11	SHFTL_T2:PRMX_LOG	0.84	0.10	WAS_AREA:GRATMICI	0.78	0.10

Table 8-10 – Ranked regression analysis for mean direct brine releases, replicate 3

	Expected Normalized Release					
	CRA14_SEN4 Replicate 3			APCS Replicate 3		
Step [a]	**Variable** [b]	**R^2** [c]	**SRRC** [d]	**Variable** [b]	**R^2** [c]	**SRRC** [d]
1	SOLMOD3:SOLVAR	0.33	0.54	SOLMOD3:SOLVAR	0.32	0.55
2	CASTILER:PRESSURE	0.58	0.52	CASTILER:PRESSURE	0.47	0.40
3	GLOBAL:PBRINE	0.73	0.39	BH_SAND:PRMX_LOG	0.60	-0.33
4	BH_SAND:PRMX_LOG	0.79	-0.25	GLOBAL:PBRINE	0.72	0.35
5	DRZ_1:PRMX_LOG	0.84	-0.21	DRZ_1:PRMX_LOG	0.77	-0.24
6	(Composite):OXSTAT	0.85	-0.14	CASTILER:COMP_RCK	0.79	0.15
7	S_HALITE:PRMX_LOG	0.87	0.11	WAS_AREA:SAT_RBRN	0.81	-0.13
8	CULEBRA:APOROS	0.88	0.11	(Composite):OXSTAT	0.83	-0.14
9	WAS_AREA:SAT_RBRN	0.88	-0.09	DRZ_PCS:PRMX_LOG	0.84	-0.12
10	S_HALITE:POROSITY	0.89	0.09	S_HALITE:PRMX_LOG	0.85	0.11
11	DRZ_PCS:PRMX_LOG	0.90	-0.08	S_HALITE:POROSITY	0.86	0.09
12	WAS_AREA:BIOGENFC	0.90	0.08	SHFTL_T2:PRMX_LOG	0.87	0.08
13	WAS_AREA:PROBDEG	0.91	0.08	AM+3:MKD_AM	0.87	0.08
14	GLOBAL:TRANSIDX	0.91	0.07			

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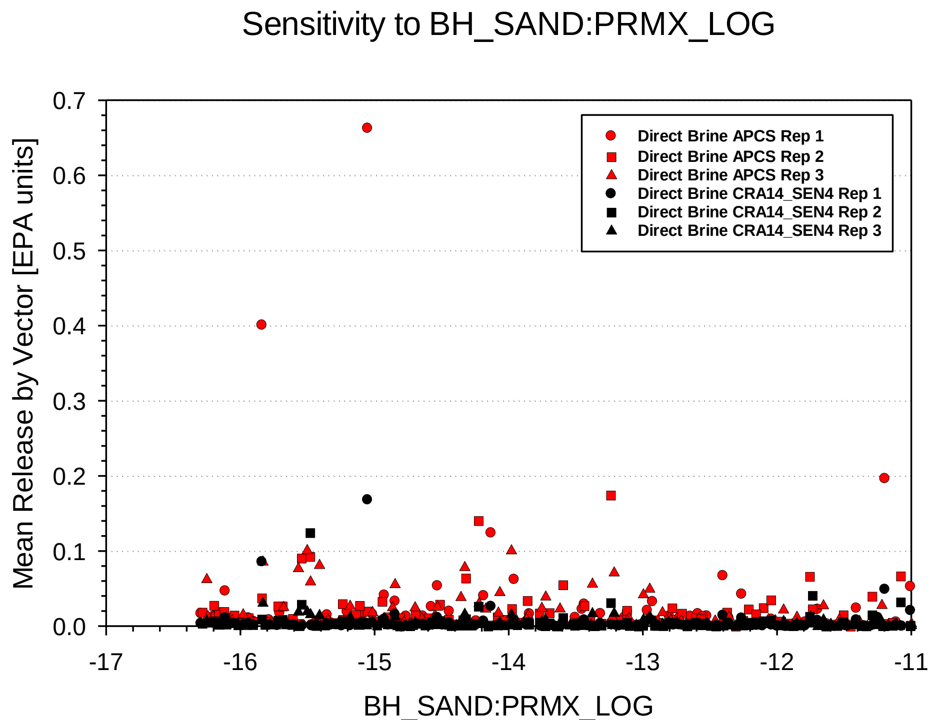

Figure 8-3– Scatterplot of (the logarithm of) borehole permeability versus mean DBR releases

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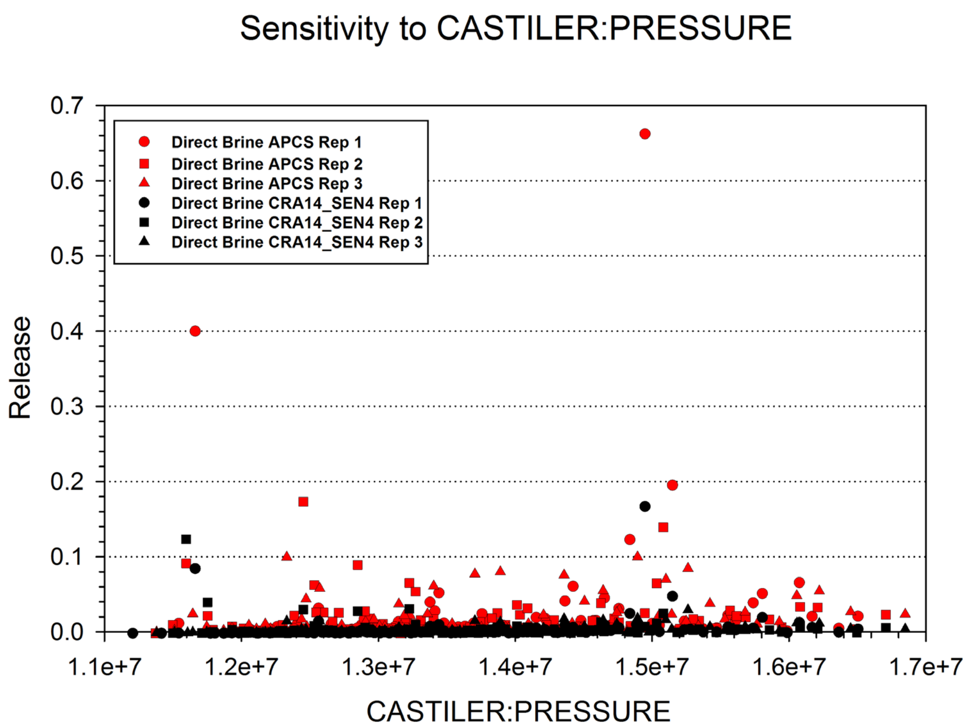

Figure 8-4 – Scatterplot of the initial brine pressure in the Castile brine reservoir versus mean DBR releases

8.2.4 Releases From the Culebra

Mean releases from the Culebra contain very few vectors with mean releases greater than 0.0001 EPA units (Table 8-1), e.g. only five for replicate 1, and thus the sensitivity results are not deemed to be meaningful. The results are included below for completeness. (Composite):MKD_U, a parameter which denotes a composite of the matrix distribution coefficients for uranium IV and VI, and BH_SAND:PRMX_LOG remain the highest ranking parameters in both the CRA14_SEN4 and APCS sensitivity analyses.

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Table 8-11 – Ranked regression analysis for mean releases from the Culebra, replicate 1

	Expected Normalized Release					
	CRA14_SEN4 Replicate 1			**APCS Replicate 1**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	(Composite):MKD_U	0.33	-0.46	(Composite):MKD_U	0.27	-0.26
2	BH_SAND:PRMX_LOG	0.54	0.47	BH_SAND:PRMX_LOG	0.44	0.44
3	CULEBRA:HMBLKLT	0.58	0.19	CULEBRA:APOROS	0.50	-0.21
4	GLOBAL:CLIMTIDX	0.61	0.17	GLOBAL:CLIMTIDX	0.53	0.19
5	CULEBRA:APOROS	0.63	-0.14	S_HALITE:COMP_RCK	0.56	0.17
6	SOLMOD3:SOLVAR	0.65	0.13	CULEBRA:HMBLKLT	0.58	0.17
7	S_HALITE:COMP_RCK	0.67	0.13	WAS_AREA:BRUCITEC	0.60	0.16
8	DRZ_PCS:PRMX_LOG	0.68	0.13	(Composite):OXSTAT	0.62	0.22
9	WAS_AREA:SAT_WICK	0.70	0.12	DRZ_PCS:PRMX_LOG	0.65	0.17
10	S_HALITE:POROSITY	0.71	-0.12	WAS_AREA:SAT_WICK	0.67	0.13

a Steps in stepwise regression analysis
b Variables listed in order of selection
c Cumulative R^2 value with entry of each variable into regression model
d Standardized Rank Regression Coefficient

Table 8-12 – Ranked regression analysis for mean releases from the Culebra, replicate 2

	Expected Normalized Release					
	CRA14_SEN4 Replicate 2			**APCS Replicate 2**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	BH_SAND:PRMX_LOG	0.47	0.64	BH_SAND:PRMX_LOG	0.44	0.61
2	(Composite):MKD_U	0.60	-0.23	(Composite):MKD_U	0.59	-0.26
3	GLOBAL:OXSTAT	0.64	0.23	CULEBRA:MINP_FAC	0.63	-0.19
4	CULEBRA:MINP_FAC	0.67	-0.15	GLOBAL:OXSTAT	0.67	0.23
5	CULEBRA:HMBLKLT	0.69	0.14	AM+3:MKD_AM	0.69	-0.14
6	CULEBRA:APOROS	0.71	-0.14	SHFTU:PRMX_LOG	0.71	0.13
7	SHFTU:PRMX_LOG	0.72	0.12	CULEBRA:APOROS	0.72	-0.12
8				CULEBRA:HMBLKLT	0.73	0.12
9				WAS_AREA:BIOGENFC	0.75	-0.12

Table 8-13 – Ranked regression analysis for mean releases from the Culebra, replicate 3

	Expected Normalized Release					
	CRA14_SEN4 Replicate 3			**APCS Replicate 3**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	BH_SAND:PRMX_LOG	0.31	0.53	BH_SAND:PRMX_LOG	0.26	0.50
2	CULEBRA:APOROS	0.44	-0.36	(Composite):MKD_U	0.42	-0.40
3	(Composite):MKD_U	0.56	-0.33	CULEBRA:APOROS	0.50	-0.28
4	PCS_T1:POROSITY	0.58	0.17	CASTILER:PRESSURE	0.53	0.18
5	GLOBAL:CLIMTIDX	0.61	0.17	SOLMOD4:SOLVAR	0.56	0.15
6	CASTILER:PRESSURE	0.63	0.13	S_MB139:PRMX_LOG	0.58	-0.16
7				GLOBAL:CLIMTIDX	0.60	0.16
8				(Composite):MKD_PU	0.62	-0.15

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8.2.5 Releases To the Culebra

For mean releases to the Culebra, the CRA14_SEN4 and APCS sensitivity results are similar, and BH_SAND:PRMX_LOG, remains the single most influential parameter. These results are included for historical completeness, as releases to the Culebra are not releases that cross the land withdrawal boundary or the surface, and thus are not directly included in the total releases. Releases from the Culebra are included in the total releases.

Table 8-14 – Ranked regression analysis for mean releases to the Culebra, replicate 1

	Expected Normalized Release					
	CRA14_SEN4 Replicate 1			**APCS Replicate 1**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	BH_SAND:PRMX_LOG	0.90	0.95	BH_SAND:PRMX_LOG	0.85	0.93
2	CASTILER:PRESSURE	0.91	0.11	CASTILER:PRESSURE	0.87	0.14
3	(Composite):OXSTAT	0.92	-0.09	S_HALITE:COMP_RCK	0.88	0.12
4	DRZ_PCS:PRMX_LOG	0.93	0.08	(Composite):MKD_U	0.89	0.09
5	SOLMOD3:SOLVAR	0.94	0.08	DRZ_PCS:PRMX_LOG	0.89	0.07
6	S_HALITE:COMP_RCK	0.94	0.07			

a Steps in stepwise regression analysis
b Variables listed in order of selection
c Cumulative R^2 value with entry of each variable into regression model
d Standardized Rank Regression Coefficient

Table 8-15 – Ranked regression analysis for mean releases to the Culebra, replicate 2

	Expected Normalized Release					
	CRA14_SEN4 Replicate 2			**APCS Replicate 2**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	BH_SAND:PRMX_LOG	0.90	0.96	BH_SAND:PRMX_LOG	0.85	0.94
2	SOLMOD3:SOLVAR	0.91	0.13	SOLMOD3:SOLVAR	0.87	0.15
3	CASTILER:PRESSURE	0.92	0.11	CASTILER:PRESSURE	0.89	0.10
4	GLOBAL:PBRINE	0.93	0.10	WAS_AREA:BIOGENFC	0.89	-0.09
5	SPALLMOD:REPIPOR	0.94	0.06	GLOBAL:PBRINE	0.90	0.09
6	CONC_PLG:PRMX_LOG	0.94	-0.06	(Composite):OXSTAT	0.91	-0.09
7	SHFTU:SAT_RGAS	0.94	-0.05	CULEBRA:DPOROS	0.91	-0.07
8	GLOBAL:OXSTAT	0.94	-0.05	S_HALITE:PRMX_LOG	0.92	-0.07
9				S_MB139:SAT_RBRN	0.92	-0.06

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Table 8-16 – Ranked regression analysis for mean releases to the Culebra, replicate 3

	Expected Normalized Release					
	CRA14_SEN4 Replicate 3			APCS Replicate 3		
Step [a]	**Variable** [b]	**R^2** [c]	**SRRC** [d]	**Variable** [b]	**R^2** [c]	**SRRC** [d]
1	BH_SAND:PRMX_LOG	0.90	0.94	BH_SAND:PRMX_LOG	0.87	0.93
2	CASTILER:PRESSURE	0.92	0.12	CASTILER:PRESSURE	0.89	0.13
3	S_HALITE:POROSITY	0.93	-0.10	S_HALITE:POROSITY	0.90	-0.14
4	SOLMOD3:SOLVAR	0.93	0.07	WAS_AREA:SAT_RGAS	0.91	0.08
5	WAS_AREA:GRATMICH	0.94	0.07	GLOBAL:PBRINE	0.92	0.09
6	CASTILER:PRMX_LOG	0.94	0.05	SOLMOD3:SOLVAR	0.93	0.07
7	GLOBAL:OXSTAT	0.94	-0.06	GLOBAL:OXSTAT	0.93	-0.07
8	GLOBAL:PBRINE	0.94	0.05	WAS_AREA:GRATMICH	0.93	0.07
9				SOLMOD4:SOLVAR	0.94	0.06
10				WAS_AREA:BRUCITEC	0.94	-0.05

8.2.6 Total Releases

The sensitivity results for total releases are different for the CRA14_SEN4 and APCS analyses, and the differences are due to the change in relative importance of the different release mechanisms between the two analyses. Across the three replicates, CASTILER:PRESSURE, SOLMOD3:SOLVAR, and GLOBAL:PBRINE are more influential in the APCS analysis compared to the CRA14_SEN4 analysis. These are the most influential parameters in the DBR mechanism, and their increase in influence on the total releases in the APCS analysis is due to the greater overall contribution of DBR releases to total releases. The same is true for BH_SAND:PRMX_LOG. The substantial decrease in influence of BOREHOLE:TAUFAIL, which is the dominant parameter for cuttings and cavings releases, on total releases is also due to the larger increase in overall DBRs. Cuttings and cavings releases simply account for a smaller portion of the total releases.

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Table 8-17 – Ranked regression analysis for Total releases, replicate 1

	Expected Normalized Release					
	CRA14_SEN4 Replicate 1			**APCS Replicate 1**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	CASTILER:PRESSURE	0.21	0.44	CASTILER:PRESSURE	0.25	0.46
2	BOREHOLE:TAUFAIL	0.39	-0.42	SOLMOD3:SOLVAR	0.47	0.50
3	SOLMOD3:SOLVAR	0.51	0.39	BH_SAND:PRMX_LOG	0.53	-0.26
4	WAS_AREA:PROBDEG	0.55	0.15	WAS_AREA:PROBDEG	0.59	0.18
5	S_HALITE:PRMX_LOG	0.58	0.16	GLOBAL:PBRINE	0.63	0.20
6	S_HALITE:POROSITY	0.61	0.19	BOREHOLE:TAUFAIL	0.66	-0.19
7	GLOBAL:PBRINE	0.64	0.17	S_HALITE:POROSITY	0.69	0.19
8	SHFTU:SAT_RGAS	0.66	-0.14	DRZ_1:PRMX_LOG	0.72	-0.16
9	BH_SAND:PRMX_LOG	0.67	-0.13	WAS_AREA:GRATMICI	0.73	0.13
10				CASTILER:COMP_RCK	0.75	0.13
11				(Composite):OXSTAT	0.76	-0.12
12				TH+4:MKD_TH	0.77	0.12

a Steps in stepwise regression analysis
b Variables listed in order of selection
c Cumulative R^2 value with entry of each variable into regression model
d Standardized Rank Regression Coefficient

Table 8-18 – Ranked regression analysis for Total releases, replicate 2

	Expected Normalized Release					
	CRA14_SEN4 Replicate 2			**APCS Replicate 2**		
Step [a]	**Variable [b]**	**R^2 [c]**	**SRRC [d]**	**Variable [b]**	**R^2 [c]**	**SRRC [d]**
1	BOREHOLE:TAUFAIL	0.27	-0.50	SOLMOD3:SOLVAR	0.27	0.54
2	SOLMOD3:SOLVAR	0.47	0.47	CASTILER:PRESSURE	0.38	0.32
3	CASTILER:PRESSURE	0.56	0.32	GLOBAL:PBRINE	0.48	0.34
4	GLOBAL:PBRINE	0.65	0.30	BH_SAND:PRMX_LOG	0.53	-0.22
5	BH_SAND:PRMX_LOG	0.68	-0.15	BOREHOLE:TAUFAIL	0.57	-0.22
6	CULEBRA:MINP_FAC	0.70	-0.15	S_HALITE:POROSITY	0.61	0.20
7	S_HALITE:POROSITY	0.72	0.14	SHFTU:SAT_RGAS	0.64	-0.16
8	SHFTU:SAT_RGAS	0.73	-0.12	CASTILER:COMP_RCK	0.67	0.19
9	BOREHOLE:DOMEGA	0.74	0.12	(Composite):OXSTAT	0.69	-0.14
10	WAS_AREA:PROBDEG	0.76	0.11			

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Table 8-19 – Ranked regression analysis for Total releases, replicate 3

	Expected Normalized Release					
	CRA14_SEN4 Replicate 3			**APCS Replicate 3**		
Step [a]	**Variable** [b]	**R^2** [c]	**SRRC** [d]	**Variable** [b]	**R^2** [c]	**SRRC** [d]
1	BOREHOLE:TAUFAIL	0.22	-0.48	SOLMOD3:SOLVAR	0.22	0.43
2	SOLMOD3:SOLVAR	0.36	0.36	BH_SAND:PRMX_LOG	0.38	-0.37
3	CASTILER:PRESSURE	0.45	0.32	GLOBAL:PBRINE	0.49	0.32
4	GLOBAL:PBRINE	0.54	0.29	CASTILER:PRESSURE	0.59	0.32
5	BH_SAND:PRMX_LOG	0.59	-0.23	DRZ_1:PRMX_LOG	0.65	-0.25
6	S_HALITE:POROSITY	0.62	0.17	BOREHOLE:TAUFAIL	0.69	-0.22
7	BOREHOLE:DOMEGA	0.65	0.18	CASTILER:COMP_RCK	0.72	0.16
8	CULEBRA:APOROS	0.67	0.15	S_HALITE:POROSITY	0.74	0.15
9	PCS_T2:POROSITY	0.68	-0.13	S_HALITE:PRMX_LOG	0.76	0.12
10	WAS_AREA:PROBDEG	0.70	0.13	WAS_AREA:SAT_RBRN	0.77	-0.11
11	DRZ_1:PRMX_LOG	0.71	-0.12	DRZ_PCS:PRMX_LOG	0.78	-0.11
12				CULEBRA:MINP_FAC	0.79	0.11

8.3 Summary and Conclusions

Two conclusions can be drawn from the sensitivity analysis results. First, the large increase in DBR releases in the APCS analysis compared to the CRA14_SEN4 analysis causes the total mean releases to be most strongly influenced by the dominant parameters in the DBR release mechanism: CASTILER:PRESSURE (the initial brine pressure in the Castile brine reservoir), SOLMOD3:SOLVAR (solubility multiplier for III oxidation states), GLOBAL:PBRINE (probability that a drilling intrusion penetrates the pressurized brine in the Castile), and BH_SAND:PRMX_LOG (the (logarithm of the) permeability of the silty-sand-filled borehole). Second, for DBR mean releases, BH_SAND:PRMX_LOG is more important in the APCS analysis compared to the CRA14_SEN4 analysis. This is because pressure buildup in the waste areas plays a more important role in determining DBR releases (as well as spallings releases), and BH_SAND:PRMX_LOG controls how much pressure dissipates into the shallower and more permeable formations. As discussed in the DBR section, this increased importance of waste area pressure buildup is due to the lack of panel closures in the APCS analysis – the lack of panel closures allows for the entire South end of the repository to act as a pressure reservoir in the event of a drilling intrusion, thus allowing brine (and waste solids) to be produced to the surface at higher and more sustained rates.[12]

[12] The sensitivity analysis describes the relative impact of sampled parameters on releases, but releases are significantly impacted by the conservativism built into the APCS model via the panel reneighboring done for CCDFGF. Teasing out the relative impact of sampled parameters apart from the model changes is not possible with this type of regression analysis, so the impact of the conservative panel reneighboring is built into the results of the regression analysis; therefore, the impact of a given parameter on releases, as presented here, should be considered in that context.

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9 Summary

This report provides the analysis approach and presents results of an analysis (**A**bandonment of **P**anel **C**losures in the **S**outh—APCS) that quantifies the impacts of a proposed DOE operational policy change on the long-term repository performance which includes abandonment of run-of-mine panel closures in Panels 3, 4, 5, and 6 and abandonment of waste emplacement in the area designated as Panel 9. The approach consists of working within the currently approved PA framework; therefore, no consideration was given to conceptual model changes, major code changes, or novel parameter values. In the BRAGFLO grid, the southernmost panel closure area (between the waste panel (WP) and south rest-of-repository (SROR)) was effectively removed as a barrier by assigning looser "open area" parameters. In the DBR grid, panel closure areas for Panels 3, 4, 5, and 6 were similarly assigned "open area" parameters. Because of limitations in the current conceptual model and code framework, explicit modeling of an open Panel 9 was not done; instead, a quantitative argument for the conservatism (with respect to releases) of including waste in Panel 9 is provided (Appendix A). While cuttings and cavings releases are not impacted by the changes implemented in APCS, increased releases are shown for all other release mechanisms. The increased communication between the WP and SROR areas allows for greater brine pressures and saturations in the SROR following Castile intrusions, 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 approach taken to address the DOE-proposed changes results in increases to the predicted total releases from the repository. However, releases calculated in the APCS analysis are below regulatory limits.

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10 References

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11 Run Control

11.1 Hardware Platform and Operating System

APCS was executed on the Solaris Cluster (Oracle/SUN X6270 m2, Oracle/SUN X4-2B, and Dell PowerEdge R820) with SunOS 5.11 11.3 i86pc i386 i86pc.

11.2 Code Versions used in APCS Calculations

The following code versions were used in APCS calculations: ALGEBRACDB v2.36, BRAGFLO v6.03, CCDFGF v7.03, CUTTINGS_S v6.03, EPAUNI 1.19, GENMESH v6.10, ICSET v2.23, LHS v2.44, MATSET v9.24, NUTS 2.06, PANEL 4.04, POSTBRAG v4.02, POSTLHS v4.11, PREBRAG v8.03, PRECCDFGF v2.01, PRELHS v2.44, RELATE v1.45, SUMMARIZE v3.02, DRSPALL v1.22,[13] STEPWISE v2.22

11.3 LHS

Table 11-1: LHS run script files

File	Repository	Comment
RunControl/LHS.py	$REP/APCS/LHS	Python run control script
RunControl/LHSlib.py	$REP/APCS/LHS	Python run control script class modules
RunControl/rc.py	$REP/APCS/LHS	Run control module
RunControl/Run.py	$REP/APCS/LHS	Main control script

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-2: LHS input file

File	Repository	Comment
Input/lhs1_APCS_r*i*_con.inp	$REP/APCS/PRELHS	PRELHS input file

Where:

i is 1-3
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

[1] DRSPALL v. 1.22 was not rerun for APCS. Instead, the DRSPALL v. 1.22 output results from a previous run (Kirchner et al. 2015) were used as input to the CUTTINGS_S code in APCS calculations.

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Table 11-3: LHS CVS repositories

CVS Repositories
$CODE/LHS
$CODE/PRELHS
$REP/APCS/LHS
$REP/APCS/PRELHS

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

Table 11-4: LHS log files

File	Repository	Comment
RunControl/LHS.log	$REP/APCS/LHS	Log file
RunControl/LHS.rtf	$REP/APCS/LHS	Formatted log file (Word file)

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-5: LHS output files

File	Repository	Comment
Output/lhs1_APCS_r*i*_con.dbg	$REP/APCS/PRELHS	PRELHS debug file
Output/lhs1_APCS_r*i*_con.trn	$REP/APCS/PRELHS	PRELHS transfer file
Output/lhs2_APCS_r*i*_con.dbg	$REP/APCS/LHS	LHS debug file
Output/lhs2_APCS_r*i*_con.trn	$REP/APCS/LHS	LHS transfer file

Where:
i is 1-3
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-6: LHS executable files

File	Repository	Comment
Build/Solaris/lhs (Ver:2.44)	$CODE/LHS	Code to sample uncertain parameters
Build/Solaris/prelhs (Ver:2.44)	$CODE/PRELHS	Pre-processes data for LHS

Where:
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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11.4 EPAUNI

Table 11-7: EPAUNI run script files

File	Repository	Comment
RunControl/EPAUNI.py	$REP/APCS/EPAUNI	Python run control script
RunControl/EPAUNIlib.py	$REP/APCS/EPAUNI	Python run control script class modules
RunControl/rc.py	$REP/APCS/EPAUNI	Run control module
RunControl/Run.py	$REP/APCS/EPAUNI	Main control script

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-8: EPAUNI input files

File	Repository	Comment
Input/epu_APCS_ch.inp	$REP/APCS/EPAUNI	Input file
Input/epu_APCS_ch_misc.inp	$REP/APCS/EPAUNI	Input file
Input/epu_APCS_rh.inp	$REP/APCS/EPAUNI	Input file
Input/epu_APCS_rh_misc.inp	$REP/APCS/EPAUNI	Input file

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-9: EPAUNI CVS repositories

CVS Repositories
$CODE/EPAUNI
$REP/APCS/EPAUNI

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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Table 11-10: EPAUNI log files

File	Repository	Comment
RunControl/EPAUNI.log	$REP/APCS/EPAUNI	Log file
RunControl/EPAUNI.rtf	$REP/APCS/EPAUNI	Formatted log file (Word file)

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-11: EPAUNI output files

File	Repository	Comment
Output/epu_APCS_ch.dat	$REP/APCS/EPAUNI	Radionuclide inventory
Output/epu_APCS_ch.dia	$REP/APCS/EPAUNI	Diagnostic file
Output/epu_APCS_ch.out	$REP/APCS/EPAUNI	Supplemental output file
Output/epu_APCS_ch.out2	$REP/APCS/EPAUNI	Supplemental output file
Output/epu_APCS_ch_activity.dia	$REP/APCS/EPAUNI	Diagnostic file
Output/epu_APCS_rh.dat	$REP/APCS/EPAUNI	Radionuclide inventory
Output/epu_APCS_rh.dia	$REP/APCS/EPAUNI	Diagnostic file
Output/epu_APCS_rh.out	$REP/APCS/EPAUNI	Supplemental output file
Output/epu_APCS_rh.out2	$REP/APCS/EPAUNI	Supplemental output file
Output/epu_APCS_rh_activity.dia	$REP/APCS/EPAUNI	Diagnostic file

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-12: EPAUNI executable file

File	Repository	Comment
Build/Solaris/epauni (Ver:1.19)	$CODE/EPAUNI	Computes decay of radionuclide components in inventory

Where:
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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11.5 BRAGFLO

Table 11-13: BRAGFLO run script files

File	Repository	Comment
RunControl/BRAGFLO.py	$REP/APCS/BRAGFLO	Python run control script
RunControl/BRAGFLOlib.py	$REP/APCS/BRAGFLO	Python run control script class modules
RunControl/rc.py	$REP/APCS/BRAGFLO	Run control module
RunControl/Run.py	$REP/APCS/BRAGFLO	Main control script

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-14: BRAGFLO input files

File	Repository	Comment
Input/alg1_bf_APCS.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg2_bf_APCS.inp	$REP/APCS/ALGEBRACDB	Input file
Input/bf1_APCS_s*n*.inp	$REP/APCS/PREBRAG	Input file
Input/bf1_APCS_s*n*_mod1.inp	$REP/APCS/PREBRAG	Input file
Input/bf1_APCS_s*n*_mod2.inp	$REP/APCS/PREBRAG	Input file
Input/bf2_APCS_closure.dat	$REP/APCS/BRAGFLO	Input file
Input/gm_bf_APCS.inp	$REP/APCS/GENMESH	Input file
Input/ic_bf_APCS.inp	$REP/APCS/ICSET	Input file
Input/ms_bf_APCS.inp	$REP/APCS/MATSET	Input file

Where:

n is 1-6
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-15: BRAGFLO CVS repositories

CVS Repositories
$CODE/ALGEBRACDB
$CODE/BRAGFLO
$CODE/GENMESH
$CODE/ICSET
$CODE/MATSET
$CODE/POSTBRAG
$CODE/POSTLHS
$CODE/PREBRAG
$REP/APCS/ALGEBRACDB
$REP/APCS/BRAGFLO
$REP/APCS/GENMESH
$REP/APCS/ICSET
$REP/APCS/MATSET
$REP/APCS/PREBRAG

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

Table 11-16: BRAGFLO log files

File	Repository	Comment
RunControl/BRAGFLO.log	$REP/APCS/BRAGFLO	Log file
RunControl/BRAGFLO.rtf	$REP/APCS/BRAGFLO	Formatted log file (Word file)

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-17: BRAGFLO output files

File	Repository	Comment
Output/alg1_bf_APCS_r*i*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/alg2_bf_APCS_r*i*_s*n*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/bf2_APCS_r*i*_s*n*_*vvvv*.inp	$REP/APCS/PREBRAG	BRAGFLO input file
Output/bf2_APCS_r*i*_s*n*_*vvvv*.log	$REP/APCS/BRAGFLO	Log file
Output/bf2_APCS_r*i*_s*n*_*vvvv*.sum	$REP/APCS/BRAGFLO	Summary file
Output/bf3_APCS_r*i*_s*n*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/gm_bf_APCS.cdb		NOT SAVED:CDB transfer file
Output/ic_bf_APCS_r*i*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/lhs3_bf_APCS_r*i*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/ms_bf_APCS.cdb		NOT SAVED:CDB transfer file

Where:

i is 1-3
n is 1-6
vvv is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-18: BRAGFLO executable files

File	Repository	Comment
Build/Solaris/algebracdb (Ver:2.36)	$CODE/ALGEBRACDB	Manipulates CAMDAT data by evaluating algebraic expressions
Build/Solaris/bragflo (Ver:6.03)	$CODE/BRAGFLO	Computes brine and gas flow in the repository
Build/Solaris/genmesh (Ver:6.10)	$CODE/GENMESH	Generates the CAMDAT computational grid
Build/Solaris/icset (Ver:2.23)	$CODE/ICSET	Assigns initial conditions to the CAMDAT grid elements
Build/Solaris/matset (Ver:9.24)	$CODE/MATSET	Assigns material properties to CAMDAT grid blocks
Build/Solaris/postbrag (Ver:4.02)	$CODE/POSTBRAG	Post-processes data for BRAGFLO
Build/Solaris/postlhs (Ver:4.11)	$CODE/POSTLHS	Assigns sampled parameters to the grid blocks and elements
Build/Solaris/prebrag (Ver:8.03)	$CODE/PREBRAG	Pre-processes data for BRAGFLO

Where:

$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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11.6 PANEL

Table 11-19: PANEL run script files

File	Repository	Comment
RunControl/PANEL.py	$REP/APCS/PANEL	Python run control script
RunControl/PANELlib.py	$REP/APCS/PANEL	Python run control script class modules
RunControl/rc.py	$REP/APCS/PANEL	Run control module
RunControl/Run.py	$REP/APCS/PANEL	Main control script

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-20: PANEL input files

File	Repository	Comment
Input/alg1_panel_APCS.inp	$REP/APCS/ALGEBRACDB	Input file
Output/alg2_bf_APCS_r*i*_s*n*_v*vvv*.cdb		NOT SAVED:CDB transfer file
Input/alg2_panel_APCS_b1.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg2_panel_APCS_b2.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg2_panel_APCS_b3.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg2_panel_APCS_b4.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg2_panel_APCS_b5.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg3_panel_APCS_b1.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg3_panel_APCS_b2.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg3_panel_APCS_b3.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg3_panel_APCS_b4.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg3_panel_APCS_b5.inp	$REP/APCS/ALGEBRACDB	Input file
Input/gm_panel_APCS.inp	$REP/APCS/GENMESH	Input file
Input/ms_panel_APCS.inp	$REP/APCS/MATSET	Input file
Input/sum_panel_con.inp	$REP/APCS/SUMMARIZE	Input file
Input/sum_panel_int.inp	$REP/APCS/SUMMARIZE	Input file
Input/sum_panel_st.inp	$REP/APCS/SUMMARIZE	Input file

Where:

i is 1-3
n is 1-6
vvv is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-21: PANEL CVS repositories

CVS Repositories
$CODE/ALGEBRACDB
$CODE/GENMESH
$CODE/MATSET
$CODE/PANEL
$CODE/POSTLHS
$CODE/SUMMARIZE
$REP/APCS/ALGEBRACDB
$REP/APCS/GENMESH
$REP/APCS/MATSET
$REP/APCS/PANEL
$REP/APCS/SUMMARIZE

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

Table 11-22: PANEL log files

File	Repository	Comment
RunControl/PANEL.log	$REP/APCS/PANEL	Log file
RunControl/PANEL.rtf	$REP/APCS/PANEL	Formatted log file (Word file)

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-23: PANEL output files

File	Repository	Comment
Output/alg1_panel_APCS.cdb		NOT SAVED:CDB transfer file
Output/alg2_panel_APCS_b1.cdb		NOT SAVED:CDB transfer file
Output/alg2_panel_APCS_b2.cdb		NOT SAVED:CDB transfer file
Output/alg2_panel_APCS_b3.cdb		NOT SAVED:CDB transfer file
Output/alg2_panel_APCS_b4.cdb		NOT SAVED:CDB transfer file
Output/alg2_panel_APCS_b5.cdb		NOT SAVED:CDB transfer file
Output/alg3_panel_APCS_b1_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/alg3_panel_APCS_b2_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/alg3_panel_APCS_b3_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/alg3_panel_APCS_b4_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/alg3_panel_APCS_b5_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/gm_panel_APCS.cdb		NOT SAVED:CDB transfer file
Output/lhs3_panel_APCS_b1_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/lhs3_panel_APCS_b2_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/lhs3_panel_APCS_b3_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/lhs3_panel_APCS_b4_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/lhs3_panel_APCS_b5_rj_vwww.cdb		NOT SAVED:CDB transfer file
Output/ms_panel_APCS.cdb		NOT SAVED:CDB transfer file
Output/panel_con_APCS_b1_rj_sq_vwww.cdb		NOT SAVED:CDB transfer file
Output/panel_con_APCS_b2_rj_sq_vwww.cdb		NOT SAVED:CDB transfer file
Output/panel_con_APCS_b3_rj_sq_vwww.cdb		NOT SAVED:CDB transfer file
Output/panel_con_APCS_b4_rj_sq_vwww.cdb		NOT SAVED:CDB transfer file
Output/panel_con_APCS_b5_rj_sq_vwww.cdb		NOT SAVED:CDB transfer file
Output/panel_decay_APCS_ri_sn_vvvv.cdb		NOT SAVED:CDB transfer file

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File	Repository	Comment
Output/panel_int_APCS_b1_r*j*_s*o*_t*ttttt*_v*www*.cdb		NOT SAVED:CDB transfer file
Output/panel_int_APCS_b2_r*j*_s*o*_t*ttttt*_v*www*.cdb		NOT SAVED:CDB transfer file
Output/panel_int_APCS_b3_r*j*_s*o*_t*ttttt*_v*www*.cdb		NOT SAVED:CDB transfer file
Output/panel_int_APCS_b4_r*j*_s*o*_t*ttttt*_v*www*.cdb		NOT SAVED:CDB transfer file
Output/panel_int_APCS_b5_r*j*_s*o*_t*ttttt*_v*www*.cdb		NOT SAVED:CDB transfer file
Output/sum_panel_con_APCS_b1_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_con_APCS_b2_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_con_APCS_b3_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_con_APCS_b4_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_con_APCS_b5_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_int_APCS_b1_r*j*_s*o*_t*ttttt*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_int_APCS_b2_r*j*_s*o*_t*ttttt*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_int_APCS_b3_r*j*_s*o*_t*ttttt*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_int_APCS_b4_r*j*_s*o*_t*ttttt*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_int_APCS_b5_r*j*_s*o*_t*ttttt*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_st_APCS_b1_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_st_APCS_b2_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_st_APCS_b3_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_st_APCS_b4_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_panel_st_APCS_b5_r*j*_s*p*.tbl	$REP/APCS/SUMMARIZE	Table file

Where:

i is 1
j is 1-3
n is 1
o is 6
p is 1-2
q is 1-6
ttttt is 00100, 00350, 01000, 02000, 04000, 06000, 09000
vvv is 001
www is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-24: PANEL executable files

File	Repository	Comment
Build/Solaris/algebracdb (Ver:2.36)	$CODE/ALGEBRACDB	Manipulates CAMDAT data by evaluating algebraic expressions
Build/Solaris/genmesh (Ver:6.10)	$CODE/GENMESH	Generates the CAMDAT computational grid
Build/Solaris/matset (Ver:9.24)	$CODE/MATSET	Assigns material properties to CAMDAT grid blocks
Build/Solaris/panel (Ver:4.04)	$CODE/PANEL	Computes release concentrations of nuclides from repository
Build/Solaris/postlhs (Ver:4.11)	$CODE/POSTLHS	Assigns sampled parameters to the grid blocks and elements
Build/Solaris/summarize (Ver:3.02)	$CODE/SUMMARIZE	Writes tables of data from many CAMDAT files

Where:

$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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11.7 NUTS

Table 11-25: NUTS run script files

File	Repository	Comment
RunControl/NUTS.py	$REP/APCS/NUTS	Python run control script
RunControl/NUTSlib.py	$REP/APCS/NUTS	Python run control script class modules
RunControl/rc.py	$REP/APCS/NUTS	Run control module
RunControl/Run.py	$REP/APCS/NUTS	Main control script

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-26: NUTS input files

File	Repository	Comment
Input/alg_nut_iso_APCS.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg_nut_scn_APCS.inp	$REP/APCS/ALGEBRACDB	Input file
Output/bf2_APCS_r*i*_s*n*_v*vvv*.inp	$REP/APCS/PREBRAG	Input file
Output/bf3_APCS_r*i*_s*n*_v*vvv*.cdb		NOT SAVED:CDB transfer file
Input/ms_nut_APCS.inp	$REP/APCS/MATSET	Input file
Input/nut_int_APCS_s*o*_t*ttttt*.inp	$REP/APCS/NUTS	Input file
Input/nut_iso_APCS_s*n*.inp	$REP/APCS/NUTS	Input file
Input/nut_scn_APCS_s*n*.inp	$REP/APCS/NUTS	Input file
Output/panel_con_APCS_b1_r*i*_s*n*_v*vvv*.cdb		NOT SAVED:CDB transfer file

Where:

i is 1-3
n is 1-5
o is 2-5
ttttt is 0100 — for S2, S4
03000, 05000, 07000, 09000 — for S3, S5
vvv is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-27: NUTS CVS repositories

CVS Repositories
$CODE/ALGEBRACDB
$CODE/MATSET
$CODE/NUTS
$CODE/SCREEN_NUTS
$CODE/SUMMARIZE
$REP/APCS/ALGEBRACDB
$REP/APCS/BRAGFLO
$REP/APCS/MATSET
$REP/APCS/NUTS
$REP/APCS/PANEL
$REP/APCS/PREBRAG
$REP/APCS/SCREEN_NUTS
$REP/APCS/SUMMARIZE

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

Table 11-28: NUTS log files

File	Repository	Comment
RunControl/NUTS.log	$REP/APCS/NUTS	Log file
RunControl/NUTS.rtf	$REP/APCS/NUTS	Formatted log file (Word file)

Where:
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-29: NUTS output files

File	Repository	Comment
Output/alg_nut_int_APCS_r*i*_s*o*_*ttttt*_*VVVV*.cdb		NOT SAVED:CDB transfer file
Output/alg_nut_iso_APCS_r*i*_s*n*_*VVVV*.cdb		NOT SAVED:CDB transfer file
Output/alg_nut_scn_APCS_r*i*_s*n*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/ms_nut_APCS_r*i*_s*n*_*VVVV*.cdb		NOT SAVED:CDB transfer file
Output/nut_int_APCS_r*i*_s*o*_*tttttt*_*VVVV*.cdb		NOT SAVED:CDB transfer file
Output/nut_iso_APCS_r*i*_s*n*_*VVVV*.cdb		NOT SAVED:CDB transfer file
Output/nut_scn_APCS_r*i*_s*n*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/screen_nut_scn_APCS_r*i*_EDIT.inp	$REP/APCS/SCREEN_NUTS	Input file
Output/screen_nut_scn_APCS_r*i*_s*n*.out	$REP/APCS/SCREEN_NUTS	Output file
Output/sum_nut_APCS_r*i*_s*n*_*tuuuuu*.tbl	$REP/APCS/SUMMARIZE	Table file
Output/sum_nut_scn_APCS_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Table file

Where:

i is 1-3
n is 1-5
o is 2-5
ttttt is 0100 for S2, S4
03000, 05000, 07000, 09000 for S3, S5
uuuuu is 0100 for s1
00100, 00350 for S2, S4
01000, 03000, 05000, 07000, 09000 for S3, S5
vvv is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES
VVV are the screened-in vectors listed in Table 6.

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Table 11-30: NUTS screened-in vectors

Replicate	Scenario	Vectors
1	1	1,2,3,5,6,7,8,9,10,11,12,13,14,17,19,20,22,23,24,25,26,27,28,29,30,31,33,34,35,36,38,39,41,43,44,45,46,47,48,49,50,51,52,53,54,55,58,59,60,61,62,63,64,66,67,68,69,70,71,72,74,75,76,78,79,80,82,83,84,86,88,89,90,91,92,93,94,95,96,97,98,99
1	2	1,2,3,5,6,7,8,9,10,11,12,13,14,17,19,20,22,23,24,25,26,27,28,29,30,31,33,34,35,36,38,39,41,43,44,45,46,47,48,49,50,51,52,53,54,55,58,59,60,61,62,63,64,66,67,68,69,70,71,72,74,75,76,78,79,80,82,83,84,86,88,89,90,91,92,93,94,95,96,97,98,99
1	3	1,2,5,6,7,8,9,10,11,12,13,14,17,19,20,22,23,24,25,26,27,28,29,30,34,35,36,38,39,41,43,44,45,46,47,48,49,50,51,52,53,54,55,58,59,60,61,62,63,64,66,67,69,70,71,72,74,76,78,79,80,82,83,84,86,88,89,90,92,93,94,96,98
1	4	7,9,12,17,22,27,30,36,45,50,53
1	5	7,9,12,17,22,27,36,45,50,53
2	1	1,2,3,4,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,43,44,45,46,48,49,50,51,52,53,54,55,56,59,61,62,63,65,66,67,68,70,71,72,74,75,77,79,80,81,83,84,87,88,89,90,92,94,95,96,98,99,100
2	2	1,2,3,4,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,43,44,45,46,48,49,50,51,52,53,54,55,56,59,61,62,63,65,66,67,68,70,71,72,74,75,77,79,80,81,83,84,87,88,89,90,92,94,95,96,98,99,100
2	3	1,2,3,4,6,8,9,11,12,14,16,17,18,19,20,21,22,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,43,44,45,48,49,50,51,52,53,54,55,56,59,63,65,67,68,70,71,72,74,75,77,79,80,81,83,84,87,89,90,92,94,95,96,98,99,100
2	4	4,17,21,24,28,33,34,36,40,68,98
2	5	4,17,21,24,28,34,40,68
3	1	2,3,5,6,7,10,11,13,14,15,16,17,18,20,21,22,24,25,26,27,28,29,30,32,33,34,35,37,38,39,40,41,42,43,44,45,46,47,49,50,52,53,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,77,78,79,81,83,84,85,86,88,89,90,91,93,94,95,96,97,99,100
3	2	2,3,5,6,7,10,11,13,14,15,16,17,18,20,21,22,24,25,26,27,28,29,30,32,33,34,35,37,38,39,40,41,42,43,44,45,46,47,49,50,52,53,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,77,78,79,81,83,84,85,86,88,89,90,91,93,94,95,96,97,99,100
3	3	2,3,5,7,10,11,14,15,16,17,18,21,22,24,25,26,27,28,30,32,33,34,35,37,38,39,40,41,42,43,44,45,47,49,50,52,53,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,73,74,75,77,78,79,81,83,84,85,86,88,89,90,91,93,94,95,96,97,99,100
3	4	30,37,42,47,49,66,86,91,93
3	5	30,37,42,47,49,66,86,91,93

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Table 11-31: NUTS executable files

File	Repository	Comment
Build/Solaris/algebracdb (Ver:2.36)	$CODE/ALGEBRACDB	Manipulates CAMDAT data by evaluating algebraic expressions
Build/Solaris/matset (Ver:9.24)	$CODE/MATSET	Assigns material properties to CAMDAT grid blocks
Build/Solaris/nuts (Ver:2.06)	$CODE/NUTS	Nuclide Transport system model
Build/Solaris/screen_nuts (Ver:1.01)	$CODE/SCREEN_NUTS	Executable file
Build/Solaris/summarize (Ver:3.02)	$CODE/SUMMARIZE	Writes tables of data from many CAMDAT files

Where:

$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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11.8 CUTTINGS_S

Table 11-32: CUTTINGS_S run script files

File	Repository	Comment
RunControl/CUTTINGS_S.py	$REP/APCS/CUTTINGS_S	Python run control script
RunControl/CUTTINGS_Slib.py	$REP/APCS/CUTTINGS_S	Python run control script class modules
RunControl/rc.py	$REP/APCS/CUTTINGS_S	Run control module
RunControl/Run.py	$REP/APCS/CUTTINGS_S	Main control script

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-33: CUTTINGS_S input files

File	Repository	Comment
Output/bf3_APCS_r*i*_s*n*_v*vvv*.cdb		NOT SAVED:CDB transfer file
Input/cusp_APCS.inp	$REP/APCS/CUTTINGS_S	Input file
Input/gm_cusp_APCS.inp	$REP/APCS/GENMESH	Input file
Input/ms_cusp_APCS.inp	$REP/APCS/MATSET	Input file
Output/mspall_drs_PABC09_r*i*.out	$REP/PABC09/DRSPALL	Input file

Where:

i is 1-3
n is 1-5
vvv is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-34: CUTTINGS_S CVS repositories

CVS Repositories
$CODE/CUTTINGS_S
$CODE/GENMESH
$CODE/MATSET
$CODE/POSTLHS
$REP/APCS/BRAGFLO
$REP/APCS/CUTTINGS_S
$REP/APCS/GENMESH
$REP/APCS/MATSET
$REP/PABC09/DRSPALL

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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Table 11-35: CUTTINGS_S log files

File	Repository	Comment
RunControl/CUTTINGS_S.log	$REP/APCS/CUTTINGS_S	Log file
RunControl/CUTTINGS_S.rtf	$REP/APCS/CUTTINGS_S	Formatted log file (Word file)

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-36: CUTTINGS_S output files

File	Repository	Comment
Output/cusp_APCS_master_r*i*.inp	$REP/APCS/CUTTINGS_S	
Output/cusp_APCS_r*i*.tbl	$REP/APCS/CUTTINGS_S	
Output/cusp_APCS_r*i*_s*n*_*ttttt*_L_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/cusp_APCS_r*i*_s*n*_*ttttt*_M_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/cusp_APCS_r*i*_s*n*_*ttttt*_U_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/gm_cusp_APCS.cdb		NOT SAVED:CDB transfer file
Output/lhs3_cusp_APCS_r*i*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/ms_cusp_APCS.cdb		NOT SAVED:CDB transfer file

Where:

i is 1-3
n is 1-5
ttttt is 00100, 00350, 01000, 03000, 05000, 10000 for S1
00550, 00750, 02000, 04000, 10000 for S2, S4
01200, 01400, 03000, 05000, 10000 for S3, S5
vvv is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-37: CUTTINGS_S executable files

File	Repository	Comment
Build/Solaris/cuttings_s (Ver:6.03)	$CODE/CUTTINGS_S	Computes cuttings/spall generated by drilling
Build/Solaris/genmesh (Ver:6.10)	$CODE/GENMESH	Generates the CAMDAT computational grid
Build/Solaris/matset (Ver:9.24)	$CODE/MATSET	Assigns material properties to CAMDAT grid blocks
Build/Solaris/postlhs (Ver:4.11)	$CODE/POSTLHS	Assigns sampled parameters to the grid blocks and elements

Where:

$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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11.9 BRAGFLO_DBR

Table 11-38: BRAGFLO_DBR run script files

File	Repository	Comment
RunControl/BRAGFLO_DBR.py	$REP/APCS/BRAGFLO_DBR	Python run control script
RunControl/BRAGFLO_DBRlib.py	$REP/APCS/BRAGFLO_DBR	Python run control script class modules
RunControl/rc.py	$REP/APCS/BRAGFLO_DBR	Run control module
RunControl/Run.py	$REP/APCS/BRAGFLO_DBR	Main control script

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-39: BRAGFLO_DBR input files

File	Repository	Comment
Input/alg1_dbr_APCS.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg2_dbr_APCS_s*o*.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg3_dbr_APCS_L.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg3_dbr_APCS_M.inp	$REP/APCS/ALGEBRACDB	Input file
Input/alg3_dbr_APCS_U.inp	$REP/APCS/ALGEBRACDB	Input file
Input/bf1_dbr_APCS_L.inp	$REP/APCS/PREBRAG	Input file
Input/bf1_dbr_APCS_M.inp	$REP/APCS/PREBRAG	Input file
Input/bf1_dbr_APCS_s*n*_100_L.inp	$REP/APCS/PREBRAG	Input file
Input/bf1_dbr_APCS_s*n*_100_M.inp	$REP/APCS/PREBRAG	Input file
Input/bf1_dbr_APCS_s*n*_100_U.inp	$REP/APCS/PREBRAG	Input file
Input/bf1_dbr_APCS_U.inp	$REP/APCS/PREBRAG	Input file
Output/bf3_APCS_r*i*_s*o*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/cusp_APCS_r*i*_s*o*_*tttttt*_L_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/cusp_APCS_r*i*_s*o*_*tttttt*_M_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/cusp_APCS_r*i*_s*o*_*tttttt*_U_*vvvv*.cdb		NOT SAVED:CDB transfer file
Input/gm_dbr_APCS.inp	$REP/APCS/GENMESH	Input file
Input/ic_dbr_APCS_s*o*.inp	$REP/APCS/ICSET	Input file
Input/ms_dbr_APCS.inp	$REP/APCS/MATSET	Input file
Input/rel1_dbr_APCS.inp	$REP/APCS/RELATE	Input file
Input/rel2_dbr_APCS_s*o*.inp	$REP/APCS/RELATE	Input file
Input/sum_dbr.inp	$REP/APCS/SUMMARIZE	Input file

Where:

i is 1-3
n is 1
o is 1-5
ttttt is 00100, 00350, 01000, 03000, 05000, 10000 for S1
00550, 00750, 02000, 04000, 10000 for S2, S4
01200, 01400, 03000, 05000, 10000 for S3, S5
vvv is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-40: BRAGFLO_DBR CVS repositories

CVS Repositories
$CODE/ALGEBRACDB
$CODE/BRAGFLO
$CODE/GENMESH
$CODE/ICSET
$CODE/MATSET
$CODE/POSTBRAG
$CODE/POSTLHS
$CODE/PREBRAG
$CODE/RELATE
$CODE/SUMMARIZE
$REP/APCS/ALGEBRACDB
$REP/APCS/BRAGFLO
$REP/APCS/BRAGFLO_DBR
$REP/APCS/CUTTINGS_S
$REP/APCS/GENMESH
$REP/APCS/ICSET
$REP/APCS/MATSET
$REP/APCS/PREBRAG
$REP/APCS/RELATE
$REP/APCS/SUMMARIZE

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

Table 11-41: BRAGFLO_DBR log files

File	Repository	Comment
RunControl/BRAGFLO_DBR.log	$REP/APCS/BRAGFLO_DBR	Log file
RunControl/BRAGFLO_DBR.rtf	$REP/APCS/BRAGFLO_DBR	Formatted log file (Word file)

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-42: BRAGFLO_DBR output files

File	Repository	Comment
Output/alg1_dbr_APCS_r*i*_s*n*_*ttttt*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/alg2_dbr_APCS_r*i*_s*n*_*ttttt*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/alg3_dbr_APCS_r*i*_s*n*_*ttttt*_L_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/alg3_dbr_APCS_r*i*_s*n*_*ttttt*_M_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/alg3_dbr_APCS_r*i*_s*n*_*ttttt*_U_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/bf2_dbr_APCS_r*i*_s*n*_*ttttt*_L_*vvvv*.inp	$REP/APCS/BRAGFLO_DBR	
Output/bf2_dbr_APCS_r*i*_s*n*_*ttttt*_M_*vvvv*.inp	$REP/APCS/BRAGFLO_DBR	
Output/bf2_dbr_APCS_r*i*_s*n*_*ttttt*_U_*vvvv*.inp	$REP/APCS/BRAGFLO_DBR	
Output/bf3_dbr_APCS_r*i*_s*n*_*ttttt*_L_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/bf3_dbr_APCS_r*i*_s*n*_*ttttt*_M_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/bf3_dbr_APCS_r*i*_s*n*_*ttttt*_U_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/gm_dbr_APCS.cdb		NOT SAVED:CDB transfer file
Output/ic_dbr_APCS_r*i*_s*n*_*ttttt*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/ms_dbr_APCS.cdb		NOT SAVED:CDB transfer file
Output/rel1_dbr_APCS_r*i*_s*n*_*ttttt*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/rel2_dbr_APCS_r*i*_s*n*_*ttttt*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/sum_dbr_APCS_r*i*_s*n*_*ttttt*_L.tbl	$REP/APCS/SUMMARIZE	
Output/sum_dbr_APCS_r*i*_s*n*_*ttttt*_M.tbl	$REP/APCS/SUMMARIZE	
Output/sum_dbr_APCS_r*i*_s*n*_*ttttt*_U.tbl	$REP/APCS/SUMMARIZE	

Where:

i is 1-3
n is 1-5
ttttt is 00100, 00350, 01000, 03000, 05000, 10000 for S1
00550, 00750, 02000, 04000, 10000 for S2, S4
01200, 01400, 03000, 05000, 10000 for S3, S5
vvv is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-43: BRAGFLO_DBR executable files

File	Repository	Comment
Build/Solaris/algebracdb (Ver:2.36)	$CODE/ALGEBRACDB	Manipulates CAMDAT data by evaluating algebraic expressions
Build/Solaris/bragflo (Ver:6.03)	$CODE/BRAGFLO	Computes brine and gas flow in the repository
Build/Solaris/genmesh (Ver:6.10)	$CODE/GENMESH	Generates the CAMDAT computational grid
Build/Solaris/icset (Ver:2.23)	$CODE/ICSET	Assigns initial conditions to the CAMDAT grid elements
Build/Solaris/matset (Ver:9.24)	$CODE/MATSET	Assigns material properties to CAMDAT grid blocks
Build/Solaris/postbrag (Ver:4.02)	$CODE/POSTBRAG	Post-processes data for BRAGFLO
Build/Solaris/postlhs (Ver:4.11)	$CODE/POSTLHS	Assigns sampled parameters to the grid blocks and elements
Build/Solaris/prebrag (Ver:8.03)	$CODE/PREBRAG	Pre-processes data for BRAGFLO
Build/Solaris/relate (Ver:1.45)	$CODE/RELATE	Transfers CAMDAT data to another CAMDAT file
Build/Solaris/summarize (Ver:3.02)	$CODE/SUMMARIZE	Writes tables of data from many CAMDAT files

Where:

$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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11.10 CCDFGF

Table 11-44: CCDFGF run script files

File	Repository	Comment
RunControl/CCDFGF.py	$REP/APCS/CCDFGF	Python run control script
RunControl/CCDFGFlib.py	$REP/APCS/CCDFGF	Python run control script class modules
RunControl/rc.py	$REP/APCS/CCDFGF	Run control module
RunControl/Run.py	$REP/APCS/CCDFGF	Main control script

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-45: CCDFGF input files

File	Repository	Comment
Input/ccgf_APCS_control_r*i*.inp	$REP/APCS/CCDFGF	Input file
Output/cusp_APCS_r*i*.tbl	$REP/APCS/CUTTINGS_S	Release table file
Output/epu_APCS_ch.dat	$REP/APCS/EPAUNI	Release table file
Output/epu_APCS_rh.dat	$REP/APCS/EPAUNI	Release table file
Input/gm_ccgf_APCS.inp	$REP/APCS/GENMESH	Input file
Input/intrusiontimes.in	$REP/APCS/PRECCDFGF	Input file
Input/ms_ccgf_APCS.inp	$REP/APCS/MATSET	Input file
Output/sum_dbr_APCS_r*i*_s*o*_t*vvvvv*_L.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_dbr_APCS_r*i*_s*o*_t*vvvvv*_M.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_dbr_APCS_r*i*_s*o*_t*vvvvv*_U.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_nut_APCS_r*i*_s*o*_t*uuuuu*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_con_APCS_b1_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_con_APCS_b2_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_con_APCS_b3_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_con_APCS_b4_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_con_APCS_b5_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_int_APCS_b1_r*i*_s*p*_t*ttttt*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_st_APCS_b1_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_st_APCS_b2_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_st_APCS_b3_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_st_APCS_b4_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_panel_st_APCS_b5_r*i*_s*n*.tbl	$REP/APCS/SUMMARIZE	Release table file
Output/sum_st2d_PABC09_r*i*_mf.tbl	$REP/PABC09/SUMMARIZE	Release table file
Output/sum_st2d_PABC09_r*i*_mp.tbl	$REP/PABC09/SUMMARIZE	Release table file

Where:

i is 1-3
n is 1-2
o is 1-5
p is 6
ttttt is 00100, 00350, 01000, 02000, 04000, 06000, 09000
uuuuu is 0100 for s1
00100, 00350 for S2, S4
01000, 03000, 05000, 07000, 09000 for S3, S5
vvvvv is 00100, 00350, 01000, 03000, 05000, 10000 for S1
00550, 00750, 02000, 04000, 10000 for S2, S4
01200, 01400, 03000, 05000, 10000 for S3, S5
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-46: CCDFGF CVS repositories

CVS Repositories
$CODE/CCDFGF
$CODE/CCDFVECTORSTATS
$CODE/GENMESH
$CODE/MATSET
$CODE/POSTLHS
$CODE/PRECCDFGF
$REP/APCS/CCDFGF
$REP/APCS/CUTTINGS_S
$REP/APCS/EPAUNI
$REP/APCS/GENMESH
$REP/APCS/MATSET
$REP/APCS/PRECCDFGF
$REP/APCS/SUMMARIZE
$REP/PABC09/SUMMARIZE

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES
$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

Table 11-47: CCDFGF log files

File	Repository	Comment
RunControl/CCDFGF.log	$REP/APCS/CCDFGF	Log file
RunControl/CCDFGF.rtf	$REP/APCS/CCDFGF	Formatted log file (Word file)

Where:

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

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Table 11-48: CCDFGF output files

File	Repository	Comment
Output/ccgf_APCS_reltab_r*i*.dat	$REP/APCS/PRECCDFGF	CCDFGF Results
Output/ccgf_APCS_r*i*.out	$REP/APCS/CCDFGF	CCDFGF Results
Output/gm_ccgf_APCS.cdb		NOT SAVED:CDB transfer file
Output/lhs3_ccgf_APCS_r*i*_*vvvv*.cdb		NOT SAVED:CDB transfer file
Output/ms_ccgf_APCS.cdb		NOT SAVED:CDB transfer file

Where:

i is 1-3
vvv is 001-100
$REP = /nfs/data/CVSLIB/WIPP_ANALYSES

Table 11-49: CCDFGF executable files

File	Repository	Comment
Build/Solaris/ccdfgf (Ver:7.03)	$CODE/CCDFGF	Constructs complimentary cumulative distribution functions for radionuclide releases
Build/Solaris/ccdfvectorstats	$CODE/CCDFVECTORSTATS	Executable file
Build/Solaris/genmesh (Ver:6.10)	$CODE/GENMESH	Generates the CAMDAT computational grid
Build/Solaris/matset (Ver:9.24)	$CODE/MATSET	Assigns material properties to CAMDAT grid blocks
Build/Solaris/postlhs (Ver:4.11)	$CODE/POSTLHS	Assigns sampled parameters to the grid blocks and elements
Build/Solaris/preccdfgf (Ver:2.01)	$CODE/PRECCDFGF	Pre-processes data for CCDFGF

Where:

$CODE = /nfs/data/CVSLIB/WIPP_CODES/PA_CODES

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11.11 STEPWISE

Input files for the STEPWISE code were generated using the *PA_AnalysisRemote.accdb* Microsoft Access database that has links to the official PA results (PA_Results) and parameter (ParamDB) databases located on the TGW machine. A copy of the *PA_AnalysisRemote.accdb* database is included in a directory with the final output tables. Input files were generated using this database on a machine using Microsoft Windows 10 by selecting the menu button in the MainForm form entitled "Create Stepwise Input Files (3)," selecting the APCS analysis, and then selecting the "Create Stepwise Files" button. Input files and run scripts were generated and the user then chose a destination folder for the input files.

Input files and run scripts were then transferred to the Solaris cluster. The input files and run scripts as-created on a Windows machine are not readable by the STEPWISE code on Solaris. After transfer to the Solaris cluster, a utility program dos2unix was used to remove end-of-line characters from each input file. Table 11-50 lists the input and run script filenames.

Table 11-50 – STEPWISE input file and run script files.

File	Repository	Comment
RunSTEPWISE.sh	$REP	Run script
STP_APCS_LHS_R1	$REP/Input	Rep. 1 input file
STP_APCS_LHS_R2	$REP/Input	Rep. 2 input file
STP_APCS_LHS_R3	$REP/Input	Rep. 3 input file
STP_APCS_MEANS_R1	$REP/Input	Rep. 1 input file
STP_APCS_MEANS_R2	$REP/Input	Rep. 2 input file
STP_APCS_MEANS_R3	$REP/Input	Rep. 3 input file
STP_APCS_Rank_ALL_R1.inp	$REP/Input	Rep. 1 input file
STP_APCS_Rank_ALL_R1.sh	$REP/Input	Rep. 1 run script
STP_APCS_Rank_ALL_R2.inp	$REP/Input	Rep. 2 input file
STP_APCS_Rank_ALL_R2.sh	$REP/Input	Rep. 2 run script
STP_APCS_Rank_ALL_R3.inp	$REP/Input	Rep. 3 input file
STP_APCS_Rank_ALL_R3.sh	$REP/Input	Rep. 3 run script

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES/APCS/STEPWISE

The STEPWISE version 2.22 executable was extracted from a CVS repository (/nfs/data/CVSLIB/WIPP_CODES/PA_CODES/STEPWISE) and run on the Solaris using the three run scripts (one script for each replicate). Table 11-51 lists the output files generated from the runs of the STEPWISE code.

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Table 11-51 – STEPWISE output files

File	Repository	Comment
STP_APCS_Rank_ALL_R1.sigma	$REP/Output	Rep. 1 output file
STP_APCS_Rank_ALL_R1.txt	$REP/Output	Rep. 1 output file
STP_APCS_Rank_ALL_R2.sigma	$REP/Output	Rep. 2 output file
STP_APCS_Rank_ALL_R2.txt	$REP/Output	Rep. 2 output file
STP_APCS_Rank_ALL_R3.sigma	$REP/Output	Rep. 3 output file
STP_APCS_Rank_ALL_R3.txt	$REP/Output	Rep. 3 output file

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES/APCS/STEPWISE

A utility program unix2dos was used to put in end-of-line characters into each output file in order to make them compatible with the Windows environment. Output files were then transferred to a machine running Windows 10. The PA_AnalysisRemote.accdb database was then used to analyze the results of the STEPWISE runs by selecting the menu button in the *MainForm* form entitled "Extract Results from STEPWISE files," selecting the "Open Files" button, then selecting the output files by name. For each output file selected (one per replicate), the Access database produced a Microsoft Word document containing output tables (Table 11-52). The output tables are included in the STEPWISE Results section below. Input files, run scripts, and output files were stored in a CVS repository.

Table 11-52 – Table files generated by PA_AnalysisRemote.accbd database

File	Repository	Comment
STP_APCS_Rank_ALL_R1.rtf	$REP/Output_db	Rep. 1 output table file
STP_APCS_Rank_ALL_R2.rtf	$REP/Output_db	Rep. 2 output table file
STP_APCS_Rank_ALL_R3.rtf	$REP/Output_db	Rep. 3 output table file

$REP = /nfs/data/CVSLIB/WIPP_ANALYSES/APCS/STEPWISE

11.12 Reference

Kirchner, T., A. Gilkey, and J. Long. 2015. Addendum to the Summary Report on the Migration of the WIPP PA Codes. Sandia National Laboratories, Carlsbad, NM. ERMS 564675.

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12 Appendix A: Justification for Modeling Waste in Panel 9

With the abandonment of the south end of the repository, a new panel to replace Panel 9 would presumably be located to the north of Panel 8. The removal of waste from Panel 9 and relocation of waste to a new panel above Panel 8 in the repository would be expected to increase overall total repository DBR releases by an amount equal to DBR releases from similar panels in the north rest-of-repository simply due to an increase in probability of intersecting the new panel. That is, there would be 11 panels, 10 of which have solid waste, but all 11 of which have contaminated brine that could potentially be released during a DBR event.[14] Thus, with respect to only the repository footprint, it is a non-conservatism to not explicitly model a new replacement for Panel 9 in the north. From a detailed evaluation of panel-based DBR results for CRA14_SEN4, it is observed that the total cumulative DBR release (EPA Units) associated with Panel 8 for E1 and E2 intrusions in same, adjacent, and non-adjacent panels over all replicates is 1644 (Table 12-1).[15] In comparison with the total cumulative DBR release over all replicates from all panels of 15497, Panel 8 represents approximately 11% of the total DBR releases for CRA14_SEN4.

It has been asserted for the APCS analysis that it is appropriate to model waste within Panel 9 in lieu of adding a new panel in the north by maintaining a consistent BRAGFLO and BRAGFLO_DBR grid representation of waste in three areas: waste panel, south rest-of-repository, and north rest-of-repository. This approach is conservative due to the removal of panel closures between Panels 3, 4, 5, 6, and 9, which effectively equilibrates the brine pressures and saturations in these panels such that adjacent panel releases are effectively equivalent to same releases and non-adjacent releases are effectively equivalent to adjacent releases. This is appropriate and required when modeling DBR releases from panels in the south due to the lack of separating panel closures, but represents a major conservatism when modeling DBR releases from panels in the north that have panel closures. For example, for a CCDFGF future that encounters an initial brine intrusion into Panel 10, a subsequent intrusion in Panels 1, 2, 7, 8, and/or 9 are all treated as an adjacent release scenarios due to the definition of Panel 10 neighbors. 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 do not allow brine pressures and saturations in the initially intruded panel to readily equilibrate with that of the subsequently intruded panel. As such under APCS, all adjacent intrusions in the north are mapped to middle (adjacent) intrusion results from BRAGFLO_DBR which are effectively equivalent to lower (same) intrusions (due to equilibration across the abandoned southernmost panel closure area).

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[14] This is based on the conservative assumption that Panel 9 remains "open" throughout the 10,000-year calculation period. If it were to close tightly, creating a barrier to communication among its panel neighbors, releases would presumably be less.

[15] Information in the Tables in this Appendix were derived from postprocessing of the CCDFGF debug output files. Details can be found in Appendix D.

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The conservatism associated with representing adjacent intrusions in the north more than compensates for the non-conservatism associated with not addressing the probability of DBR release from a new Panel 9 replacement in the north rest-of-repository. As previously discussed, the non-conservatism associated with not representing a replacement for Panel 9 explicitly is on the order of 11% due to the increased probability of borehole intersections with the new panel and its neighbors. An evaluation of the total cumulative DBR release (EPA units) associated with Panel 8 for E1 and E2 intrusions in same, adjacent, and non-adjacent panels over all replicates of APCS is 2989, where approximately 43% of the release is attributed to adjacent panel intrusions (Table 12-2). Note that under CRA14_SEN4, only 2% of Panel 8 DBR releases are attributed to adjacent and non-adjacent intrusions because panel closures attenuate the impact of adjacent panels on brine saturations and pressures. Conversely, the 43% of Panel 8 total cumulative DBR releases attributed to adjacent and non-adjacent intrusions are due to the conservative treatment of adjacent and non-adjacent intrusions in the north described above. The total cumulative DBR release from Panel 8 under APCS (2989) is approximately 1.8 times the release calculated for CRA14_SEN4 (1644), and this correlation follows for Panels 1, 2, and 7. As such, the adjacent and non-adjacent representation for intrusions in Panels 1, 2, 7, and 8 under APCS result in an over-estimation of releases from these panels equal to 5106 - 145 = 4961 EPA Units. This more than accounts for any non-conservatism (by a factor of 4961 / 1644 = 3X) associated with not explicitly modeling a new replacement for Panel 9 in the north.

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Table 12-1: Cumulative DBR Releases (EPA Units) for E1 and E2 Intrusions for CRA14_SEN4 over all Replicates

	E1				E2				E1 + E2
	Same	Adj	Non-adj	Total	Same	Adj	Non-adj	Total	Total
Panel	(EPA Units)								
1	1436	12	3	1451	206	15	2	224	1676
2	1500	19	2	1521	183	23	2	208	1729
3	1487	18	2	1507	159	22	2	184	1691
4	1505	12	3	1519	143	13	3	159	1678
5	1507	11	3	1521	133	12	2	148	1669
6	1475	17	2	1495	126	18	2	146	1641
7	1513	16	2	1531	106	18	2	125	1657
8	1515	11	3	1529	101	12	2	115	1644
9	855	22	1	878	64	22	1	87	966
10	1024	24	1	1050	72	26	1	98	1148
Total	13817	164	22	14003	1292	182	19	1493	15497

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Table 12-2: Cumulative DBR Releases (EPA Units) for E1 and E2 Intrusions for APCS over all Replicates

	E1				E2				E1 + E2
	Same	Adj	Non-adj	Total	Same	Adj	Non-adj	Total	Total
Panel	(EPA Units)								
1	1697	1277	4	2978	124	1	1	125	3103
2	1742	1260	4	3006	109	1	1	110	3116
3	1692	6267	2	7961	93	4	0	97	8058
4	1714	6273	2	7989	83	4	0	87	8076
5	1694	6231	2	7927	75	3	0	78	8005
6	1640	6271	2	7913	68	3	0	72	7985
7	1669	1266	4	2938	60	1	1	61	3000
8	1648	1281	4	2933	55	1	1	56	2989
9	929	5065	1	5996	34	3	0	38	6033
10	1102	8840	0	9942	31	4	0	35	9977
Tot	15526	44030	27	59583	732	24	4	759.9	60343

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13 Appendix B: Qualification of CCDFVECTORSTATS

CCDFVECTORSTATS is a program designed to compute across vector and across-replicate statistics for the CCDFGF releases. A previous qualification of the code was made by Kirchner et al. (2015). This appendix describes current testing of CCDFVECTORSTATS on the Solaris running SunOS 5.11. The source code and executable are stored in modules Build/Solaris and Source, respectively of the CVS repository The source code and executable are stored in modules Build/Solaris and Source, respectively of the CVS repository $CVSLIB/WIPP_CODES/PA_CODES/CCDFVECTORSTATS.

13.1 Testing

The performance of CCDFVECTORSTATS was tested by comparing the statistics from CCDFVECTORSTATS to statistics using built-in functions in Access. Data for this test is the CCDFGF output for the APCS analysis. The across-replicate mean for total releases across the three replicates of the APCS CCDFGF output was determined to be a sufficient point of comparison for the two cases because it is a composite test of the binning and interpolation functions, as well as computational functions necessary for computing across vectors and across replicates.

To produce the baseline Access results, the APCS CCDFGF output (*.out) files for the three replicates were loaded into the Access database CCDFGF_Analysis.mdb, which stored the data in CCDFGF_Data.mdb. The built-in Access functions were used to calculate the across-replicate mean for total releases (Table 13-1).

Equivalent statistics were calculated using CCDFVECTORSTATS. For the comparison test of CCDFVECTORSTATS, the code was run (as described in Section 11.10 above), which inserted the release statistics into the PA_Results database. That database was then queried for total mean results at the P=0.1 and 0.001 levels using the PA_AnalysisRemote.accdb database—results are presented in Table 13-1. Differences were determined to be acceptable. Access databases are stored in $CVSLIB/WIPP_ANALYSES/APCS/CCDFGF/Auxiliary/CCDFVECTORSTATS.

Table 13-1 Mean Total Releases Calculated using Built-in Access Functions and CCDFVECTORSTATS

Probability	Access Baseline	CCDFVECTORSTATS	Percent Difference
0.1	0.072687	0.072687	0
0.001	1.3624	1.3618	-0.04

13.2 Reference

Kirchner, T., A. Gilkey, and J. Long. 2015. Addendum to the Summary Report on the Migration of the WIPP PA Codes. Sandia National Laboratories, Carlsbad, NM. ERMS 564675.

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14 Appendix C: Qualification of SCREEN_NUTS

Utility SCREEN_NUTS is qualified under NP 9-1 (Safley, 2012). It was originally qualified on VMS as SCREEN (or SCREEN.FOR) Version 1.00, then later qualified under a "one-time test" as SCREEN_NUTS Version 1.01 (Kirchner et al. 2014).

This appendix describes current testing of SCREEN_NUTS Version 1.01 on the Solaris running SunOS 5.11.

14.1 Build Information

Build information can be found in Kirchner et al. (2014).

14.2 Code Execution and Files

14.2.1 Input Files

A SUMMARIZE input file is required for each scenario. The first three lines are header lines and are ignored. Data lines follow for each vector. Each line has the following columns: 1) vector number, 2) time, 3) SMB38N1C, 4) SMB38S1C, 5) SMBABN1C, 6) SMBABS1C, 7) SMB39N1C, 8) SMB39S1C, 9) BHUP1C, and 10) SHUP1C. These columns represent the values of global variables on the final time step of the output CAMDAT file from the NUTS code. Note that there must be a blank line (or *break line) between the lines for each vector, and only one time step is allowed. SCREEN_NUTS reads all vectors in a file.

14.2.2 Output Files

SCREEN_NUTS generates an output file for each scenario. Each file has a header. (Note that the analysis and replicate no longer appear in the header.) The screened-in vectors for the scenario are listed one per line between lines "NONUNION_BEGIN" and "NONUNION_END". Each line also lists the type of tolerance exceeded (markerbed, or borehole or both) and the value that exceeded the tolerance. The output file for Scenario 1 also lists the union of all screened-in vectors for all scenarios. These vectors are listed one per line, in numerical order with no repetitions, between lines "UNION_BEGIN" and "UNION_END".

14.3 Regression Test

SCREEN Version 1.00 was validated on a Compaq ES47 running OpenVMS 8.2 for the CRA-2009 PA (Ismail and Garner, 2008). Regression testing against the VMS results was conducted to demonstrate the validity of SCREEN_NUTS Version 1.01 on a Solaris Blade with SunOS 5.11.

SCREEN_NUTS Version 1.01 was tested in the following environment:

Platform:	Dell PowerEdge R820 / SunOS 5.11 11.x i86pc i386 i86pc
Host:	santana.sandia.gov
Test Date:	August 22, 2017

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All files related to validation testing are stored in the SCREEN_NUTS CVS Repository under the APCS analysis.

CVS Repository:	$CVSLIB/WIPP_ANALYSES/APCS/SCREEN_NUTS/Auxiliary/Files
Log file:	run.log
Input files:	/Test/Input/
Output files:	/Output/
V1.00 Output:	/Test/Output/VMS_100

The SCREEN_NUTS test suite consists of a single test case, with two scenarios. Each test is briefly described below. Each test sub-section contains the command line used to run SCREEN_NUTS for the test. The command line indicates the test input files and test output files. The output file for each scenario is then differenced with the output file from the SCREEN_NUTS 1.00 VMS test using the UNIX diff command. Floating point values must match to six digits. The output is written in free-format, so differences in the numerical formats are expected.

14.4 Test Case #1

Test Case #1 inputs SUMMARIZE files for two scenarios (screen_test1_s^.tbl), each with data for 12 vectors. Two output files (screen_101_test1_s^.out) are generated and compared with the output from SCREEN 1.00.

Below is the run script that checks out the screen_nuts executable, VMS output, and SCREEN_NUTS input, as well as runs the tests and creates .dif files that document the differences between the SCREEN 1.00 results and SCREEN_NUTS 1.01 results.

Figure 14-1 Run script for SCREEN_NUTS test

```
#!/bin/sh

#Simple test script for one-time testing of SCREEN_NUTS code
#Created by Todd R. Zeitler; 8/2017

#Get executable
cvs -d $CVSLIB/WIPP_CODES/PA_CODES/SCREEN_NUTS co Build/Solaris/screen_nuts

#Get input files from qualified version
cvs -d $CVSLIB/WIPP_CODES/PA_CODES/SCREEN_NUTS co Test/Input

#Get output files from qualified version for later comparison
cvs -d $CVSLIB/WIPP_CODES/PA_CODES/SCREEN_NUTS co
Test/Output/VMS_100/screen_test1_s1.out
cvs -d $CVSLIB/WIPP_CODES/PA_CODES/SCREEN_NUTS co
Test/Output/VMS_100/screen_test1_s2.out
```


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```
#Setup output directory for current test cases
mkdir Output

#Run Test 1 (scenarios 1 and 2)
./Build/Solaris/screen_nuts -sum ./Test/Input/screen_test1_s^.tbl -output
./Output/screen_101_test1_s^.out -tol 1d-10 -scen 2

#Diff results for Test 1
diff -w ./Output/screen_101_test1_s1.out ./Test/Output/VMS_100/screen_test1_s1.out | tee
./Output/screen_101_test1_s1.dif
diff -w ./Output/screen_101_test1_s2.out ./Test/Output/VMS_100/screen_test1_s2.out | tee
./Output/screen_101_test1_s2.dif

echo "script completed"
```

Below is the portion of the log file run.log listing the diff of the output files for each scenario. Each output file diff shows that the analysis and replicate lines are missing from the output file headers, the input file name is in lower case with a directory, and the tolerance is in a different format. These changes are acceptable. The output files show no significant differences.

Figure 14-2 Portion of log file run.log

```
 Tolerance:  1.0E-10
 Scenarios:  2

 Scenario  2 : ./Test/Input/screen_test1_s2.tbl
              ./Output/screen_101_test1_s2.out
 Scenario  1 : ./Test/Input/screen_test1_s1.tbl
              ./Output/screen_101_test1_s1.out
STOP: SCREEN Normal Completion
1c1,3
<  data source: ./Test/Input/screen_test1_s1.tbl
---
>  analysis: CRA1BC
>  replicate:           1
>  data source: SCREEN_TEST1_S1.TBL
3c5
<  nuts tolerance:  1.0E-10
---
>  nuts tolerance:   1.000000000000000E-010
1c1,3
<  data source: ./Test/Input/screen_test1_s2.tbl
---
>  analysis: CRA1BC
>  replicate:           1
```


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> data source: SCREEN_TEST1_S2.TBL
3c5
< nuts tolerance: 1.0E-10

> nuts tolerance: 1.000000000000000E-010
script completed

14.5 References

Kirchner, T, A. Gilkey and J. Long. 2014. Summary Report on the Migration of the WIPP PA Codes from VMS to Solaris, AP-162, Rev. 1. Sandia National Laboratories. Carlsbad, NM. ERMS 561757.

Safley, L. E. 2012. NP 9-1 Analyses. Rev. 9. Sandia National Laboratories. Carlsbad, NM. ERMS 558879.

Ismail, A. E., and J. W. Garner. 2008. Analysis Package for Salado Transport Calculations: Compliance Recertification Application 2009. Sandia National Laboratories. Carlsbad, NM. ERMS 548845.

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15 Appendix D: Postprocessing of CCDFGF Output

Postprocessing of CCDFGF debug (.dbg) files was done for CRA14_SEN4 and APCS. A Python script *ccdfgetdbrs.py* was created to parse the CCDFGF output and counts instances of E1 and E2 intrusions. It also sums cumulative DBR releases over all futures for "Same," "Adjacent," and "Non-adjacent" DBR intrusion cases on a replicate basis. The Excel file summary_ccdfgf.xlsx summarizes the results across replicates. The Python script and input and output files are located in: /nfs/data/CVSLIB/WIPP_ANALYSES/APCS/CCDFGF/Auxiliary/.

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