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SANDIA NATIONAL LABORATORIES
WASTE ISOLATION PILOT PLANT

AP-214
Revision 0

Analysis Plan for the 2026 WIPP Compliance Recertification Application Performance Assessment

Task 4.4.1.2.1

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1 Introduction and Objectives

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. WIPP PA models are used to support the periodic recertification of WIPP.

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 (FEPs) 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.

This analysis plan describes the models and parameters to be used in the PA for the 2026 Compliance Recertification Application (CRA-2026). Changes in the repository design, inventory, models, and parameters are described relative to the Replacement Panels Planned Change Request (RPPCR) PA (Hansen et al., 2023; Brunell et al., 2024) and the CRA-2019 (DOE, 2019).

1.1 Changes to the Repository Design

WIPP was originally certified as a repository containing 10 panels, which were excavated for the placement and long-term storage of waste. The 10-panel original state of the repository was used as the basis for the CRA-2019 PA. For operational reasons, the entirety of the 10-panel volume is not available for waste disposal. The DOE submitted the RPPCR in March 2024 seeking EPA approval for waste emplacement in two new waste panels, termed replacement panels, that would lie to the west of the existing operations area. It is anticipated that the RPPCR will be approved by the EPA prior to the submittal of CRA-2026, making the 12-panel repository design the basis for recertification in the CRA-2026 PA.

The addition of two replacement panels is not expected to provide sufficient space for the disposal of the allowable waste volume for WIPP designated in the LWA; the 12-panel representation is therefore considered an interim state of the repository. DOE may seek approval for waste disposal in up to seven more panels, deemed additional panels, to accommodate the entirety of the allowable volume of waste. This 19-panel representation is considered the final state of the repository.

Thus, the CRA-2026 PA will consider two repository designs:

- An interim state repository comprising ten original and two replacement panels containing a portion of the allowable inventory volume. This interim state configuration represents the anticipated certified repository design at the time of submittal of CRA-2026.

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- A final state repository comprising ten original, two replacement, and seven additional panels. The 19-panel final state repository provides sufficient volume for disposal of the full allowable waste volume.

Figure 1 illustrates the anticipated final state repository design with ten original panels, two replacement panels, and seven additional panels.

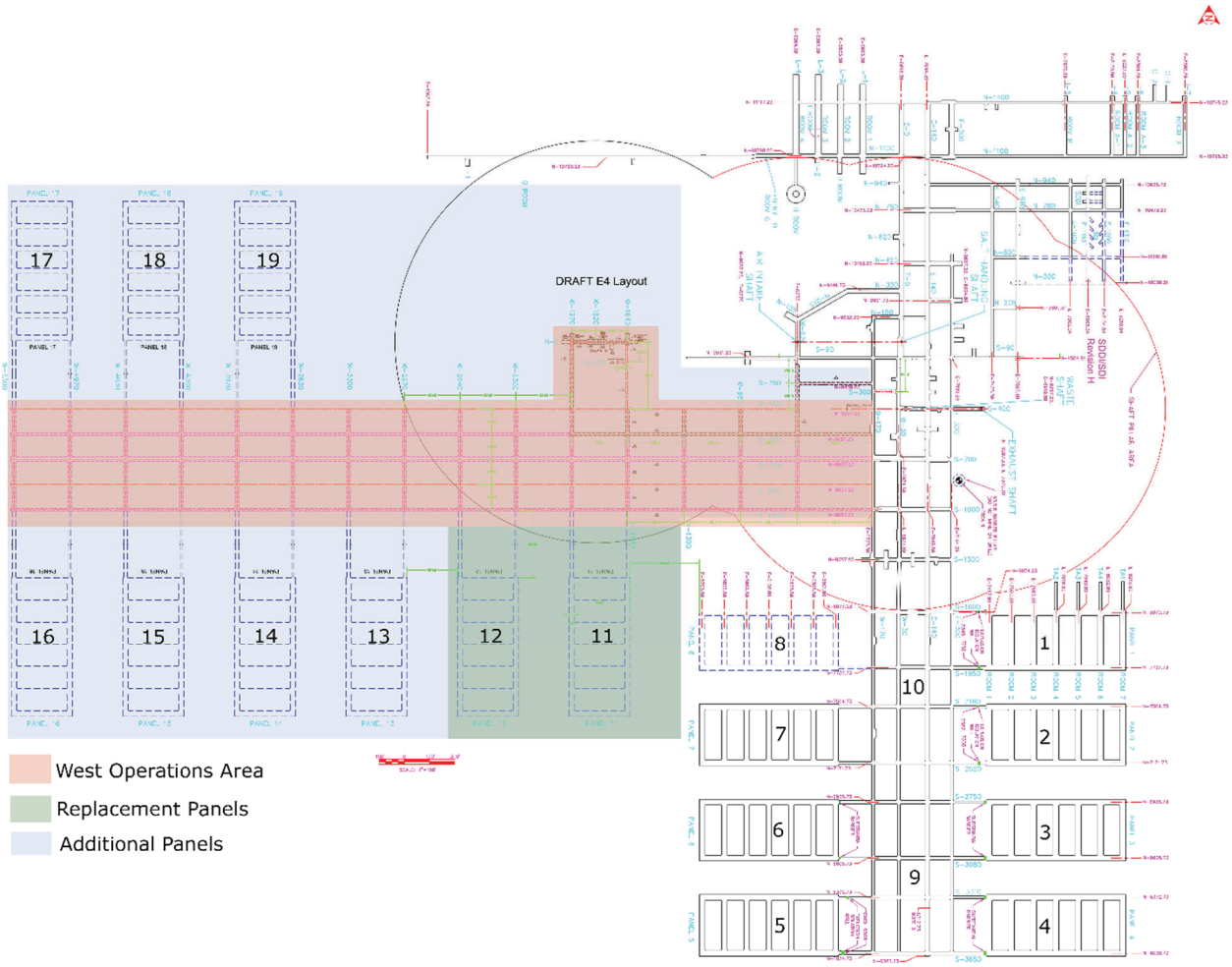


Figure derived from Sjomeling, (2019).

Figure 1. Current Repository Footprint, Replacement Panels, and Additional Waste Panels

1.2 Analysis Baseline and Summary of Changes

The analysis described in this plan is based on the models and parameters used for the RPPCR PA[1]. Differences between the CRA-2026 and the RPPCR are summarized below. Differences between the RPPCR and the CRA-2019 are also summarized to provide a full list of changes relative to the CRA-2019.

[1] While the PCR requested approval for use of two replacement panels for the interim state repository, the RPPCR PA was executed using a 19-panel final state repository design. A 12-panel interim state sensitivity study (Zeitler et al. 2025) was executed at the request of EPA as part of their review of the PCR.

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1.2.1 Summary of differences between the CRA-2026 PA and the RPPCR PA

The CRA-2026 PA differs from the RPPCR PA as follows:

- The inventory for the final state repository will be based on the Full Repository Performance Assessment Inventory Report – 2024 (PAIR) (Van Soest, 2025). An inventory for the interim state repository will be developed based on the 2024 ATWIR.
- The Salado flow and transport computational grid for the final state repository is adjusted primarily for consistency with repository design information. A Salado flow and transport computational grid for the interim state repository will be developed which represents a total of 12 waste panels, rather than 19 waste panels as in the RPPCR.
- Repository parameters ABERM, VREPOS, AREA_CH, and FVW are updated to be consistent with the interim and final state repositories.
- For anhydrite marker beds, the van Genuchten-Parker capillary pressure function (selected when parameter RELP_MOD=6) is modified to include a lower bound on capillary pressure (Day, 2025).
- The parameter DBRMINBV for the minimum brine volume for a DBR release is updated for each repository state, since this parameter depends on repository excavated volume.
- Baseline solubilities for +III, +IV and +V actinides are updated in conjunction with the inventory for each repository state.
- Baseline solubility for +VI actinides is updated based on analysis by Los Alamos National Laboratory (LANL).
- Uncertainties for baseline solubilities are updated to account for new information since the RPPCR.
- Colloid concentration parameters are updated based on new analyses since the RPPCR.
- The location of the Culebra Release Point 2 (CRP 2) that represents Panels 11, 12 and 13 in the RPPCR is adjusted to represent only the replacement Panels 11 and 12 for the interim state repository. The same CRP 2 location is used for Panels 11, 12 and 13 in the final state repository.
- The drilling rate and frequencies of borehole plugging patterns are updated to account for new information since the RPPCR.

The above changes are detailed in Section 2 of this analysis plan.

1.2.2 Summary of differences between the CRA-2026 interim state repository and the CRA-2026 final state repository

The CRA-2026 12-panel interim state repository analysis and the CRA-2026 19-panel final state repository analysis differ as follows:

- The different number of waste panels in each repository state require different computational grids for Salado flow and transport (Section 2.4.2). Repository parameters ABERM, VREPOS, AREA_CH, FVW, and DBRMINBV are adjusted accordingly (Table 14; Tasks 4 and 5).
- Panel neighbor assignments are extended for 19 panels in the final state repository (Section 2.7.4).

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- Two Culebra release points (CRP 1 and CRP 2) are used for Culebra transport simulations for the interim state repository. Two additional release points (CRP 3 and CRP 4) are added for the final state repository.
- A different inventory, requiring different baseline solubilities, is used for each repository state.

1.2.3 Summary of differences between the RPPCR PA and the CRA-2019 PA

The RPPCR PA differed from the CRA-2019 PA (DOE, 2019) as documented in Brunell et al. (2024).

Changes made to represent the replacement and additional panels:

- New values for the repository area and volume parameters.
- An update to waste area pressure at time of closure with the new waste storage volume.
- Additions to the computational grid of the BRAGFLO repository flow model for the new waste panel regions.
- A new waste region in the BRAGFLO direct brine release model.
- New panel neighboring relationships for the CCDFGF software.
- New mass release points in the SECOTP2D Culebra transport models to simulate mass discharge from the additional panels.

Changes made to models and parameters for new or revised information:

- The waste inventory was based on the 2022 PAIR.
- Actinide mobilization and colloidal parameters were updated with the new thermodynamic database and inventory parameters.
- The actinide oxidation state model was extended to accommodate actinide-specific oxidation state distributions.
- Iron surface area was calculated with the iron inventory rather than projected inventory based on optimal loading.
- The BRAGFLO porosity surface was updated with a new model of creep closure.
- Model inputs for the Castile brine reservoir porosity and pore volume were updated based on a reassessment of WIPP-12 data.
- The upper bound of the borehole permeability parameter distribution was updated based on a new analysis of flow in degraded boreholes.
- Transmissivity fields in the Culebra were recalibrated with additional observation data and an updated calibration method.
- Drilling frequency and borehole plugging patterns were updated with new data.

1.3 Related Performance Assessments and Analyses

The Additional Panels Performance Assessment (APPA) (Hansen, 2020; Brunell et al., 2021) was performed prior to the RPPCR PA (Hansen, 2023; Brunell et al., 2024). The APPA was based on the CRA-2019 with modifications for the 19-panel repository design and the attendant modifications to the DBR grid and panel neighbor assignments.

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The RPPCR was supplemented by an analysis that considered a total of 12 waste panels, which closely resembles the design of the interim state repository (Zeitler et al., 2025). The RPPCR 12-panel sensitivity analysis was based on parameters and models consistent with the CRA-2019.

2 Analysis Approach

The CRA-2026 PA is organized as a sequence of tasks:

1. Review of FEPs and conceptual models.
2. Preparation of inventory and related quantities.
3. Generating a sample of uncertain parameters.
4. Salado flow modeling.
5. Salado transport modeling.
6. Modeling of direct releases.
7. Culebra flow and transport modeling.
8. Calculation of complementary cumulative distribution functions (CCDFs) that quantify potential releases from the repository.
9. Calculation of Culebra travel times.
10. Sensitivity analyses.

Each task is detailed in the subsequent sections. Deviations from the planned approach will be detailed in analysis reports and in revisions to this plan, as warranted.

Differences in the analysis approach for the interim and final state repositories are noted within the description of each task.

2.1 Review of FEPs and Conceptual Models

The addition of excavated areas to the west of the repository, the proposed emplacement of waste in these areas, and new information since the CRA-2019, may affect the screening of FEPs for the PA and the conceptual models that represent FEPs.

A FEPs assessment will be conducted following SP 9-4, Performing FEPs Baseline Impact Assessments for Planned or Unplanned Changes (Table 14, Task 16).

A FEPs assessment was performed for the APPA according to SP 9-4, Performing FEPs Baseline Impact Assessments for Planned or Unplanned Changes (Kirkes, 2021). The FEPs assessment found that no changes to FEP screening decisions were warranted. For the APPA, the conceptual models used in the PA were also reviewed to identify those models that are affected by the additional and replacement panels (Hansen, 2021). The review concluded that 3 of the 24 conceptual models were affected:

- Disposal System Geometry
- Repository Fluid Flow
- Direct Brine Release

The Additional Panels Performance Assessment (APPA) Changed Conceptual Models Peer Review examined the changes affecting these three conceptual models and concluded that the

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changed conceptual models provide an adequate and reasonable representation of the repository system (Falta et al., 2021).

The 19-panel final state repository considered in the CRA-2026 is consistent with the repository design considered by the APPA Changed Conceptual Models Peer Review. The 12-panel interim state repository in the CRA-2026 PA comprises a subset of the 19 waste panels in the final state repository. Features and processes that influence flow and transport are the same in both the interim and final state repositories. Due to the similarity of the interim and final state repositories and the repository represented in the APPA, the conceptual models approved by the APPA Changed Conceptual Models Peer Review are adequate and reasonable for the repositories represented in the CRA-2026.

2.2 Waste Inventory

The inventory for the CRA-2026 final state repository is documented in the Performance Assessment Inventory Report (PAIR) for 2024 (Van Soest, 2025). The PAIR contains updated estimates to the radionuclide content and waste material parameters, scaled to a full repository. To incorporate these changes, parameters for the initial radionuclide, chemical components, waste material inventories and the Waste Unit Factor (WUF) will be developed and reported in a 19-panel inventory screening analysis report (Table 14, Task 1). The code EPAUNI will be used to calculate the radionuclide concentration in each waste stream over time.

An inventory for the CRA-2026 interim state repository will be developed by LANL. Parameters for this inventory will be reported in an inventory screening analysis report (Table 14, Task 2).

2.3 Sample of Uncertain Parameters

Uncertain parameters will be sampled with LHS. With the migration of LHS to the GNU Fortran compiler on the CentOS platform (Long and King, 2022), the seeded random number generator used by previous versions of LHS is no longer able to produce the same random samples. To maintain the same sampling for comparison between analyses, LHS 3.00 has the ability to read in a list of random numbers instead of using a seeded random number generator. For the CRA-2026, LHS will read a table of random numbers containing the same values used in the RPPCR and the CRA-2019 PA. Retaining the same set of random numbers allows for direct comparison between these analyses.

2.4 Salado Flow

The CRA-2026 PA will consider two repositories: the 12-panel interim state repository including two replacement waste panels, and a 19-panel final state repository including two replacement and seven additional waste panels. Numerical calculations will be done with the BRAGFLO code.

2.4.1 Replacement and Additional Panels

The DOE plans to excavate two replacement panels to provide disposal volume equivalent to the unused volume in the ten original panels. In the future, the DOE may consider excavating additional waste panels beyond the two replacement panels to provide sufficient repository volume for the statutory limit of waste. Figure 1 illustrates the replacement and additional panels. Panels

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11 through 19 will be similar to Panels 1 through 8, except that the abutment pillars (between the waste rooms and the access drift) are increased from 61.0 m (200 ft) to 122 m (400 ft) and the isolation pillars (separating any two panels) are increased from 61.0 m (200 ft) to 91.5 m (300 ft).

2.4.1.1 Panel Closures

Panel closures for the new (replacement and additional) panels comprise 100 feet of run-of-mine (ROM) salt in the intake and exhaust drifts, the same as for the waste panels in the current repository. The analysis assumes that there are no panel closures in the drifts that connect the west panels to the operations and experimental areas (Sjomeling, 2019).

2.4.1.2 Non-Waste Areas

Five access drifts running east-west connect the new panels with the rest of the repository. This analysis assumes that no waste is emplaced in the west access drifts.

2.4.2 BRAGFLO Grids

2.4.2.1 CRA-2019 BRAGFLO grid

In the CRA-2019 (DOE, 2019, Appendix PA) the repository is modeled as comprising ten waste panels with emplaced waste and additional excavated volumes without waste. Other significant repository features represented in the PA include the panel closures and shafts. There are five shafts currently located in the repository north end. All five shafts are modeled as a single combined shaft in the computational grid. Figure 2 displays the computational grid used by the BRAGFLO model to calculate brine and gas flow in the Salado, showing each represented feature.

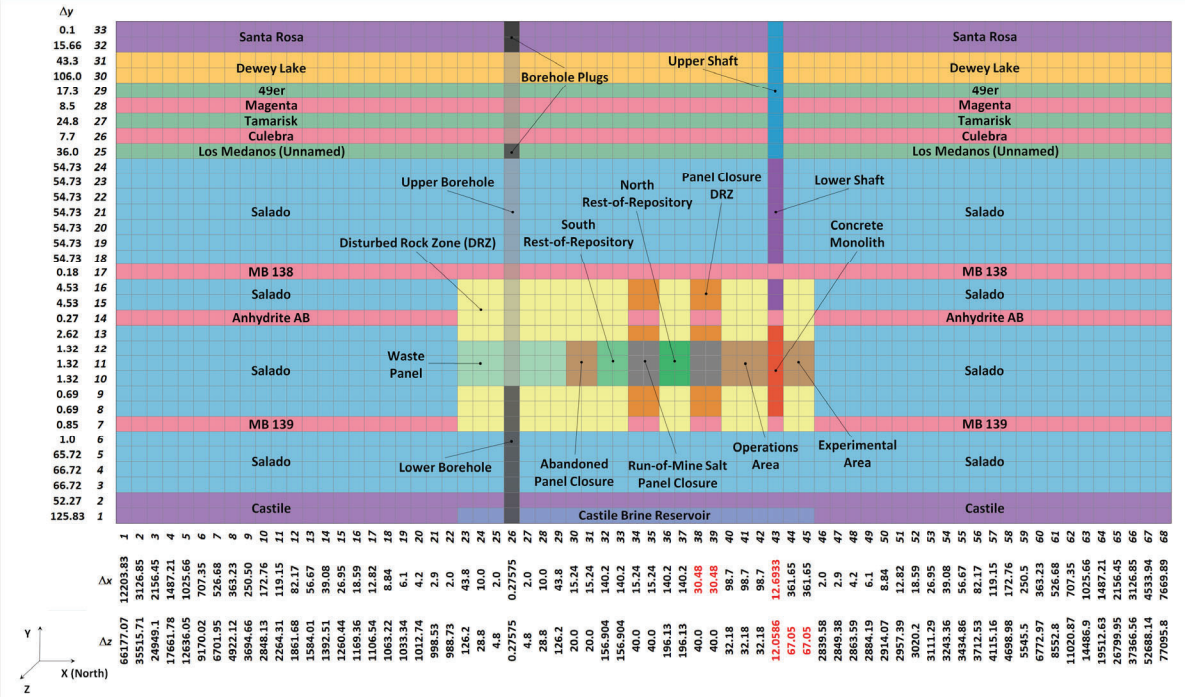


Figure 2. CRA-2019 BRAGFLO Grid (DOE, 2019, Appendix PA, Figure PA-12)

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2.4.2.2 RPPCR BRAGFLO grid

The replacement and additional panels shown in Figure 1 necessitated changes to the computational grid shown in Figure 2. Figure 3 shows the computational grid developed for the RPPCR; details of this grid are found in King (2023). The major assumptions used in the RPPCR grid were reviewed by the APPA Changed Conceptual Models Peer Review. The peer review panel found the assumptions to be justified and the model adequate and reasonable for its intended application (Falta et al., 2021). The RPPCR used the same Salado Flow grid as the APPA, except for one correction to the shaft dimensions.

The RPPCR BRAGFLO grid (Figure 3) aggregates waste panels into four waste-bearing areas denoted Waste Panel (WAS), South Rest of Repository (SRR), North Rest of Repository (NRR), and West Rest of Repository (WRR). Table 1 lists the panels which comprise each waste-bearing area. One representative borehole is placed in the grid in the Waste Panel area.

Table 1. Panel Groups in the RPPCR

Panel Group	Repository Section	Panels in Panel Group
Waste Panel (WAS)	South	5
South Rest of Repository (SRR)	South	3, 4, 6, 9
North Rest of Repository (NRR)	South	1, 2, 7, 8, 10
West Rest of Repository (WRR)	West	11, 12, 13, 14, 15, 16, 17, 18, 19

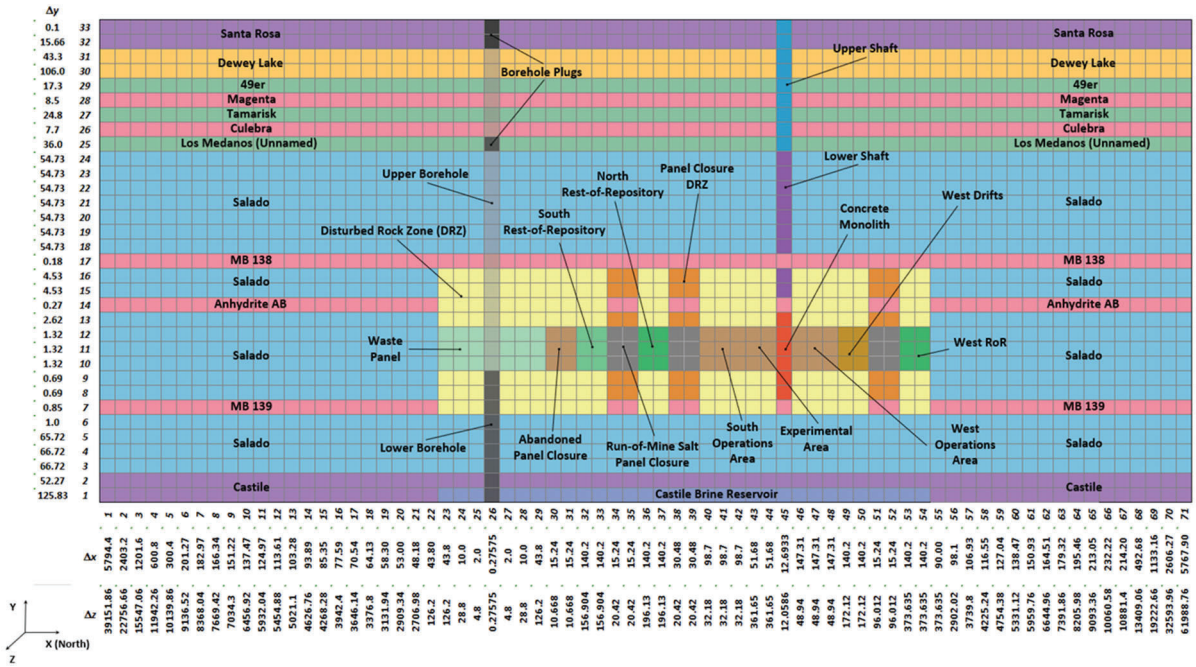


Figure 3. BRAGFLO Grid for the RPPCR

2.4.2.3 CRA-2026 interim and final state computational grids

Separate Salado flow grids for the interim state (12-panel) and final state (19-panel) repository will be defined (Table 14, Task 3). Both grids will follow the conceptual models defined for the APPA and used for the RPPCR Salado flow grid. The CRA-2026 grids will represent repository and geologic features in the same patterns as used in the RPPCR grid. However, repository

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dimensions will be reevaluated based on updated information on mining in the repository and planned changes. A document will be produced describing each grid and detailing the information used to derive the grid dimensions.

2.4.2.4 Waste Emplacement in Panel 9

The DOE no longer plans to emplace waste in Panel 9. However, as was done in the RPPCR and the CRA-2019, the CRA-2026 will model Panel 9 as containing waste to simplify the modeling. The waste inventory will be represented as homogeneous over the volume of the repository.

2.4.3 Limiting of capillary pressure within anhydrite marker beds

Within Marker Bed 138, Anhydrite AB and Marker Bed 139, relative permeability and capillary pressure is determined by one of two models: the modified van Genuchten-Parker and the second modified Brooks-Corey models, as selected by the uncertain RELP_MOD parameter for these materials. For the marker bed materials, for the CRA-2026 a minimum capillary pressure (parameter PO_MIN) is applied using a new capillary pressure modification model (parameter CAP_MOD=6) so that the modified van Genuchten-Parker model does not decrease to zero capillary pressure as brine saturation approaches 1 minus the residual gas saturation (Day, 2025).

2.4.4 Scenarios for Salado Flow Modeling

The Salado flow model computes two-phase (brine and gas) spatially and temporally varying pressure, saturation, and flow in both undisturbed and disturbed conditions. Disturbed conditions are modeled by imposing a borehole representing a drilling intrusion in the BRAGFLO grid. Table 2 lists the intrusion scenarios and their characteristics; the intrusion scenarios for the CRA-2026 are unchanged from those used in the RPPCR and the CRA-2019.

Table 2. Intrusion Scenarios for the CRA-2026.

Scenario	Description
E0	Undisturbed repository
E1	Drilling intrusion that intersects a brine reservoir in the Castile
E2	Drilling intrusion that does not intersect a brine reservoir in the Castile
E1E2	Multiple intrusions into the same waste panel with at least one E1 intrusion

For the RPPCR a representative borehole is placed in the south half of the repository as indicated in Figure 3. The BRAGFLO scenarios for the CRA-2026 are unchanged from those used for the RPPCR and CRA-2019 as indicated in Table 3.

Table 3. BRAGFLO Modeling Scenarios for the CRA-2026

Scenario	Description
S1-BF	Undisturbed repository
S2-BF	E1 intrusion at 350 years in Waste Panel
S3-BF	E1 intrusion at 1,000 years in Waste Panel
S4-BF	E2 intrusion at 350 years in Waste Panel
S5-BF	E2 intrusion at 1,000 years in Waste Panel
S6-BF	E2 intrusion at 1,000 years; E1 intrusion at 2,000 years in Waste Panel

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2.5 Radionuclide Mobilization

2.5.1 Oxidation State Model

In the CRA-2019 PA, Np, Pu, and U actinides were assigned to either a low or high oxidation state (e.g., Pu(III) or Pu(IV)) to reflect epistemic uncertainty in which oxidation state would control solubility in future repository conditions. Each state (low or high) was considered equally likely.

As described in LANL (2022), the binary-state model assumes that all actinides are found in the same low or high oxidation state. In the RPPCR, the oxidation state model was extended to include more combinations of states, to represent the behavior of the different actinides across a range of redox (oxidation-reduction) potentials. Accordingly new parameters (property OXCUTOFF for materials NP, PU, and U) were added. The OXCUTOFF parameter specifies the likelihood of low or high oxidation state for an actinide; selection is correlated across actinides.

The CRA-2026 will use the same oxidation state model as the RPPCR. Updated OXCUTOFF values are anticipated from Los Alamos National Laboratory (LANL).

2.5.2 Radionuclide Mobilization

The PANEL code calculates mobilized radionuclide concentration as the sum of the dissolved and colloidal contributions for 13 elements (Am, Cf, Cm, Cs, Np, Pa, Pb, Pm, Pu, Ra, Sr, Th and U) and their isotopes inside the waste panels during the 10,000-year regulatory period. These calculations are revised from those done for the RPPCR with new baseline solubilities, solubility uncertainty factors and new parameter values for colloids.

2.5.3 Actinide Solubilities

Development of actinide baseline solubilities and their associated uncertainty factors is described in AP-153 (Brush et al., 2012).

The solubilities of actinide elements are influenced by the chemical components of the waste and the amount of halite available for reaction. Actinide baseline solubilities will be updated for the CRA-2026 (Table 14, Tasks 6 and 7) based on the inventory for each repository state (interim state and final state). Except for +VI actinides, baseline solubilities will be calculated at five integer multiples of the minimum brine volume needed for a DBR event (GLOBAL:DBRMINBV), which will be determined separately for each repository state (Table 10, Task 5).

Baseline solubility for +VI actinides are not defined by thermodynamic modeling as are baseline solubilities for other oxidation states. The baseline solubility for +VI actinides will be updated for the CRA-2026 calculations based on analysis by LANL.

Solubility uncertainty factors for the CRA-2026 will be updated for the CRA-2026 (Table 14, Task 8), as described in AP-153 (Brush et al., 2012).

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2.5.4 Updates to Colloid Parameters

Table 4 lists the colloid parameters that are anticipated to change for the CRA-2026. Parameter values will be documented in the Parameter Report (Table 14, Task 21).

Table 4. Colloid Parameters

Materials	Property	Description
Am, Np, Pu, Th, U	CONCMIN	Concentration of mineral colloids (M)
Am, Np, Pu, Th, U	CONCINT	Concentration of intrinsic colloids (M)
Am+3, Np+4, Np+5, Pu+3, Pu+4, Th+4, U+4, U+6	CAPMIC	Maximum concentration on microbial colloids (M)
Np+5, Pu+3, Pu+4, Th+4, U+4, U+6	PROPMIC	Moles of actinide mobilized on microbial colloids per mole dissolved (-)
PHUMOX3, PHUMOX4	PHUMSIM	Proportionality constant for humic colloids in Salado brine (-)
PHUMOX3, PHUMOX4	PHUMCIM	Proportionality constant for humic colloids in Castile brine (-)

Parameters related to mineral (CONCMIN), intrinsic (CONCINT) and microbial colloids (CAPMIC and PROPMIC) are expected to be updated to account for new information from experiments conducted by Los Alamos National Laboratories. The microbial colloid model is expected to be extended to depend on the solubility-controlling oxidation state of each actinide.

Proportionality constants for the moles of actinides mobilized on humic colloids per moles of dissolved actinides are specified for +III and +IV actinides in both Castile (PHUMCIM) and Salado (PHUMSIM) brines. The method for developing the proportionality constants (Mariner (2016, 2018)) uses the actinide baseline solubilities as inputs. Consequently, these proportionality constants will be re-examined using the CRA-2026 baseline solubilities (Table 14, Task 9).

2.6 Salado Transport

Models to estimate transport in the Salado are implemented in the PANEL and NUTS codes. The PANEL code simulates radionuclide decay and mobilization in brine, resulting in time-dependent mobilized concentrations in the waste panels. The NUTS code simulates radionuclide decay and advective transport in the Salado formation for the E0, E1, and E2 scenarios using the same 2D grid as BRAGFLO. A second usage of PANEL is to compute radionuclide transport to the Culebra in the E1E2 intrusion scenario.

2.6.1 Models for Salado Transport

The models for Salado transport for the CRA-2026 are the same as for the RPPCR and the CRA-2019 (DOE, 2019, Appendix PA).

The NUTS code simulates advective transport of radionuclides in the Salado for the E0, E1 and E2 intrusion scenarios, using the 2D BRAGFLO grid (Figure 3). NUTS takes as input inventories of 5 lumped radionuclides, effective solubility limits (mobilized concentrations in the absence of

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inventory limits) calculated by PANEL, and transient brine flow fields calculated by BRAGFLO. It returns radionuclide mass fluxes which are summed to calculate cumulative radionuclide release up the shafts or boreholes to the Culebra and through the marker beds to the land withdrawal boundary. Transport calculations are performed with intrusion times of 350 and 1000 years (in Table 3) as well as other intrusion times (100, 3000, 5000, 7000 and 9000 years).

The PANEL code is used to calculate cumulative radionuclide release through a borehole to the Culebra for the E1E2 scenario. This scenario assumes a sequence of two intrusions: an E2 followed by an E1 intrusion that admits Castile brine to the repository. To calculate cumulative radionuclide release, PANEL integrates the product of brine flow rate from the BRAGFLO S6-BF scenario and time-dependent mobilized radionuclide concentration. Transport calculations are performed with E1 intrusion times of 100, 350, 1000, 2000, 4000, 6000, and 9000 years. The PANEL code internally shifts brine flow times from BRAGFLO S6-BF scenario (E1 intrusion at 2000 years) to get brine flows for other E1 intrusion times.

2.7 Direct Releases

Direct releases of radionuclides to the surface following a drilling intrusion include direct brine releases (DBRs), spallings, cuttings, and cavings. Direct releases are calculated by models for each process applied to several direct release scenarios that vary with time of intrusion, intrusion location relative to previous intrusions, and the type of previous intrusions.

For the CRA-2026, the direct brine release conceptual models are the same as in the RPPCR. These models were modified from those of the CRA-2019. Changes, summarized below, have been deemed appropriate by a peer review (Falta et al., 2021). The scenarios for calculating DBR volumes (Table 5) for the CRA-2026 are the same as in RPPCR and CRA-2019; the grid used for DBR volume calculations in the CRA-2026 is the same as in the RPPCR.

2.7.1 Direct Brine Release in the CRA-2019

In the CRA-2019, DBR volumes were calculated for the scenarios listed in Table 5 using the BRAGFLO_DBR code on a horizontal grid (Figure 4) at each of three representative boreholes: Lower (L), Middle (M), and Upper (U). The Lower intrusion was modeled as occurring in Panel 5 and represents a subsequent intrusion into the same panel as the previous intrusion (all previous intrusions are modeled as occurring in Panel 5, as indicated in Figure 4). The Middle intrusion was modeled as occurring in Panel 3 and represents a subsequent intrusion into a panel adjacent (i.e., separated by one or no panel closure) to a panel with a previous intrusion. The Upper intrusion was modeled as occurring in Panel 10 and represents a subsequent intrusion into a panel with no previous intrusions in its adjacent panels, but with previous intrusions into non-adjacent panels (i.e., with more than one intervening panel closures). A full description of the CRA-2019 approach to calculating DBR volumes is provided in Bethune (2019).

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Table 5. Direct Brine Release Scenarios in the CRA-2019

Scenario	Previous Intrusion Type and Time	DBR Intrusion Times (yr)
S1-DBR	None	100, 350, 1000, 3000, 5000, 10000
S2-DBR	E1 intrusion at 350 yr (S2-BF)	550, 750, 2000, 4000, 10000
S3-DBR	E1 intrusion at 1000 yr (S3-BF)	1200, 1400, 3000, 5000, 10000
S4-DBR	E2 intrusion at 350 yr (S4-BF)	550, 750, 2000, 4000, 10000
S5-DBR	E2 intrusion at 1000 yr (S5-BF)	1200, 1400, 3000, 5000, 10000

2.7.2 Direct Brine Release in the RPPCR

For the RPPCR, the DBR grid for the RPPCR (Figure 5) retained the 10 notional "panels," termed here DBR panels, used in the CRA-2019 (Figure 4). For the RPPCR, a new panel group (Other) was formed by changing the grouping of the 10 DBR panels, and a new representative borehole was placed in Panel 1. The Other panel group was used for estimating DBR volumes from intrusions into the proposed replacement and additional waste panels. Details of the DBR grid for the RPPCR are provided in Docherty and King (2023).

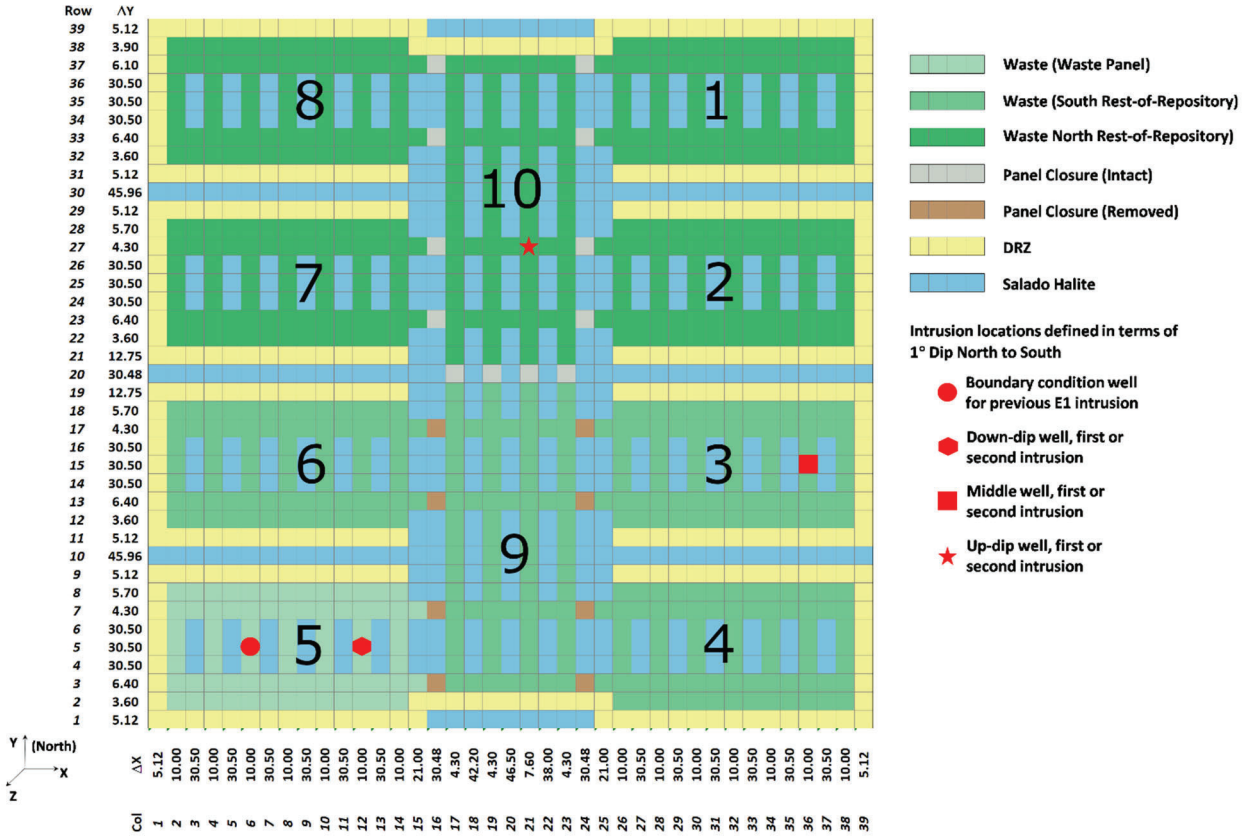


Figure 4. BRAGFLO_DBR Grid for the CRA-2019.

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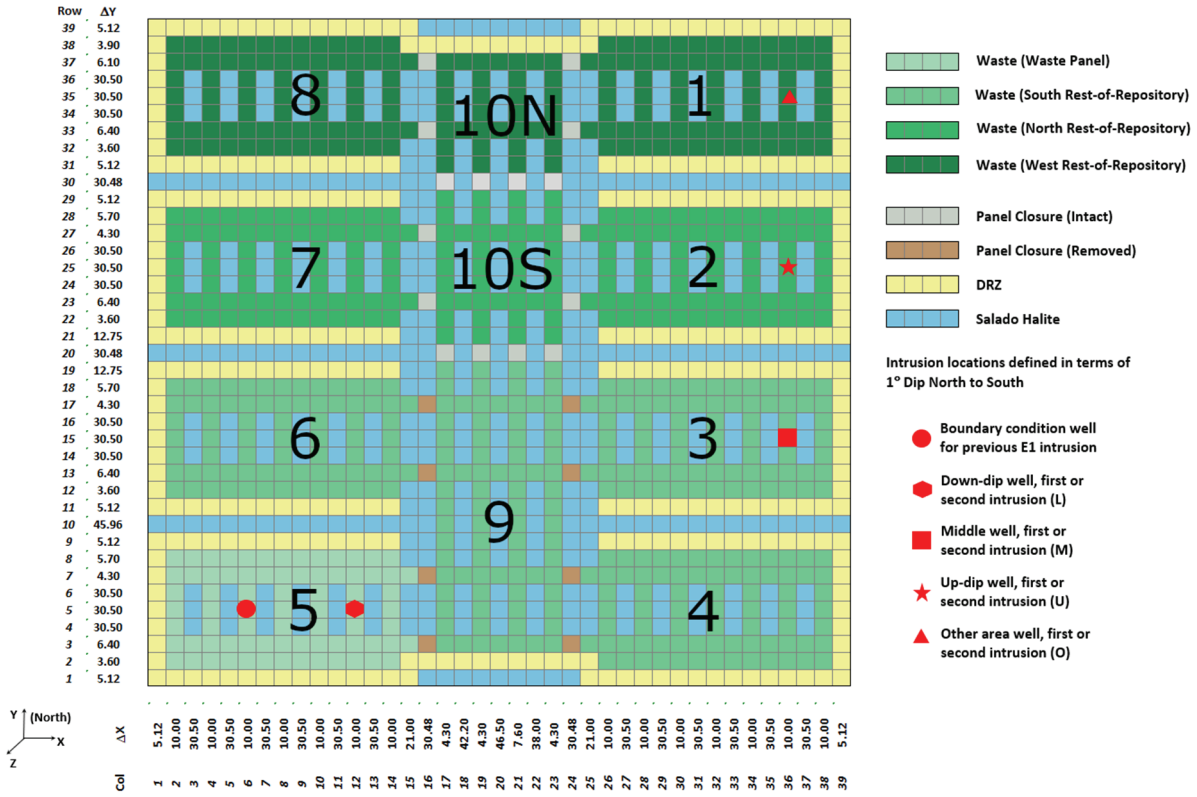


Figure 5. BRAGFLO_DBR Grid for the CRA-2026.

2.7.3 Direct Brine Release in the CRA-2026

The grid for calculating DBR volumes for the CRA-2026 (Figure 5) is the same as in the RPPCR (Docherty and King, 2023). The same DBR grid is used for both the CRA-2026 interim state and the final state repository calculations, differing only in the assignment of initial conditions.

The approach taken in the CRA-2026 final state repository calculations and the RPPCR is the same as in the APPA. The assumptions and DBR model were reviewed by the APPA peer review panel. The peer review panel found the assumptions used to be justified, and the DBR model was found to be adequate and reasonable for its intended purpose (Falta et al., 2021).

2.7.3.1 Initial Conditions for DBR

The scheme for assigning initial conditions to the DBR grid is the same in the CRA-2026 as in the RPPCR. Initial conditions for a DBR panel (Figure 5) are taken from the panel groups in the BRAGFLO grid (Figure 3), and releases are separately calculated for four representative boreholes (lower, middle, upper and other):

- The lower (L) borehole is located in DBR Panel 5 and initial conditions for the DBR panel containing this borehole are taken from the Waste Panel (WAS) region of the BRAGFLO grid.
- The middle (M) borehole is located in DBR Panel 3 and initial conditions for the group of DBR panels containing this borehole (comprising DBR Panels 3, 4, 6 and 9) are taken from the South Rest of Repository (SRR) region of the BRAGFLO grid.

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- The upper (U) borehole is located in Panel 2 and initial conditions for the group of DBR panels containing this borehole (comprising DBR Panels 2, 7 and the south half of DBR Panel 10) are taken from the North Rest of Repository (NRR) region of the BRAGFLO grid.
- The other (O) borehole is located in DBR Panel 1 and initial conditions for the group of DBR panels containing this borehole (comprising DBR Panels 1, 8 and the north half of DBR Panel 10) are taken from the West Rest of Repository (WRR) region of the BRAGFLO grid. Note that the WRR region comprises panels 11 and 12 in the 12-panel repository, and panels 11 through 19 in the 19-panel repository.

2.7.3.2 Representative Boreholes for DBR

DBRs from an intrusion into the repository are modeled by results of the DBR scenarios (Table 5); and the representative borehole for an intrusion is determined as shown in Table 6. The representative borehole for a DBR from an intrusion into the repository with undisturbed conditions is determined by the intruded panel. After the initial intrusion, DBRs for a subsequent intrusion are based on the distance between the panel containing the subsequent intrusion and the nearest panel with a previous E1 intrusion. If no previous E1 intrusion has occurred, releases are determined by the nearest panel with an E2 intrusion. The distances between panels are specified by the panel groups indicated in Table 8, in order of nearest to farthest: Same, Connected, Adjacent, and Non-Adjacent. Panel groups and neighbors are described in Section 2.7.4. The representative borehole associated with each distance is identified in Table 6.

Table 6. Use of Representative Boreholes for DBR

Representative Borehole	Initial Intrusion: Intruded Panel	Subsequent Intrusion: Panel Group
Lower	5	Same
Middle	3, 4, 6, 9	Connected
Upper	1, 2, 7, 8, 10	Adjacent
Other	11 – 12 (12-panel) 11 – 19 (19-panel)	Non-Adjacent

2.7.4 Panel Groups and Neighbors

The CRA-2019 classified panels into one of three groups as determined by the number of panel closures separating each waste panel from Panel 5: same, adjacent, and non-adjacent (Brunell, 2019).

For the RPPCR the panel neighbor groups were extended to same, connected, adjacent, and non-adjacent. Two panels are connected if there are no intervening panel closures, e.g., Panels 4 and 5 are connected. Two panels are adjacent if both panels are in the same half of the repository (i.e., south or west) but are separated by one or more intervening panel closure, e.g., Panels 1 and 5 are adjacent. Two panels are non-adjacent if the panels are in different halves of the repository, e.g., Panels 1 and 11 are non-adjacent. The path between panels is traced through excavated areas only. The panel neighboring is the same as in the APPA.

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As discussed in Section 2.7.3, the panels are grouped according to their relative location within the repository for the purpose of interpolating releases from calculations for specific DBR scenarios. The lower panel group comprises Panel 5. Conditions in the lower panel group are used to estimate releases from an intrusion into a previously intruded panel. The middle group comprises Panels 3, 4, 6, and 9; conditions in this panel group are used to estimate releases from intrusions into a panel that has no previous intrusion but is not separated by a panel closure from a panel with a previous intrusion. The upper panel group comprises Panels 1, 2, 7, 8 and 10. Conditions in the upper panel group are used to calculate releases from an intrusion into a panel that has no previous intrusions, no connected panel has a previous intrusion, and previous intrusions have occurred in adjacent panels. The other panel group comprises all panels in the west portion of the repository numbered 11 and 12 for the interim state repository, and panels 11 through 19 for the final state repository. Conditions in the other panel group are used to estimate releases from an intrusion into a panel without a previous intrusion and is in a different half of the repository than all panels with previous intrusions (i.e., the south section vs. the west section).

The CCDFGF code simulates random sequences of drilling intrusions. Each intrusion is placed in one of the waste panels using probabilities based on panel areas. Intrusion probabilities will be developed in accordance with the 12-panel and 19-panel BRAGFLO grids (Table 14, Task 3). When a new intrusion occurs, previous intrusions in the same, connected, and adjacent panels determine the conditions for calculating releases from the new intrusion. Table 7 summarizes the panel neighbor scheme for the CRA-2026 interim state repository. Panels not designated as same, connected, or adjacent are defined as non-adjacent. Table 8 summarizes the panel neighbor scheme for the CRA-2026 final state repository; the same scheme was used in the RPPCR.

Table 7. Panel neighbors in the CRA-2026 interim state repository

Intruded Panel	Connected Panels	Adjacent Panels
1	-	2 – 10
2	-	1, 3 – 10
3	4, 5, 6, 9	1, 2, 7, 8, 10
4	3, 5, 6, 9	1, 2, 7, 8, 10
5	3, 4, 6, 9	1, 2, 7, 8, 10
6	3, 4, 5, 9	1, 2, 7, 8, 10
7	-	1 – 6, 8, 9, 10
8	-	1 – 7, 9, 10
9	3, 4, 5, 6	1, 2, 7, 8, 10
10	-	1 – 9
11	-	12
12	-	11

Table 8. Panel neighbors in the RPPCR and the CRA-2026 final state repository

Intruded Panel	Connected Panels	Adjacent Panels
1	-	2 – 10
2	-	1, 3 – 10
3	4, 5, 6, 9	1, 2, 7, 8, 10

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Intruded Panel	Connected Panels	Adjacent Panels
4	3, 5, 6, 9	1, 2, 7, 8, 10
5	3, 4, 6, 9	1, 2, 7, 8, 10
6	3, 4, 5, 9	1, 2, 7, 8, 10
7	-	1 – 6, 8, 9, 10
8	-	1 – 7, 9, 10
9	3, 4, 5, 6	1, 2, 7, 8, 10
10	-	1 – 9
11	-	12 – 19
12	-	11, 13 – 19
13	-	11 – 12, 14 – 19
14	-	11 – 13, 15 – 19
15	-	11 – 14, 16 – 19
16	-	11 – 15, 17 – 19
17	-	11 – 16, 18 – 19
18	-	11 – 17, 19
19	-	11 – 18

2.7.5 Spallings

Spalling releases are calculated by combining a spalling volume obtained by interpolation on a table of single borehole spalling volumes with a time-dependent radionuclide concentration in the contact-handled (CH) waste. The CRA-2026 will use the table of single borehole spallings volumes from the RPPCR and the CRA-2019, as none of the changes since the CRA-2019 affect the calculation of these volumes. The spalling release volume for an intrusion is determined by interpolating the table to the pressure in the intruded panel at the intrusion time. The panel conditions for spallings are determined using the scenarios for DBR release volumes. The DBR release scenario is determined by the borehole location and the type and distance to any previous intrusions as described in Section 2.7.3. The pressure in the intruded panel is estimated by interpolating the initial conditions for DBR releases to the intrusion time using the DBR calculation cases listed in Table 5.

2.7.6 Cuttings and Cavings

For the CRA-2026, cutting and cavings releases will be estimated using the CRA-2019 models (DOE, 2019, Appendix PA), as was done in the RPPCR. If the borehole intersects contact-handled waste, cuttings and cavings release volumes are calculated by multiplying the eroded borehole diameter by the repository height; cuttings and cavings releases are then calculated by multiplying 1/3 of the release volume with the time-dependent radionuclide concentration in each of three randomly selected CH-waste streams. The probability of selecting a waste stream is equal to the waste stream's volume fraction in the inventory.

If the borehole intersects remote-handled waste, cuttings and cavings release volumes are calculated by multiplying the eroded borehole diameter by the remote handled waste height of 0.509 m (Parameter REFCON:HRH). Cuttings and cavings releases are then calculated by

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multiplying the release volume with the time-dependent radionuclide concentration in a randomly selected RH-waste stream.

2.8 Culebra Flow and Transport

Radionuclides may be transported to the Culebra via boreholes or through the shaft. For the CRA-2026, models and codes for transport to the Culebra are the same as in the RPPCR.

For the RPPCR, three aspects of Culebra flow and transport modeling were revised from the CRA-2019:

- New transmissivity fields for flow in the Culebra were calculated (Bowman et al., 2023).
- New flow fields were calculated using MODFLOW6 (Langevin et al., 2017) in place of MODFLOW2000.
- Four release points were placed in the Culebra, to represent borehole locations where radionuclides may enter the Culebra. The CRA-2019 used a single Culebra Release Point (CRP).

Culebra transport calculations for the CRA-2026 12-panel interim state repository will use two release points (CRP 1 and CRP 2) while the 19-panel final state repository will use a total of four release points (CRP 1 through CRP 4). Release points are described in Section 2.8.1 and shown in Figure 6. Culebra flow fields are unaffected by the change in radionuclide source locations.

2.8.1 Culebra Release Points

In each transport simulation, 1 kg of each of ^{241}Am, ^{239}Pu, ^{234}U, and ^{229}Th is released during the first 50 years after repository closure and the mass fraction reaching the LWB is tabulated over time. In the CRA-2019 PA and the APPA, all radionuclides were introduced into the Culebra at a single location over the centroid of the current ten waste panels. For the RPPCR, a total of four release locations were used to represent the spatial extent of the proposed replacement and additional waste panels. The predominant regional flow in the Culebra is to the south. However, the proposed new panels extend westward into areas affected by potash mining in the full-mining scenario, where enhanced transmissivity can draw flow toward the western delineation of the land withdrawal boundary.

For the RPPCR, Culebra transport calculations included releases into the Culebra at four locations to account for the potential for westward transport above the new panels (Bethune, 2023). Particle tracking analysis, as outlined in Bethune and Brunell (2022), was used to define groups of waste panels with similar particle transport direction, travel distance and travel time. For each group a release point was located in the Culebra at the centroid of the group's panels.

The CRA-2026 uses the same panel groups as in the RPPCR:

- Group 1 comprises Panels 1 through 10. Discharge to the Culebra from an undisturbed repository, from boreholes in Panels 1 through 10, and through the shafts are modeled with a release point near the centroid of the existing repository, as was done for CRA-2019. The release point for Group 1 is labeled CRP 1.
- Group 2 is composed of Panels 11, 12, and 13, which are characterized by particle tracks with predominately southward flow and shorter travel distances and times to the land

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withdrawal boundary relative to Group 3. The release point for Group 2 panels is labeled CRP 2.

- Group 3 is composed of Panels 14 and 19, which are characterized by having particle tracks that predominately flow to the south and east, but with longer travel distances and times to the land withdrawal boundary relative to Group 2. The release point for Group 3 panels is labeled CRP 3.
- Group 4 is composed of Panels 15, 16, 17, and 18, which are characterized by having a relatively high percentage of particle tracks that exit the western land withdrawal boundary in the full-mining scenario. Waste panels in Group 4 are all at least partially inside the full-mining region. The release point for Group 4 panels is labeled CRP 4.

For the CRA-2026 CRP 2 will be moved from the centroid of panels 11, 12, and 13 to the centroid of panels 11 and 12 (Wilgus and Brunell, 2025), the same location that was used in the RPPCR 12-panel interim state sensitivity study (Zeitler et al., 2025). CRP 2 will be at the same location in both the CRA-2026 interim and final state repositories to simplify comparisons between these analyses.

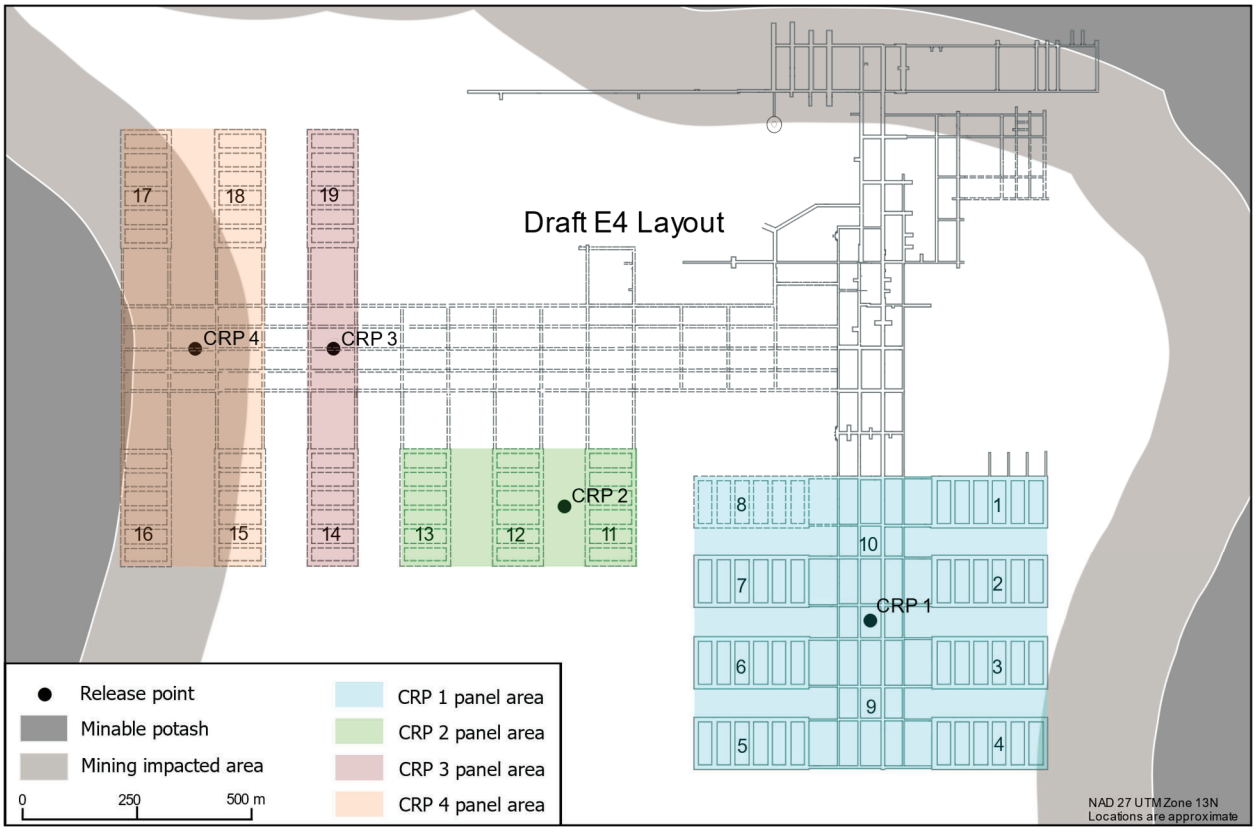


Figure 6. Culebra release point locations for the CRA-2026

2.9 Calculation of CCDFs for Releases

The conceptual structure of the CRA-2026 remains the same as for the RPPCR and CRA-2019. For each element in a sample of uncertain parameters, many 10,000-yr futures are randomly generated. Each future comprises a sequence of simulated drilling and mining intrusions. For each intrusion, direct releases are tabulated using output from the models described above, and over the

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course of the entire future, releases through the Salado and Culebra to the land withdrawal boundary are recorded using output from the Salado and Culebra transport models. The total of these various releases at the end of the 10,000-yr period yields one data point for total releases; the collection of total release data points over all futures comprises the data that forms one complementary cumulative distribution function (CCDF) of releases. The code CCDFGF generates the random futures and estimates the CCDFs. A formal definition of this conceptual structure is found in Appendix PA of DOE, 2019.

2.9.1 Drilling Rates and Plugging Pattern Probabilities

WIPP regulations require that current drilling practices be assumed for future inadvertent intrusions. The DOE continues to survey drilling activity in the Delaware Basin in accordance with the criteria established in 40 CFR 194.33. Local well operators are surveyed annually to provide the WIPP project with information on drilling practices, Castile brine encounters, etc.

Drilling parameters, to include the drilling rate and the probability of one-, two- and three-plug wellbore plugging patterns, will be updated for the CRA-2026 (King, 2025) from the information in DOE (2025).

3 Summary of Parameter Changes

Table 9 through Table 13 list parameter changes relative to the RPPCR and the CRA-2019:

- Table 9 contains a summary of inventory parameter changes;
- Table 10 contains parameter updates related to repository dimensions;
- Table 11 contains parameter updates related to the Salado flow model;
- Table 12 summarizes parameter updates related to actinide mobilization; and
- Table 13 contains parameter updates related to boreholes and direct releases.

All parameters changed for the CRA-2026 will be published in the CRA-2026 Parameter Report (Table 14, Task 21). Updates to parameters will follow Nuclear Waste Management Procedure NP 9-2, Parameters.

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Table 9. Summary of Inventory Parameter Changes for the CRA-2026

Material(s)	Property(s)	Description	Changed from the CRA-2019 for the RPPCR	Planned to change from the RPPCR for the CRA-2026	Different for 12-panel and 19-panel repositories
AM241, AM243, CF252, CM243, CM244, CM245, CM248, CS137, NP237, PA231, PB210, PM147, PU238, PU238, PU240, PU241, PU242, PU244, RA226, RA228, SM147, SR90, TH229, TH230, TH232, U233, U234, U235, U236, U238	INVCHD and INVRHD	WIPP-scale initial radionuclide inventory of contact- and remote-handled waste	X	X	X
AM241L, TH230L, PU238L, U234L, PU239L	INVCHD and INVRHD	WIPP-scale initial lumped radionuclide inventory of contact- and remote-handled waste	X	X	X
BOREHOLE	WUF	Waste Unit Factor	X	X	X
NITRATE, SULFATE	QINIT	WIPP-scale amounts of nitrate and sulfate	X	X	X

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Material(s)	Property(s)	Description	Changed from the CRA-2019 for the RPPCR	Planned to change from the RPPCR for the CRA-2026	Different for 12-panel and 19-panel repositories
WAS_AREA	IRONCHW, IRNCCHW, CELLCHW, CELCCHW, CELECHW, PLASCHW, PLSCCHW, PLSECHW, RUBBCHW, RUBCCHW, RUBECHW	Mass of iron, cellulose, plastic and rubber in contact-handled (CH) waste materials, waste container (packaging) materials, and waste emplacement materials	X	X	X
WAS_AREA	IRONRHW, IRNCRHW, CELLRHW, CELCRHW, CELERHW, PLASRHW, PLSCRHW, PLSERHW, RUBBRHW, RUBCRHW, RUBERHW	Mass of iron, cellulose, plastic and rubber in remote-handled (RH) waste materials, waste container (packaging) materials, and waste emplacement materials	X	X	X

Table 10. Summary of Parameter Changes Related to Repository Dimensions for the CRA-2026

Material(s)	Property(s)	Description	Changed from the CRA-2019 for the RPPCR	Planned to change from the RPPCR for the CRA-2026	Different for 12-panel and 19-panel repositories
REFCON	VREPOS	Excavated storage volume of the repository	X	X	X
REFCON	ABERM	Area of the berm placed over waste panels	X		X
REFCON	AREA_CH	Area for contact-handled (CH) waste disposal	X	X	X
REFCON	FVW	Fraction of the repository volume occupied by waste	X	X	X

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Table 11. Summary of Salado Flow Model Parameter Changes for the CRA-2026

Material(s)	Property(s)	Description	Changed from the CRA-2019 for the RPPCR	Planned to change from the RPPCR for the CRA-2026	Different for 12-panel and 19-panel repositories
CAVITY1	PRESSURE	Initial pressure in the representative waste panel	X		
CAVITY2	PRESSURE	Initial pressure in waste-filled regions other than the representative waste panel	X		
WAS_AREA	EGRATMIC	Moles of gas generated per kilogram of cellulose from early-time rapid CPR biodegradation.	X		
REFCON	FESAPKG	Iron surface area per kilogram of iron inventory	X		
CASTILER	PRESSURE	Initial pore pressure of a Castile brine reservoir	X		
CASTILER	PRMX_LOG, PRMY_LOG, PRMZ_LOG	Permeability (log base 10) of Castile reservoir	X		
CASTILER	COMP_RCK	Bulk compressibility of Castile reservoir host rock	X		
BH_SAND	PRMX_LOG PRMY_LOG PRMZ_LOG	Permeability (log base 10) of degraded borehole material	X		
S_MB138, S_ANH_AB, S_MB139	CAP_MOD	Model number, capillary pressure model		X	
S_MB138, S_ANH_AB, S_MB139	PO_MIN	Minimum brine pressure for capillary model KPC=3 or minimum capillary pressure for capillary model KPC=6		X	

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Table 12. Summary of Parameter Changes Related to Actinide Mobilization for the CRA-2026

Material(s)	Property(s)	Description	Changed from the CRA-2019 for the RPPCR	Planned to change from the RPPCR for the CRA-2026	Different for 12-panel and 19-panel repositories
SOLMOD3, SOLMOD4, SOLMOD5	SOLCOH, SOLSOH, SOLCOH2, SOLSOH2, SOLCOH3, SOLSOH3, SOLCOH4, SOLSOH4, SOLCOH5, SOLSOH5	Actinide baseline solubilities in Castile and Salado brines	X	X	X
SOLMOD6	SOLSOH	+6 Actinide baseline solubilities in Salado brine		X	
SOLMOD6	SOLCOH	+6 Actinide baseline solubilities in Castile brine		X	
SOLMOD3, SOLMOD4	SOLVAR	Actinide solubility multiplier	X	X	
AM, TH	CONCINT	Intrinsic colloid concentration	X		
AM+3, NP+4, NP+5, PU+3, PU+4, TH+4, U+4, U+6	PROPMIC CAPMIC	Microbial colloid parameters	X[2]	X	
NP, PU, U	OXCUTOFF	Probability of low oxidation state controlling element solubility	X[3]		

[2] For the CRA-2019 and RPPCR calculation, CAPMIC and PROPMIC were specified for the element specific materials of AM, NP, PU, TH, and U.
[3] Prior to the RPPCR calculation, OXCUTOFF was set at a hard-coded value of 0.5 for materials NP, PU, and U, and not specified as a PA parameter.

Table 13. Summary of Parameter Changes Related to Boreholes and Direct Releases for the CRA-2026

Material(s)	Property(s)	Description	Changed from the CRA-2019 for the RPPCR	Planned to change from the RPPCR for the CRA-2026	Different for 12-panel and 19-panel repositories
GLOBAL	LAMBDAD	Drilling rate per unit area	X	X	
GLOBAL	ONEPLG	Probability of having Plug Pattern 1 (full plug)	X	X	
GLOBAL	TWOPLG	Probability of having Plug Pattern 2	X	X	
GLOBAL	THREEPLG	Probability of having Plug Pattern 3	X	X	
GLOBAL	DBRMINBV	Minimum volume of brine in the repository required for a direct brine release	X	X	X
GLOBAL	PBRINE	Probability that a borehole intersects pressurized brine in the Castile	X		

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4 Analyses

For the interim state repository, analysis reports will include:

1. discussion of any implementation changes (parameters, modeling assumptions, etc.) relative to the RPPCR; and
2. analysis of results relevant to the long-term performance of the repository. Analyses will include comparisons with the RPPCR. Analyses will also describe the uncertainty of the results and provide a sensitivity analysis to determine the input uncertainty that primarily impacts the uncertainty in the results.

For the final state repository, a single analysis report will address:

1. implementation changes relative to the interim state repository; and
2. analysis of results relevant to the long-term performance of the repository. Analyses will include comparison with results for the interim state repository. Analyses will focus primarily on CCDFs of radionuclide releases.

4.1 Sensitivity Analyses

Sensitivity analyses quantify the influence of uncertain parameters on the uncertainty in select outputs from the PA models. Sensitivity analyses will be done on mean values of CCDFs for each release type (cuttings, cavings, spallings, direct brine release and Culebra transport) and on total releases, for both the interim and final state repositories.

For the interim state repository, sensitivity analyses will also examine the relationship between uncertain parameters and the following intermediate outputs:

- Pressure and saturation in the excavated areas for assumed intrusions (BRAGFLO scenarios).
- Brine flow in the borehole for assumed intrusions (BRAGFLO scenarios).
- Radionuclide transport through the Culebra from each release point resulting from placement of unit masses at simulation start (SECOTP2D scenarios).

In the sensitivity analysis of Culebra transport, the explanatory variables will include two intermediate variables: the travel time computed from the Culebra flow fields, and the retardation factor computed from other uncertain parameters. Travel times from each release point to the LWB will be calculated with the DTRKMF code for non-sorbing, non-decaying particles in the no-mining, full-mining, and partial-mining scenarios. Travel times will be used in sensitivity analyses to quantify the importance of the T-field selection to uncertainty in mass transport. If travel times are highly correlated among release points, travel times for one release point will be retained in the sensitivity analysis while the others will be dropped. The T-field selection index (GLOBAL:TRANSIDX) will be excluded from the sensitivity analysis because, being an index, TRANSIDX should have no monotonic relationship to releases. The retardation factor R_l is defined as:

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$$R_l = 1 + \rho_s k_d^l \frac{(1-\phi)}{\phi}$$

where:

ρ_s = density of fluid in the Culebra.
k_d^l = matrix distribution coefficient (e.g., MKD_PU) which in turn is a function of oxidation state (OXSTAT).
ϕ = matrix porosity (MPOROS).

Because the retardation factor is included as an explanatory variable, neither the matrix distribution coefficient, oxidation state selector nor the matrix porosity will be included.

4.2 Comparison with previous PAs

Results from the interim state repository calculations will be compared with corresponding results from the RPPCR. CCDFs of total releases will also be compared with the corresponding results from the CRA-2019 PA.

Results from the final state repository calculations will be compared with corresponding results from the interim state repository calculations.

5 Tasks and Schedule

The tasks, responsible personnel, and estimated task schedule are summarized in Table 14. Calculations described in Section 2 will be carried out and documented in analysis reports.

A record of the run control will be created for the CRA-2026. This document will contain:

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 or file directory where each file is stored.
6. File naming conventions.

Additional analyses, calculations, and documentation performed as part of the regulatory review and approval process for the RPPCR will also fall under this analysis plan.

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Table 14: Task List and Estimated Schedule for the RPPCR

Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
1	Inventory Analysis Report: Final State Repository	NP 9-1	5/1/2025	Kicker
2	Inventory Analysis Report: Interim State Repository	NP 9-1	5/15/2025	Kicker
3	Salado Flow and Transport Grids	AP-214	3/31/2025	Day, King
4	Repository parameters memo	AP-214	3/31/2025	Day, Brunell
5	DBRMINBV and DRZ volume memo	AP-214	3/31/2025	Day, Brunell
6	Actinide baseline solubilities: final state repository	AP-153	4/15/2025	Domski
7	Actinide baseline solubilities: interim state repository	AP-153	5/15/2025	Domski
8	Actinide solubility uncertainty memo	AP-153	4/15/2025	Domski
9	Humic colloids parameters memo	AP-167	4/15/2025	Mariner
10	Input Files Prepared	AP-214	4/8/2025	Bethune, Brunell, Day, Docherty, Kicker, Kim, King, Zeitler, Wilgus
11	Input File Review	AP-214	4/8/2025	Hansen
12	Parameter Data Entry and QA Review: final state	NP 9-2	4/28/2025	Long
13	Parameter Data Entry and QA Review: interim state	NP 9-2	5/29/2025	Long
14	Main PA Calculations: final state	AP-214	5/15/2025	Long
15	Main PA Calculations: interim state	AP-214	5/30/2025	Long
16	FEPs assessment	SP 9-4	7/28/2025	Kirkes
17	Analysis Reports: interim state	NP 9-1	8/19/2025	Hansen
17.1	Parameter Sampling	AP-214	7/28/2025	King, Zeitler
17.2	EPA Unit	AP-214	8/19/2025	Kim, Kicker
17.3	Salado Flow	AP-214	7/28/2025	Day, King
17.4	Cuttings, Cavings, and Spallings	AP-214	7/28/2025	Brunell, Kicker
17.5	Actinide Mobilization and Salado Transport	AP-214	7/28/2025	Docherty, Kim
17.6	Culebra Flow and Transport	AP-214	8/19/2025	Wilgus, Bethune
17.7	Direct Brine Release	AP-214	7/28/2025	Zeitler, King

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Task	Description	Guiding Document	Approximate Completion Date	Responsible Individual(s)
17.8	CCDF Construction	AP-214	8/19/2025	King, Brunell, Zeitler
17.9	Run Control Document: interim state	AP-214	8/19/2025	Long
18	Summary Report: interim state	NP 9-1	9/30/2025	Brunell, Bethune, Day, Docherty, Hansen, Kicker, Kim, King, Long, Wilgus, Zeitler
19	Run Control Document: final state	AP-214	8/19/2025	Long
20	Analysis Report for final state	NP 9-1	9/30/2025	Brunell, Bethune, Day, Docherty, Hansen, Kicker, Kim, King, Long, Wilgus, Zeitler
21	Parameter Report interim and final state	AP-214	8/19/2025	Feng, Kicker

6 Software

The major WIPP PA codes to be used for the CRA-2026 are listed in Table 15. The execution of these codes for the analysis described herein comprises a compliance decision calculation. These codes will be executed on the WIPP PA HPC/Linux Cluster. The WIPP PA HPC/Linux Cluster consists of the login node FWM, and 24 Dell PowerEdge C6420 compute nodes running CentOS 7. Additionally, General Support (GS) software and Software Support Applications (SSA) may be used in the development of the analysis reports, including Matlab®, Sigma Plot®, Excel®, Access®, or Python. The use of any software will be documented and verified per Nuclear Waste Management Procedures NP 9-1, Section 2.2 and NP 19-1 as appropriate. All software used in the development of the analysis report will be classified and graded prior to use under NP 19-1.

DRSPALL and MERGESPALL will not be run for the CRA-2026. Instead, output results from a previous analysis (Kirchner et al., 2014; Kirchner et al., 2015) will be used as input. The inputs to these codes would be the same for the CRA-2026 as for the previous analysis.

Since the RPPCR, several PA codes have been modified as listed below.

6.1 EPAUNI

The EPAUNI code was updated to version 1.21 to increase the number of characters for the waste stream names in the output files to avoid truncation of long waste stream names. A warning message was also added about the assumed 2033 closure year when the IFLAGC value is greater than 0. As the waste stream names do not flow down into other PA code calculations, and the closure year and inventory year have been appropriately set, these updates to EPAUNI will have no impact on the PA calculation.

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6.2 BRAGFLO

The BRAGFLO version 8.00 code will be used for the CRA-2026 PA. The RPPCR used BRAGFLO version 7.02. BRAGFLO version 8.00 was developed from BRAGFLO version 7.02 to add a new capillary pressure model (KPC=6). The new capillary pressure model implements a limit on maximum capillary pressure equivalent to an existing capillary pressure model (KPC=2) for both the modified van Genuchten-Parker (KRP=1) and second modified Brooks-Corey (KRP=4) capillary pressure functions. The new capillary pressure model also implements a lower bound on capillary pressure (PO_MIN) for the modified van Genuchten-Parker (KRP=1) capillary pressure function (Section 2.4.3).

6.3 PANEL

The PANEL code was updated to fix a problem that occurred during an intrusion mode calculation with forward time shifting. When an intrusion is shifted forward in time the flow simulation results of brine volume in the waste panel need to be extrapolated past the calculated end time. If the brine volume was declining at late time, this extrapolation could lead to negative brine volumes leading to a computational failure. The brine volume is now limited to a minimum value during the extrapolation, consistent with a minimum brine volume implemented elsewhere in the PANEL algorithm. This failure is a rare occurrence that has never happened in a WIPP compliance calculation. This PANEL code update will have minimal impact on the PA calculation.

6.4 DTRKMF

The DTRKMF code was updated to version 2.00 to add the capability to read flow fields and grid information from MODFLOW6. Previously, when MODFLOW6 flow fields and grid information were used, a script was needed to convert the information before executing DTRKMF. Those conversion scripts will no longer be needed. This update to DTRKMF will not impact the PA calculation.

6.5 CCDFGF

The CCDFGF code was updated to version 8.02 to increase bounds on some data structures. Previously, a few data structures related to the number of boreholes in a future were defined as static with a fixed maximum number of boreholes. With the increase in drilling rate seen in recent analyses, it was necessary to allow those data structures to grow dynamically. The CCDFGF function `DefineBorehole` was modified accordingly. The change only affects the sizing of data structures; it has no impact on the design or functionality of the CCDFGF code.

Table 15. Codes to be Used for the CRA-2026

Code	Version	Executable	Build Date
ALGEBRACDB	2.37	algebracdb	8/17/2020
BRAGFLO	8.00	bragflo	1/14/2025
CCDFGF	8.02	ccdfgf	9/16/2024

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Code	Version	Executable	Build Date
CCDFVECTORSTATS	1.02	ccdfvectorstats	8/19/2020
CUTTINGS_S	6.04	cuttings_s	11/13/2020
DTRKMF	2.00	dtrkmf	9/25/2024
EPAUNI	1.21	epauni	2/9/2024
GENMESH	6.11	genmesh	8/20/2020
GROPECDB	2.14	gropecdb	6/16/2020
ICSET	2.24	icset	8/20/2020
LHS	3.00	lhs	11/1/2021
MATSET	9.25	matset	9/8/2020
MODFLOW6	6.2.2	modflow6	5/16/2022
NUTS	2.08	nuts	11/16/2021
PANEL	5.03	panel	4/24/2024
POSTBRAG	4.03	postbrag	9/8/2020
POSTSECOTP2D	1.06	postsecotp2d	8/17/2020
POSTLHS	4.12	postlhs	9/17/2020
PREBRAG	9.01	prebrag	8/20/2020
PRECCDFGF	3.01	preccdfgf	7/28/2022
PRELHS	2.46	prelhs	8/29/2022
PRESECOTP2D	1.25	presecotp2d	1/25/2023
RELATE	1.46	relate	8/20/2020
SCREEN_NUTS	1.03	screen_nuts	8/19/2020
SECOTP2D	1.44	secotp2d	8/20/2020
STEPWISE	2.23	stepwise	10/28/2020
SUMMARIZE	3.03	summarize	8/17/2020

7 Special Considerations

None.

8 Applicable Procedures

All applicable WIPP QA procedures will be followed when conducting these analyses.

- Training of personnel will be conducted in accordance with the requirements of NP 2-1, *Qualification and Training*.
- FEPs assessment will be conducted according to SP 9-4, *Performing FEPs Impact Assessment for Planned or Unplanned Changes*.
- Analyses will be conducted and documented in accordance with the requirements of NP 9-1, *Analyses*.

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- All software used will meet the requirements laid out in NP 19-1, *Software Requirements* and NP 9-1, as applicable.
- The analyses will be reviewed following NP 6-1, *Document Review Process*.
- All required records will be submitted to the WIPP Records Center in accordance with NP 17-1, *Records*.
- New and revised parameters will be created as discussed in NP 9-2, *Parameters.*

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