Summary of the Panel Closure Redesign and Repository Reconfiguration Performance Assessment (PC3R PA)

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Topics and Take-Aways

- Evolution of repository and panel closure representations in PA
  - Baseline repository representation has changed significantly since the CCA
  - Many prior analyses have looked specifically at panel closure impacts
  - Brine migration occurring between repository regions is much lower now than in the CCA or PAVT

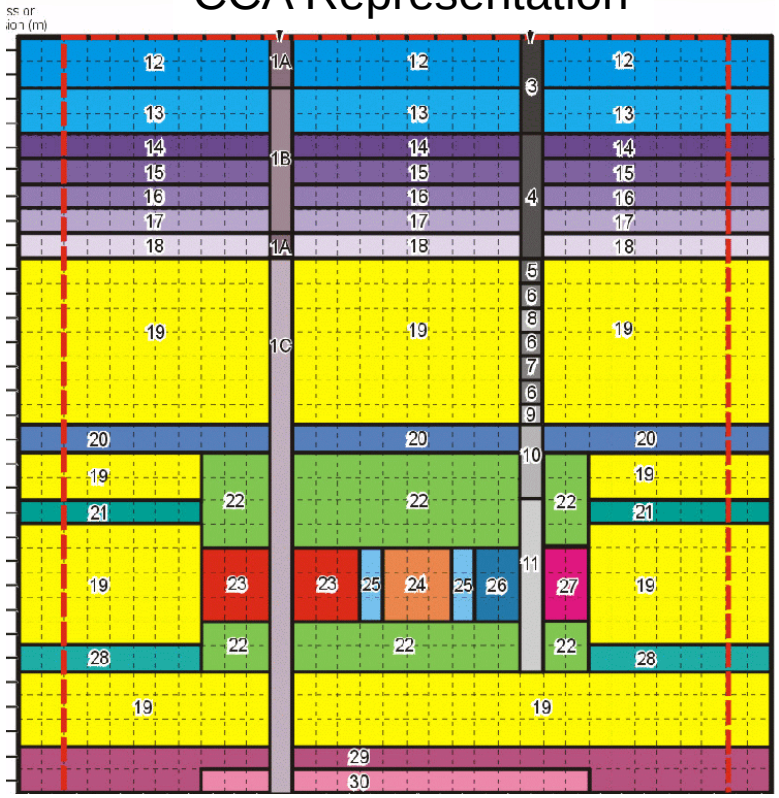
- PC3R PA
  - Parameter changes are consistent with current baseline and prior analyses
  - Grid changes are consistent with proposed repository configuration changes
  - Intrusion impacts are effectively isolated to the intruded region
  - Restricting drilling intrusions to only waste-containing regions is conservative
  - The reconfigured repository with redesigned panel closures satisfies regulatory compliance requirements

PA Repository and Panel Closure Evolution

CCA

The representation of panel closures and the WIPP repository in PA has continually evolved since the CCA. Regulatory compliance has always been met.

CCA Representation



- Waste area represented as two regions
- Panel closures and the DRZ assigned equal, constant permeabilities of $1x10^{-15}$ m^2
- Waste area permeabilities of ~ $1x10^{-13}$ m^2
- Conc_Mon permeabilities of $1x10^{-14}$ m^2
- Ops/Exp permeabilities of $1x10^{-11}$ m^2 constant 18% porosity

- Compliance Met

1. Borehole (first 200 years)
   1A. Borehole concrete plug
   1B. Upper unrestricted borehole
   1C. Lower unrestricted borehole
2. Shaft
3. Earth fill
4. Rustler compacted clay column
5. Asphalt
6. Concrete
7. Crushed salt (compacted salt column)

Boundary of accessible environment

8. Upper Salado compacted clay column
9. Lower Salado compacted clay column
10. Lower clay component
11. Concrete monolith
12. Units above the Dewey Lake
13. Dewey Lake
14. Forty-niner
15. Magenta
16. Tamarisk
17. Culebra
18. Unnamed lower Member
19. Impure halite

20. MB138
21. Anhydrite layer a and b
22. Disturbed rock zone
23. Waste panel
24. Rest of repository
25. Panel closures
26. Operation region
27. Experimental area
28. MB139
29. Castile
30. Brine reservoir

CCA-013-2

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PAVT

The PAVT was performed following submission of the CCA PA. It used the CCA repository representation with some parameters modified by EPA.

- DRZ permeability changed from constant value ($1x10^{-15}$ m^2) to uniform distribution ranging from $1x10^{-19.4}$ m^2 to $1x10^{-12.5}$ m^2
- No changes made to panel closure permeabilities (1×10^{-15} m^2)
- Waste area permeabilites changed slightly, but kept on same order (~ 10^{-13} m^2)

Compliance met with no significant difference in releases due to panel closure impacts when compared to CCA results.

2002 Panel Closure Impact Assessment

Following the PAVT, a panel closure impact assessment was performed in 2002. The goal was to assess the impact of panel closure characteristics on repository performance.

- Used the same BRAGFLO grid and material map as in the CCA and PAVT
- First implementation of "Option D" in WIPP PA (effective properties)
- Used the same DRZ representation as developed in the PAVT
- Compared repository performance with Option D to generic closures implemented in the CCA and PAVT.

Property	PAVT Value	Option D Value
Permeability (X-direction)	1×10^{-15} m^2	9.01×10^{-19} m^2
Permeability (Y-direction)	1×10^{-15} m^2	1.93×10^{-13} m^2
Permeability (Z-direction)	1×10^{-15} m^2	1.93×10^{-13} m^2
Porosity	0.075	0.15

The two panel closure cases produced nearly identical distributions of total normalized releases, as well as nearly identical distributions for each release component.

Technical Baseline Migration (TBM) 2002 - 2003

The TBM PA was conducted to incorporate several changes to the Technical PA Baseline in a single analysis and was vetted via peer review.

- Repository configuration in BRAGFLO was refined to allow for adequate representation of Option D and its individual components
  - Material DRF_PCS was introduced to represent drift portion and explosion wall of Option D (assigned properties corresponding to waste area)
  - Option D concrete monolith represented by material CONC_PCS (assigned properties corresponding to CCA shaft material CONC_T1)
  - Material DRZ_PCS was introduced to represent DRZ region above the Option D concrete monolith (assigned permeability range corresponding to CONC_PCS)

- Rest-of-repository region implemented since CCA was split into southern and northern regions – waste area represented by three regions in BRAGFLO grid

The TBM and PAVT produced nearly identical distributions of total normalized releases. Repository compliance not affected by panel closure property changes.

Panel Closure Redesign Impact Assessment (2006)

Changes developed during the TBM were incorporated into the CRA-2004. Following EPA approval of the CRA-2004, an impact assessment was performed to quantify impacts of replacing Option D with a redesigned panel closure.

- Redesigned panel closure consisted of a 30 foot concrete block wall and 100 feet run-of-mine salt.
- Utilized the PABC-2004 repository representation with a modified material map.
- Panel closures modeled as having short-term and long-term characteristics.
  - Modeled by materials PCS_T1 and PCS_T2
  - Short-term properties (material PCS_T1) dominated by concrete component
  - Long-term properties (material PCS_T2) dominated by salt component
- DRZ above the panel closure modeled as having short and long-term properties for consistency with panel closure properties and the PABC-2004 implementation.
- Results were compared to the PABC-2004.

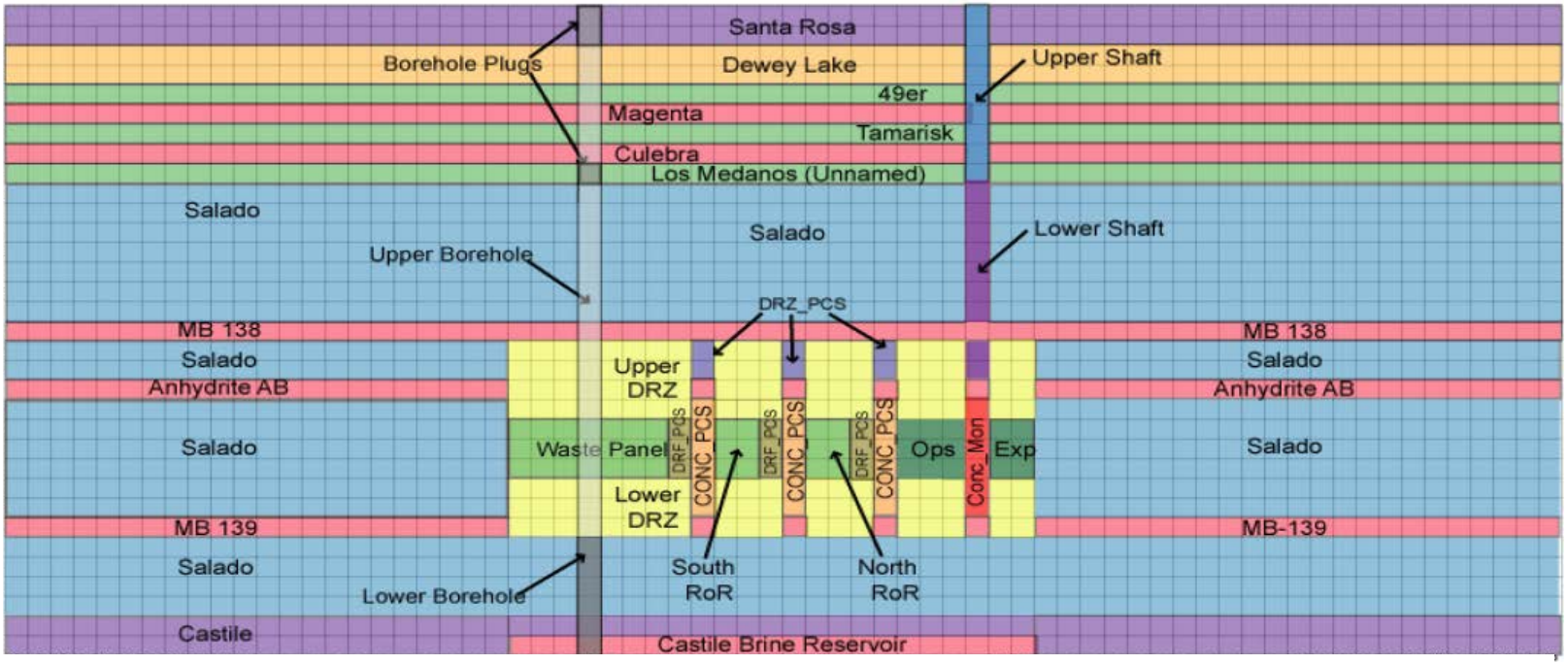
Total normalized releases remained an order of magnitude below release limits, with changes observed between the two analyses attributed to changes in DBRs.

Current Baseline (PABC-2009)

The current repository representation incorporates many refinements developed after the CCA, particularly in the TBM.

- Waste region split into three regions in BRAGFLO
- Option D panel closures implemented with modeled components
- DRZ above panel closures given same permeability range as panel closure concrete
  - sampled from triangular distribution with min = $1x10^{-20.699}$ m^2 and max = $1x10^{-17.0}$ m^2
- Remaining DRZ permeability sampled from uniform distribution with min = $1x10^{-19.4}$ m^2 and max = $1x10^{-12.5}$ m^2
- Waste Area permeability assigned constant value of ~ $1x10^{-12.62}$ m^2
- OPS and EXP area assigned constant permeability and porosity
  - permeability of $1x10^{-11}$ m^2
  - 18% porosity
  - Values established in CCA and used in every certification calculation since then

PABC-2009 Repository Representation



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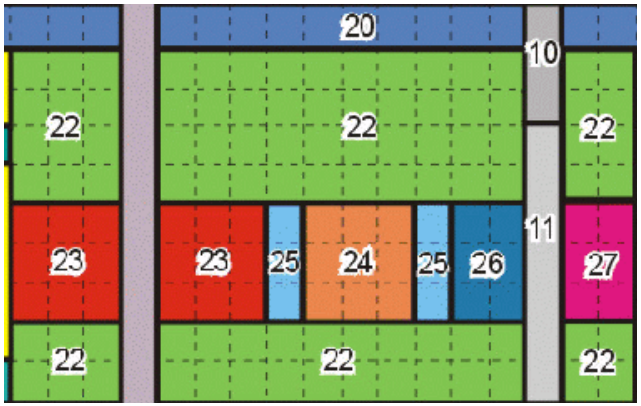
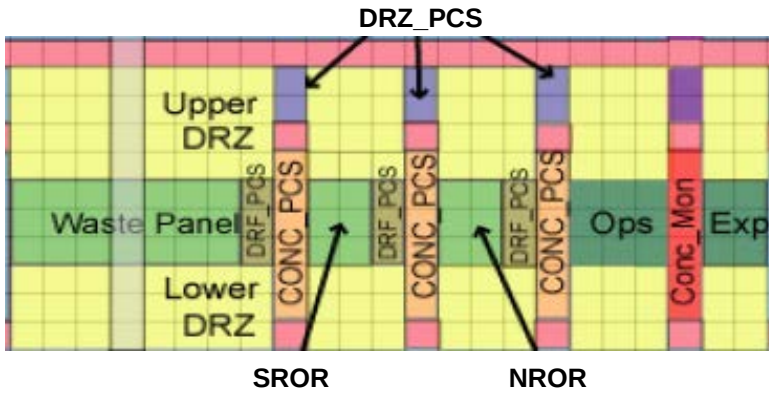
Important Comparisons



CCA

- 2 Waste Areas
- “Generic” Panel Closures with DRZ permeabilites
- No impact of panel closure on DRZ



PABC-2009

- 3 Waste Areas
- Option D Panel Closures with individual elements modeled
- DRZ healing above panel closures
  - assigned same permeability range as Option D concrete

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PC3R PA

PC3R PA (2011)

Following EPA approval of the CRA-2009, a performance assessment was done to quantify impacts of replacing Option D with a redesigned panel closure and relocating waste panels 9 and 10.

Informing results from prior analyses:

- Previous analyses have shown that panel closure properties do not significantly impact compliance results.
- Previous analyses have incorporated changes to panel closure and repository configuration representations simultaneously with no significant impact to compliance results.

Conclusions drawn from the PC3R PA:

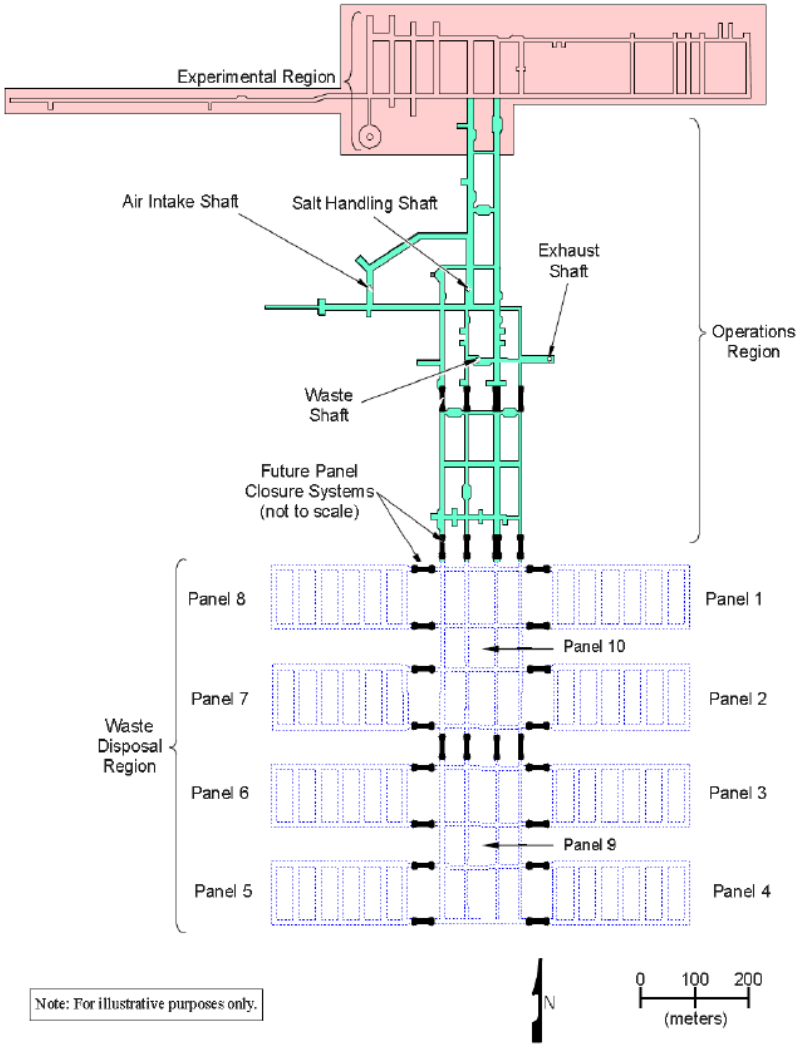
- The panel closure and repository configuration changes investigated in the PC3R PA do no significantly impact compliance results when compared to the current baseline (PABC-2009).

Scope

The PC3R PA investigates potential impacts to WIPP long-term performance due to proposed repository changes (panel closure redesign and repository reconfiguration).

- Panel closure and repository reconfiguration impacts addressed in a single PA
- PC3R results compared to PABC-2009 results (current baseline)
- Parameter sets and computational grids modified from PABC-2009 versions to be consistent with redesigned closures and proposed repository layout.

Current WIPP Configuration



- Option D Panel Closures
- Panels 9 and 10 in central drift area
- Waste panels isolated from each other by at least one panel closure

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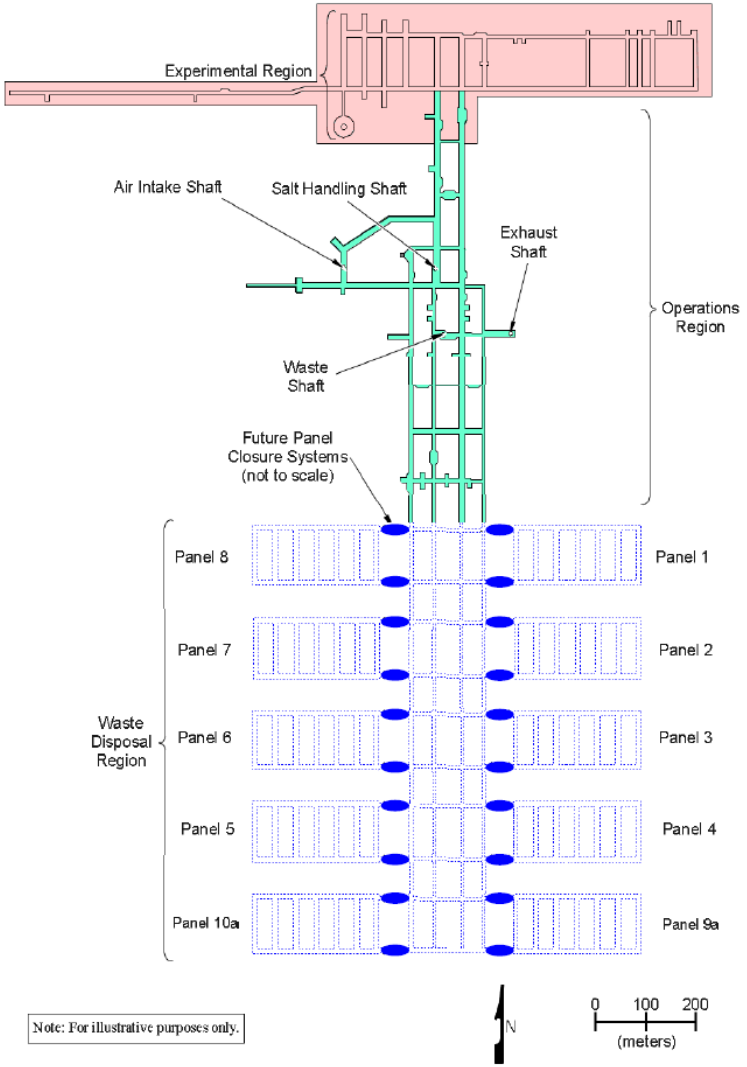
Proposed WIPP Configuration



- Redesigned panel closures
- Panels 9 and 10 removed from central mains area and relocated south of panels 4 and 5
- Waste panels isolated from each other by two panel closures
- Waste panels isolated from non-waste regions by one panel closure

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PC3R PA Panel Closures

Option D replaced with a redesign consisting of 100 feet run-of-mine salt.

- Redesigned Panel Closures assigned short-term and long-term properties

  - Redesigned Panel Closures modeled by two materials, PCS_T1 and PCS_T2
  - Short-term duration defined by length of time necessary for the porosity of run-of-mine salt to fall below 5% → PCS_T1 implemented for first 100 years
  - PCS_T2 implemented for remaining 9,900 years

- DRZ above and below panel closures assigned short-term and long term properties for consistency with panel closure time dependence and panel closure implementation since the TBM

  - DRZ unaffected for first 100 years
  - DRZ assigned PCS_T2 properties for remaining 9,900 years

Panel Closure Parameters (First 100 Years)

PC3R

PCS_T1	**Permeability (m^2)**	**$1x10^{-11}$**
	Porosity	**0.33**
DRZ_PCS	**Permeability (m^2)**	**Uniform with Min = $1x10^{-19.4}$ Max = $1x10^{-12.5}$**
	Porosity	**Cumulative with Min = 0.0039 Max = 0.0548**

No impact of PC3R Panel Closure on DRZ during first 100 years.

PABC-2009

CONC_PCS	**Permeability (m^2)**	**Triangular with Min = $1x10^{-20.669}$ Max = $1x10^{-17}$**
	Porosity	**0.05**
DRZ	**Permeability (m^2)**	**Uniform with Min = $1x10^{-19.4}$ Max = $1x10^{-12.5}$**
	Porosity	**Cumulative with Min = 0.0039 Max = 0.0548**
DRZ_PCS	**Permeability (m^2)**	**Triangular with Min = $1x10^{-20.669}$ Max = $1x10^{-17}$**
	Porosity	**Cumulative with Min = 0.0039 Max = 0.0548**

Panel Closure Parameters (Last 9,900 Years)

PC3R

PCS_T2	Permeability (m^2) (Developed in 2006 PCS PA)	Triangular with Min = $1x10^{-22.8}$ Max = $1x10^{-17.6}$
	Porosity	0.05
DRZ_PCS	Permeability (m^2)	Triangular with Min = $1x10^{-22.8}$ Max = $1x10^{-17.6}$
	Porosity (Same as PABC-2009)	Cumulative with Min = 0.0039 Max = 0.0548

PABC-2009

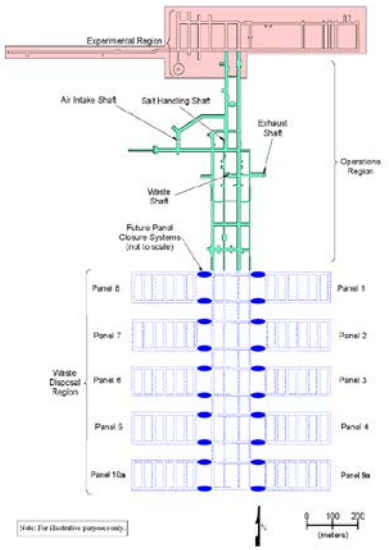
CONC_PCS	Permeability (m^2)	Triangular with Min = $1x10^{-20.669}$ Max = $1x10^{-17}$
	Porosity	0.05
DRZ_PCS	Permeability (m^2)	Triangular with Min = $1x10^{-20.669}$ Max = $1x10^{-17}$
	Porosity	Cumulative with Min = 0.0039 Max = 0.0548

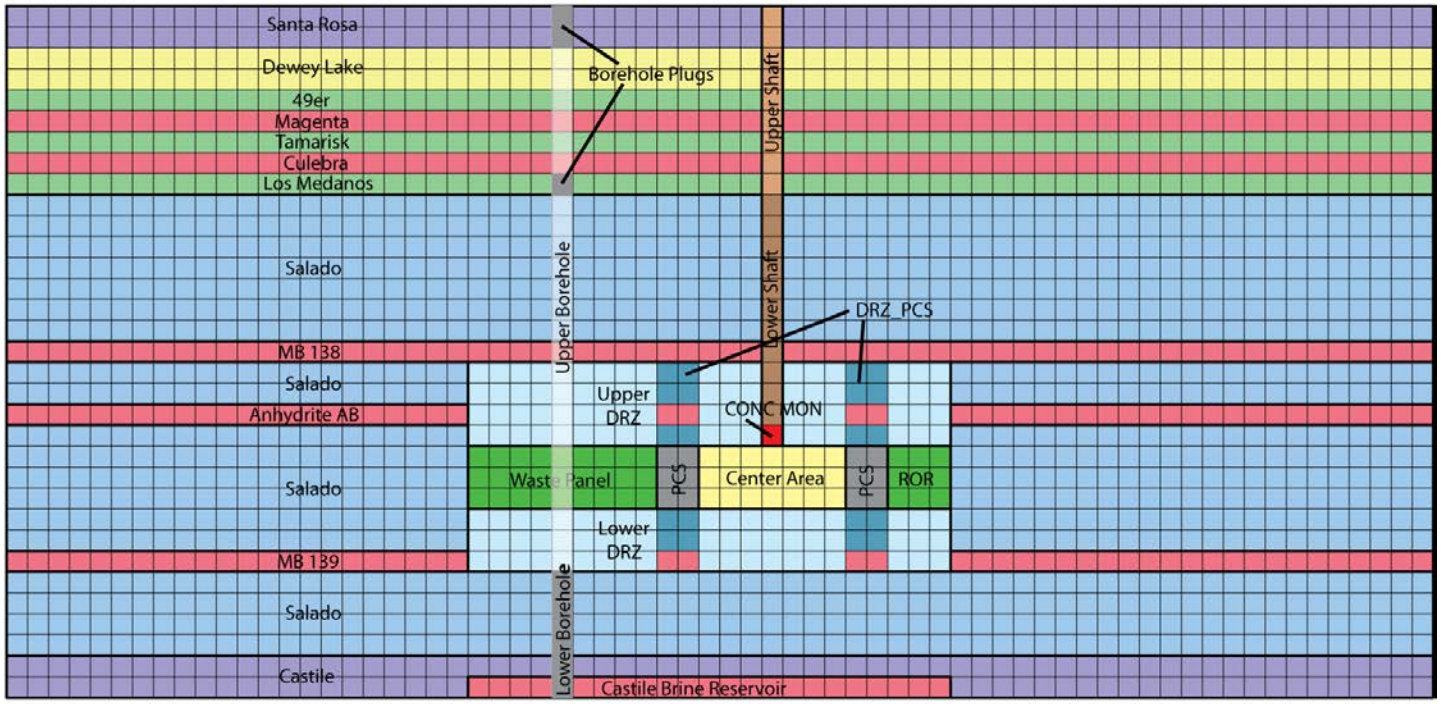
PC3R and PABC-2009

Salado Halite	Permeability (m^2)	Uniform with Min = $1x10^{-24}$ Max = $1x10^{-21}$
	Porosity	Cumulative with Min = 0.001 Max = 0.00519

PC3R PA Repository Representation

In the reconfigured repository, the intruded waste panel (10a) is separated from all other panels by the central mains region.





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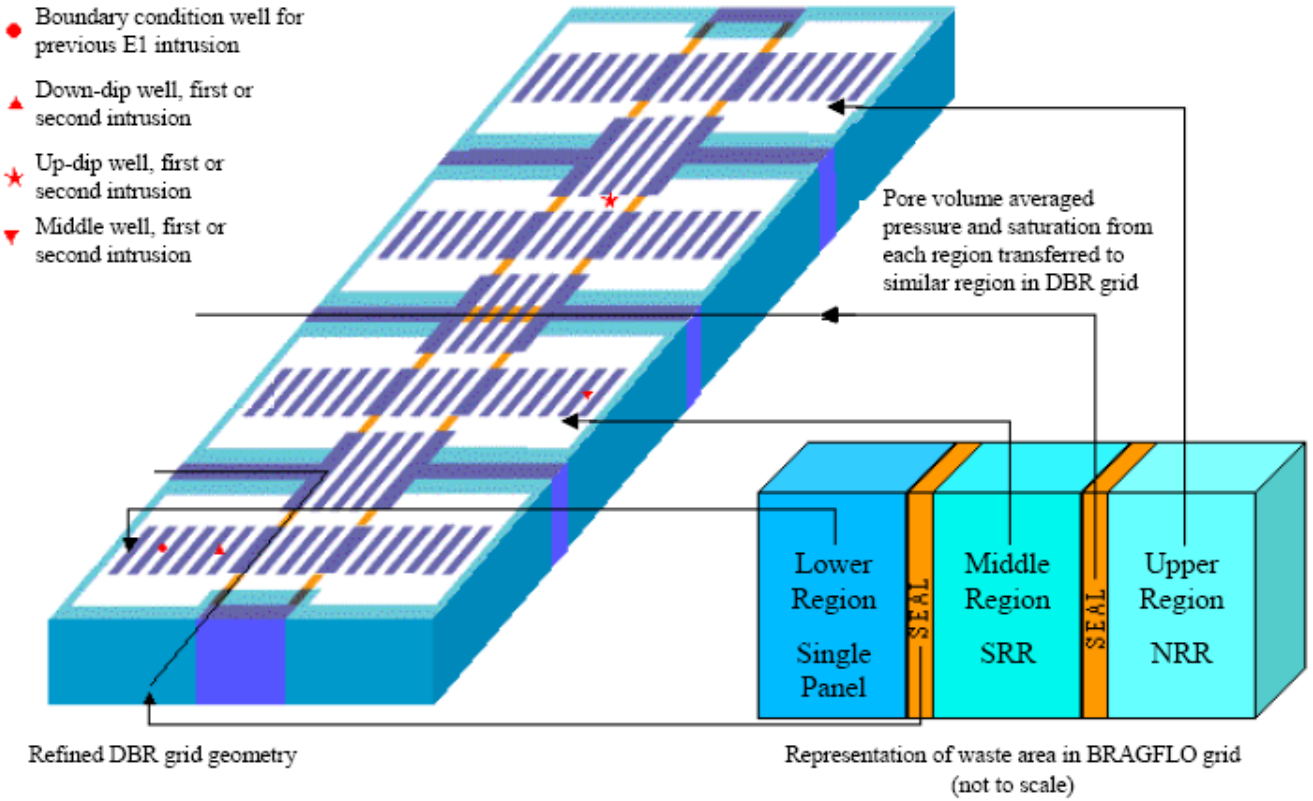
Representation for DBR Calculation (PABC-2009)



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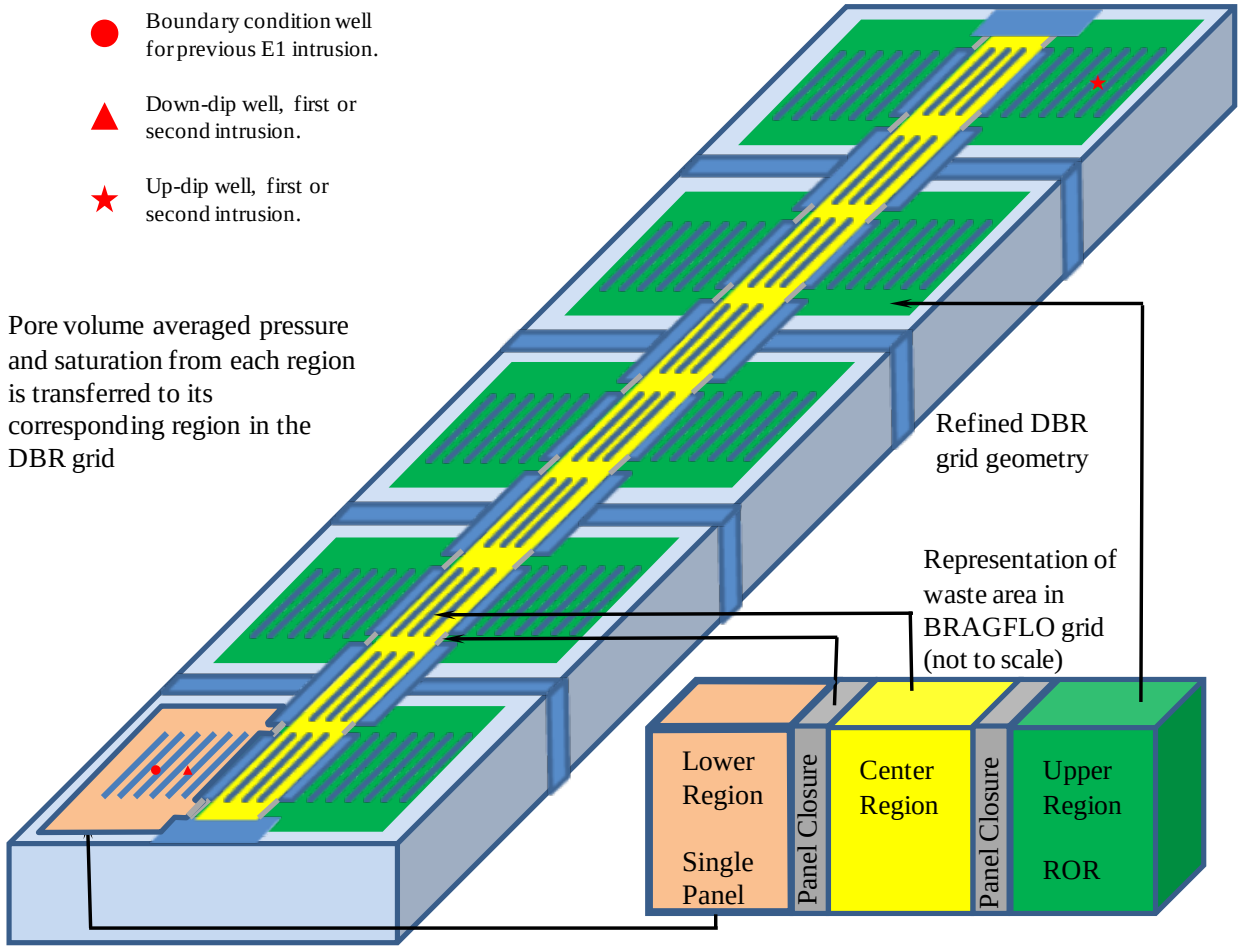
Representation for DBR Calculation (PC3R PA)



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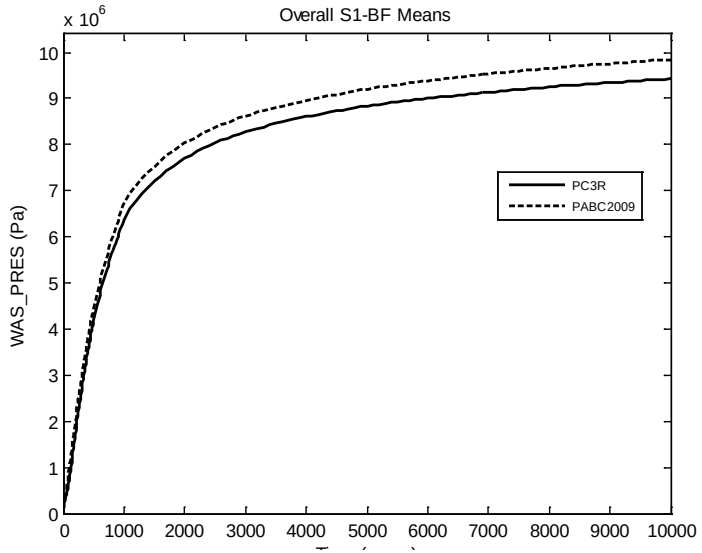
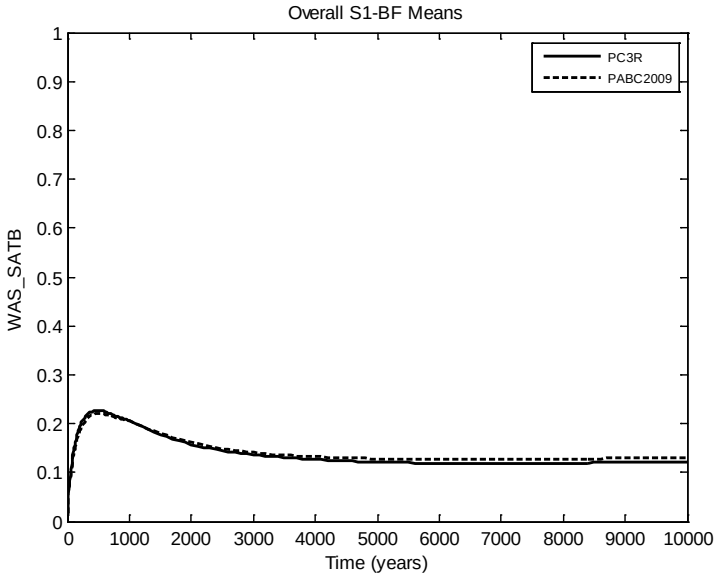
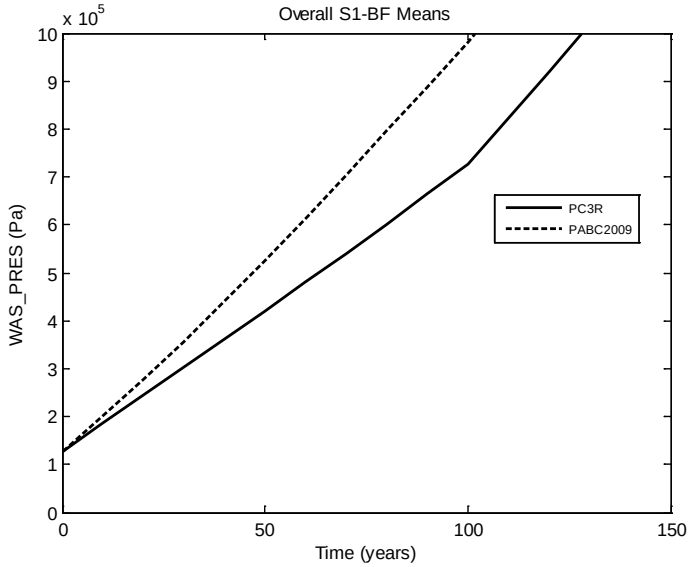
PC3R PA Results

Undisturbed Results







- High permeability of panel closure allows panel pressure venting during first 100 years.
- Low pressure (large volume) in central region also contributes to pressure reduction in panel.
- Impact to panel brine saturation is minor.

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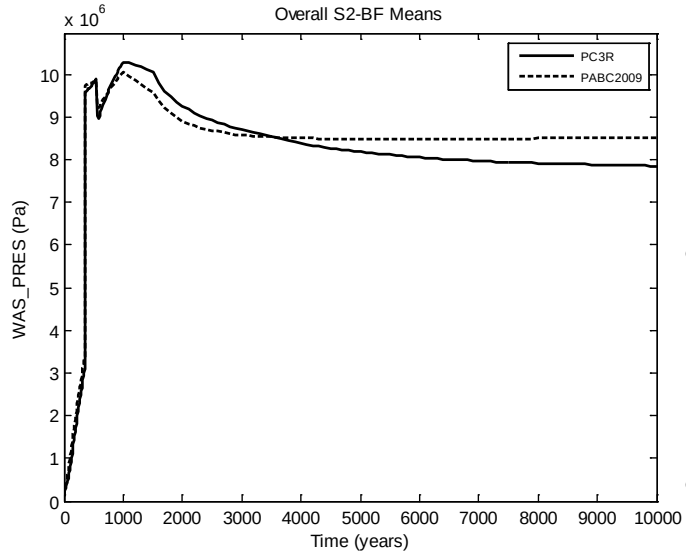
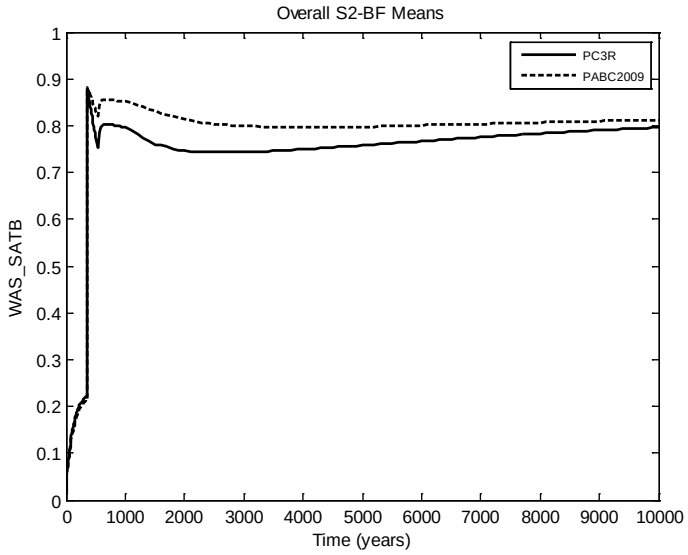
Results for an E1 Intrusion at 350 Years





- Low permeability of panel closure after 100 years results in increased pressurization of panel for a period of time after intrusion.
- Increased pressure reduces (on average) the volume of brine and resulting brine saturation in the panel.
- Reduced brine saturation, and consequently gas generation, yields long-term reduction in panel pressure. Low pressure (large volume) in center area also contributes to pressure reduction.

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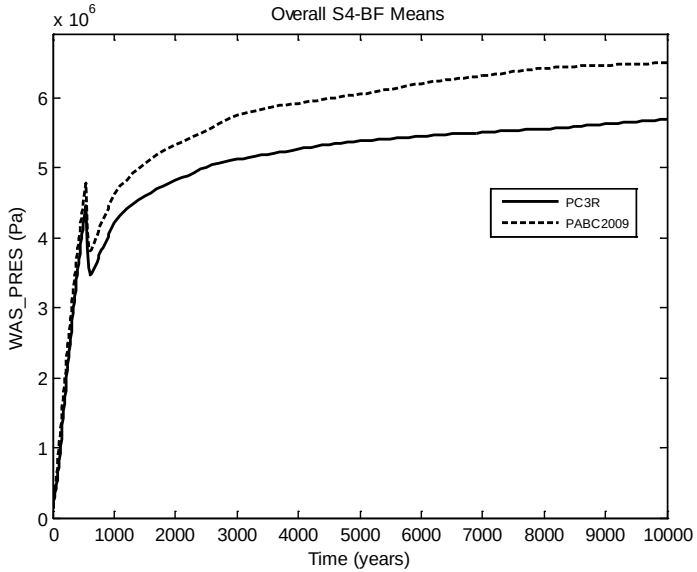
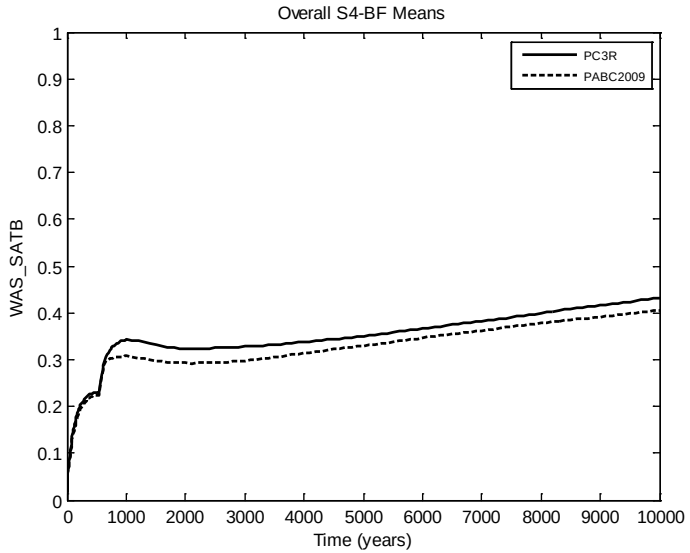
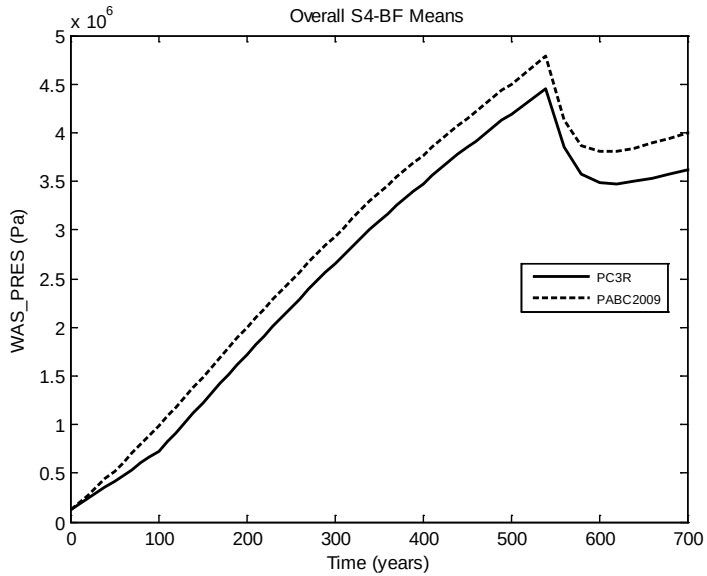
Results for an E2 Intrusion at 350 Years







- High permeability of panel closure allows panel pressure venting during first 100 years.
- Low pressure (large volume) in center region also contributes to pressure reduction in panel.
- Pressure reduction yields slight increase in panel brine saturation.

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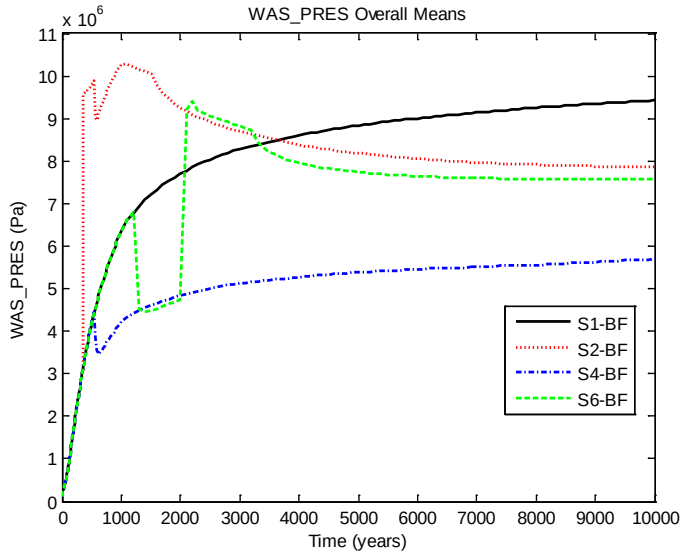
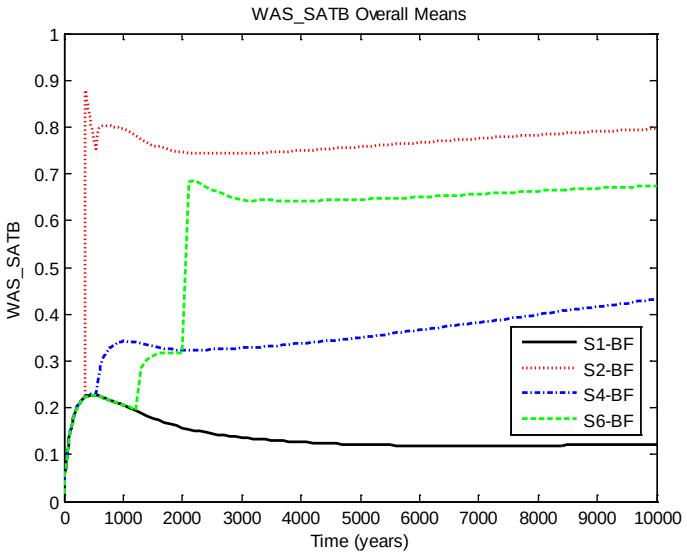
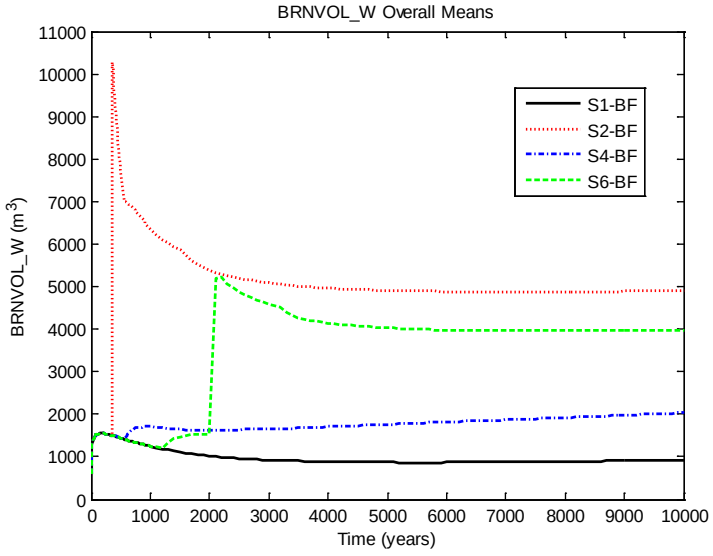
Variability in Intruded Region







- Mean pressure varies greatly over all scenarios, from 0 MPa to over 10 MPa.
- Mean brine volume varies from less than 1000 m^3 to over 10,000 m^3.
- Mean brine saturation varies from zero to almost fully saturated.

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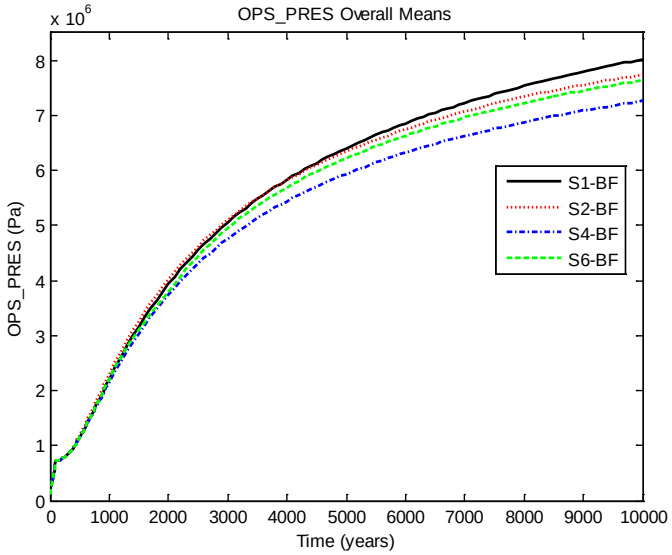
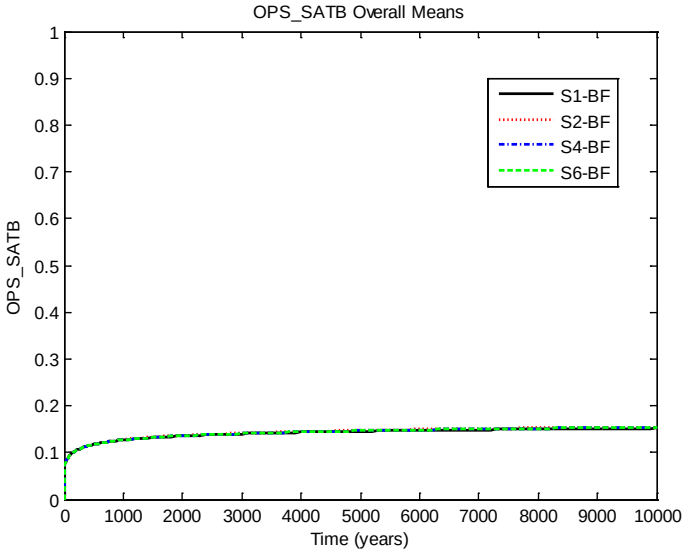
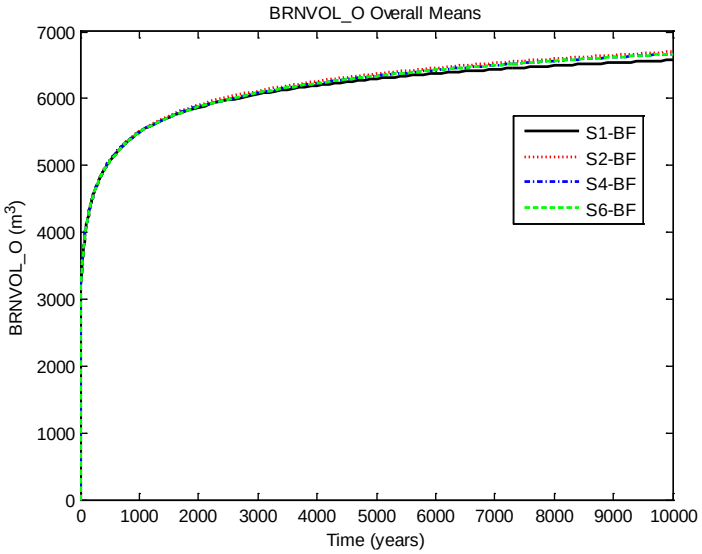
Variability in Region Across Panel Closure (Central Mains Area)







- Mean pressure in central area is reduced as compared to undisturbed conditions.
- Mean brine volume in central area is nearly identical to undisturbed case for all scenarios.
- Mean brine saturation in central area is nearly identical to undisturbed case for all scenarios.

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Panel Closure Isolation of Intrusion Impacts

A drilling intrusion on one side of a panel closure results in:

- An eventual slight reduction in pressure in the region opposite the closure
- No consequential change to brine volume or saturation in the region opposite the closure

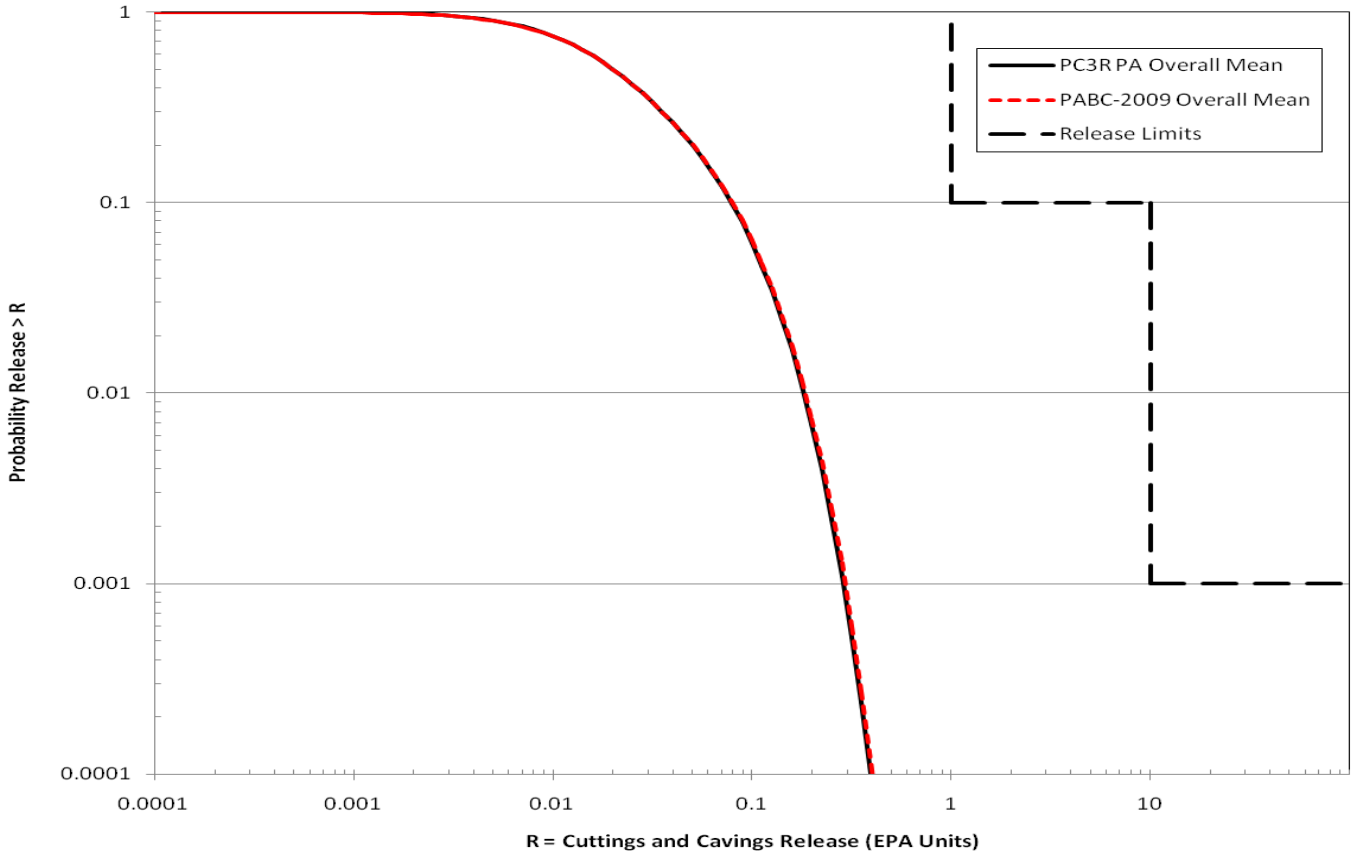
A drilling intrusion into the central drift region will result in:

- Zero cuttings and cavings releases, zero spallings releases, and a possible release of brine present in undisturbed conditions
- Zero change to cuttings and cavings releases from the waste area
- A reduction in pressure in the waste area (spallings reduced slightly)
- Practically no change to brine saturation in the waste area (DBRs reduced)

  - A reduction in total normalized releases from a waste panel intrusion

Restricting drilling intrusions to only waste-containing regions is conservative.

Cuttings and Cavings



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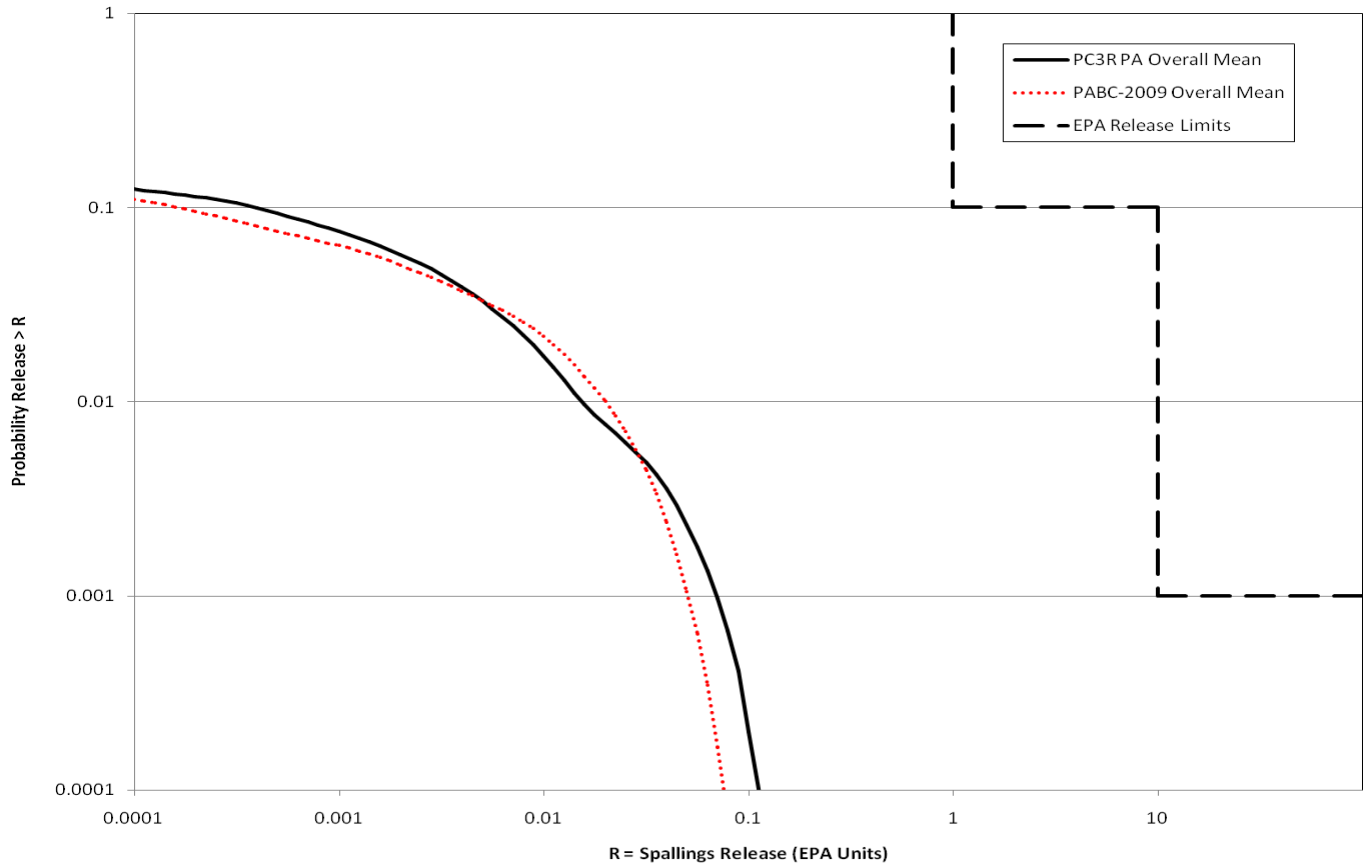
Spallings



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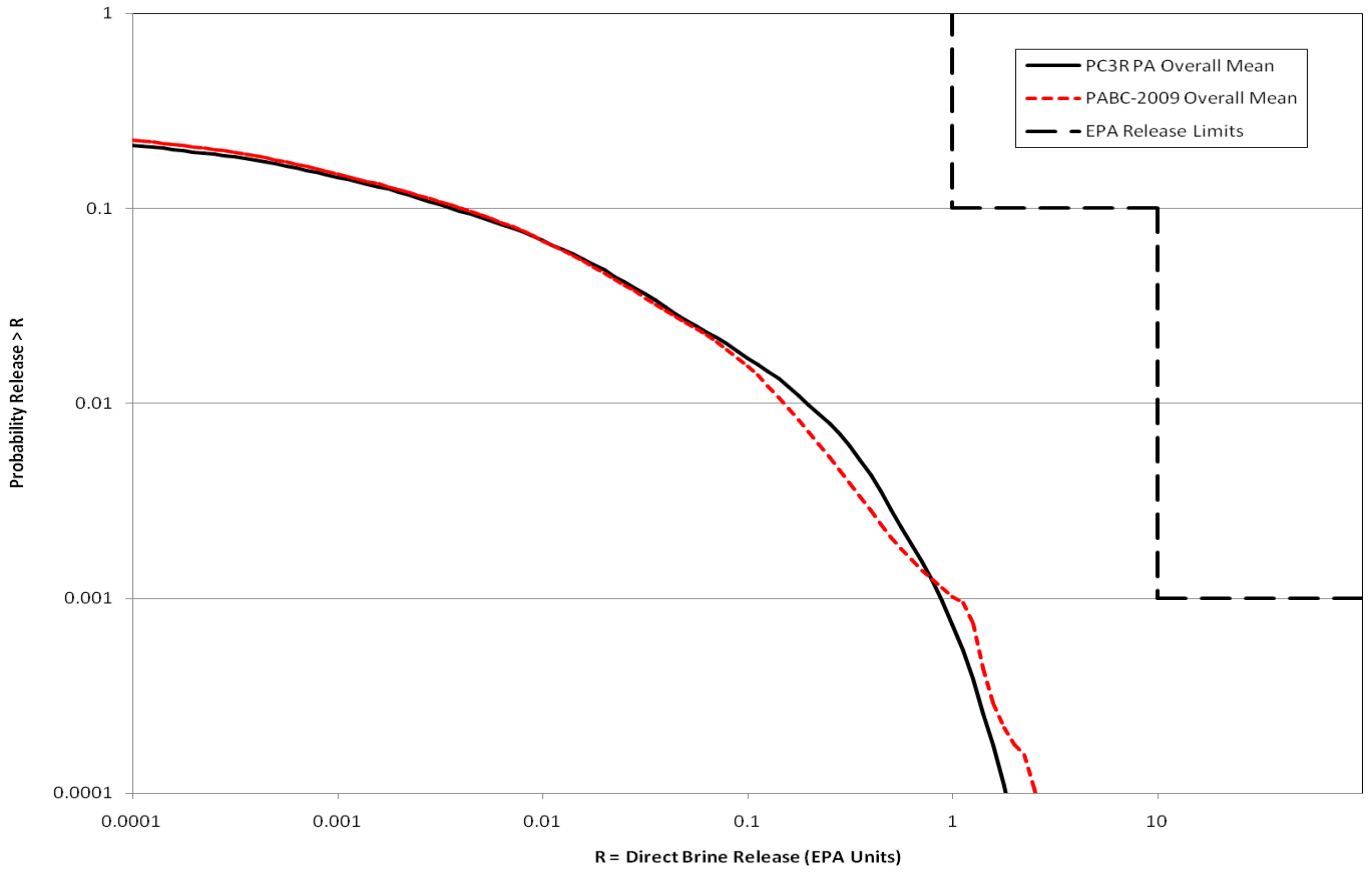
DBRs



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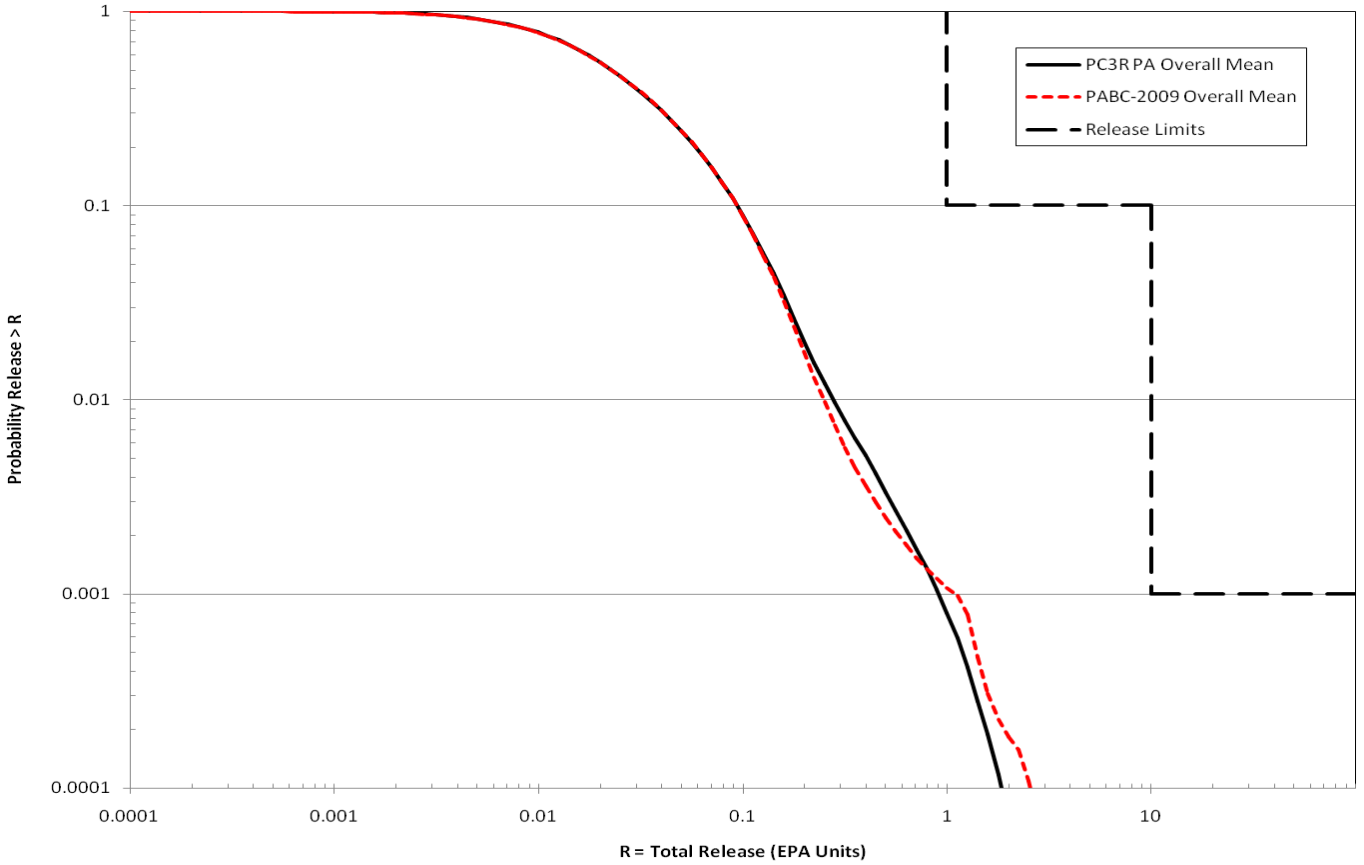
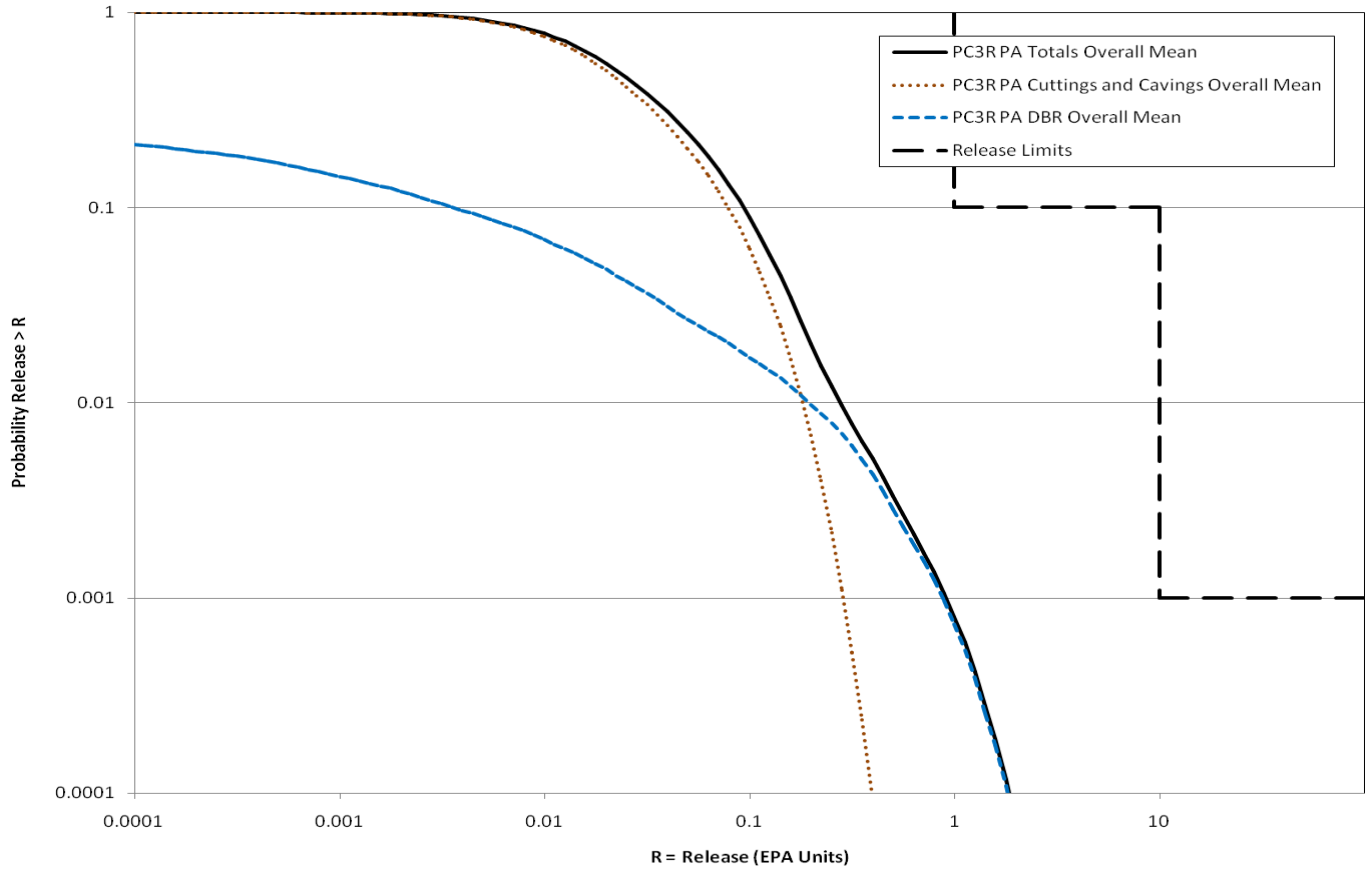
Total Normalized Releases



Probability	Analysis	Mean Total Release	90th Percentile	Lower 95% CL	Upper 95% CL	Release Limit
0.1	PC3R PA	0.09	0.16	0.09	0.10	1
	PABC-2009	0.09	0.16	0.09	0.10	1
0.001	PC3R PA	0.89	1.00	0.34	1.41	10
	PABC-2009	1.10	1.00	0.37	1.77	10

Primary Release Components



Releases Dominated by Cuttings & Cavings and DBRs

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PC3R PA Summary

- The reconfigured repository with redesigned panel closures meets regulatory compliance requirements.
- Total releases are dominated by Cuttings & Cavings and DBRs (same as PABC-2009).
- Redesigned panel closures effectively isolate intrusion impacts to area being intruded.
- A drilling intrusion into the center mains area can only reduce releases from intrusions into the waste area with no releases resulting from center intrusion. Restricting drilling intrusions to only waste-containing regions is conservative.