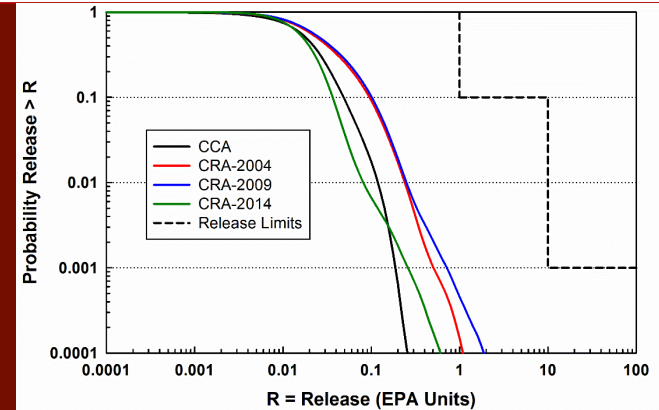
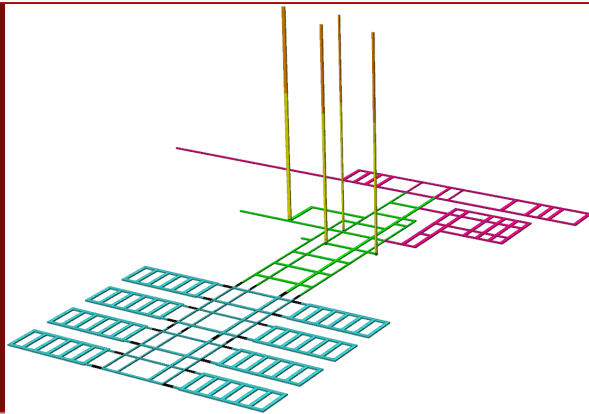


Exceptional service in the national interest



WIPP Performance Assessment: Surplus Pu Disposition

National Academies of Sciences, Engineering, and Medicine's (NASEM's)
Committee on the Disposal of Surplus Plutonium in the Waste Isolation Pilot Plant
April 16th, 2019

Sean Dunagan, Brad Day, and Todd R. Zeitler



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SAND2019-4067PE

- WIPP Regulatory Requirements and Performance Assessment
 - WIPP Regulations
 - WIPP PA Framework
 - Release Mechanisms Considered in WIPP PA
 - Regulatory Compliance Metric
- Abandonment of Panel Closures in South (APCS)
 - APCS Methodology Changes and Implementation
 - APCS Results
- Surplus Plutonium Disposition (SPD) Analysis
 - Overall Approach to SPD PA
 - Added Waste Stream (SR-KAC-SPD)
 - SPD Analysis Results
- Summary

Overall Conclusions

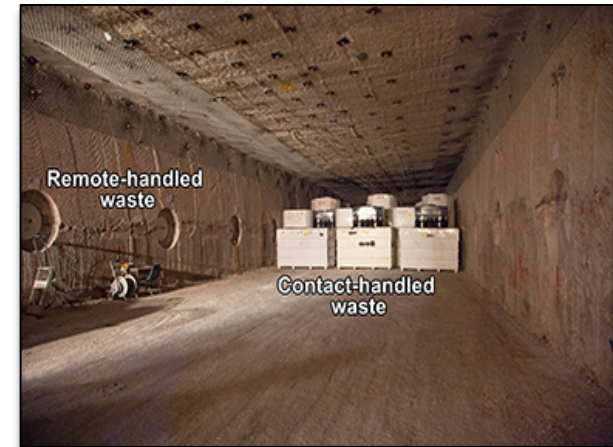
- WIPP has been in compliance since the original certification with considerable margin below the compliance points.
- WIPP PA has been and continues to be updated with changes to the repository, inventory, DOE decisions, etc.
- The impact of the addition of the Surplus Pu inventory on the long-term performance is mixed and has minimal impact with respect to long-term repository performance through the 10,000 year post-closure regulatory time frame.
- The WIPP will continue to comply with the addition of the Surplus Pu

Regulatory Requirements and Performance Assessment

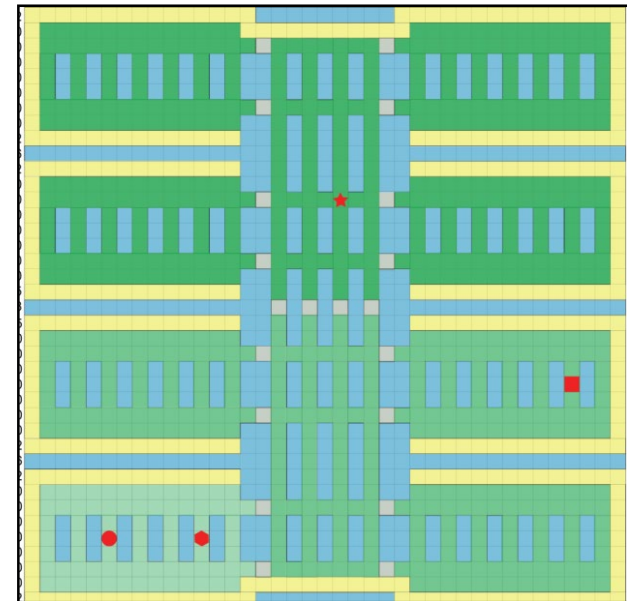
WIPP PA

Long-Term Regulatory Requirements and Criteria

- Regulatory requirements guide the WIPP PA framework.
 - 40 CFR 191: Standards for TRU disposal (SNF and HLW standards also)
 - 40 CFR 194: WIPP-specific rules for certification and re-certification
 - The WIPP must be designed to provide reasonable expectation that cumulative releases of radionuclides to the accessible environment for 10,000 years after closure from all significant processes and events shall be less than specified release limits
- Recertification required every 5 years



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Regulatory Requirements (1)

- Reasonable expectation: Regulations acknowledge substantial uncertainties
- 10,000 years: PA must represent behavior for entire regulatory time period
- Significant processes and events: PA must include all of these, including the possibility of inadvertent human intrusion



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Regulatory Requirements (2)

- Releases are not measured as a dose (e.g., Sv)
- Releases are measured in normalized “EPA units”
- EPA unit is defined in part by total initial inventory
- EPA compliance limits are based on EPA units
- Greater initial inventory allows a greater activity release in Ci

$$R = \sum \frac{Q_i}{L_i} \left(\frac{1 \times 10^6 \text{ curies}}{C} \right)$$

TABLE 1—RELEASE LIMITS FOR CONTAINMENT REQUIREMENTS	
[Cumulative releases to the accessible environment for 10,000 years after disposal]	
Radionuclide	Release limit per 1,000 MTHM or other unit of waste (see notes) (curies)
Americium-241 or -243	100
Carbon-14	100
Cesium-135 or -137	1,000
Iodine-129	100
Neptunium-237	100
Plutonium-238, -239, -240, or -242	100
Radium-226	100
Strontium-90	1,000
Technetium-99	10,000
Thorium-230 or -232	10
Tin-126	1,000
Uranium-233, -234, -235, -236, or -238	100
Any other alpha-emitting radionuclide with a half-life greater than 20 years	100
Any other radionuclide with a half-life greater than 20 years that does not emit alpha particles	1,000

Table from 40 CFR 191

R = Normalized release in “EPA units”

Q_i = 10,000-year cumulative release (in curies) of radionuclide i

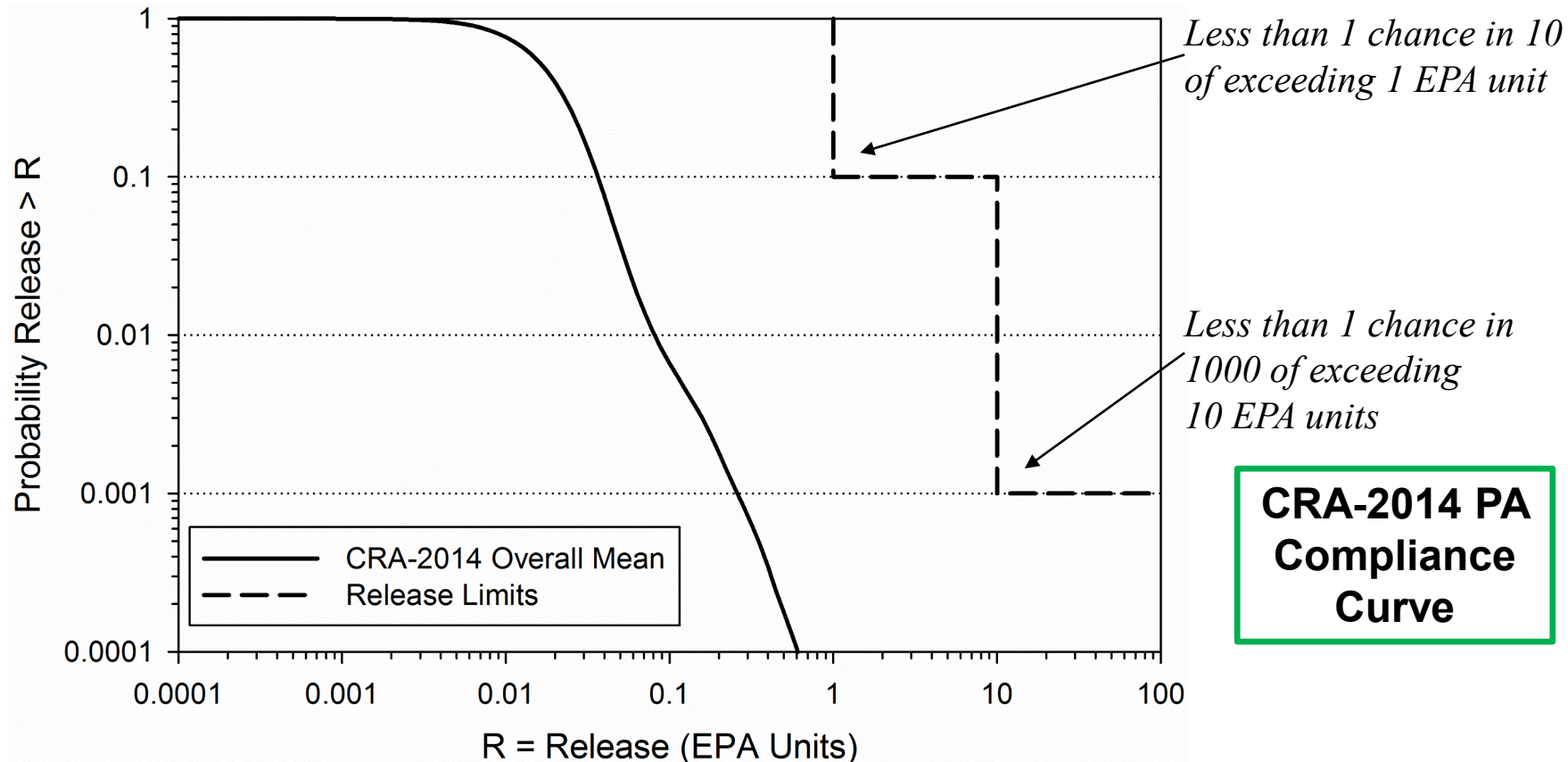
L_i = Release Limit for radionuclide i

C = Total initial transuranic inventory (in Ci of α -emitters w/half-lives > 20 years)



Regulatory Requirements (3)

- Total release mean Complementary Cumulative Distribution Function (CCDF) curve is the measure of compliance
- Releases are compared to regulatory release limits
- Log-Log scale





FEPs and Scenario Development

- Features, events, and processes (FEPs) are screened in/out in PA models
 - If $P(\text{event}) < 10^{-4}$ in 10^4 y, don't consider
 - Low consequence or beneficial FEPs also screened out
 - Also be screened by regulatory mandate
- Potential release scenarios are developed for FEPs that are “screened-in”
- WIPP PA considers multiple scenarios
 - Undisturbed case (base-case)
 - Inadvertent drilling intrusion from the surface
 - Release through high permeability features to the Land Withdrawal Boundary



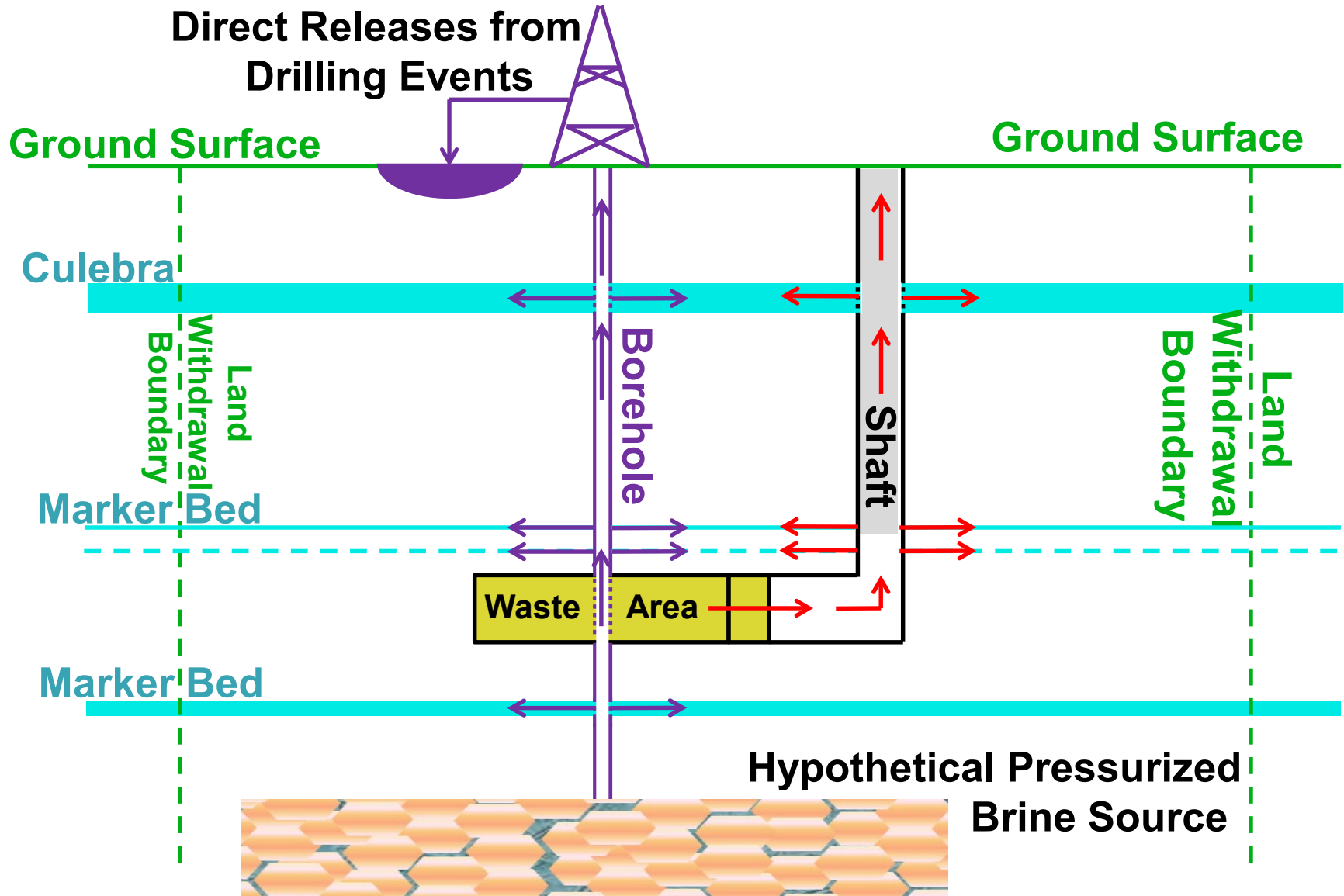
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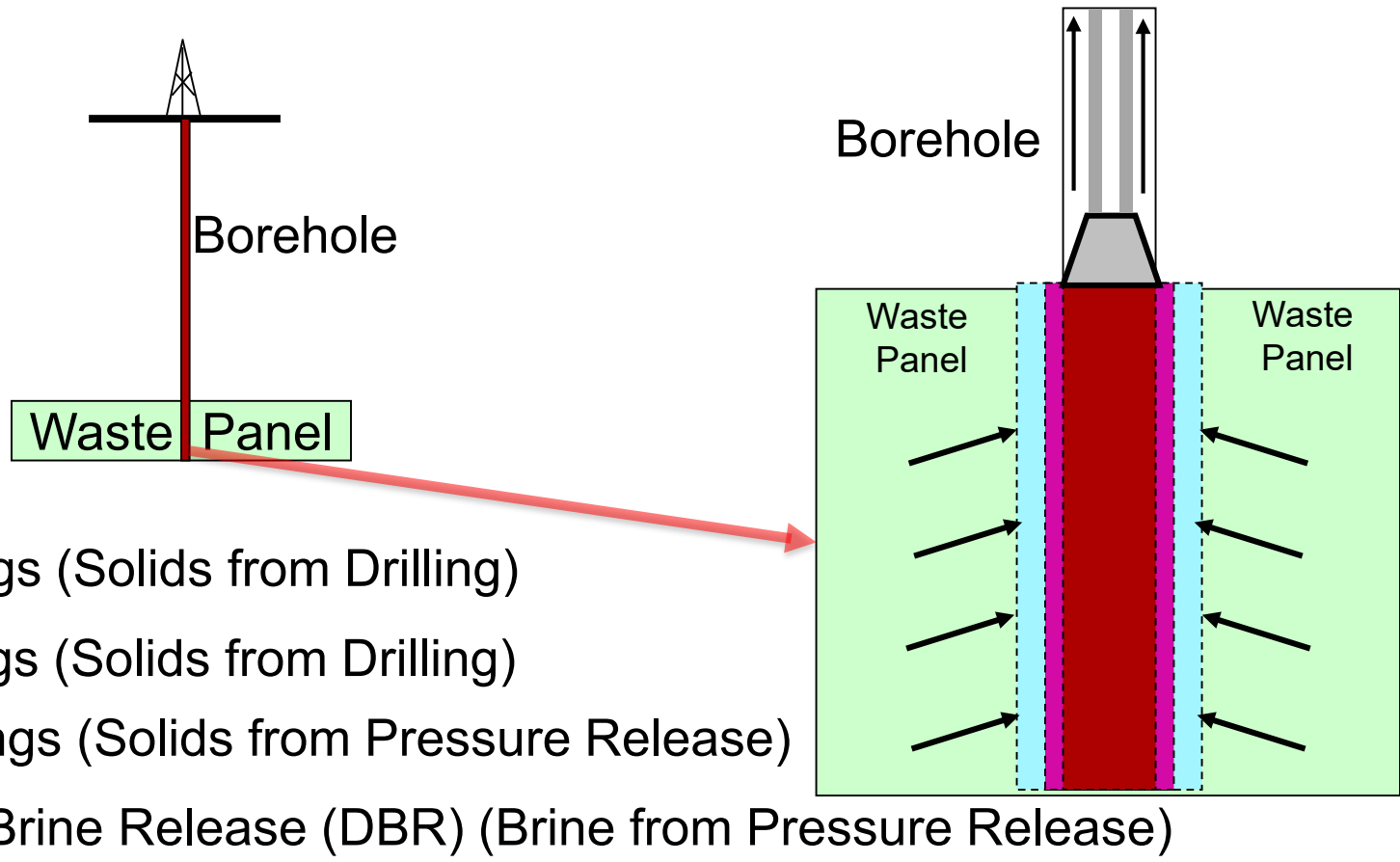
Release Pathways in WIPP PA





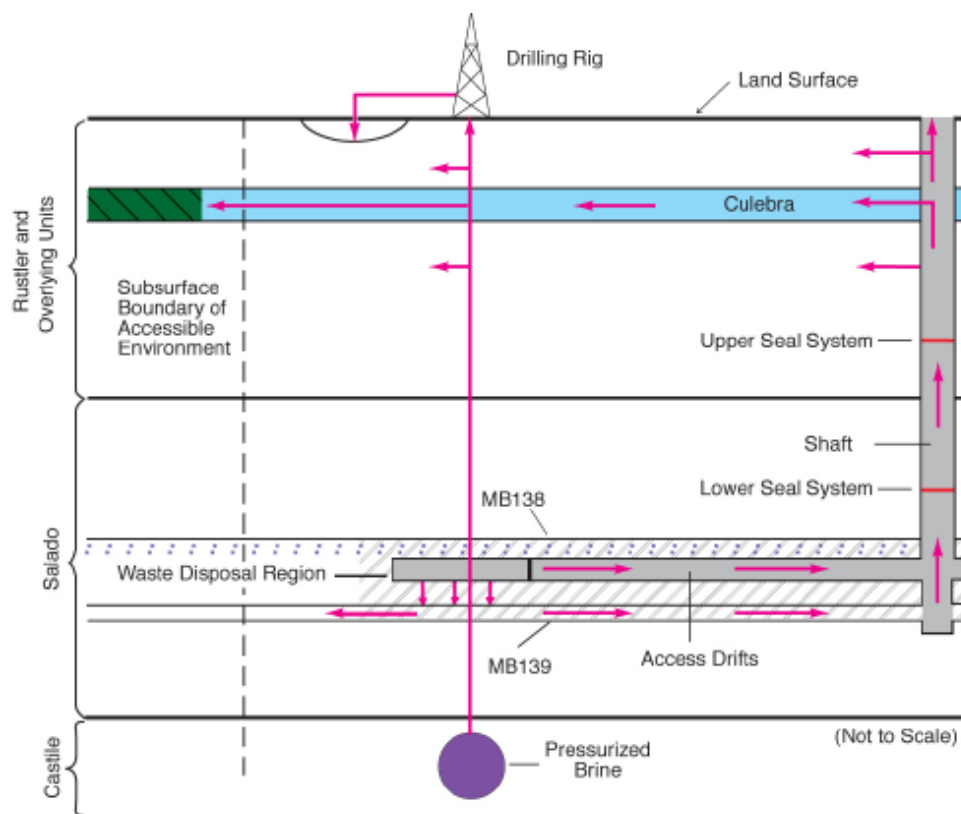
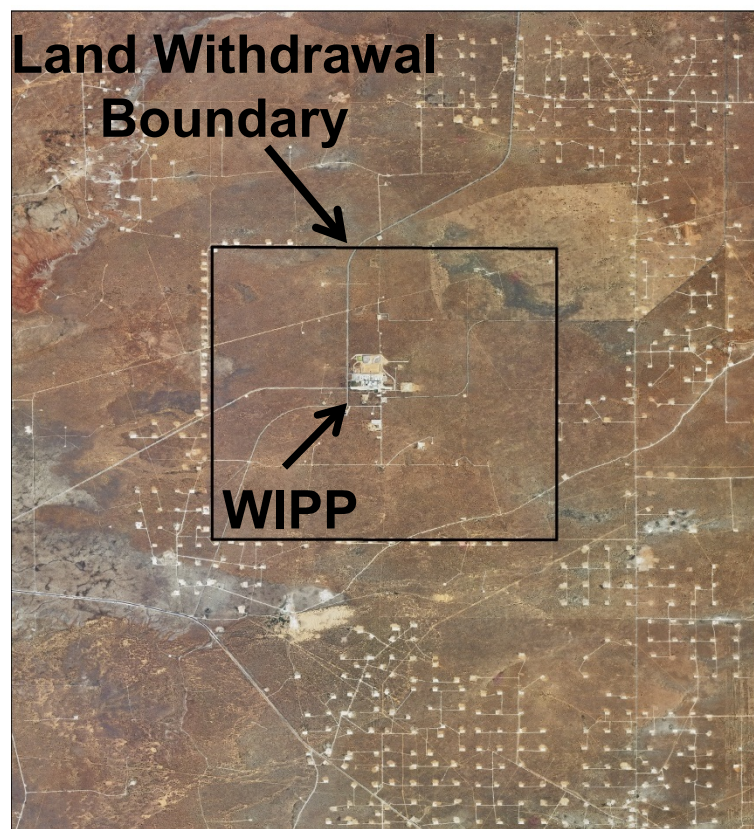
Direct Release Mechanisms

- Direct releases dominate total releases
- Releases due to inadvertent borehole intrusion



Long-term Release Mechanism

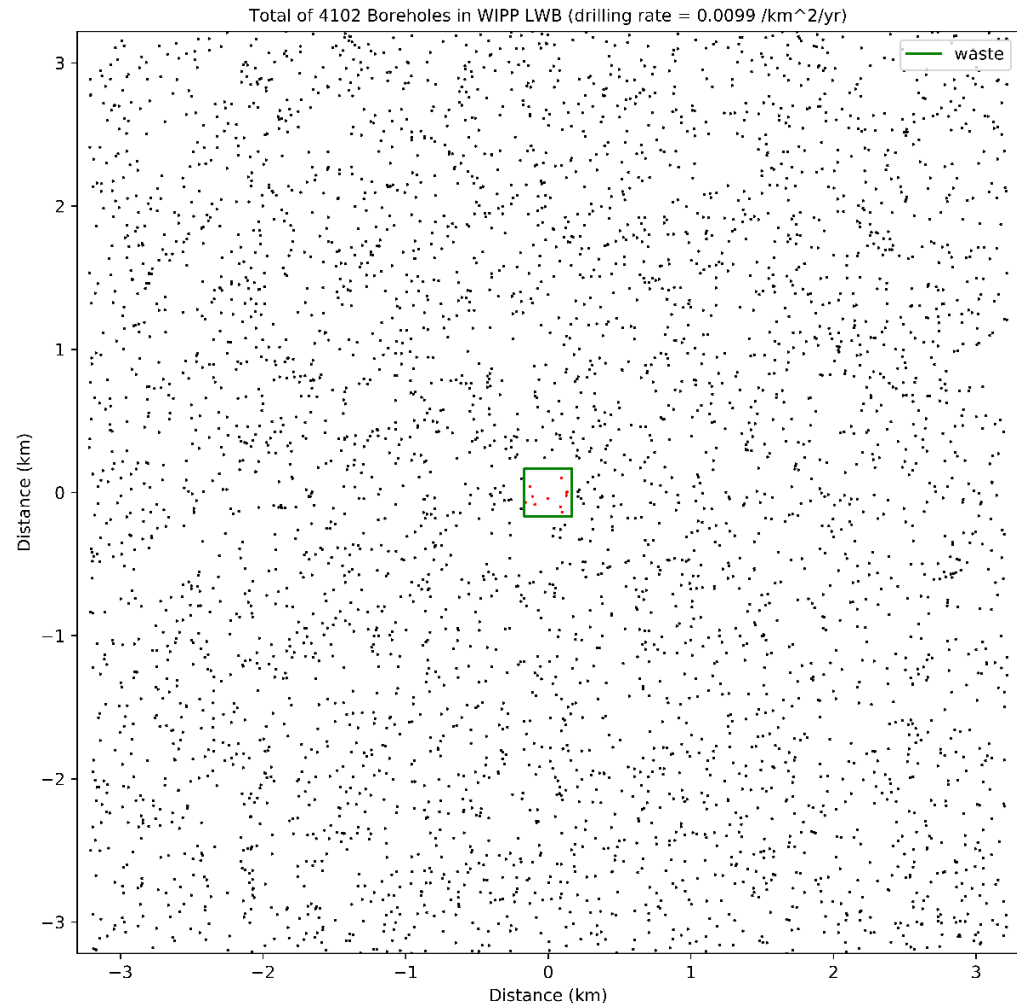
- Radionuclide transport through groundwater comprise long-term releases (differ from direct releases)





Drilling Rate

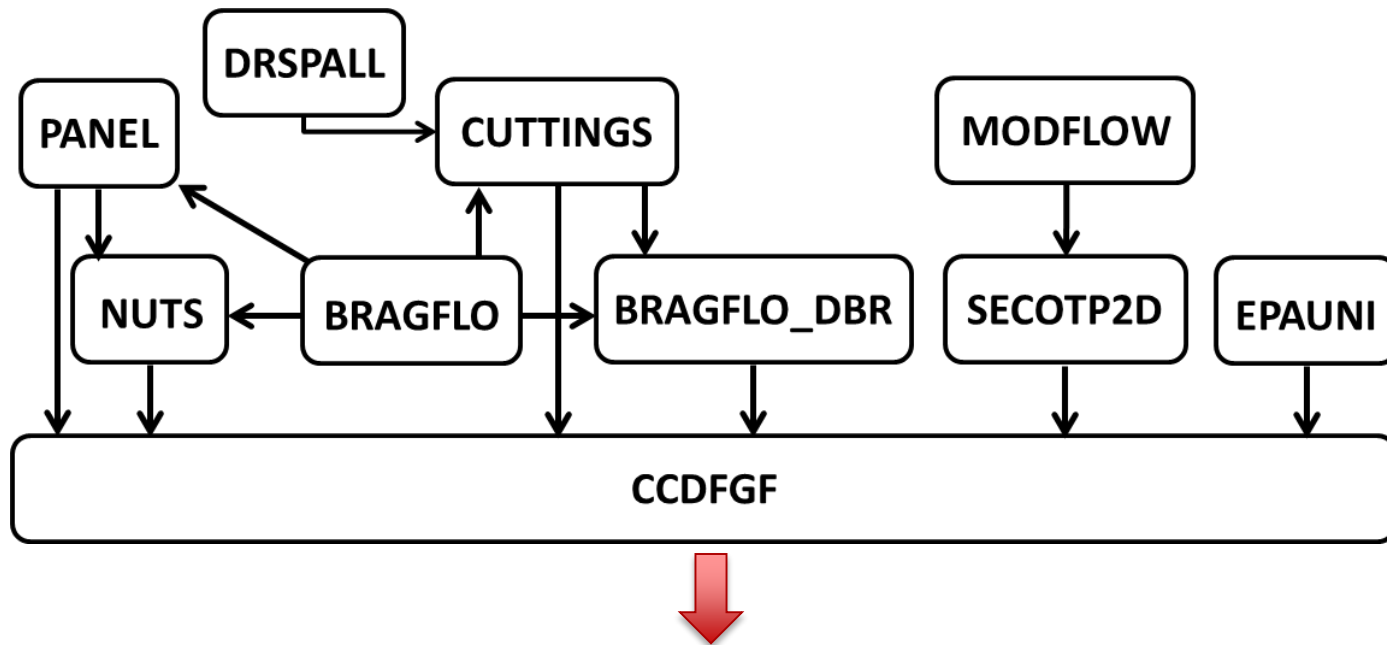
- Based on past 100 years of boreholes in Delaware Basin
- Has continued to increase since the CCA (46.8 boreholes per km^2 per 10k years), CRA-2014 (67.3 boreholes per km^2 per 10k years), and CRA-2019 (99.0 boreholes per km^2 per 10k years).
- For the CRA-2019 rate that is 4102 boreholes within the Land Withdrawal Boundary during the 10,000 performance period





WIPP Performance Assessment

- PA calculations include 24 peer-reviewed conceptual models
- PA uses 10 principal codes and many utility codes

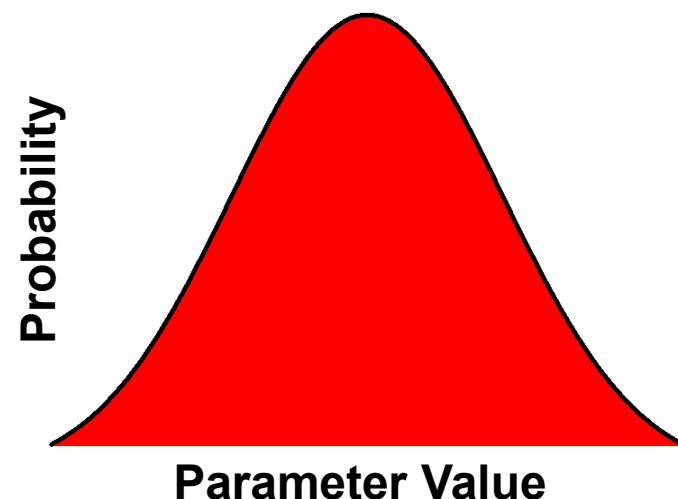


Compliance Curve for Total Normalized Releases

Probabilistic Framework: Uncertainty

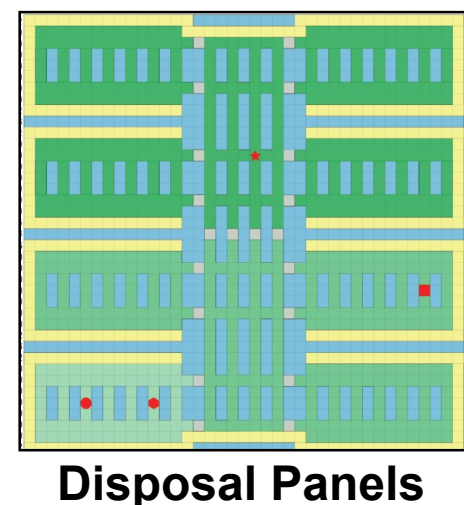
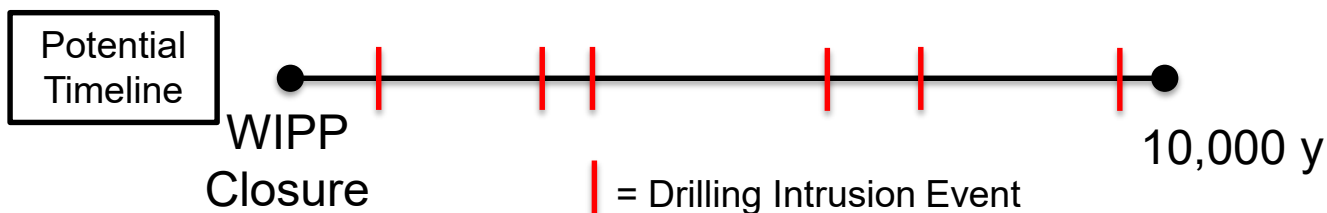
- **Epistemic (Subjective) Uncertainty**

- Arises from a lack of knowledge about parameters that are considered constants
- Parameter values sampled from probability distributions that cover the range of uncertainty
- Examples: permeability, porosity, etc.



- **Aleatory (Stochastic) Uncertainty**

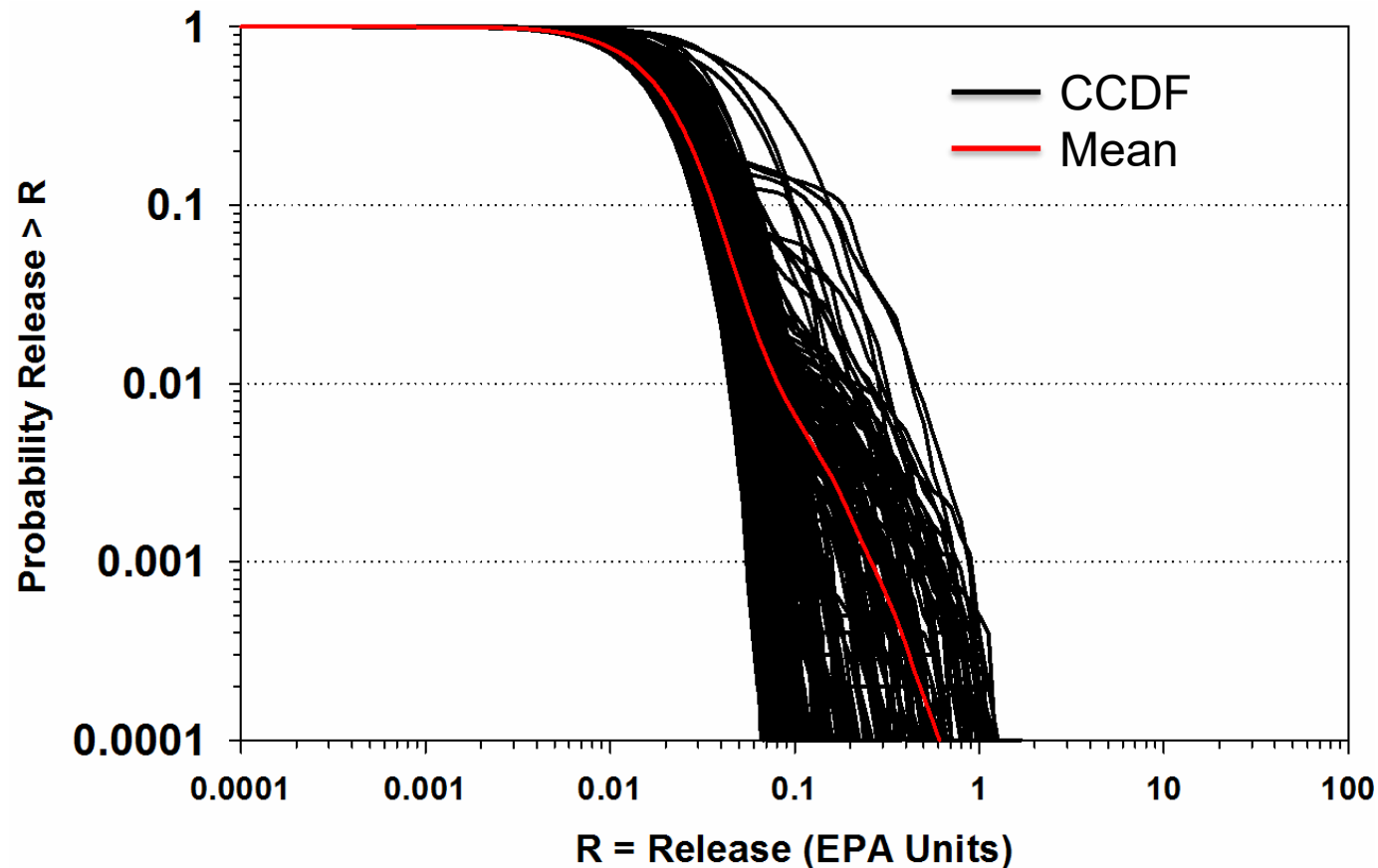
- Arises from a lack of knowledge about future events
- Monte Carlo sampling on possible futures
- Example: Timing and location of future drilling events





Intermediate Results

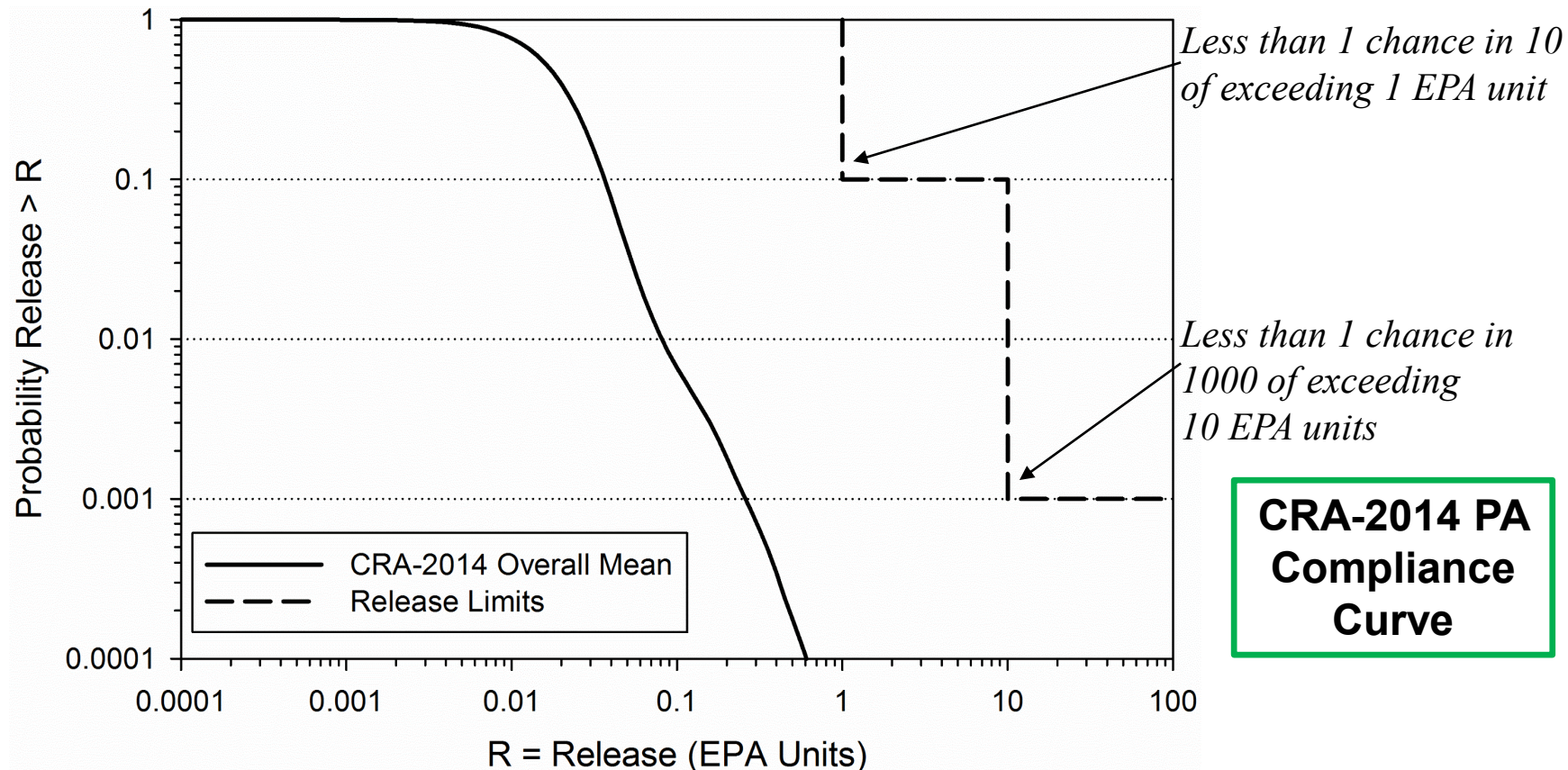
- Complementary Cumulative Distribution Function (CCDF) Curves
- Cumulative releases from 10,000 potential futures for each realization are ordered into a single “horsetail”
- 300 horsetail plots (one for each realization)





Mean Total Release CCDF

- Total release Complementary Cumulative Distribution Function (CCDF) curve is the measure of compliance
- Releases are compared to regulatory release limits

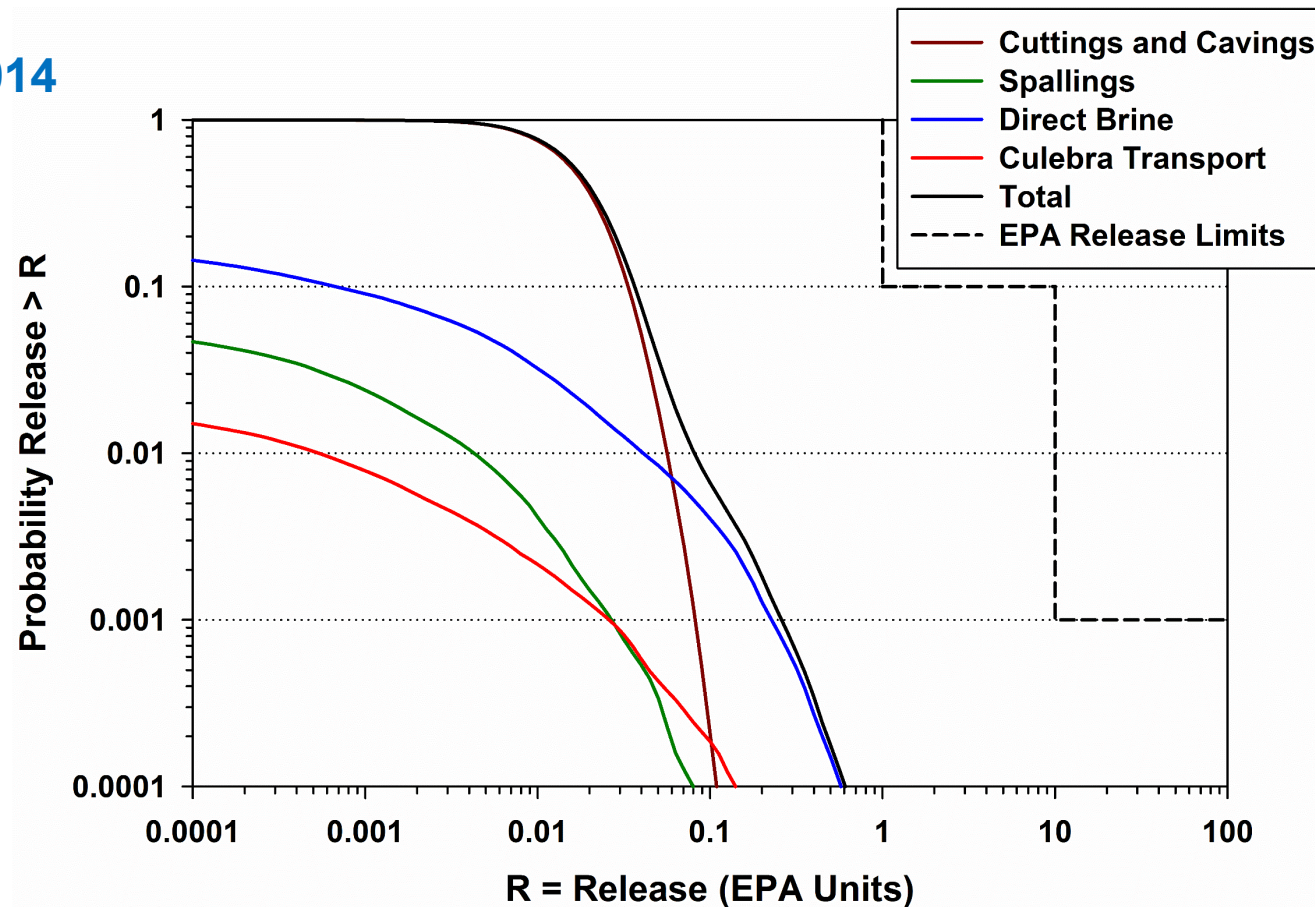




CCDFs for each Release Mechanism

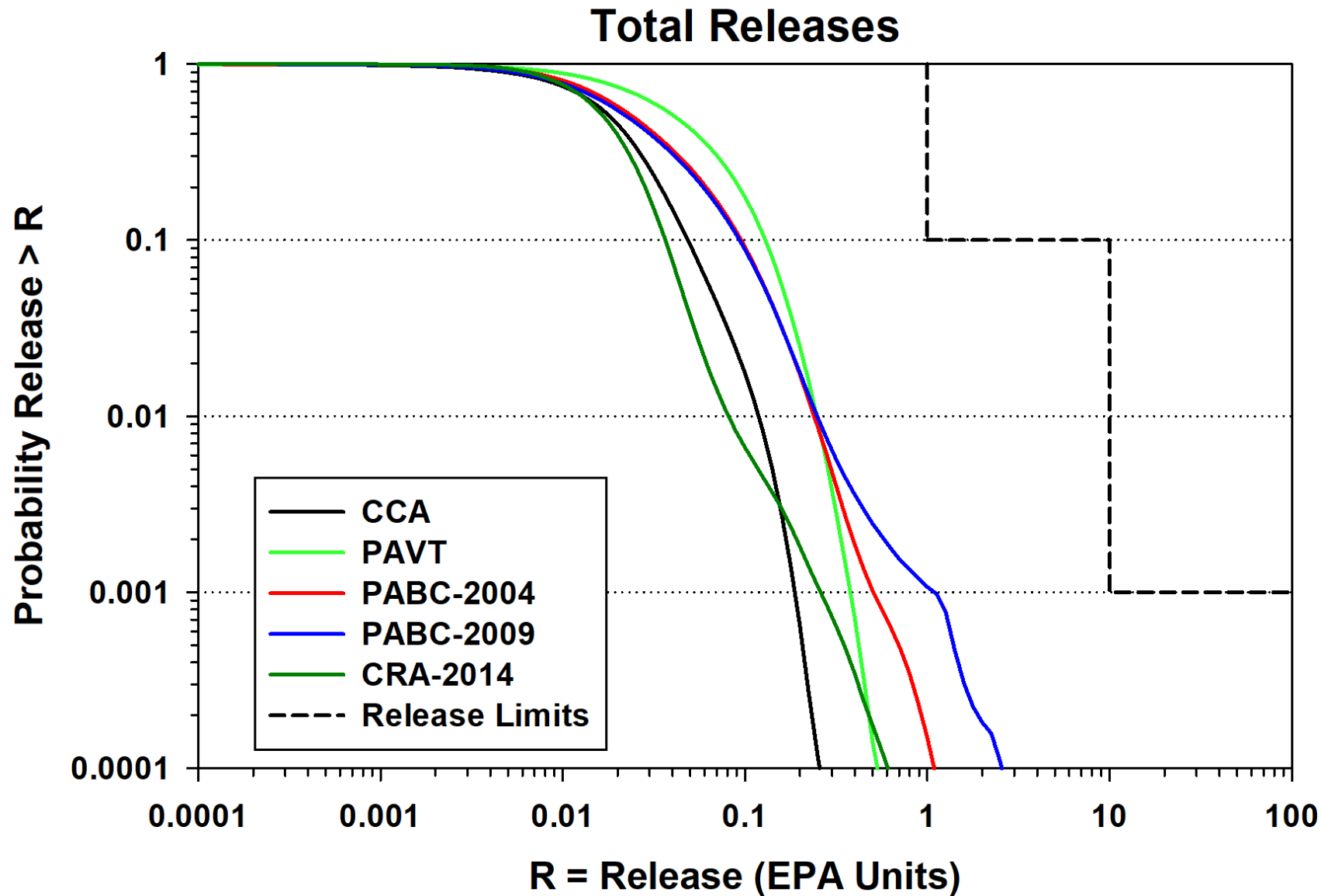
Each Release Component is Quantified by a
Complementary Cumulative Distribution Function (CCDF)

CRA-2014





Historical Compliance Calculations





Sensitivities in Past Calculations

- Parameters impacting repository pressure and brine availability are important to PA releases.
- PA calculations are sensitive to model/methodology changes as will be discussed later.
- Sampled parameters that have impacted PA
 - Waste Shear Strength
 - Pressure in the Castile
 - Solubility Uncertainty
 - Microbial reactions
- Historically, WIPP PA has shown little difference to releases solely as a result of inventory changes.



Historical Inventory Changes

PA Analysis Name	Inventory Name	CH Scaling Factor	Waste Unit Factor (WUF)	Total Inventory Contributing to WUF (Ci) ^a	Total Inventory in PA (EPA units)
CCA	TWBIR Revision 2	2.05	4.07	4.07x10 ⁶	10,120
PAVT	TWBIR Revision 3	2.05	3.44	3.44x10 ⁶	10,100
CRA-2004	TWBID Revision 2.1 Version 3.12, Data Version D.4.08	2.11	2.48	2.48x10 ⁶	10,100
PABC-2004	TWBID Revision 2.1, Version 3.13, Data Version D.4.15	1.48	2.32	2.32x10 ⁶	10,170
CRA-2009	TWBID Revision 2.1, Version 3.13, Data Version D.4.15	1.48	2.32	2.32x10 ⁶	10,170
PABC-2009	PAIR-2008	5.72	2.60	2.60x10 ⁶	10,080
CRA-2014	PAIR-2012	2.66	2.06	2.06x10 ⁶	10,197

^a Consists of inventory from α -emitting radionuclides with half-lives greater than 20 y.

Regulations and History

Summary/Conclusions

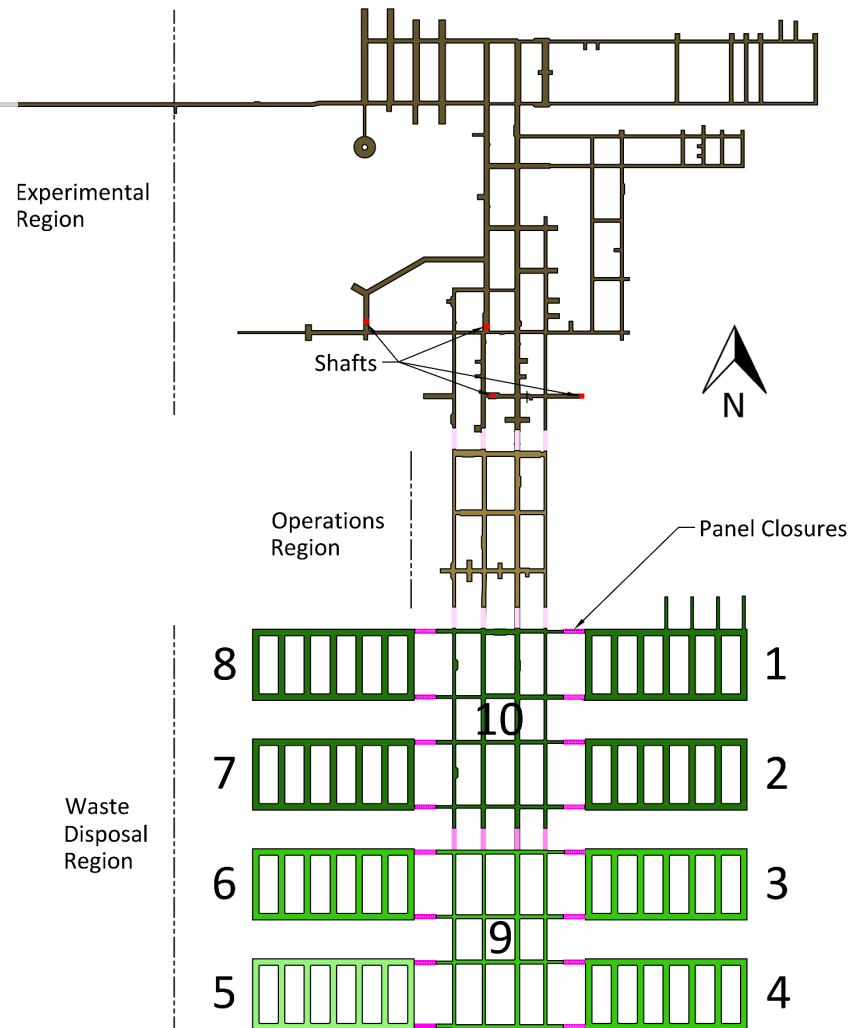
- Probabilistic not deterministic framework
- Regulated to the mean release in EPA units over 10,000 years.
- Screening to identify what should be included, required to consider accidental intrusion scenario.
- Impact from inventory alone has been minor. Regulation utilizes a normalized release standard.
- WIPP has been in compliance since the original certification with considerable margin below the compliance points.

Abandonment of Panel Closures in South

APCS

Abandonment of South End of Mine

- Fire and release events in 2014
- Access to south end was limited
 - Ground control maintenance deficiencies resulted in back instability and eventual roof falls
- Worker safety issue identified
 - Most effective resolution was to abandon the south end that contains Panels 3, 4, 5, 6, and 9
 - Waste was already emplaced in south Panels 3, 4, 5, and 6, but not 9
 - Unable to install run-of-mine-salt panel closures (ROMPCS) in Panels 3, 4, 5, and 6



APCS Performance Assessment

- Objective

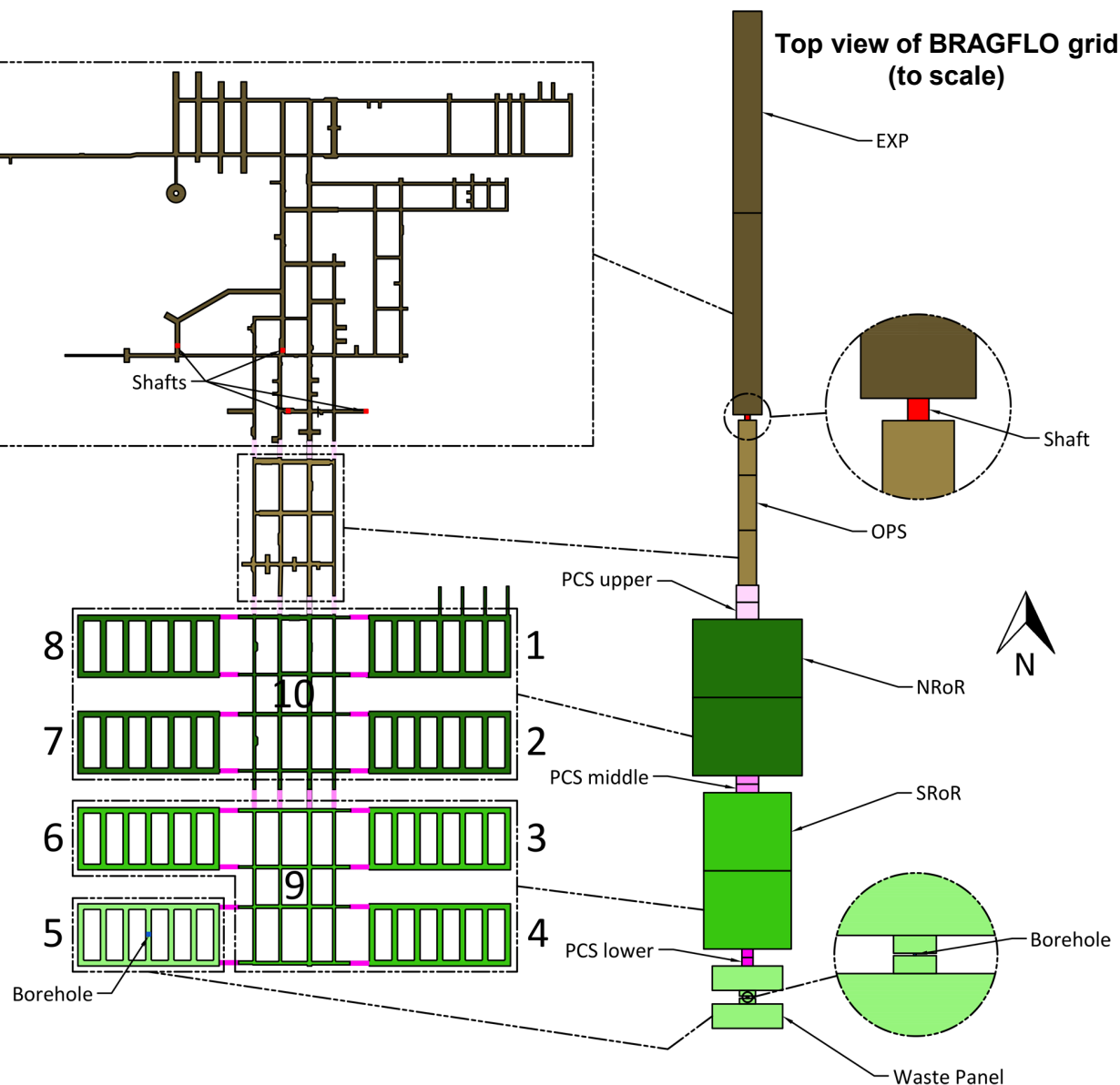
- Use existing abstractions, tools, and models (2-D) in compliance with peer-reviewed conceptual models to conservatively assess the impacts of
 - not installing ROMPCS in the south (i.e., between Panels 3, 4, 5, 6, and 9)
 - not emplacing waste in Panel 9 and adding a “Panel 9 replacement” in the north

- Challenges

- Current model abstraction uses a lumped repository representation with a 2-D flared grid that relies on repository symmetry and the concept of radially-concentric flow
- Current computational codes are aligned with the current (and long-standing) model abstraction

Current Model Abstraction

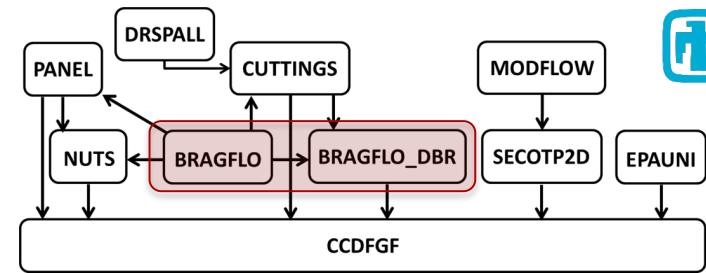
- 3-D repository represented by 2-D flared grid
 - Radial concentric flow assumption was deemed adequate to predict performance prior to CCA
 - Unable to model asymmetry in panel layout
- Panels are lumped
 - Panel closures in SRoR and NRoR are implied, but not explicitly modeled
 - Panel closures between OPS and EXP are combined with panel closures above Panel 10
- Communication
 - Flow through waste panel is across the borehole restriction
 - Flow from OPS to EXP is across the shaft restriction



APCS Conceptualization

- Represent panel closure drifts between Panels 3, 4, 5, 6, and 9 as “open areas”
 - Conservatively facilitates enhanced communication during an E1 intrusion that results in increased brine saturation, gas generation, and brine/gas pressure in five panels rather than only in the intruded panel
- Model waste in Panel 9
 - Provides for a conservative determination of all releases that would alternatively be associated with a replacement panel containing waste in the north
- Treat existing panels in the north (with ROMPCS) the same as for the south (without ROMPCS) and not model a new replacement for Panel 9
 - Conservatively accounts for the increased probability of an intrusion into an empty panel with radionuclide-bearing brine
 - Necessary to comply with the current 2-D flared grid representation of the repository

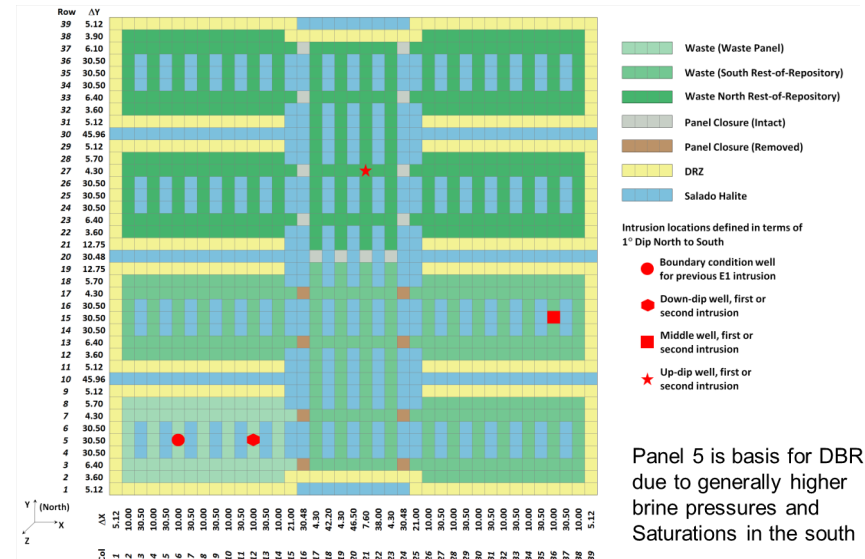
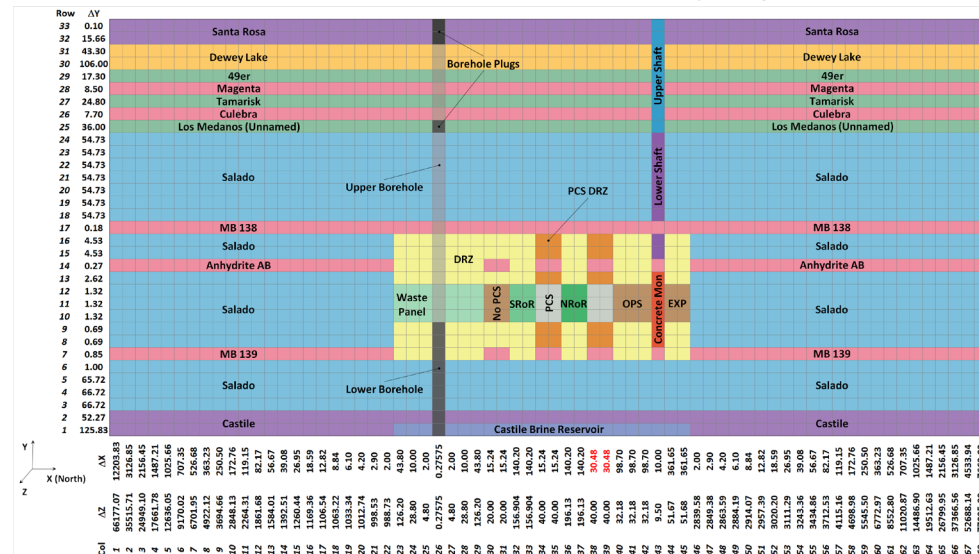
APCS Methodology



■ BRAGFLO/BRAGFLO_DBR

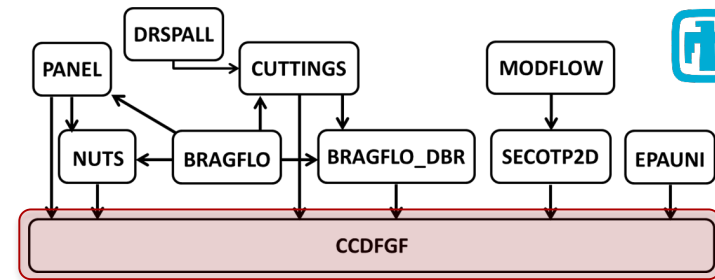
- Introduce PCS_NO material (consistent with open area OPS/EXP material parameters) at Time = 0 for the southernmost panel closure in the BRAGFLO grid and for panel closures between Panels 3, 4, 5, 6 and 9 in the BRAGFLO_DBR grid to represent the “abandoned” panel closures

- Waste Panel – Panel 5
- South Rest-of-Repository – Panels 3, 4, 6, 9
- North Rest-of-Repository – Panels 1, 2, 7, 8, 10



Panel 5 is basis for DBR due to generally higher brine pressures and Saturations in the south

APCS Methodology

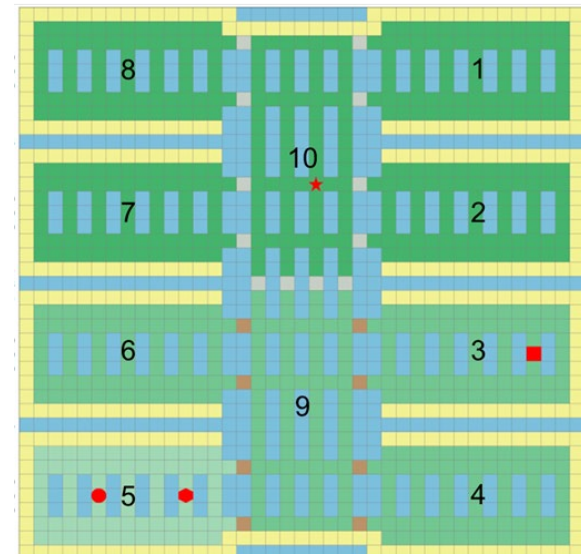


■ CCDFGF

- Modify panel neighbor definitions to consistently associate adjacent panels that are connected through either an open panel closure drift or a panel closure drift filled with run-of-mine salt
- Maintain Lower, Middle, and Upper (L,M,U) panel designations for the Waste Panel, SRoR, and NRoR
 - Lower = Panel 5
 - Middle = Panels 3, 4, 6, 9
 - Upper = Panels 1, 2, 7, 8, 10

Neighbor Relationships

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



APCS Results – Salado Flow

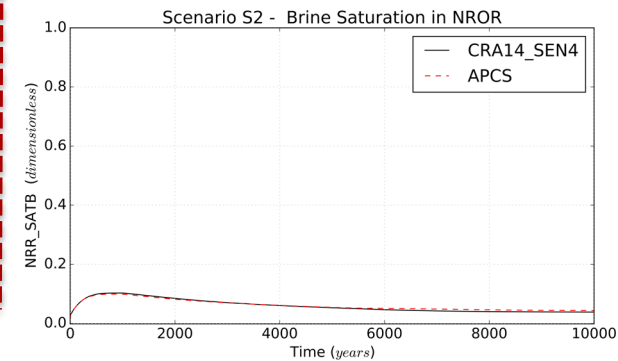
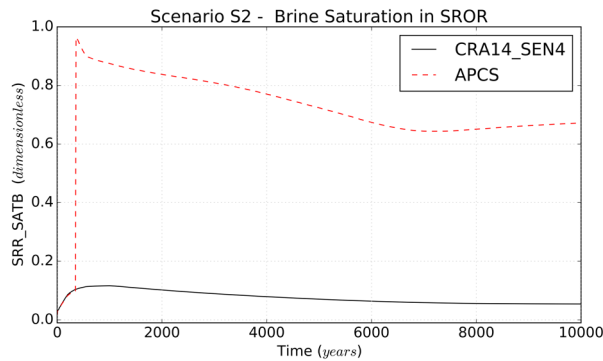
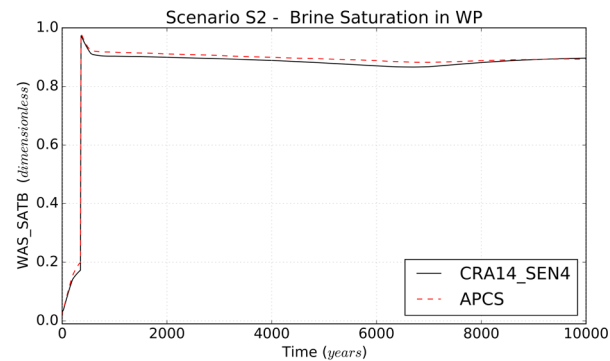
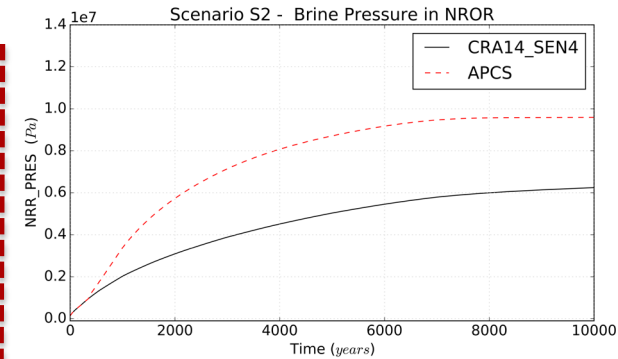
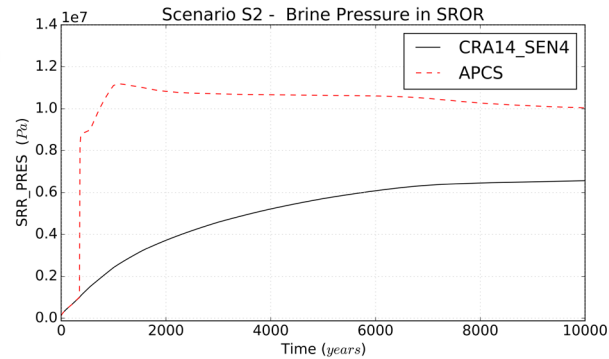
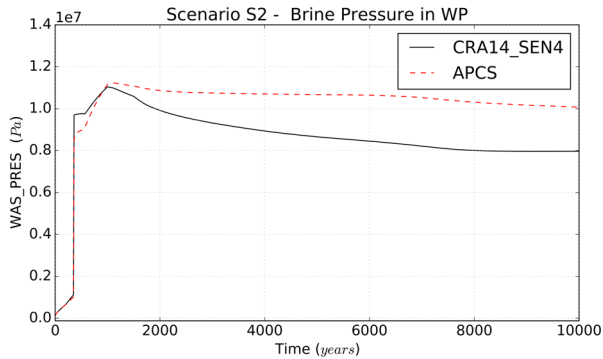
- Primary impact is from scenarios that model intersection of the intrusion borehole with a hypothetical Castile brine reservoir
- Results presented for 350 yr intruded scenario – S2
 - Pressures in waste areas that have enhanced communication with the intruded Waste Panel (Panel 5) are significantly increased along with brine saturations
 - Waste areas not separated by a ROMPCS from the intruded Waste Panel are flooded with brine until pressures equilibrate as brine flows north

APCS Results – Salado Flow (cont.)

WP
(Panel 5)

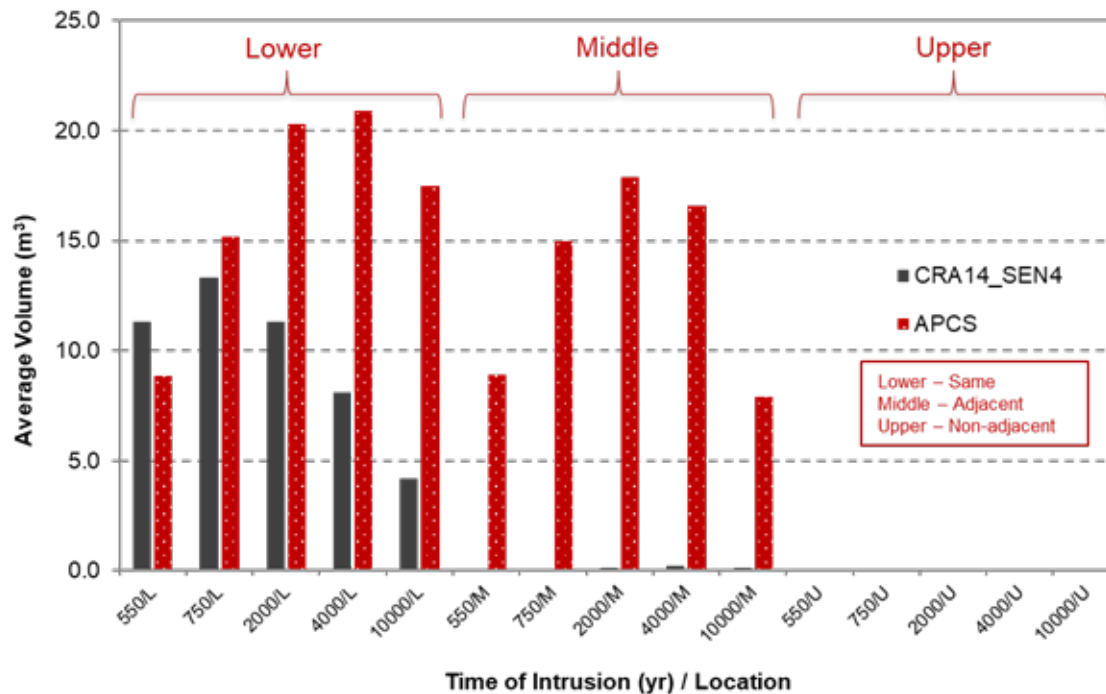
SROR
(Panels 3, 4, 6, 9)

NROR
(Panels 1, 2, 7, 8, 10)



APCS Results – Direct Brine Release

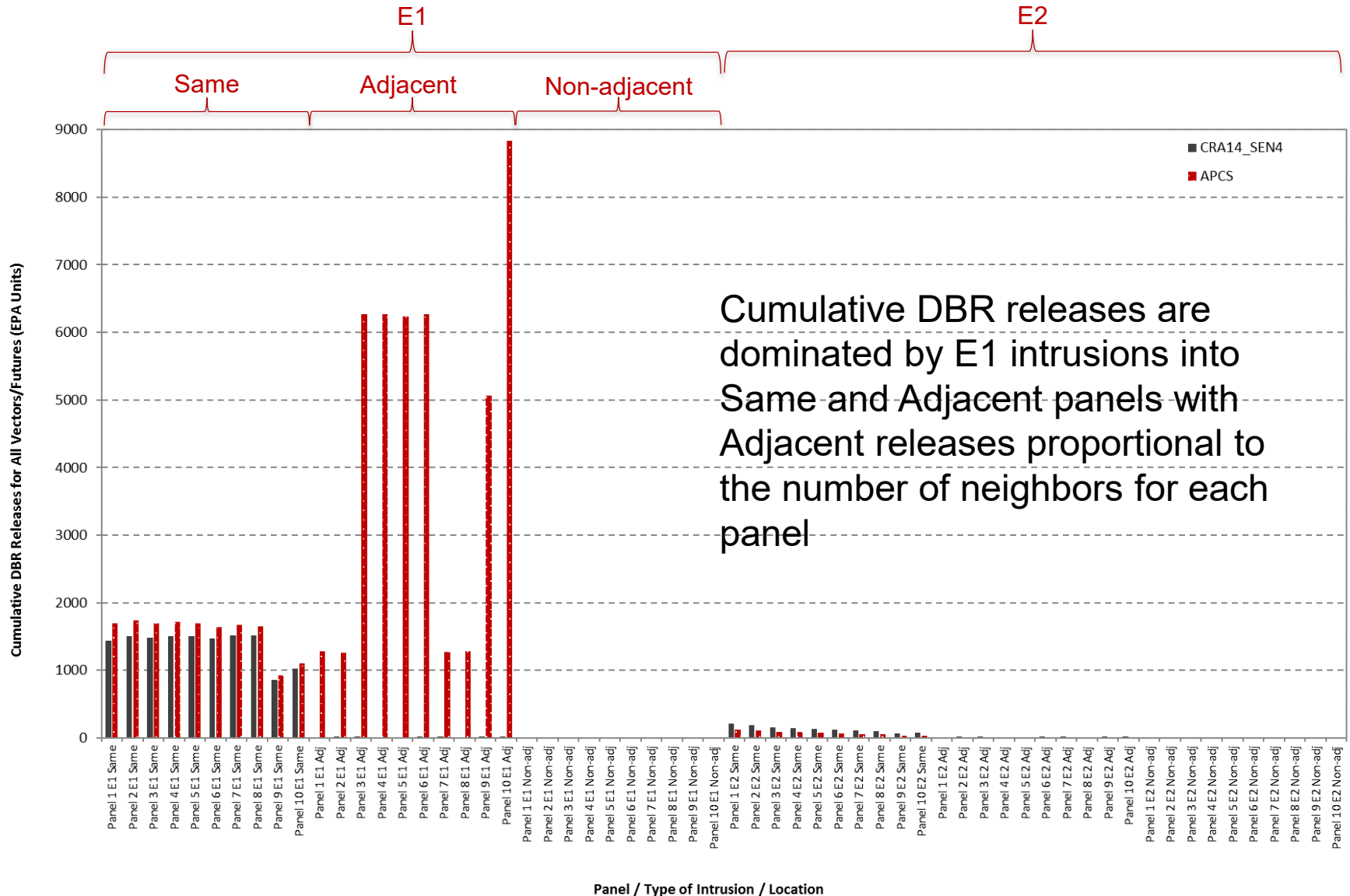
- Volume of contaminated brine releases increased substantially for Lower intrusions at later times, with Middle intrusions substantially increased over all intrusion times, and Upper intrusions marginally affected
- Quantity of DBR release for a given pressure is increased due to generally increased brine saturation



- ## Neighbor Relationships

A 20x20 grid map showing a central blue path and eight green rectangular areas labeled 1 through 8. Area 1 is top-right, 2 is middle-right, 3 is bottom-right, 4 is bottom-right, 5 is bottom-left, 6 is middle-left, 7 is middle-left, 8 is top-left, and 9 is bottom-center. Area 10 is a central blue path. A red star is in area 10, and a red square is in area 3. Two red circles are in area 5.

DBR Releases by Panel, Type, Loc

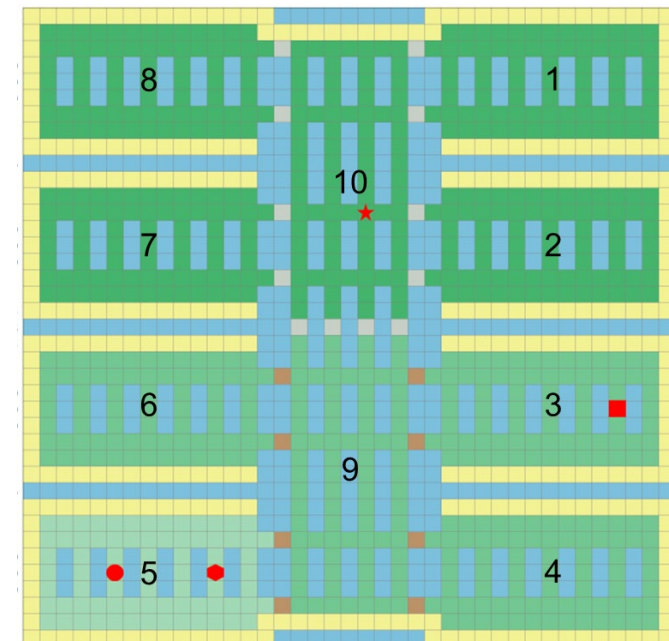


APCS Results – CCDFGF, Spallings

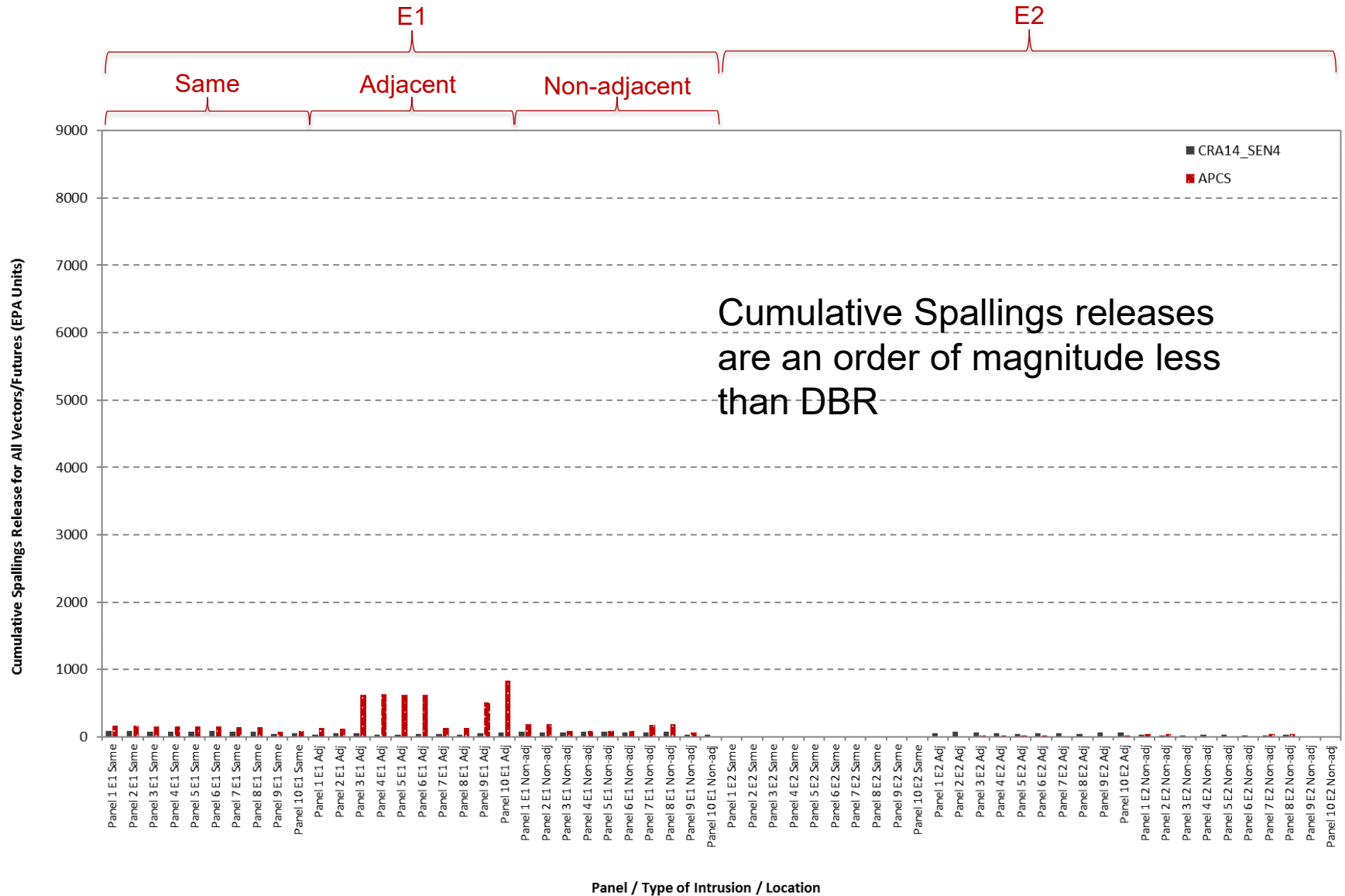
- Conservative estimate of Spallings releases is similarly justified/correlated to conservative estimate of DBR releases
 - The current location of Panel 9 with waste and the potential for associated solids releases maximizes the number of adjacent panels (in comparison with a new replacement panel to the north that would only have one neighbor)
 - Adjacent panels generally have higher Spallings-driving pressures at early times and equivalent pressures at later times in comparison with Non-adjacent panels

Neighbor
Relationships

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



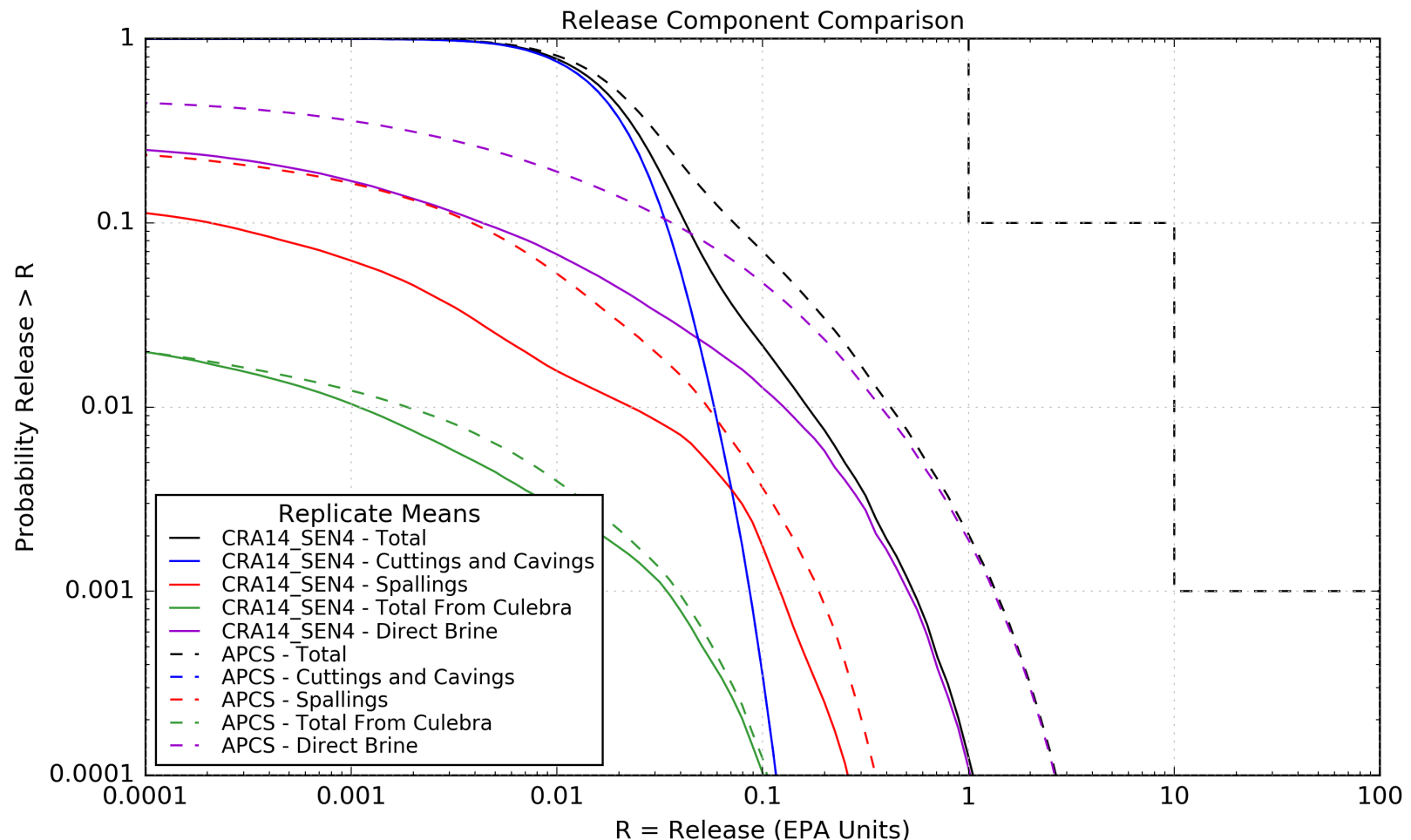
Spallings Releases by Panel, Type, Loc



APCS Results – CCDFGF

- Cuttings and Cavings
 - No impact from location of waste for Panel 9 since releases are not dependent upon the Salado flow solution, the probability of waste intersection is unchanged, and the appropriate total volume of solids is modeled
- Total From Culebra
 - Releases are conservatively estimated due to higher repository pressures resulting from modeling gas generating waste in Panel 9 without any additional volume to attenuate pressures (i.e., an empty Panel 9 and a new panel in the north)

APCS Results – Release Components



Mean Total release increase factor for CRA14_SEN4 to APCS:
Low-probability = 1.7X, High-probability = 2.5X

APCS Summary/Conclusions

- The APCS analysis incorporates a highly conservative representation of the repository that addresses no panel closures in Panels 3, 4, 5, and 6 and no waste in Panel 9 (that could be located in a new panel to the north)
- The APCS analysis results demonstrate with a reasonable expectation the modified representation of the repository would continue to ensure compliance with release limits
- This is an example of how we reevaluate, and modify when needed, WIPP PA as a result of changes (i.e. changes from design, regulators, inventory, waste form, etc.)
- The APCS methodology has been recognized by the EPA as the methodology that will be used for the CRA-2019 PA.

Surplus Plutonium Disposition

SPD



Surplus Plutonium Disposition (SPD)

- Disposition of surplus Pu via “Dilute and Dispose” approach
 - 42.2 metric tons (MT) surplus Pu
 - 34 MT pit Pu (Plutonium Management and Disposition Agreement)
 - 7.1 MT pit Pu (declared in 2007 to be excess to US defense needs)
 - 1.1 MT excess, non-pit Pu
- LANL tasked with providing new inventory information
 - PA inventory report (PAIR) provided to SNL
- Features, events, processes (FEPs) reassessment
 - One change in screening decision
 - Radiolysis of brine was out, now in with refinement of gas generation process model implemented
 - New arguments for three FEPs to keep same screening decision (out)
 - Criticality FEP
 - Two repository heat FEPs

SPD PA Calculations (Approach)

- Basis is Abandonment of Panel Closures in South (APCS) PA
 - Derivation from CRA-2014 PA that is similar to expected CRA-2019 PA
 - Inventory data based on December 31, 2011 information
- New inventory parameters
 - Based on waste inventory in PAIR (2015 data with some updates)
 - Include updates not related to 42.2 MT waste stream (e.g., 6 MT Pu)
- New radionuclide solubility parameters
 - Based on organic ligand inventory in PAIR
 - Organic ligand and solubility parameter memos
- Code revision (BRAGFLO) for refined process model
 - Radiolysis of brine from decaying radionuclides
- Code revisions (PANEL and NUTS) to correct solubilized radionuclide source term, not related to SPD.

SPD Inventory from LANL PAIR

- Baseline inventory taken from Annual Transuranic Waste Inventory Report - 2016 (ATWIR-2016)
 - Defense-related TRU waste information as of December 31, 2015
 - Considers emplaced (already shipped) and WIPP-bound (likely to be shipped to WIPP) waste streams
- Addition of one SRS waste stream
 - Represents 42.2 MT surplus Pu + other radionuclides
 - Designated as SR-KAC-SPD
- Removal of three SRS waste streams
 - Represent waste otherwise generated by Mixed Oxide (MOX) process
 - SR-T001-WSB-1, SR-W026-WSB-2, SR-W026-MFFF-1
- Total of 591 waste streams

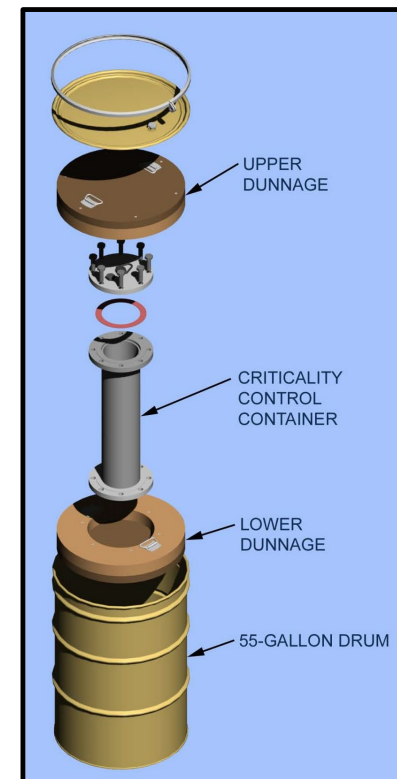
SR-KAC-SPD Waste Stream

- Hypothetical waste stream representing potential waste from the “Dilute and Dispose” option
 - Represents 42.2 MT surplus Pu + other radionuclides
 - 2.61 MCi ^{239}Pu (3.36 MCi ^{239}Pu in entire inventory)
 - Contact-handled waste
 - Assumed to arrive in Criticality Control Overpack (CCOs)
 - Waste stream volume comes from outer container volume
 - Largest waste stream by volume
 - Contains largest initial inventory of various RNs (table)

Percentage of Total Waste Inventory (Selected RNs, Curie Basis)

Volume	^{241}Am	^{237}Np	^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{236}U
16*	43*	21*	10	78*	68*	46*	29

* - indicates maximum across all 591 waste streams



CCO Schematic

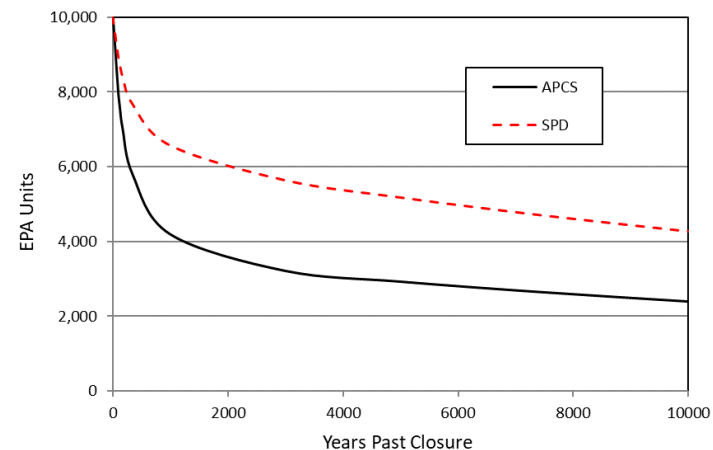
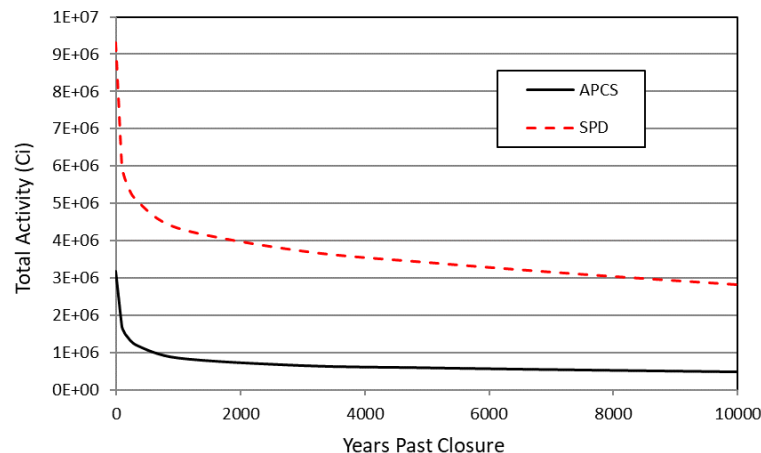
SPD PA Calculations (Results-1)

■ Inventory

- SR-KAC-SPD waste stream is largest by EPA units
 - 59% at t=0; 72% at t=10,000 y
- Total increased curie (Ci) content, but initial EPA units are ~same
 - Waste unit factor (WUF) increased from 2.06 to 6.59 (factor of 3.2)
 - Normalization by WUF brings initial inventory to ~10,000 EPA units
 - Activity greater than that for APCS over time due to long-lived ^{239}Pu

$$\text{WUF} = \text{C}/10^6$$

C = Total initial TRU activity

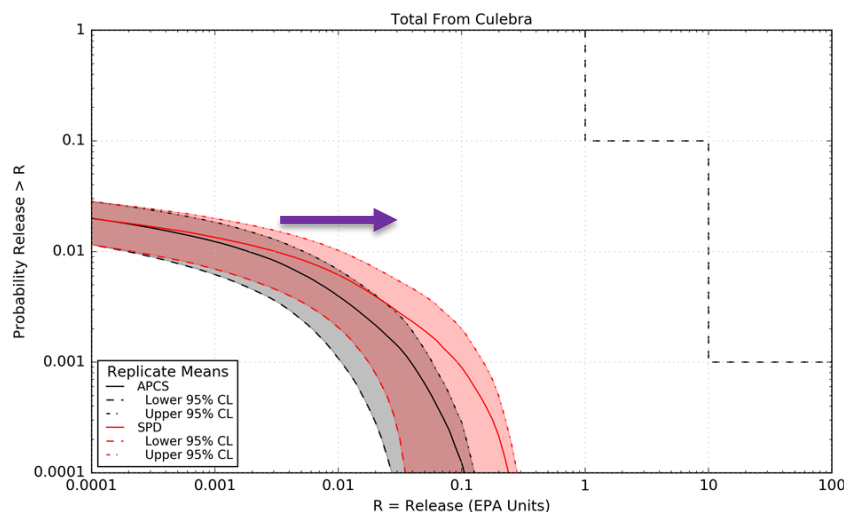


Total WIPP CH- and RH-TRU Waste Activity from Closure to 10,000 Years

SPD PA Calculations (Results-2)

■ Releases from the Culebra

- Based on radionuclide transport to the Culebra and Culebra properties
- Radionuclide transport to the Culebra is similar or decreased for SPD, except release of uranium is increased due to increased ^{234}U inventory
- Some increase in releases from Culebra due to fast transport of U
 - Matrix partition coefficient (K_D) for U is $\sim 100\times$ smaller than other RNs
- Solubility, WUF, and inventory changes also play counteracting roles



Overall Mean CCDFs for Releases
from Culebra: APCS and SPD

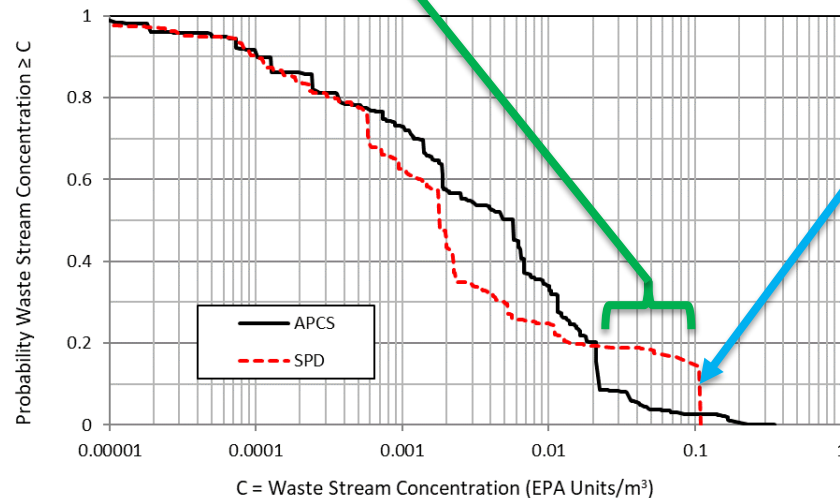


SPD PA Calculations (Results-3)

■ Cuttings and Cavings Releases

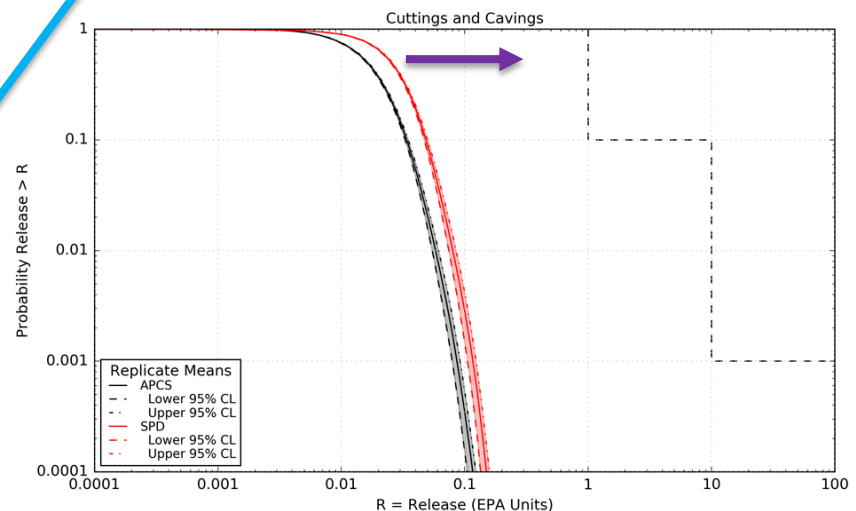
- Based on w.s. volume (probability) and concentration (consequence)
- Overall increase for SPD due to increased probability of encountering high concentration waste streams, including SR-KAC-SPD

Increased probability of intersection at high concentrations



WIPP CH- and RH-TRU Waste CCDF for Activity Concentration (t=10,000 y)

SR-KAC-SPD

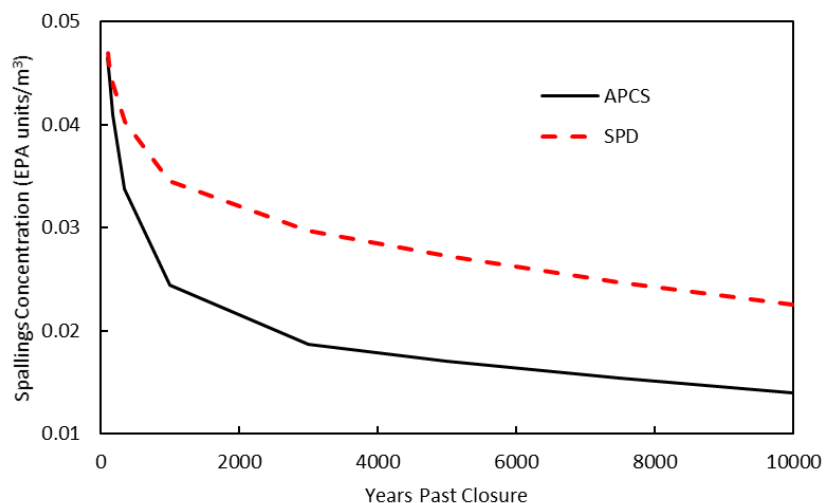


Overall Mean CCDFs for Cuttings and Cavings Releases: APCS and SPD

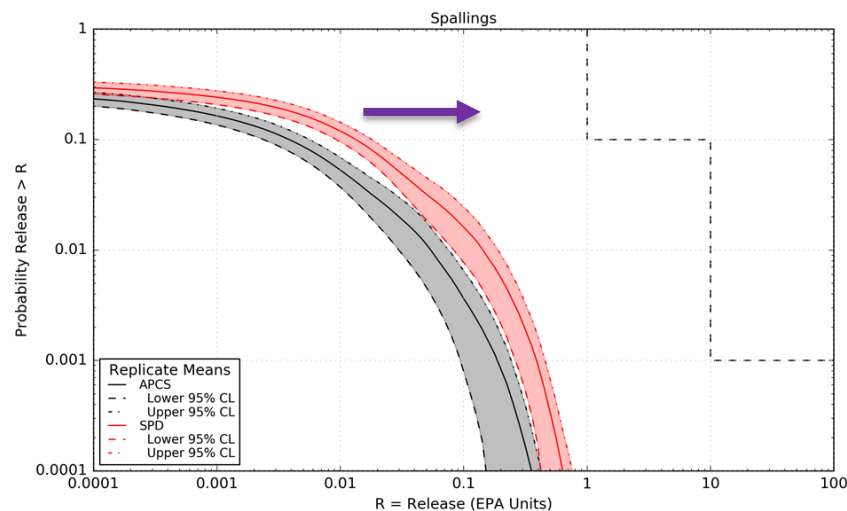
SPD PA Calculations (Results-4)

■ Spallings Releases

- Based on spallings volumes and spallings (average CH) concentration
- Overall increase in spallings releases for SPD
 - Spallings volumes increase due to repository pressure increase (radiolysis)
 - Spallings concentration increases due to long-lived ^{239}Pu



Spallings Concentration from Closure to 10,000 Years

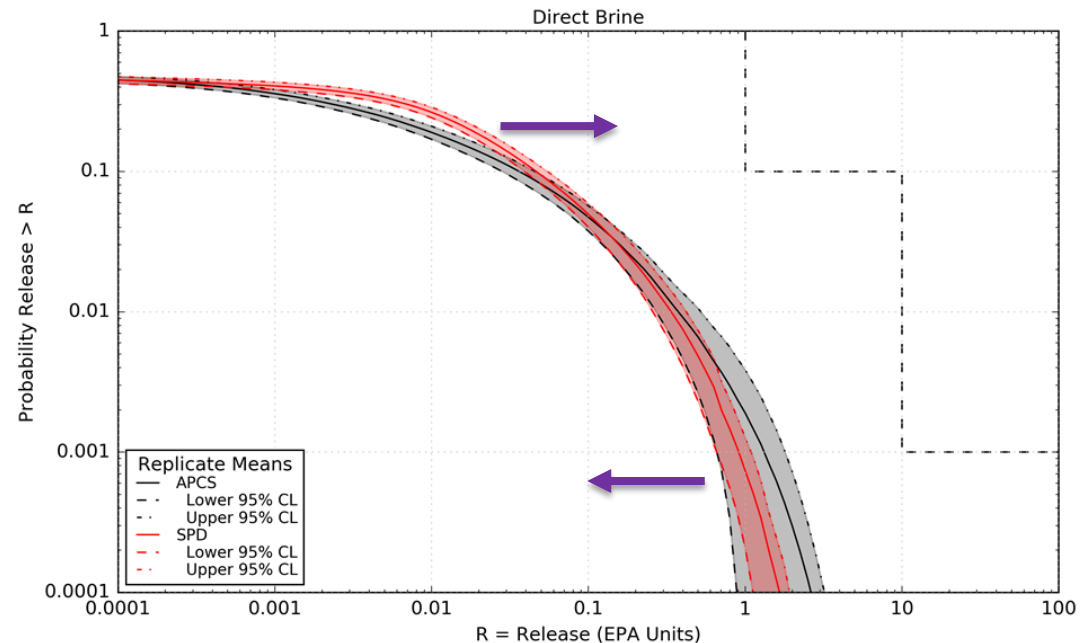


Overall Mean CCDFs for Spallings Releases:
APCS and SPD



SPD PA Calculations (Results-5)

- Direct Brine Releases (DBRs)
 - Based on DBR volumes and mobilized RN concentrations
 - DBR volumes decrease due to decreased waste panel saturations
 - Solubility, WUF, and inventory changes play roles in concentrations
 - Overall mixed impact on DBRs
 - Increased at 0.1 prob.
 - Decreased at 0.001 prob.



Overall Mean CCDFs for DBR Releases: APCS and SPD

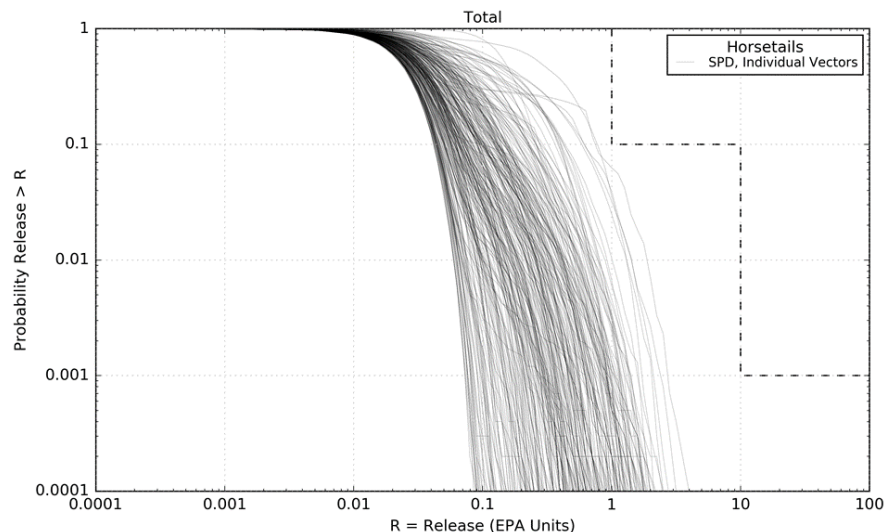


SPD PA Calculations (Results-6)

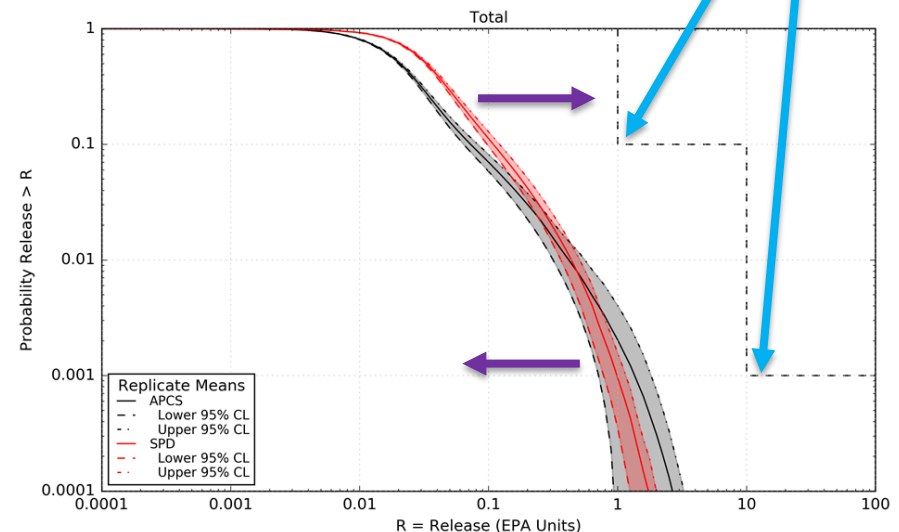
- Total Normalized Releases
 - Dominated by Cuttings and Cavings and DBRs
 - Overall mixed impact on total releases
 - Increased at 0.1 prob.
 - Decreased at 0.001 prob.

Probability	Analysis	Mean Total Release	% Change	Release Limit
0.1	APCS	0.0727	+49.9	1
	SPD	0.1090		
0.001	APCS	1.3622	-27.3	10
	SPD	0.9904		

Release Limits



Total Normalized Releases (300 Vectors): SPD



Overall Mean CCDFs for Total Releases: APCS and SPD

SPD PA Summary/Conclusions

- WIPP PA calculations are performed by SNL and used by DOE to demonstrate long-term repository performance
- The WIPP PA framework has been applied to assess the long term performance of WIPP with an added waste stream (42.2 MT Pu) from a potential “Dilute and Dispose” option
- Methodology accounts for changes in panel closures and absence of waste in equivalent panel 9.
- Calculated mean releases remain below EPA release limits
- Thanks to WIPP PA team, especially:
 - James Bethune
 - Dwayne Kicker
 - Ross Kirkes
 - Ramesh Sarathi
 - Steve Wagner

Questions

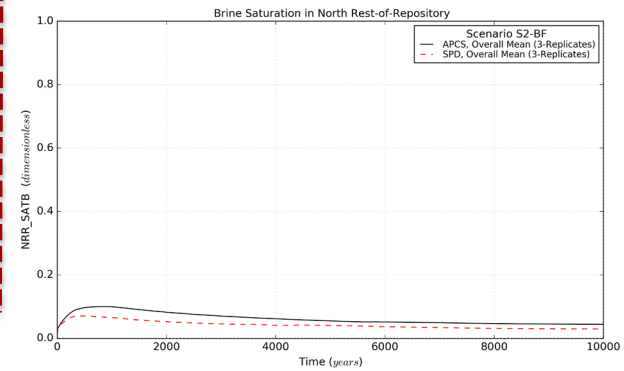
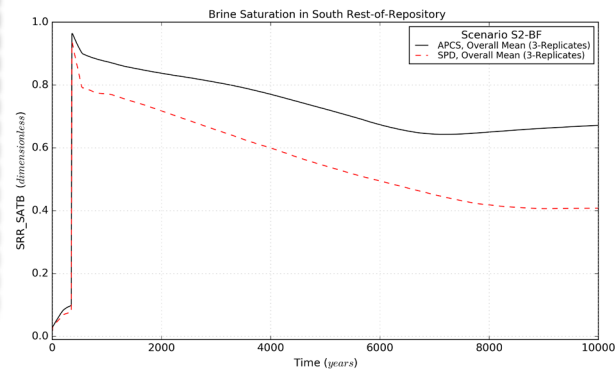
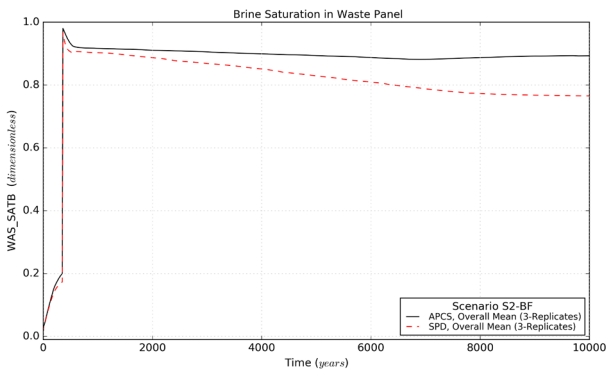
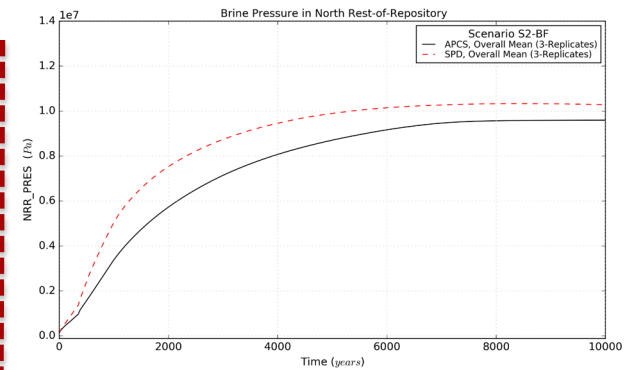
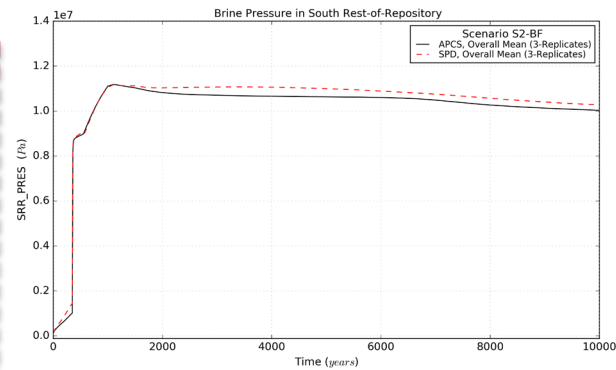
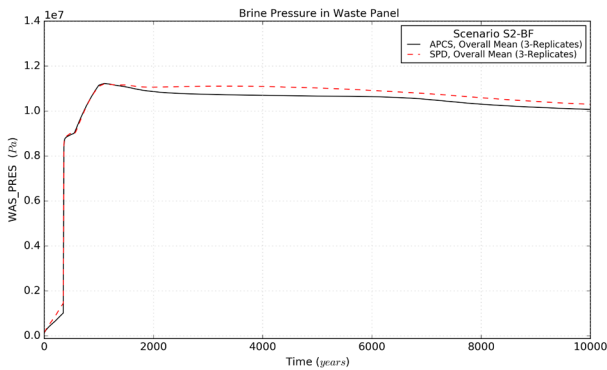


SPD Results – Salado Flow

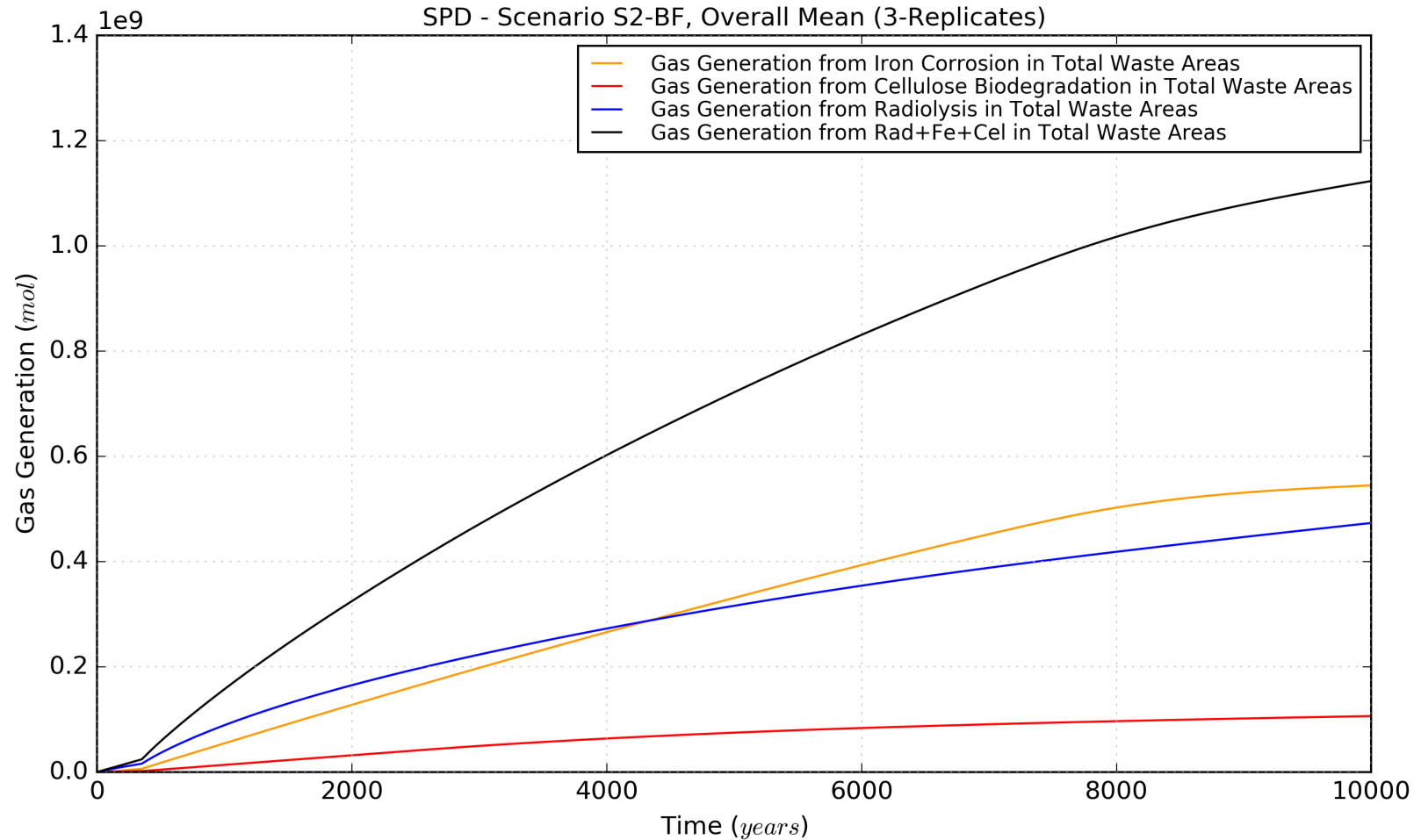
WP
(Panel 5)

SROR
(Panels 3, 4, 6, 9)

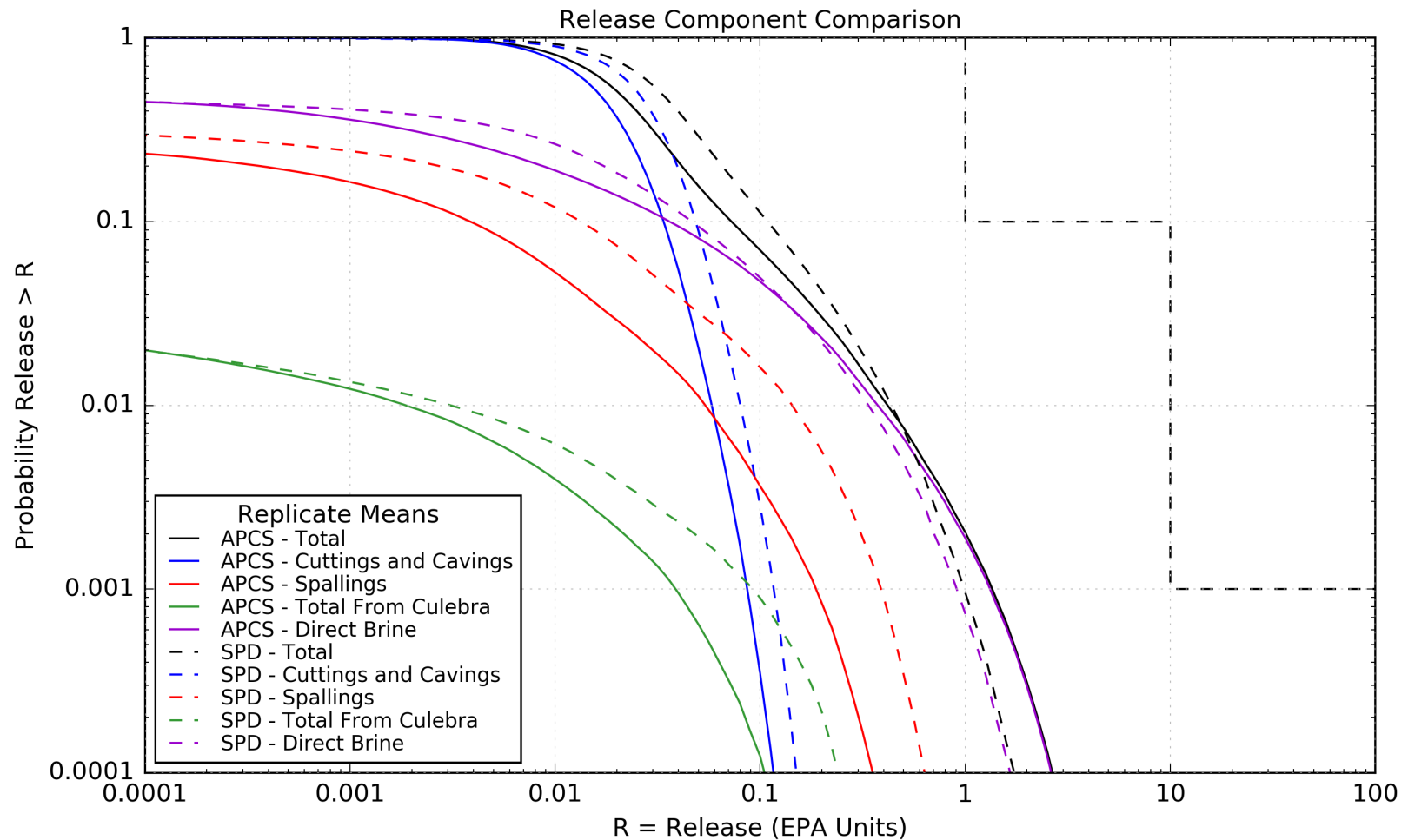
NROR
(Panels 1, 2, 7, 8, 10)



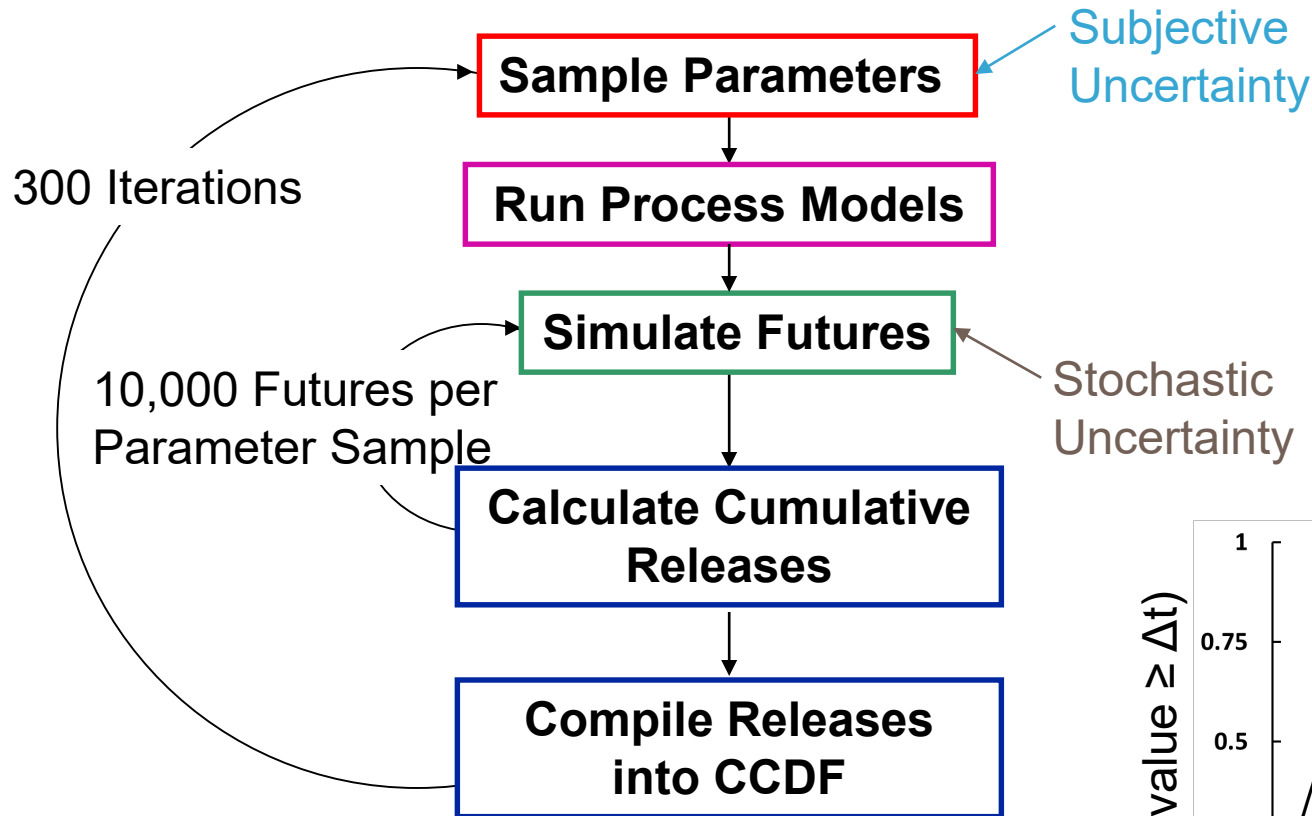
SPD Results – Gas Generation



SPD Results – Release Components



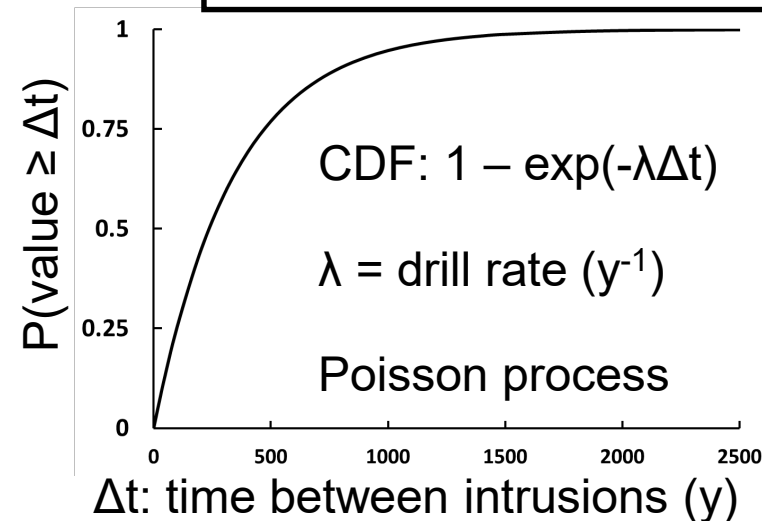
WIPP PA Computational Flow



Latin Hypercube sampling (LHS) is used to define 300 sets of uncertain parameters

LHS minimizes the correlation between parameters (unless directed otherwise)

Monte Carlo sampling for timing and location of drilling events yields independent timelines (futures).

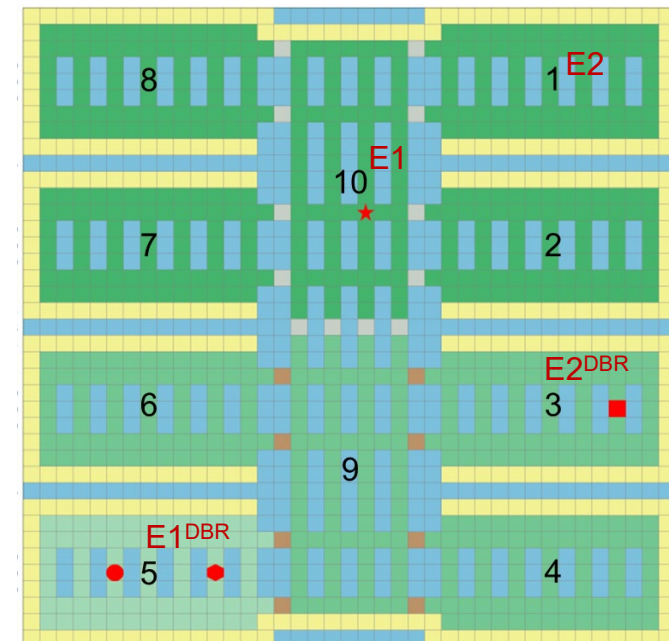


APCS Results – CCDFGF, DBR Ex.

- Future Example - E1 intrusion into Panel 10 followed by E2 intrusion into Panel 1
 - Panel 1 is a neighbor of Panel 10 which is an Adjacent release
 - Adjacent releases are correlated from DBR results for a Middle intrusion
 - Middle intrusion results are determined from DBR results for an E1 intrusion in Panel 5 followed by an E2 intrusion into Panel 3
 - Panel 3 and 5 pressures and saturations are effectively the same and higher DBR releases result
 - In actuality, Panel 10 and Panel 1 are separated by ROMPCS, and saturations and pressures in Panel 1 are much lower than in Panel 10 for much of the 10,000 yr duration

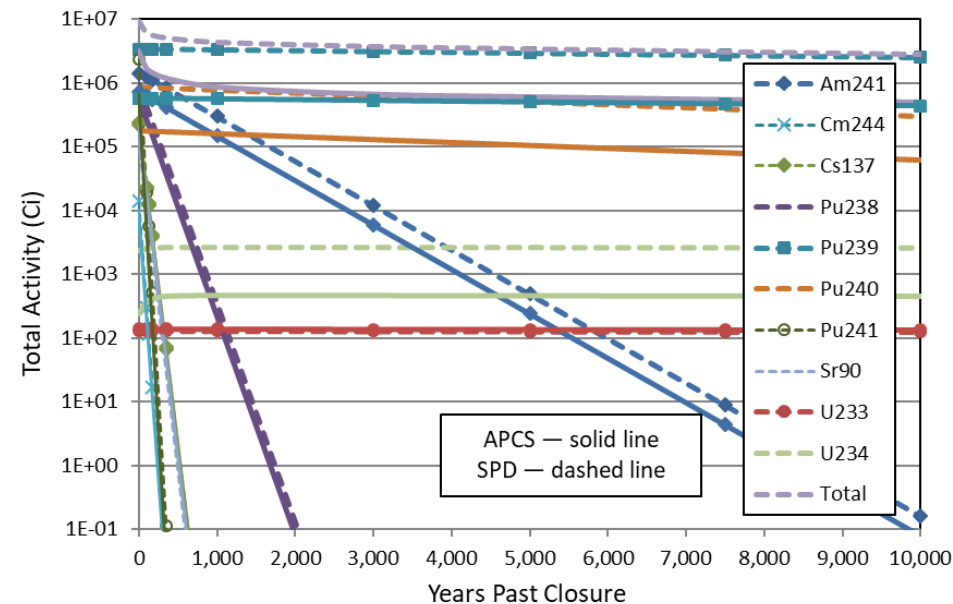
Neighbor
Relationships

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

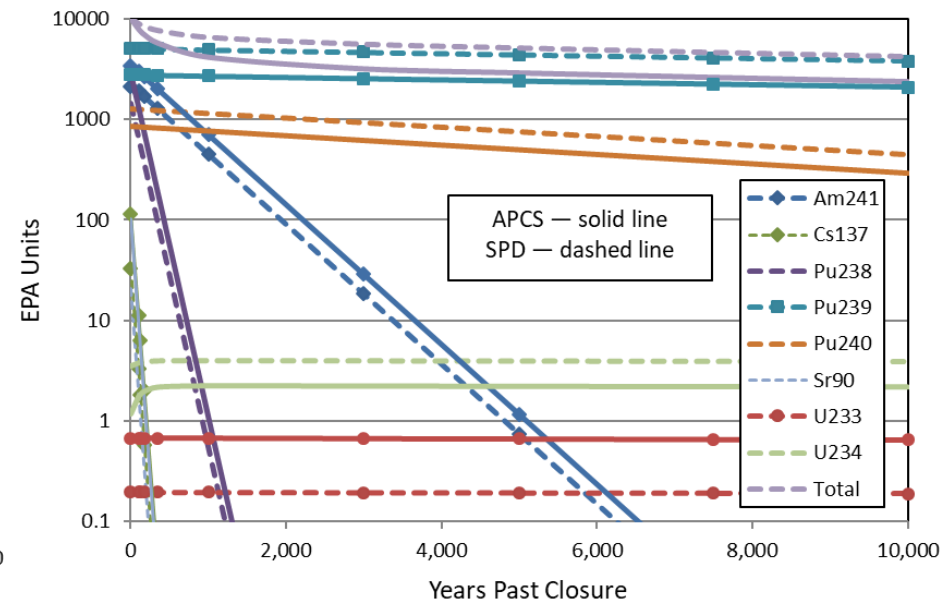


SPD Inventory

- Inventory dominated by ^{239}Pu at long times
- Initial ^{239}Pu inventory plays a large role in long time radionuclide concentrations



SPD Activity in Ci



SPD Activity in EPA Units

Implementation

