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Direct Brine Release Modeling in WIPP Performance Assessment

KHNP Training Program
Module 6: Assembly of a Safety Case

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Outline

I. Introduction to Direct Brine Releases

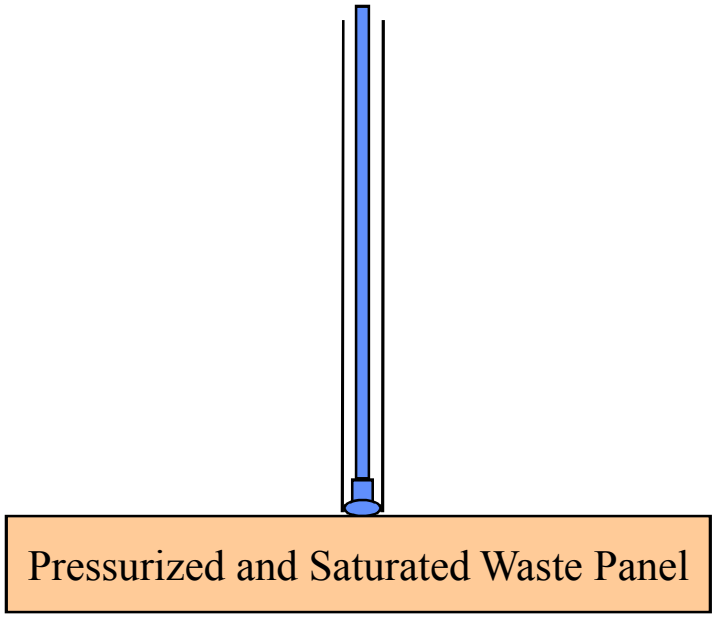
II. Description of Conceptual Model

III. Numerical Implementation

IV. PABC Results

I. Introduction

- Gas generation and brine flow can pressurize and saturate the WIPP waste panels.
- Drilling into a pressurized and saturated waste panel could result in contaminated brine being released at the surface during the drilling process.
- Direct Brine Release (DBR) is explicitly included as a process model in WIPP PA.



II. DBR Conceptual Model

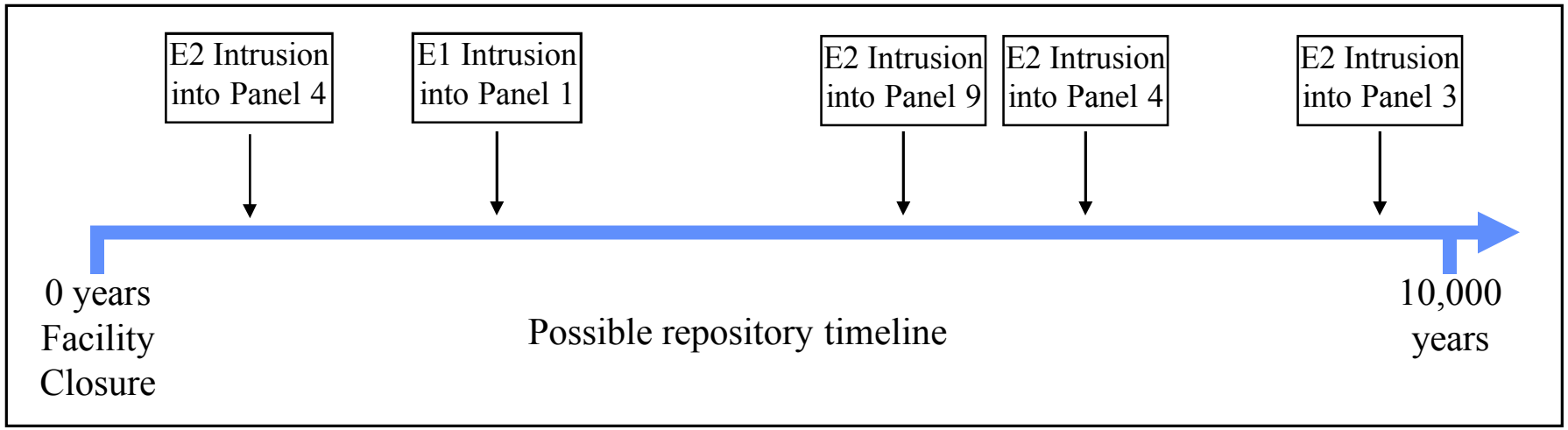
- A driller intrudes into a pressurized and saturated waste panel while looking for natural resources and contaminated brine flows from the waste panel to the surface.

- For a DBR to occur, two conditions must be met:
    1. The pressure in the waste panel must be sufficiently high, and
    2. There must be mobile brine available.
- If either condition is not met, there is no DBR.

- There is a set duration for the DBR, based on time needed to control the flow and drill through the formation.

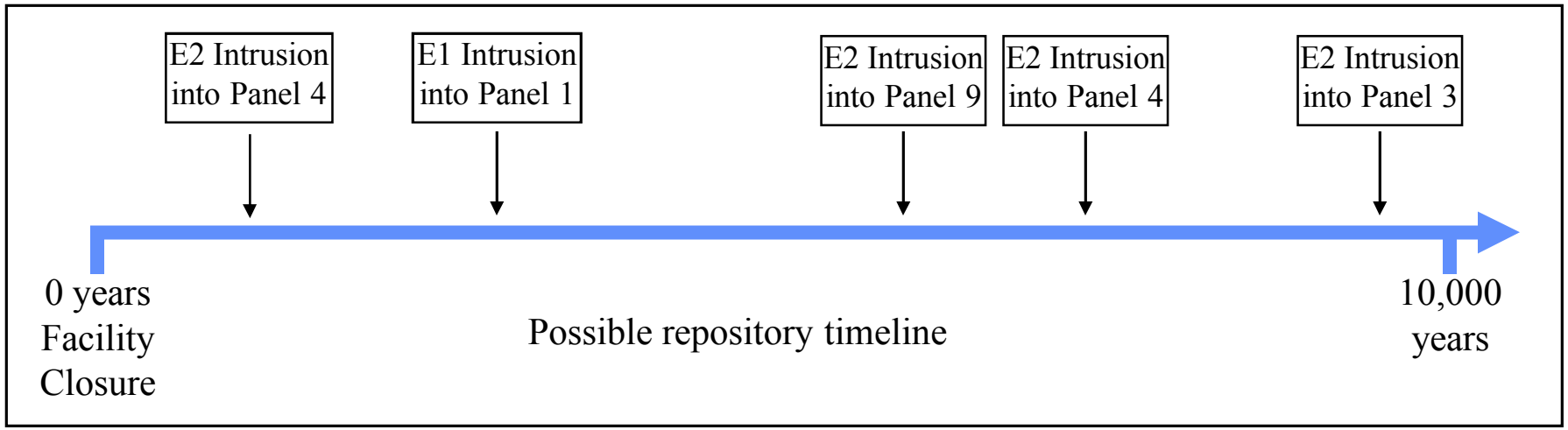
III. Numerical Implementation

- **Need to calculate the DBR for each intrusion.**
- **Not computationally efficient to calculate the DBR from a full model for every intrusion in all future-location-vector-replicate combinations.**
- **A lookup table is computationally fast.**

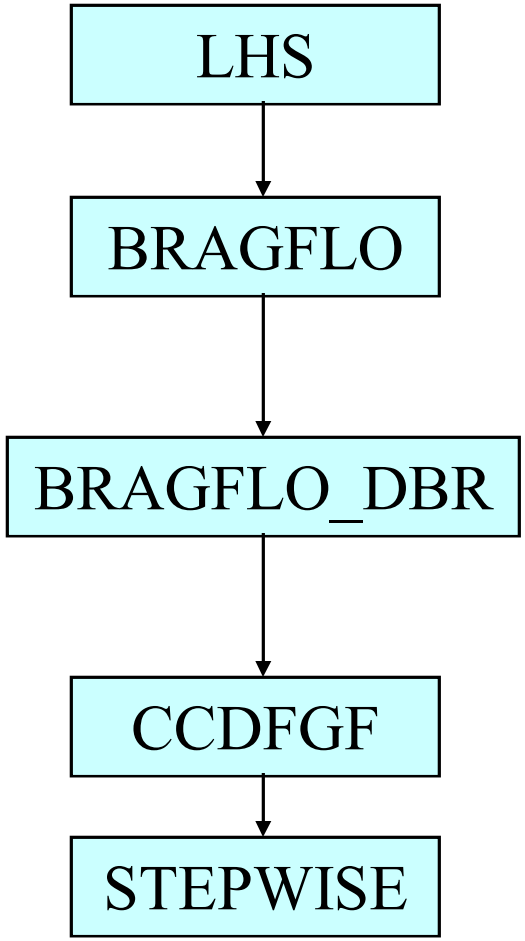


DBR Lookup Table Generation

- **DBR as a function of panel state, location and time (7,800 total runs).**
  - **Undisturbed, E1 intrusion and E2 intrusion states.**
  - **5-6 times for each state.**
  - **3 locations for each time and state.**



DBR Methodology: Code Flow



- **Subjectively samples uncertain parameters**
- **Calculates repository pressures and saturations for all times, locations and scenarios**
- **Calculates DBR volumes for a specific intrusion time, location and scenario using BRAGFLO for initial conditions**
- **Calculates normalized releases**
- **Sensitivity analysis**

DBR Volumetric Flow rate (q)

- **Determined from well deliverability equation, which is the product of:**
  - **The phase productivity index, J_p (m^3/Pa/s), and**
  - **The difference between the waste panel pressure, $P_w(t)$ (Pa), and the flowing bottom-hole pressure, P_{bh} (Pa).**

$$q(t) = J_P [P_w(t) - P_{bh}]$$

Phase Productivity Index (J_P)

k = intrinsic permeability (m^2)
k_{rp} = relative permeability
h = crushed panel height (m)
μ_p = phase viscosity (Pa·s)
r_e = grid cell equivalent radius (m)
r_w = well radius (m)
s = skin factor (accounts for cavings)
c = -0.5 for pseudo steady state

$$J_P = \frac{2\pi k k_{rp} h}{\mu_p \left[\ln\left(\frac{r_e}{r_w}\right) + s + c \right]}$$

$$q(t) = J_P \left[P_w(t) - P_{bh}\right]$$

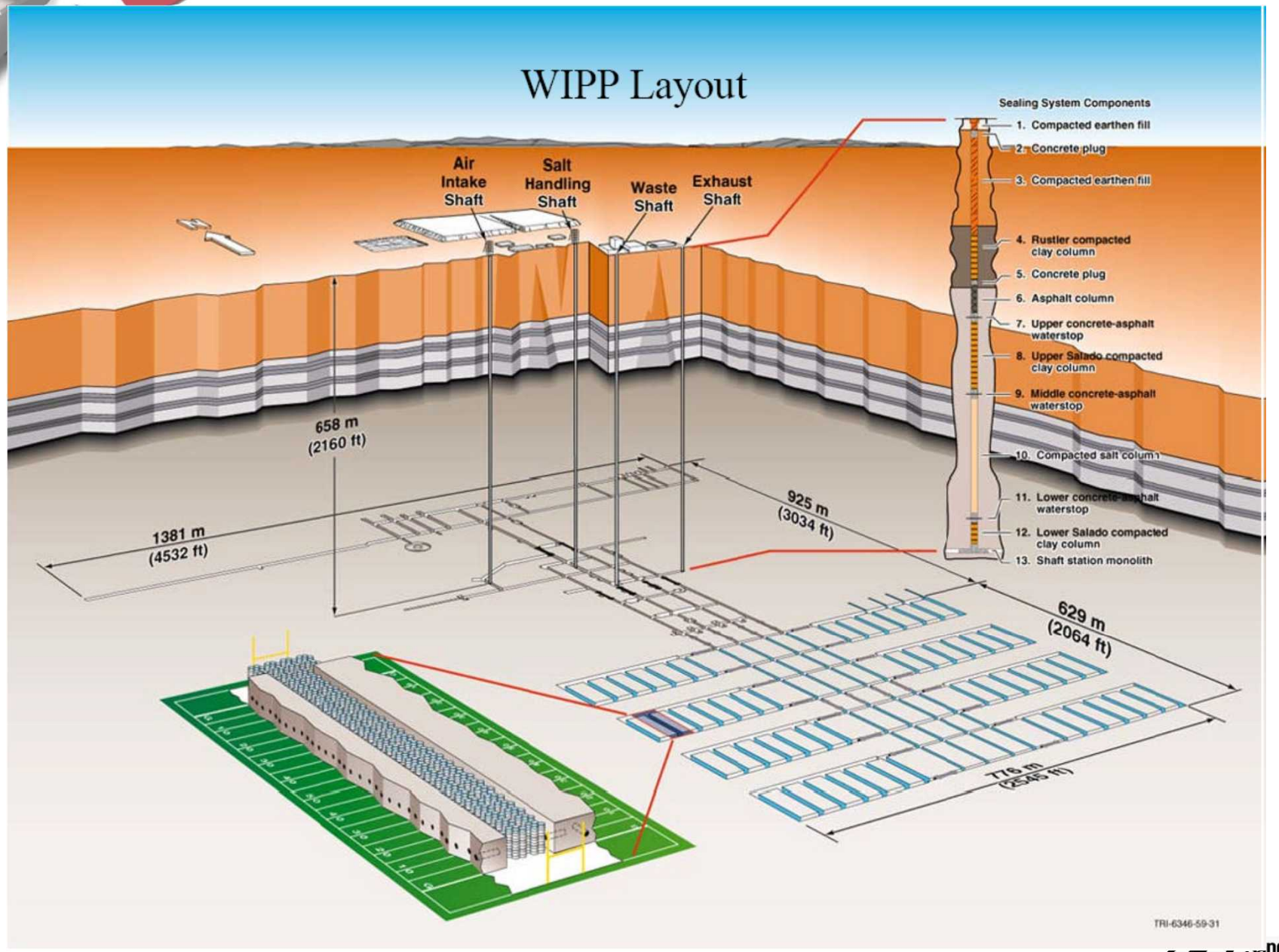
Waste Panel Pressure

- The initial waste panel pressure is determined based on the BRAGFLO results.
- The pressure as a function of time is calculated with the BRAGFLO code using the DBR grid.

$$q(t) = J_P [P_w(t) - P_{bh}]$$

DBR Grid Description

- Two-dimensional mesh of 39x39 grid cells.
- Only models flow in the waste area.
- Includes smaller features such as:
  - Salt pillars
  - Rooms
  - Panel seals
  - Passageways


WIPP Layout
Air Intake Shaft
Salt Handling Shaft
Waste Shaft
Exhaust Shaft
Sealing System Components
1. Compacted earthen fill
2. Concrete plug
3. Compacted earthen fill
4. Rustler compacted clay column
5. Concrete plug
6. Asphalt column
7. Upper concrete-asphalt waterstop
8. Upper Salado compacted clay column
9. Middle concrete-asphalt waterstop
10. Compacted salt column
11. Lower concrete-asphalt waterstop
12. Lower Salado compacted clay column
13. Shaft station monolith
658 m (2160 ft)
1381 m (4532 ft)
925 m (3034 ft)
629 m (2064 ft)
776 m (2545 ft)
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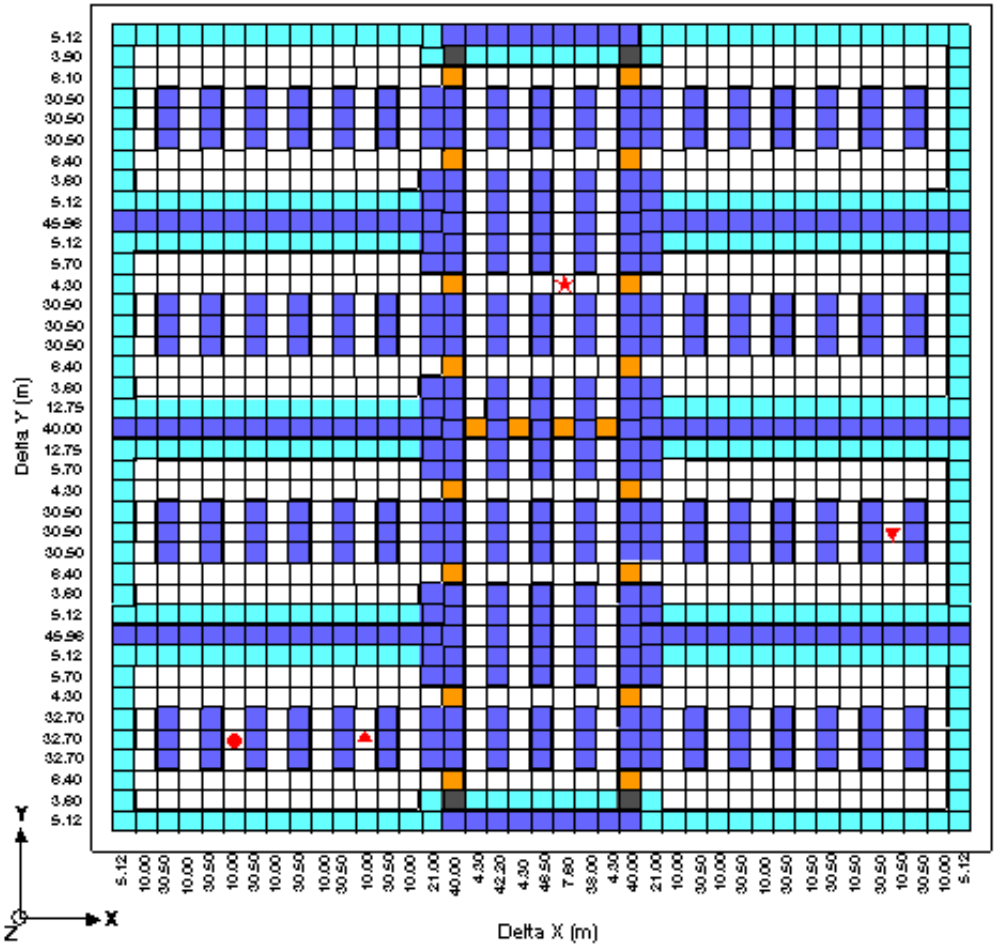
DBR Grid used in the PABC



Note: Model cells are not to scale. The actual dimensions of the grid blocks are indicated along the edge of the diagram.

Flowing Bottom-Hole Pressure (P_{bh})

- Dynamic pressure adjacent to the point of entry into the repository, that accounts for elevation, friction and acceleration effects using the Poettmann-Carpenter Wellbore Model.
- A lookup table was generated using the expected ranges of panel pressures, brine saturation, permeability, crushed height and skin factor.
- The lookup table provides the flowing bottom-hole pressure from the panel pressure and the flow conditions.

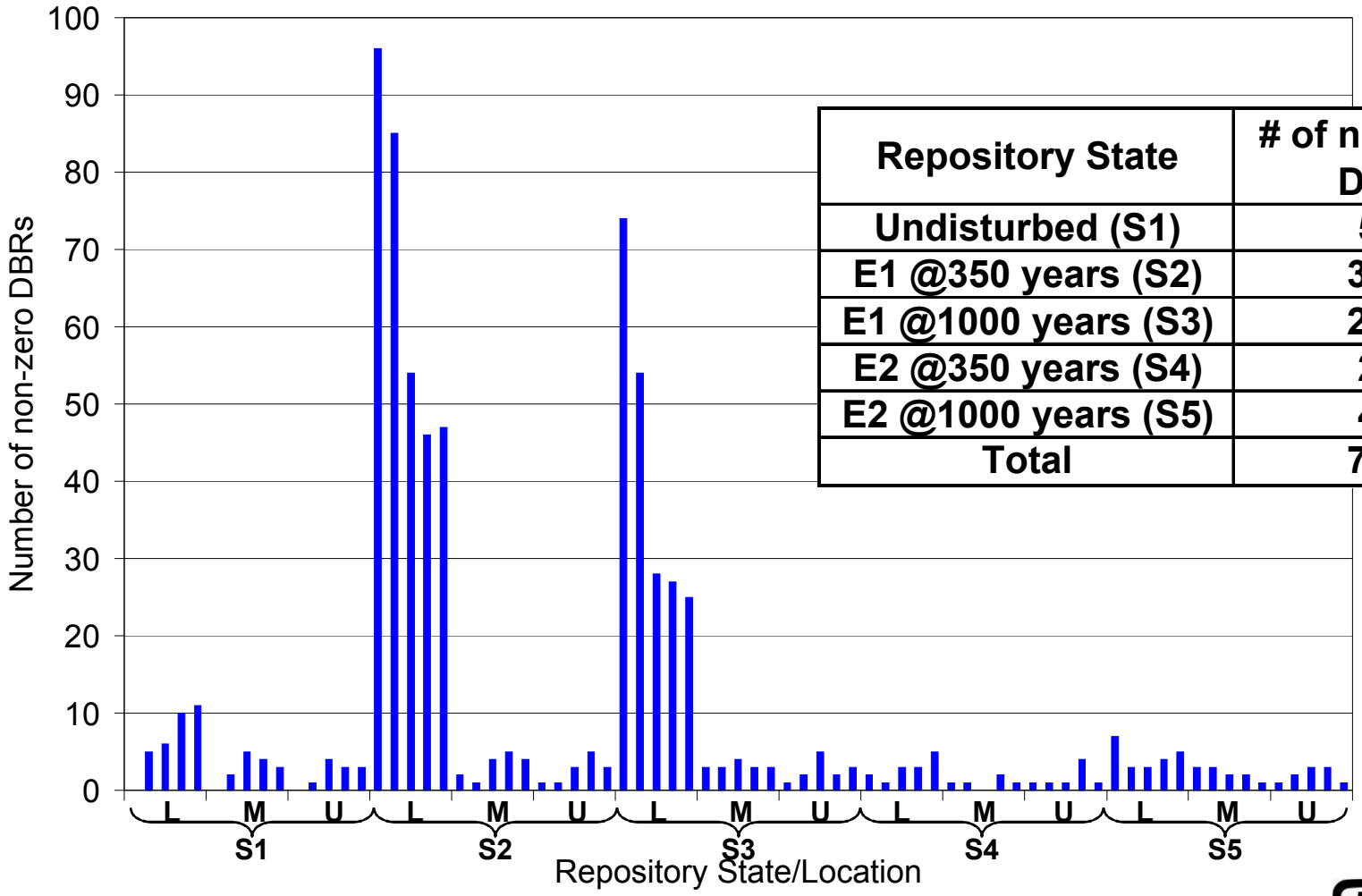
$$q(t) = J_P [P_w(t) - P_{bh}]$$

IV. PABC DBR Results

- Summary of the 7,800 results grouped by scenario (state of repository).
- Plot showing distribution with each scenario based on time and location.

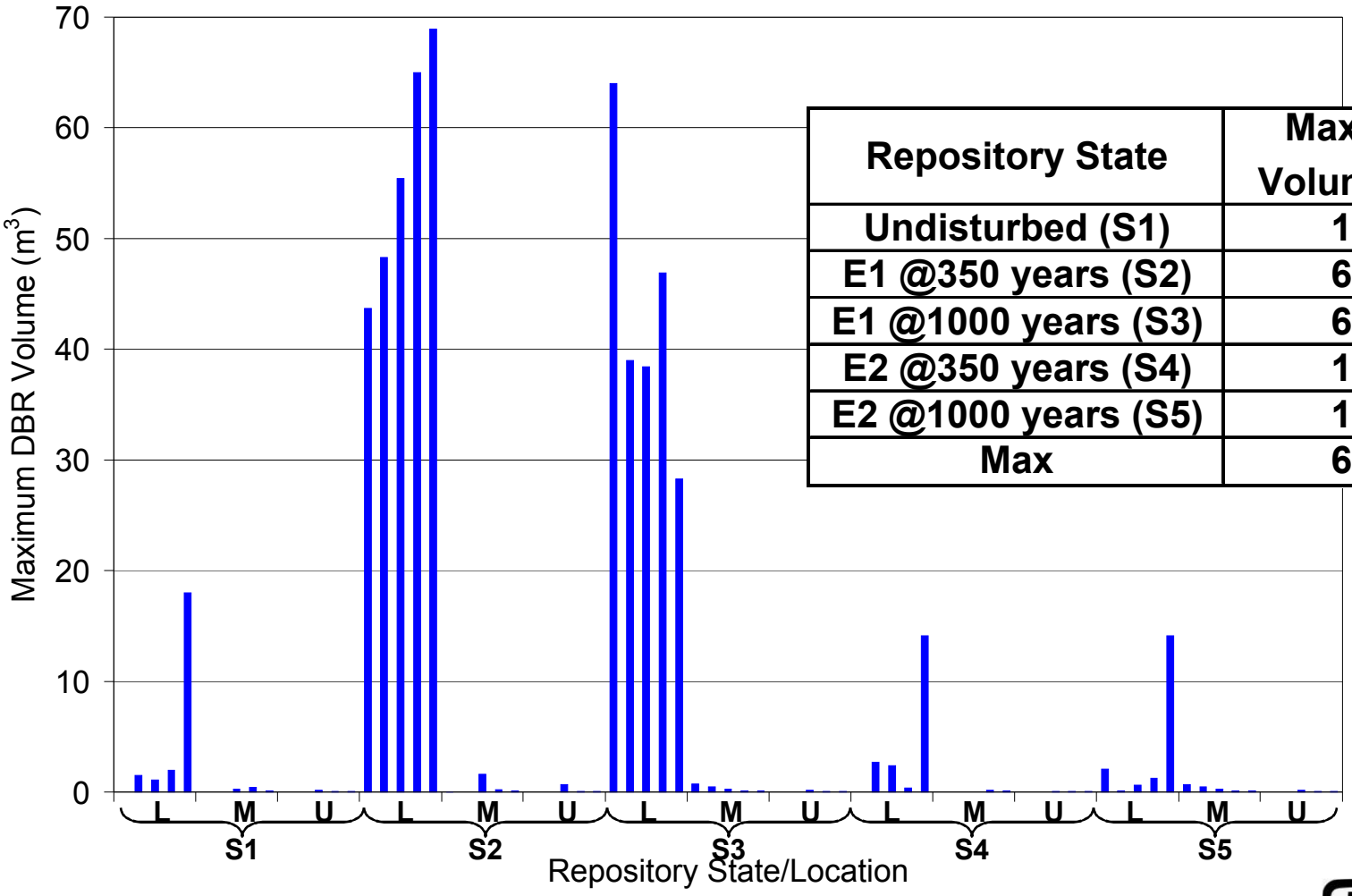
- Number of vectors with non-zero DBR volumes.
- Maximum DBR volumes.
- Average of non-zero DBR volumes.

Number of non-zero DBRs



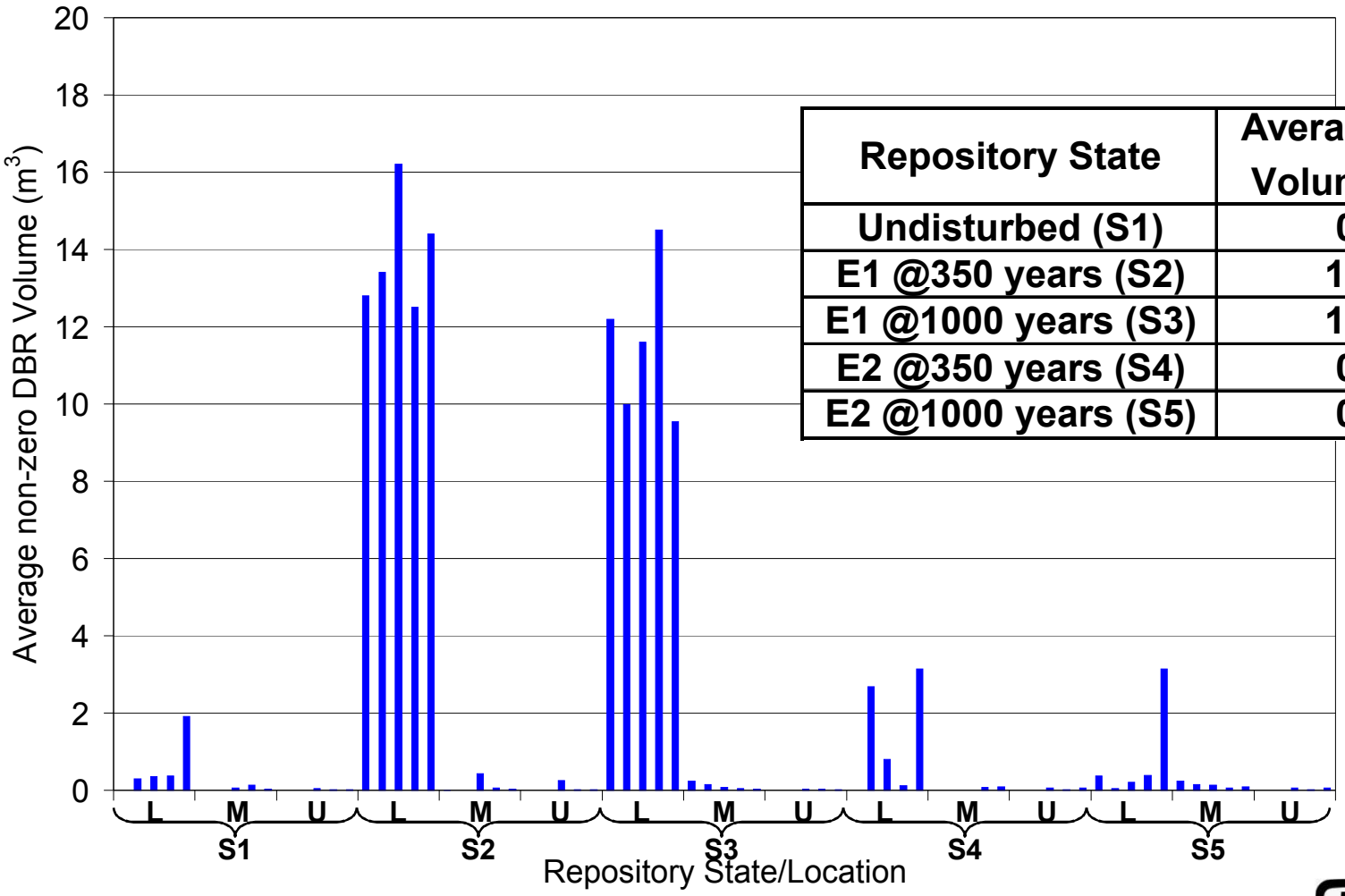
Repository State	# of non-zero DBR
Undisturbed (S1)	57
E1 @350 years (S2)	357
E1 @1000 years (S3)	237
E2 @350 years (S4)	27
E2 @1000 years (S5)	43
Total	721

Maximum DBR Volumes



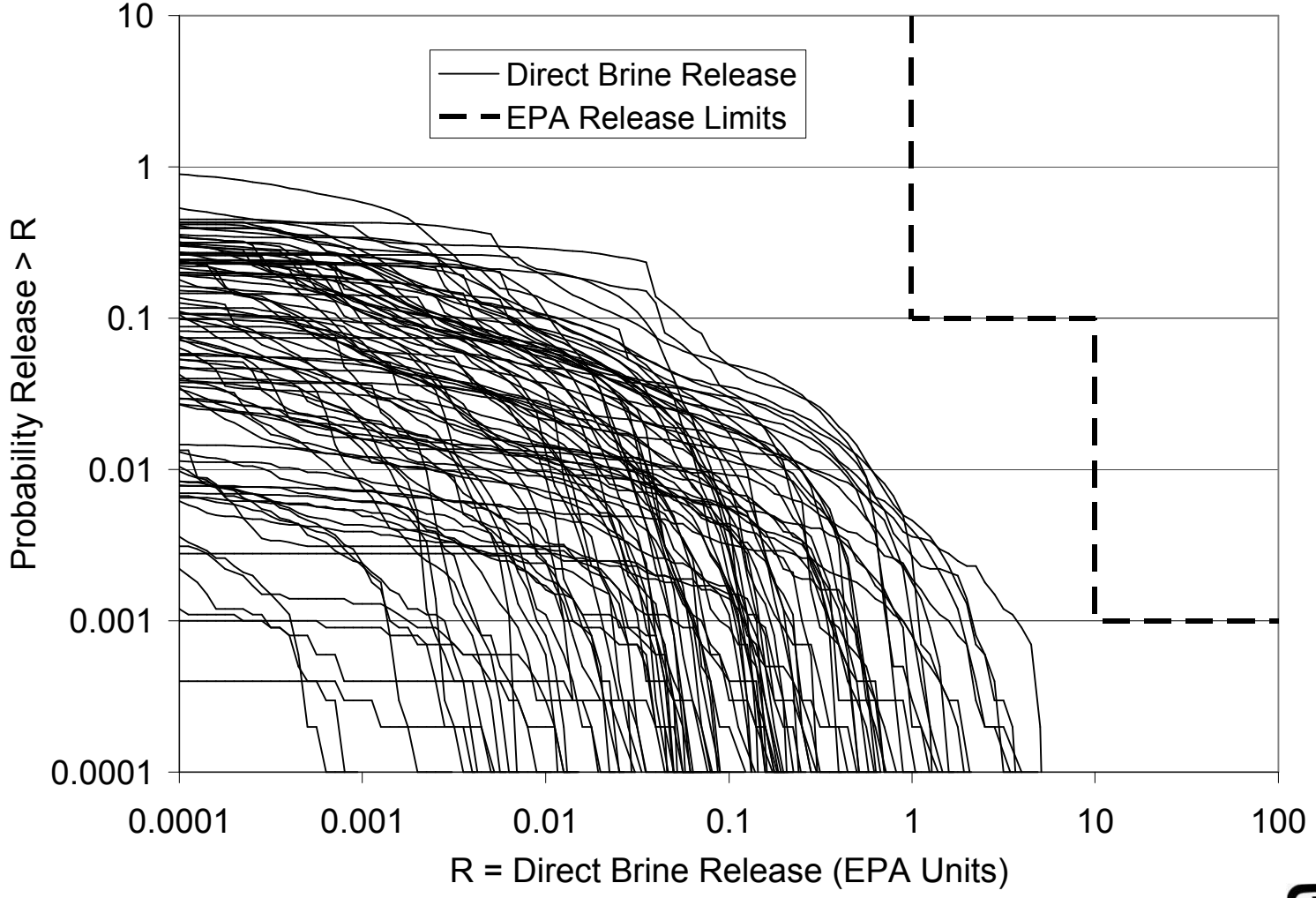
Repository State	Max DBR Volume (m^3)
Undisturbed (S1)	18.0
E1 @350 years (S2)	68.9
E1 @1000 years (S3)	64.0
E2 @350 years (S4)	14.1
E2 @1000 years (S5)	14.1
Max	68.9

Average of non-zero DBR Volumes



Repository State	Average DBR Volume (m^3)
Undisturbed (S1)	0.5
E1 @350 years (S2)	12.6
E1 @1000 years (S3)	10.1
E2 @350 years (S4)	0.8
E2 @1000 years (S5)	0.5

PABC Direct Brine Release CCDF by vector



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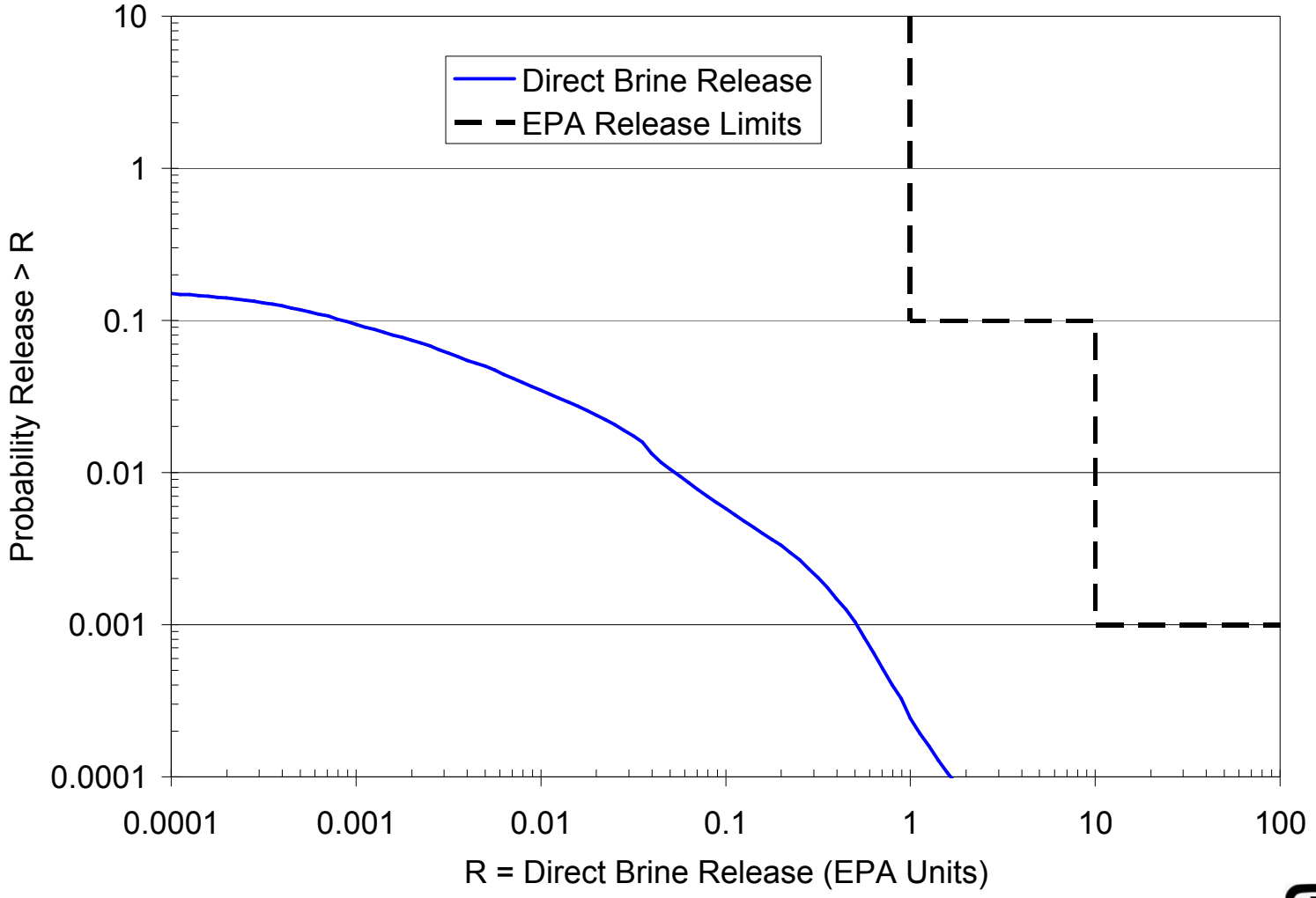
Mean PABC Direct Brine Release CCDF



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