SAND2008-2110P

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

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Repository Barrier Capability

Presented to:
NRC/DOE Technical Exchange on Total Systems Performance Assessment for Yucca Mountain

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April 03, 2008
Las Vegas, Nevada

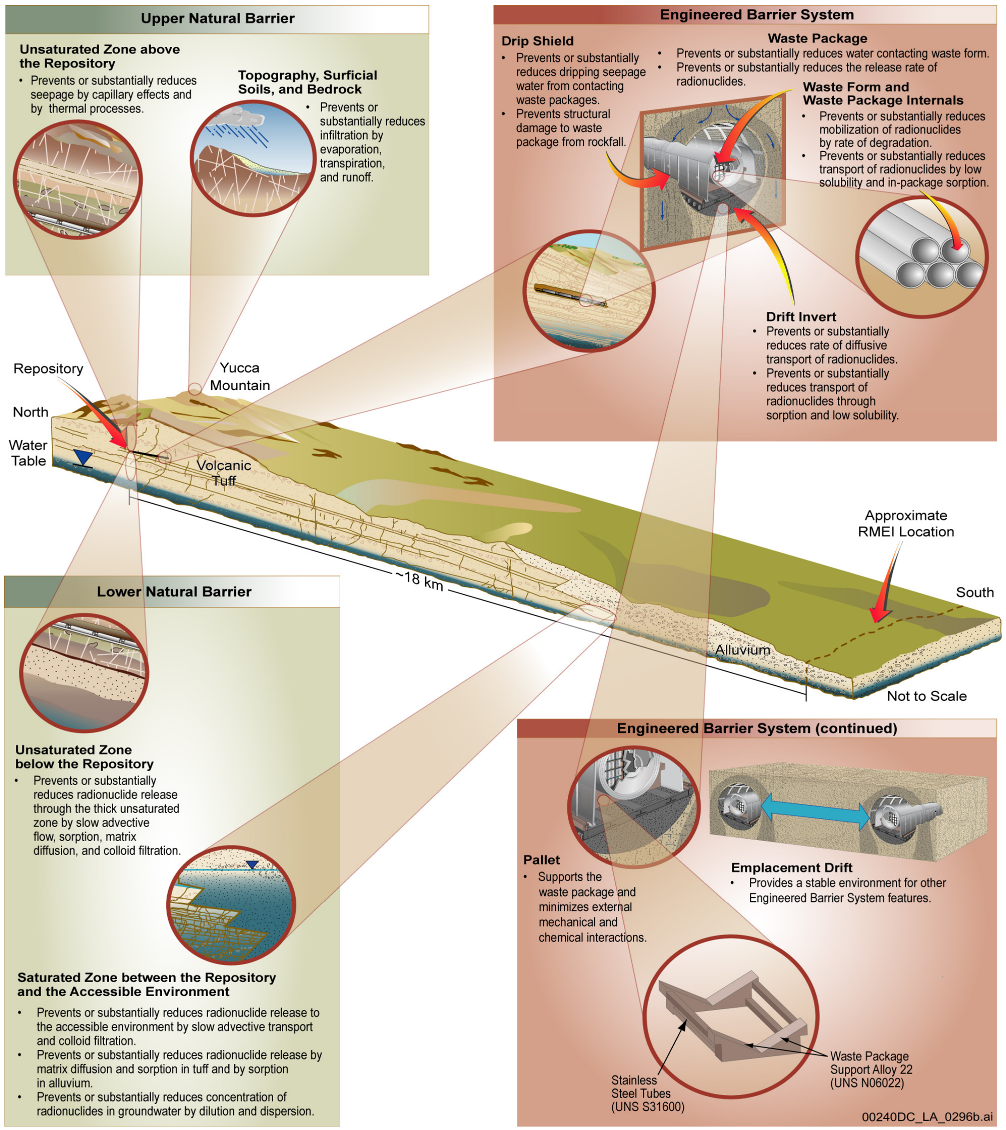
Presentation Outline

- Introduction
- Multiple barrier repository system
- Quantification of barrier capability
  - Upper Natural Barrier (UNB)
  - Engineered Barrier System (EBS)
  - Lower Natural Barrier (LNB)
- Summary
- Supporting documentation

Introduction

- The repository system is composed of natural and engineered features that function together as two natural barriers and an engineered barrier system
- A barrier is defined in 10 CFR 63.2 as any material, structure, or feature that, for a period to be determined by the NRC, prevents or substantially reduces the rate of movement of water or radionuclides from the Yucca Mountain Repository to the accessible environment, or prevents the release or substantially reduces the release rate of radionuclides from the waste
- As defined by 10 CFR 63.2, important to waste isolation (ITWI), with reference to design of the EBS and characterization of natural barriers, means those engineered and natural barriers whose function is to provide a reasonable expectation that HLW can be disposed of without exceeding the requirements of 63.113(b) & (c)

Schematic of the Multiple Barrier Repository System



- **The technical bases for the assessment of the capability of the three barriers are the same as the bases used for the compliance of the repository system with the postclosure performance assessment objectives and requirements**
- **Barrier capability is based on the abstraction models of processes included in the performance assessment as well as an evaluation of FEPs that have been excluded from the performance assessment**

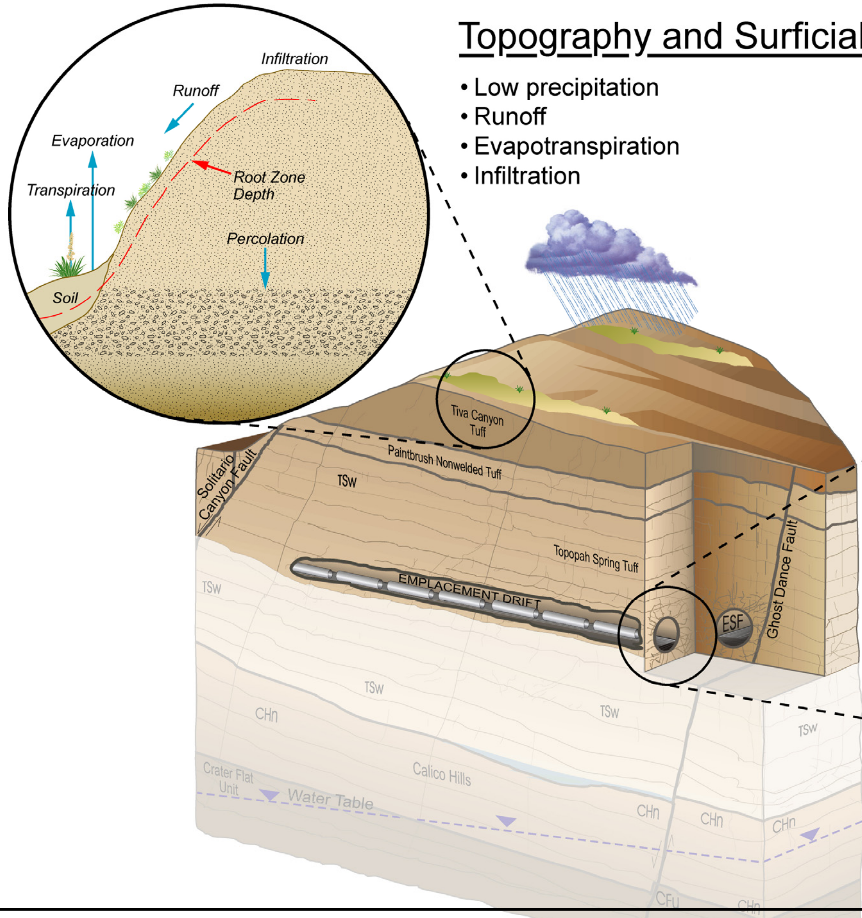
Quantification of Barrier Capability

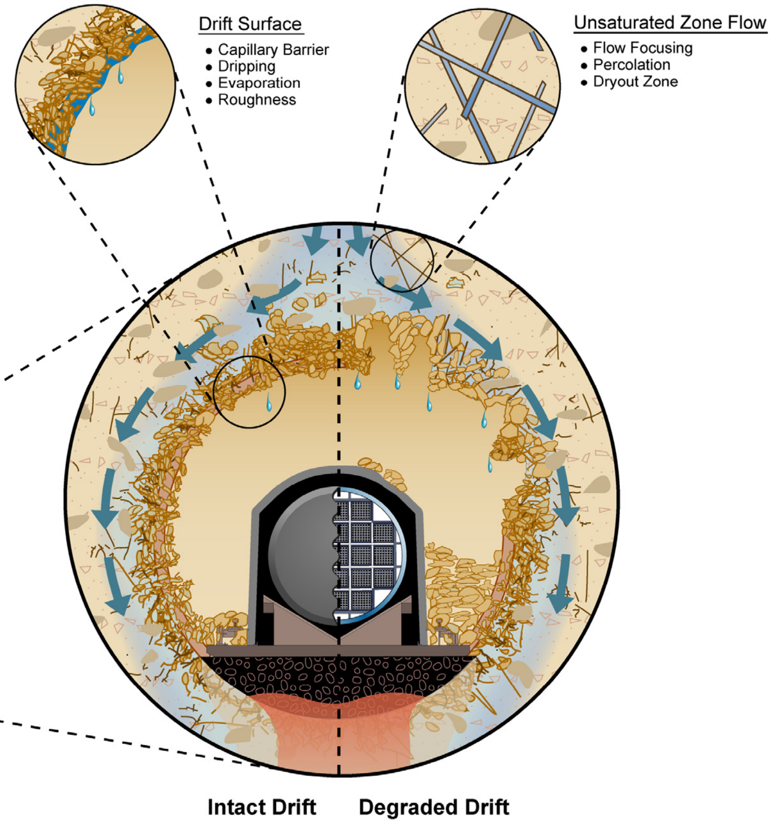
- **Two modeling cases considered for demonstrating barrier capability**
  - **Combined nominal/early failure modeling case**
    - **Drip shield and waste package early failure modeling cases and the nominal modeling case are combined into one modeling case**
    - **Representation of repository futures in which disruptive events do not occur**
    - **Provides a projection of a reference capability**
  - **Seismic ground motion modeling case**
    - **Addresses barrier capability as a function of disruptive conditions**
    - **Important to demonstration of compliance with the regulatory standards**

Upper Natural Barrier

Topography and Surficial Soils

- Low precipitation
- Runoff
- Evapotranspiration
- Infiltration





Unsaturated Zone above Repository

- Percolation
- Capillarity
- Flow Diversion around Emplacement Drifts

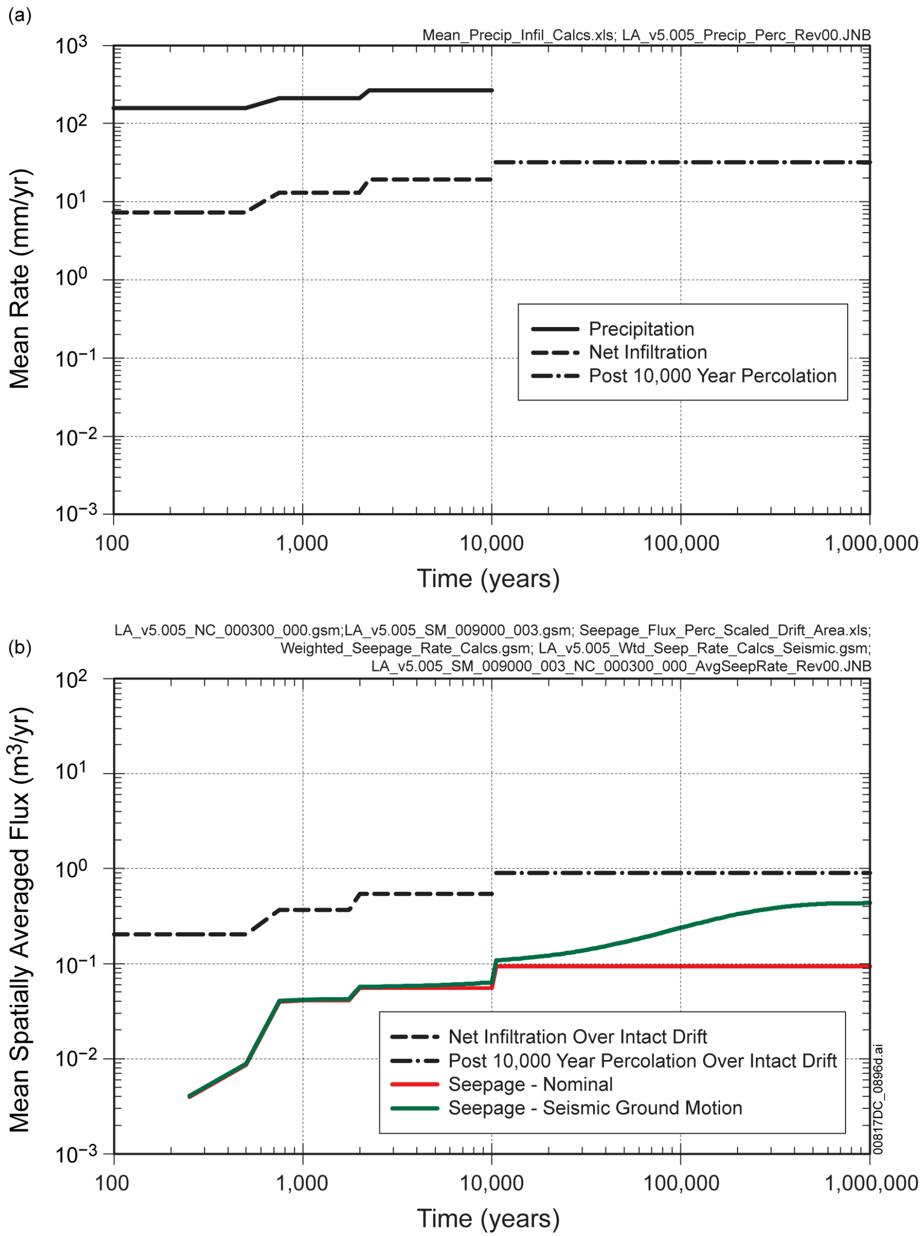
The Upper Natural Barrier (UNB), by preventing or substantially reducing the rate of movement of water into the repository, prevents or substantially reduces the rate of movement of radionuclides from the repository to the accessible environment

Quantification of UNB Capability

- **Topography and surficial soils**
  - **Run-on and runoff, evaporation, and transpiration combine to divert water and permit only a small fraction of the precipitation at the site to infiltrate into the unsaturated zone (*Simulation of Net Infiltration For Present-Day And Potential Future Climates*, SNL 2008)**
- **Unsaturated zone above the repository**
  - **Damping of episodic pulses of precipitation and infiltration (*UZ Flow Models and Submodels*, SNL 2007)**
  - **Capillary forces in rock adjacent to emplacement drifts limit seepage into drifts (*Abstraction of Drift Seepage,* SNL 2007)**
  - **Elevated temperatures in the rock during thermal period limit seepage into the drifts (*Abstraction of Drift Seepage,* SNL 2007)**

Quantification of UNB Capability (continued)

- **Characteristics and properties of the topography and surficial soils are not expected to change in the 10,000 years after closure (YMP 1993, Topical Report YMP/92-41-TPR, Section 3.4)**
- **Drift collapse caused by seismic ground motion may reduce effectiveness of capillary barrier**
  - **Increase in seepage rates**
  - **Increase in seepage fraction**
- **Metrics: Net infiltration, drift seepage rate, seepage fraction**



<u>Key Points</u>:

Mean Net Infiltration (I) as % of Precipitation rate:

- Ranges ~5% during present-day climate to 7% during glacial-transition climate
- ET accounts for 85 to 88% of reduction in net infiltration

Mean Drift Seepage (S) as % of ambient seepage flux (first 10K yrs)

- S ~ 2 to 11%
- Nominal & Seismic GM almost identical

Mean Drift Seepage as % of Post-10K Percolation

- Nominal, S ~ 11%
- Seismic GM, S ~ 12 to 48% (drift-degradation reduces effectiveness of capillary barrier effect)

(Ref: SNL 2008 MDL-WIS-PA-000005 REV 00 AD 01, Section 8.3.3.1.1[a])

Nominal/Early Failure Modeling Case for 10,000-year Period (Glacial-transition)

Percolation Subregion		Seepage Fraction for CSNF Waste Packages		
Subregion Index	Quantile Range	5th Percentile	Mean	95th Percentile
1	$p < 0.05$	0.0020	0.0887	0.2823
2	$0.05 \leq p < 0.30$	0.0217	0.2308	0.5780
3	$0.30 \leq p < 0.70$	0.0455	0.3294	0.7439
4	$0.70 \leq p < 0.95$	0.0431	0.3848	0.7998
5	$p \geq 0.95$	0.0870	0.4666	0.8386
Repository Average		0.0424	0.3134	0.6950

Nominal/Early Failure Modeling Case for Post-10,000-year Period

Percolation Subregion		Seepage Fraction for CSNF Waste Packages		
Subregion Index	Quantile Range	5th Percentile	Mean	95th Percentile
1	$p < 0.05$	0.0082	0.1251	0.3121
2	$0.05 \leq p < 0.30$	0.0617	0.3402	0.6555
3	$0.30 \leq p < 0.70$	0.0949	0.4369	0.7943
4	$0.70 \leq p < 0.95$	0.0606	0.4364	0.8439
5	$p \geq 0.95$	0.0934	0.4944	0.8802
Repository Average		0.0784	0.3999	0.7449

Seepage Fractions* (SF)

Seismic Ground Motion Modeling Case for Post-10,000-year Period

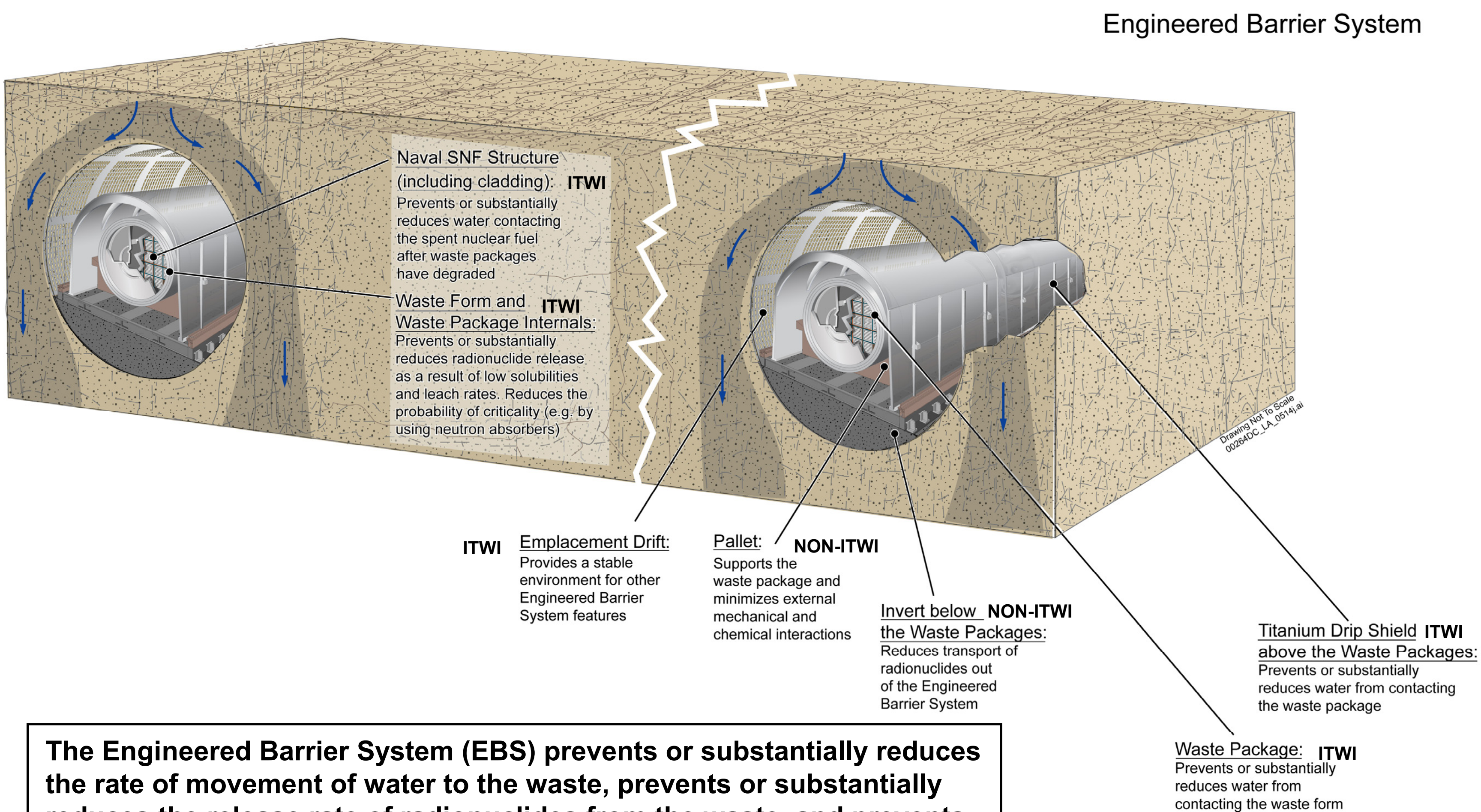
Percolation Subregion		Seepage Fraction for CSNF Waste Packages		
Subregion Index	Quantile Range	5th Percentile	Mean	95th Percentile
1	$p < 0.05$	0.3231	0.4673	0.6923
2	$0.05 \leq p < 0.30$	0.3089	0.6491	0.9173
3	$0.30 \leq p < 0.70$	0.3114	0.7193	0.975
4	$0.70 \leq p < 0.95$	0.226	0.7041	0.9803
5	$p \geq 0.95$	0.3107	0.7518	0.9869
Repository Average		0.2912	0.6870	0.9465

Key Points:

- **Nominal & Seismic GM SF identical for 10K yrs (on average 70% of WPs experience non-seep environments for 10K yrs)**
- **Nominal & Seismic GM SF increase with drift degradation for post-10K**

(*Defined as ratio WPs experiencing seepage to all WPs in repository)

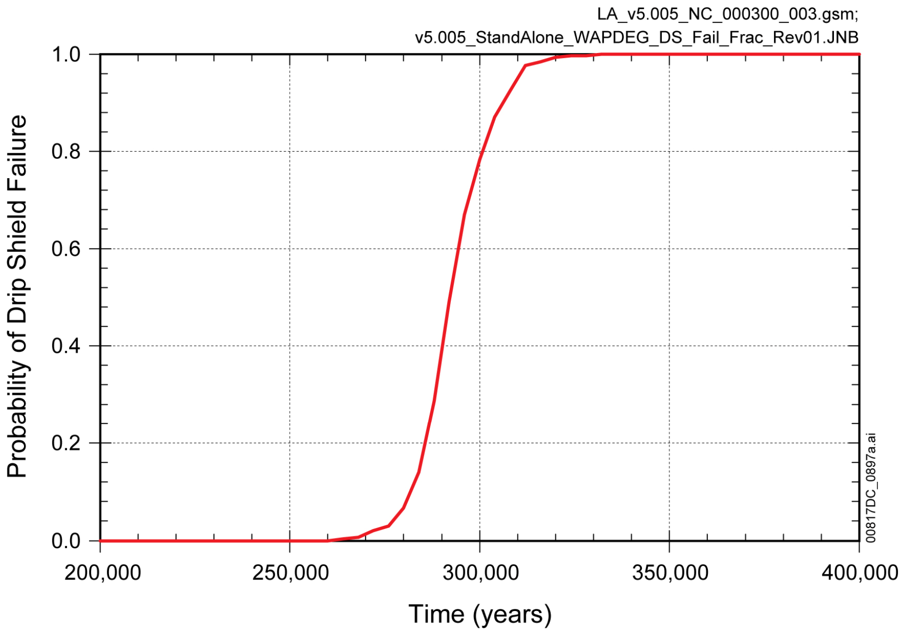
Engineered Barrier System



The Engineered Barrier System (EBS) prevents or substantially reduces the rate of movement of water to the waste, prevents or substantially reduces the release rate of radionuclides from the waste, and prevents or substantially reduces the rate of movement of radionuclides from the repository to the accessible environment.

Quantification of EBS Capability: Drip Shield

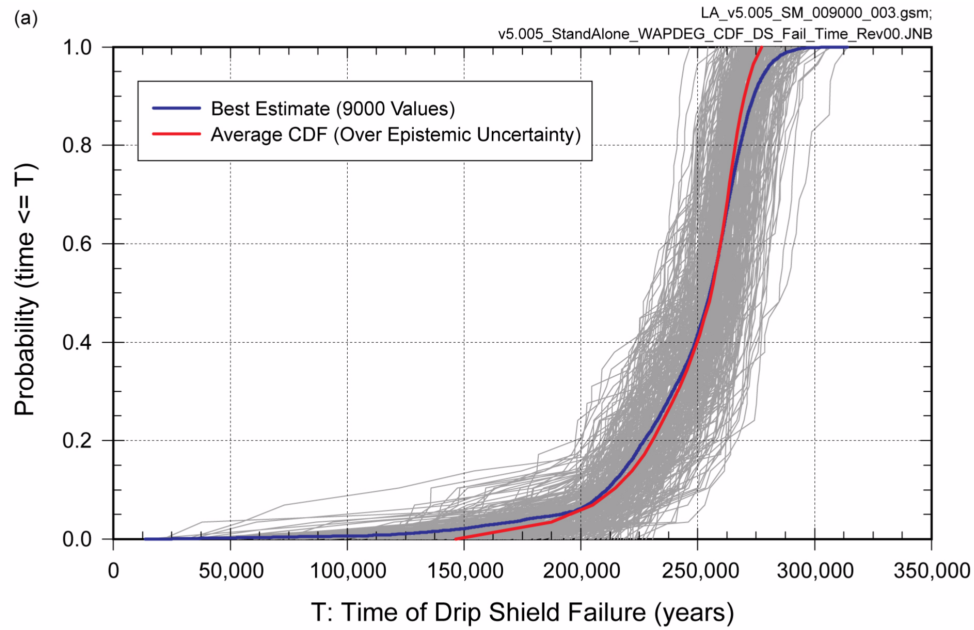
Nominal/Early Failure



Key Points:

- **DS failure under nominal conditions by general corrosion (GC) of Titanium Grade 7 plate**
- **Failure times from about 270,000 to 340,000 yrs**

Seismic Ground Motion



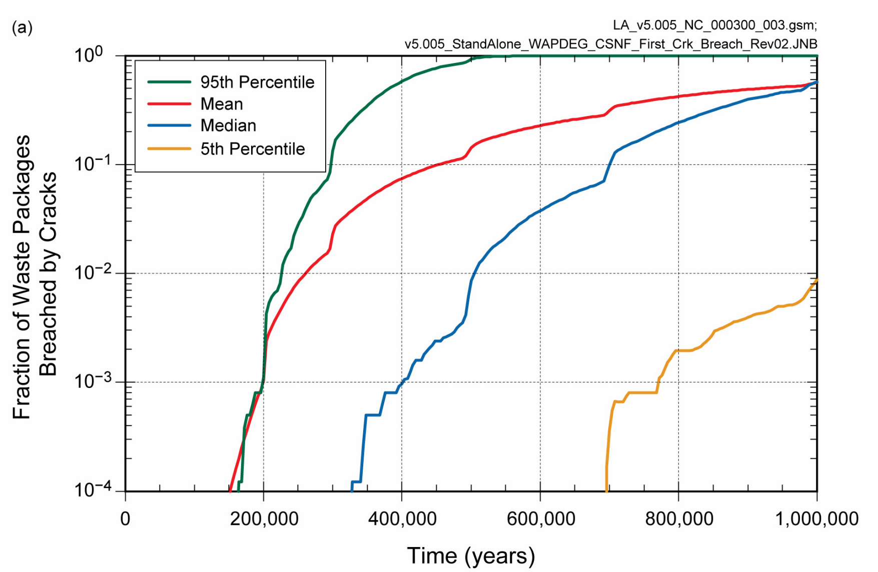
Key Points:

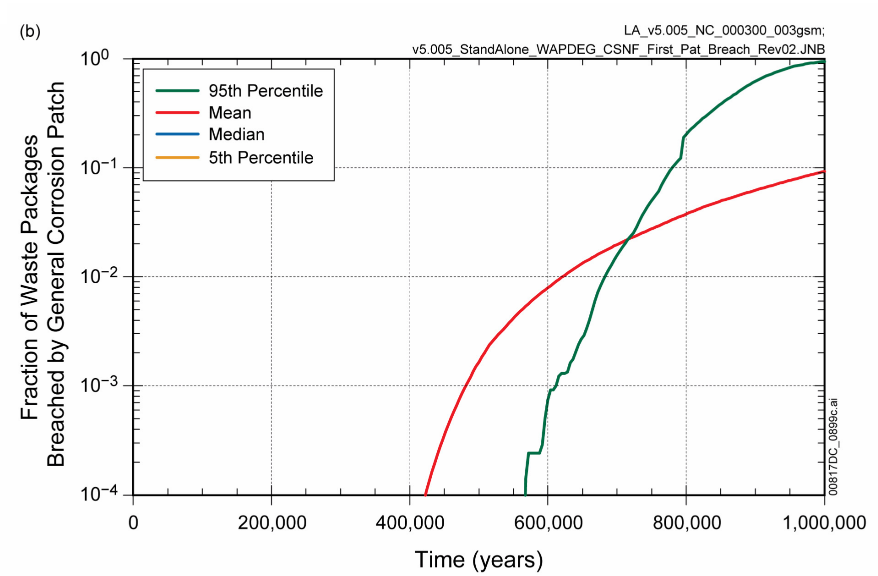
- **DS failure under seismic conditions by rubble accumulation and plate thinning by GC**
- **Probability of DS failure before 100,000 years is 0.0055**

(Note: The TSPA model does not include spatial variability in drip shield failure)

Quantification of EBS Capability: Waste Package

CSNF WP Breach for Nominal Conditions





Stress Corrosion Cracking (of closure-lid welds)

Key Points:

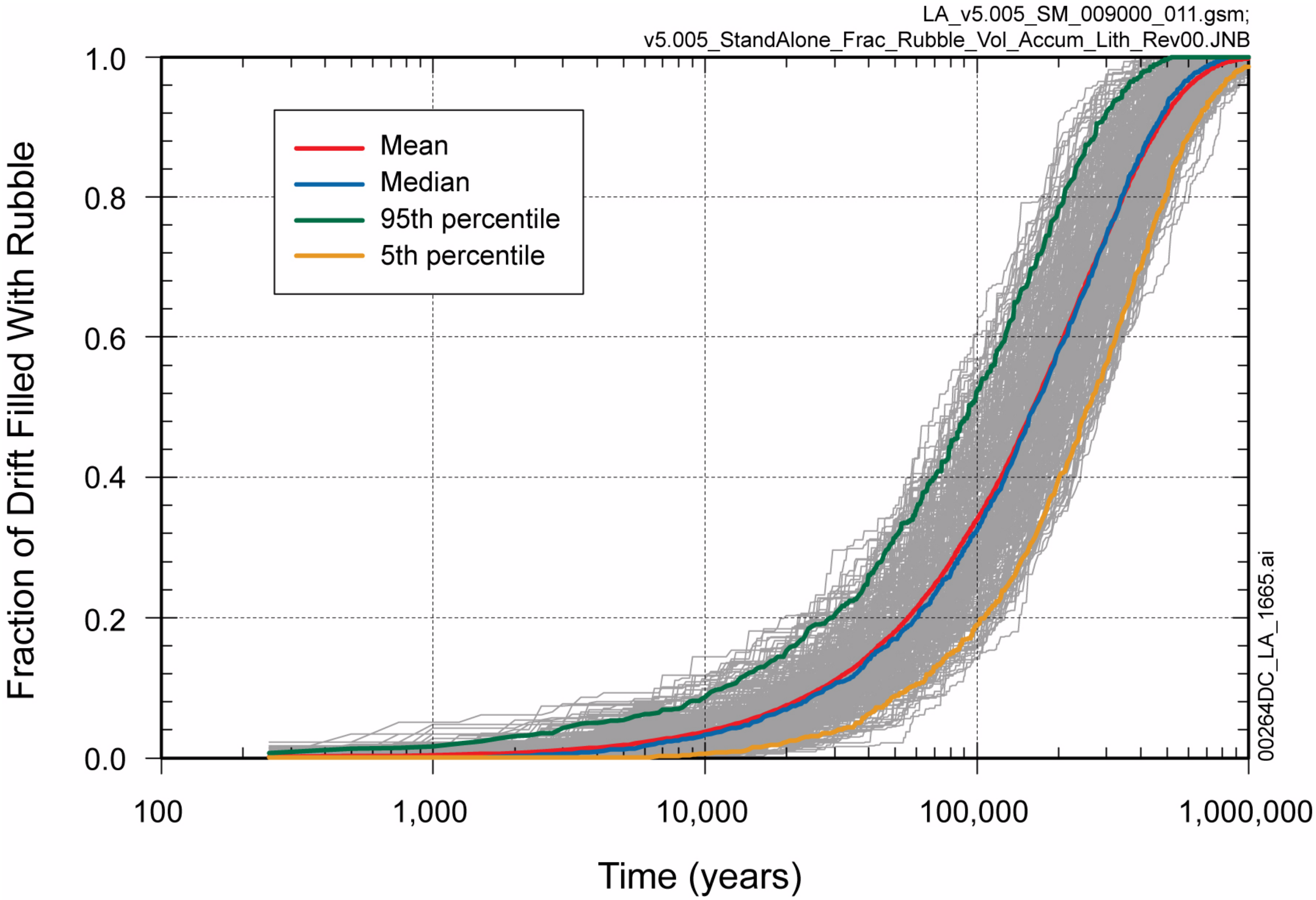
- **SCC breaches of CSNF WPs becomes more likely to occur after 170,000 yrs (based on 95th percentile curve)**
- **By 10^6 yrs, mean fraction of CSNF WPs breached by SCC is ~ 54%**

General Corrosion (of Alloy 22 outer barrier)

Key Points:

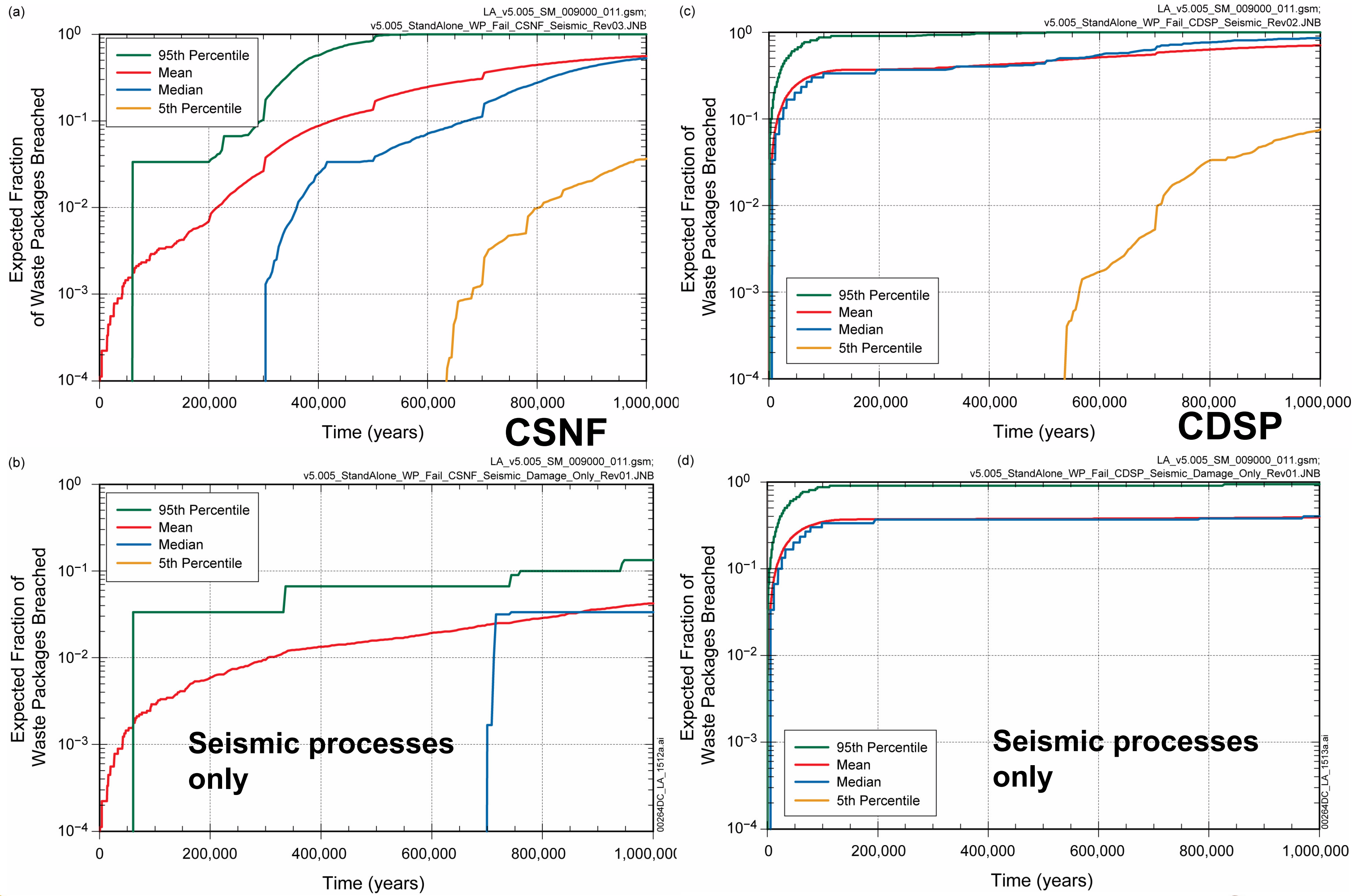
- **GC patch penetrations of CSNF WPs becomes more likely after 560,000 yrs (based on 95th percentile curve)**
- **By 10^6 yrs, mean fraction of WP penetrated by GC is ~ 9%**

Lithophysal Rubble Accumulation

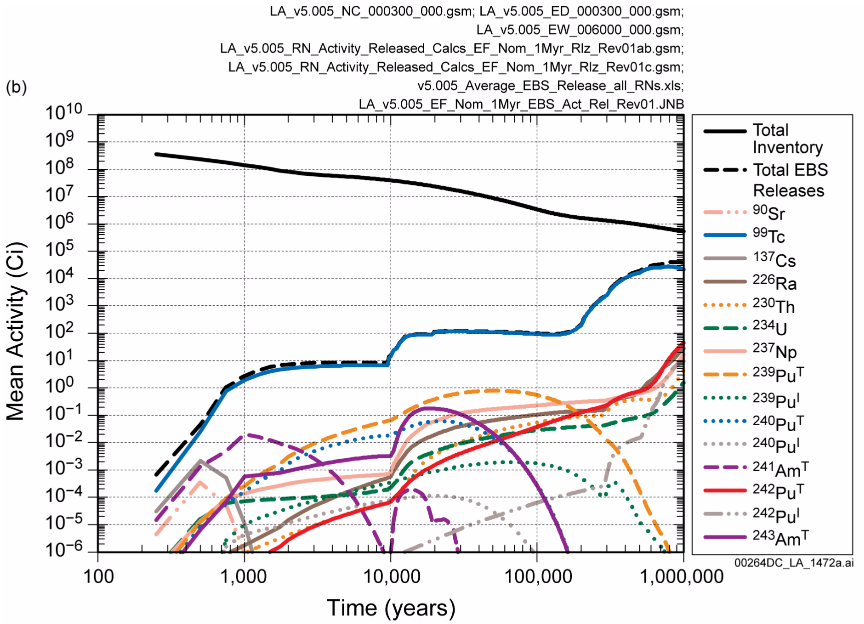


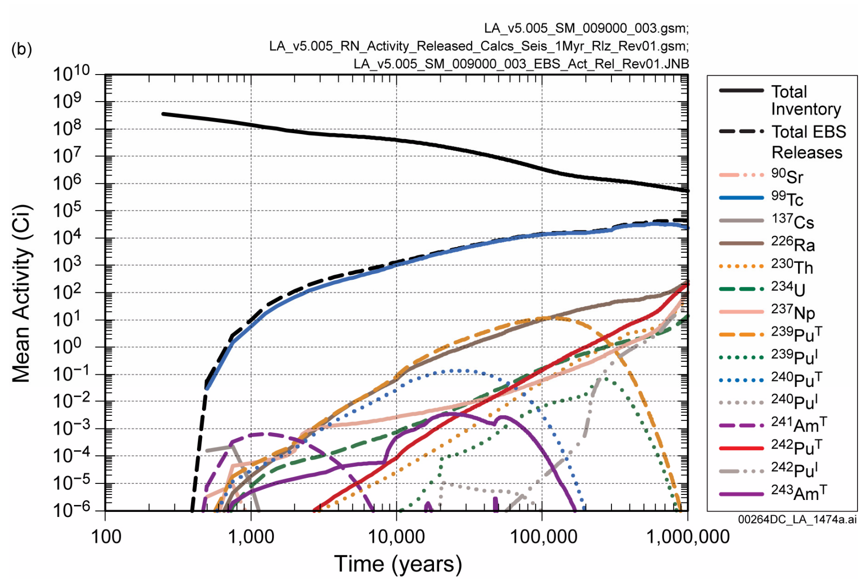
Quantification of EBS Capability: Waste Package

Seismic Ground Motion Modeling Case



Mean Activity Released from the EBS





Combined Nominal/EF

Key Points:

- **At 10^4 yrs, mean activity released from EBS is less than 4 x 10^{-5} % of the inventory**
- **By 10^6 yrs, mean activity released from EBS is about 7% of total inventory**

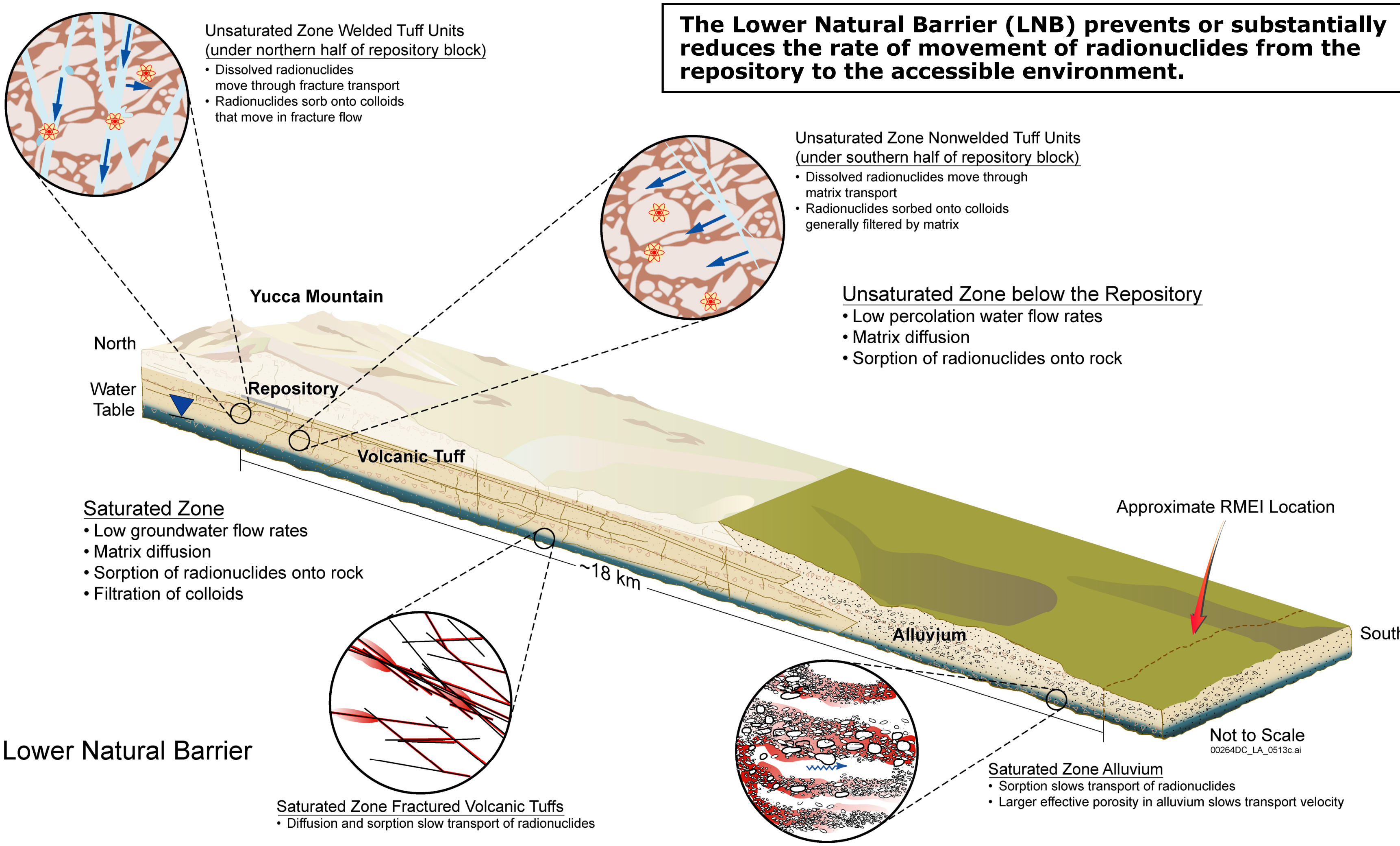
Seismic Ground Motion

Key Points:

- **At 10^4 yrs, mean activity released from EBS is about a factor of 100 higher than Nominal/EF**
- **By 10^6 yrs, mean activity released from EBS is about the same as Nominal/EF**

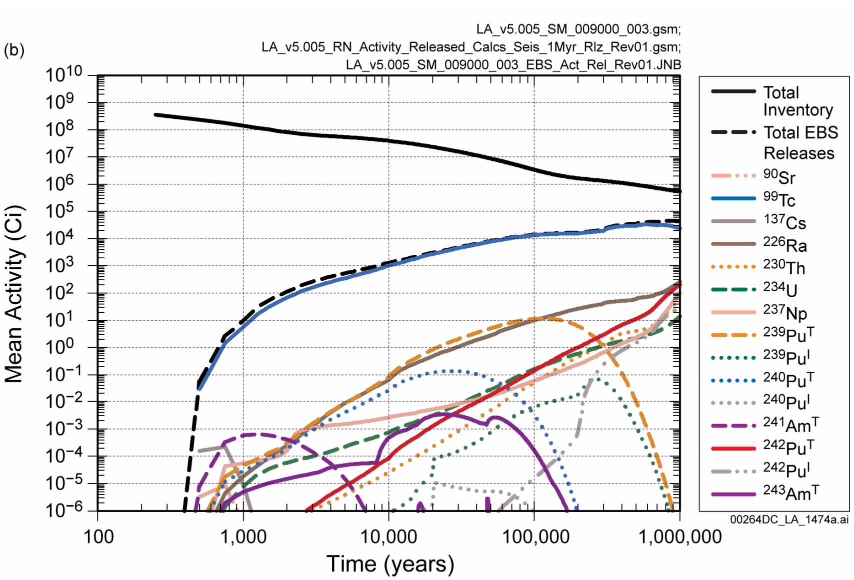
Lower Natural Barrier

The Lower Natural Barrier (LNB) prevents or substantially reduces the rate of movement of radionuclides from the repository to the accessible environment.

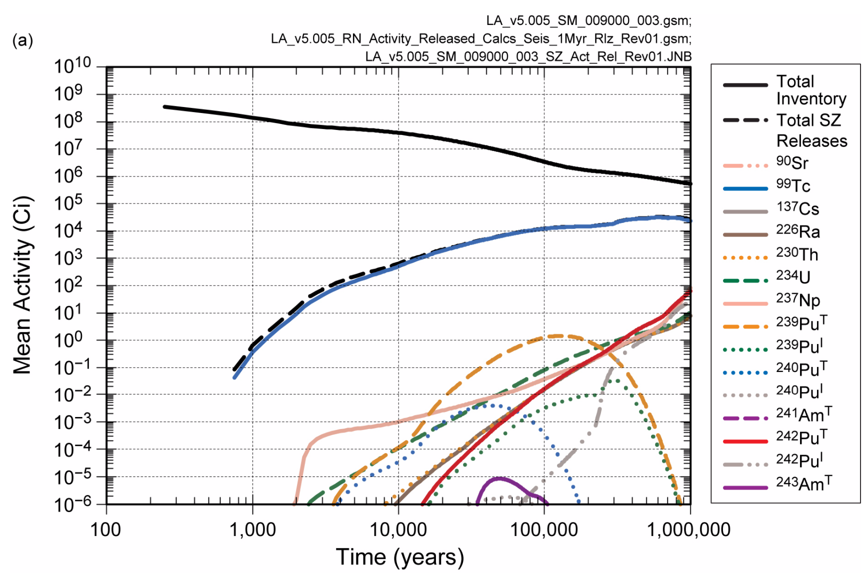


Mean Activity Released for the Seismic Ground Motion Modeling Case

EBS to UZ



SZ to Accessible Environment



Key Points:

- **At 10^4 yrs, total mean activity released from SZ is about 50% of activity released from EBS**
- **By 10^6 yrs, total mean activity released from SZ is about 5 % of total inventory (vs 7% from EBS)**
- **Mean activity releases from SZ dominated by ^{99}Tc**
- **^{90}Sr & ^{137}Cs from EBS confined to LNB**
- **Reduction in activity released from LNB (10^4 yrs and 10^6 yrs): ^{241}Am (100%), ^{239}Pu (99% and 90%), ^{242}Pu (99% and 66%), ^{237}Np (78% and 23%), ^{234}U (89% and 32%)**
- **Mean activity releases of ^{230}Th & ^{226}Ra from SZ determined by precursor ^{234}U release**

Summary

- The Yucca Mountain repository system is comprised of three barriers, the UNB, EBS, and LNB
- These barriers have the functions of (1) preventing or substantially reducing the rate of movement of water to the waste, (2) preventing or substantially reducing the release rate of radionuclides from the waste, and (3) preventing or substantially reducing the rate of movement of radionuclides from the repository to the accessible environment
- Barriers include multiple features that have processes and events that may act on or within the features to affect the capability of the performance of the barrier
- Rationale and basis for ITWI classification and qualitative demonstration of barrier capability is provided in *Postclosure Nuclear Safety Design Bases* (SNL 2008)
- A complete evaluation of all potential FEPs, including the technical basis for their inclusion or exclusion in the performance assessment, is presented in *Features, Events, and Processes for the Total System Performance Assessment: Analyses* (SNL 2008)

Supporting Documentation

- **Postclosure Nuclear Safety Design Bases (SNL 2008) provides**
  - **Rationale and basis for ITWI classification**
  - **Provides qualitative description of barrier capability**
- **Total System Performance Assessment Model / Analysis for the License Application (SNL 2008, Section 8.3[a])**
  - **Provides quantitative assessment of barrier capability**
- **Technical bases for barrier capability are contained in**
  - ***Features, Events, and Processes for the Total System Performance Assessment: Analyses* (SNL 2008)**
  - **Performance Assessment analysis and modeling reports**
- **All barrier capability identified as important to waste isolation is included in the TSPA model**