U.S. Federal Interagency Workshop

DC #42399

Reactive Transport Modeling of the Yucca Mountain Site, Nevada

QA:NA

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The Yucca Mountain site has a dry climate and deep water table, with the repository located in the middle of an unsaturated zone approximately 600 m thick. Radionuclide transport processes from the repository to the water table are sensitive to the unsaturated zone flow field, as well as to sorption, matrix diffusion, radioactive decay, and colloid transport mechanisms. The unsaturated zone flow and transport models are calibrated against both physical and chemical data, including pneumatic pressure, liquid saturation, water potential, temperature, chloride, and calcite. The transport model predictions are further compared with testing specific to unsaturated zone transport: at Alcove 1 in the Exploratory Studies Facility (ESF), at Alcove 8 and Niche 3 of the ESF, and at the Busted Butte site. The models are applied to predict the breakthroughs at the water table for nonsorbing and sorbing radionuclides, with faults shown as the important paths for radionuclide transport. Daughter products of some important radionuclides, such as ^{239}Pu and ^{241}Am, have faster transport than the parents and must be considered in the unsaturated zone transport model. Colloid transport is significantly affected by colloid size, but only negligibly affected by kinetic declogging (reverse filtering) mechanisms. Unsaturated zone model uncertainties are discussed, including the sensitivity of breakthrough to the active fracture model parameter, as an example of uncertainties related to detailed flow characteristics and fracture-matrix interaction. It is expected that additional benefits from the unsaturated zone barrier for transport can be achieved by full implementation of the shadow zone concept immediately below the radionuclide release points in the waste emplacement drifts.

April 20, 2004 at Albuquerque, NM

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

YUCCA MOUNTAIN PROJECT

Reactive Transport Modeling of the Yucca Mountain Site, NV

Presented to:
U.S. Federal Interagency Workshop

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Prepared by **Joe Wang, LBNL** with inputs form **BSC** UZ and TSPA:

LBNL: **Hui-Hai Liu, Yu-Shu Wu, Keni Zhang** on flow
Jens Birkholzer, Stefan Finsterle, Chin-Fu Tsang on seepage
Jim Houseworth, George Moridis, Yongkoo Seol on transport
Rohit Salve, Rob Trautz, Yvonne Tsang, Ken Williams on testing

LANL: **Bruce Robinson, Marleen McGraw** on transport
Wendy Soll, Jake Turin on testing

SNL: **Ron McCurley, Dan Levitt** on infiltration

USGS: **Alan Flint, Dave Hudson** on testing

BSC: **Larry Rickertsen** on dose curves

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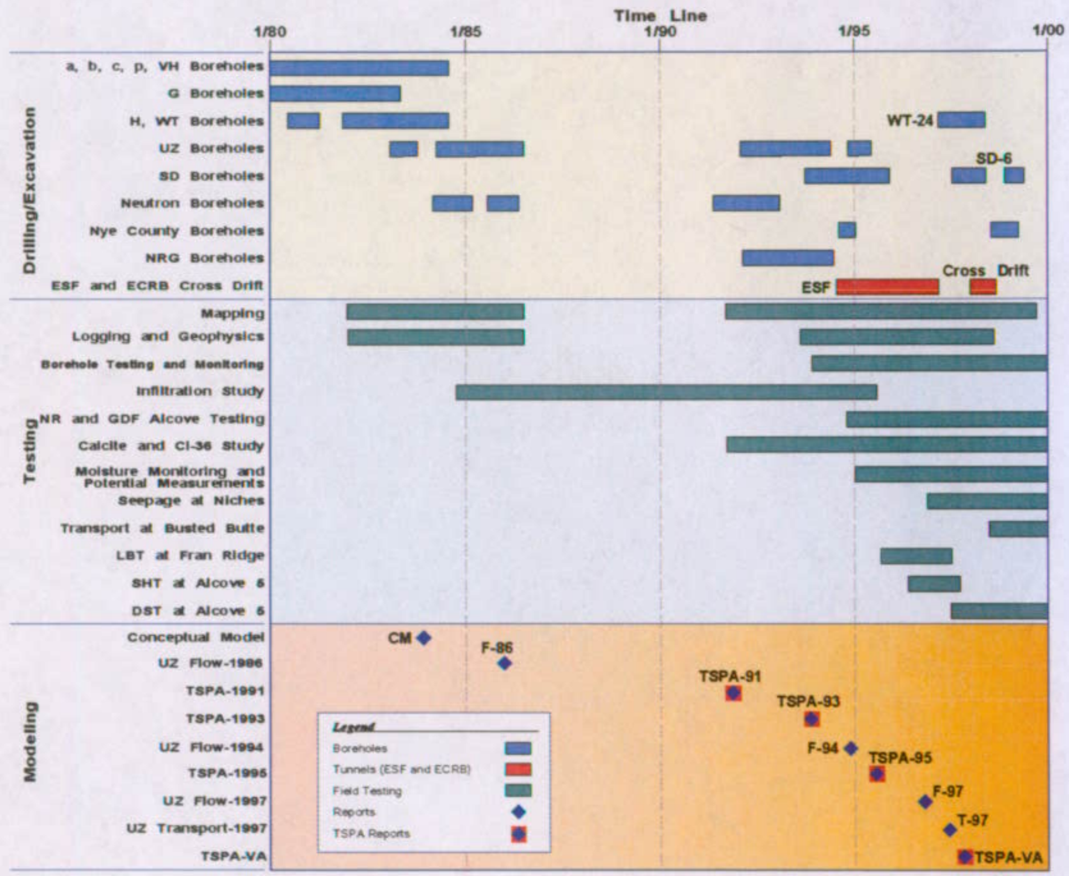
Outline

- Yucca Mountain Characteristics (dry, deep, desolate)
- Processes for Flow
- Processes for Transport
- Model Calibration
- Model Validation
- Drift Shadow Concept
- Breakthroughs of Radionuclides and Colloids
- Uncertainties and Sensitivity Evaluations
- Summary and Applications of Yucca Mountain Experience – CORES / SECUREEARTH

Yucca Mountain Experience

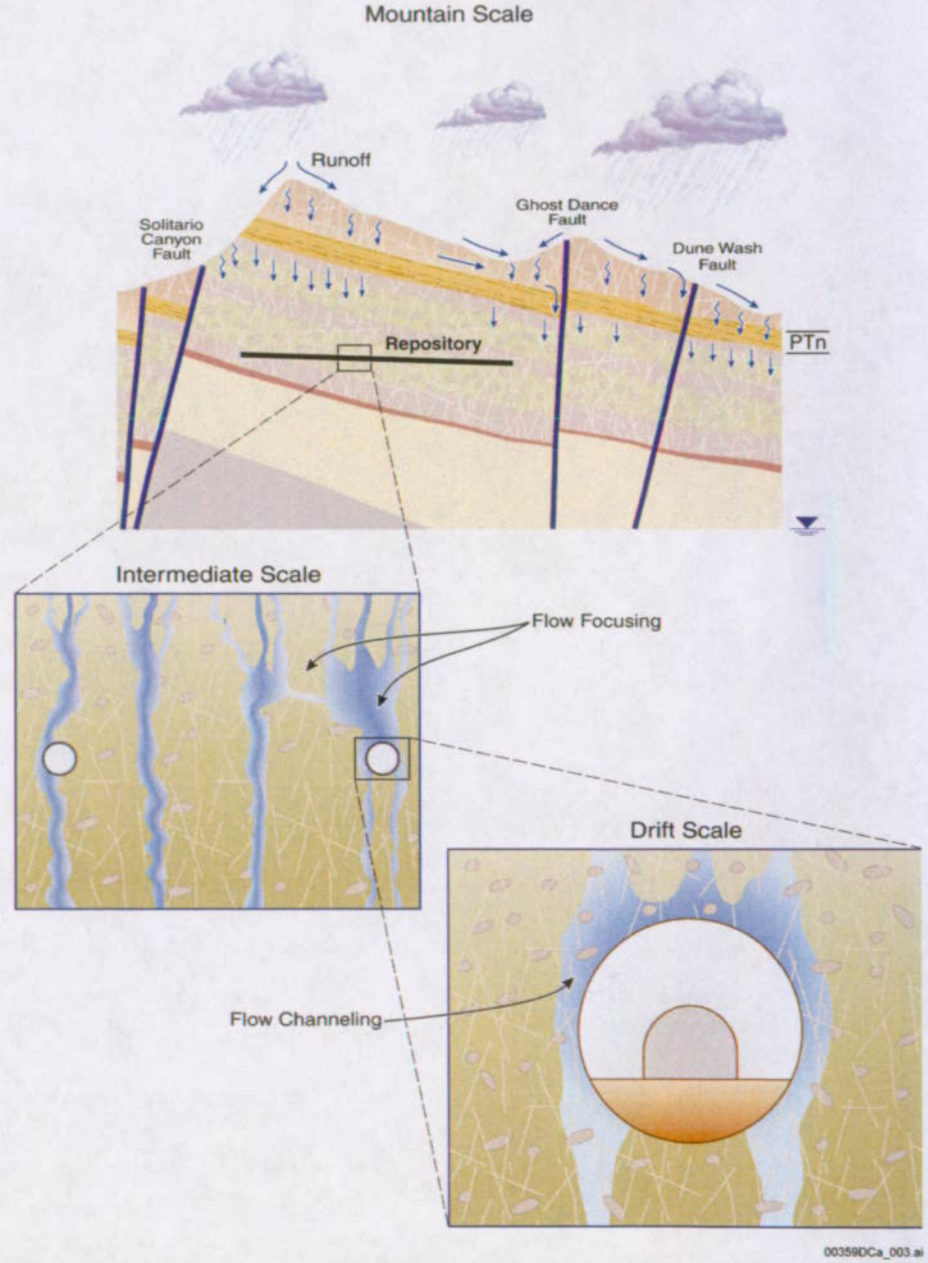
- Site Characterization and Process Evaluation (over 2 decades)
  - surface based boreholes
  - underground drifts
- Anticipate (sans Overreact) Hot Topics, e.g.:
  - seismic pumping
  - hot repository
  - bomb-pulse ^{36}Cl
- Integration with engineered barriers
  - seepage around man-made drifts
  - condensation on cooler packages



Limted Flow Path Observations

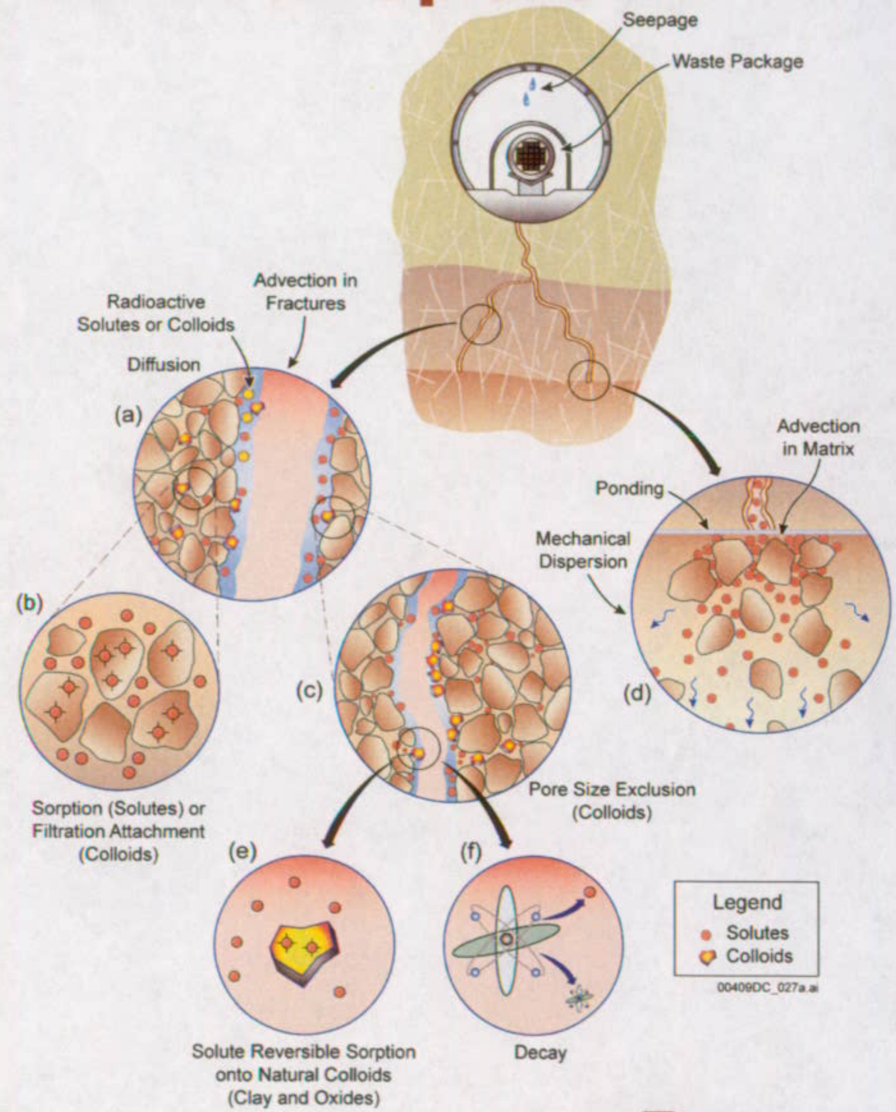
- One Wet Feature Observed during Dry Excavation
- Flow Path Spacing Determines Focused Flux Magnitude
- Seepage and chemistry determine the waste package corrosion potential

(a)



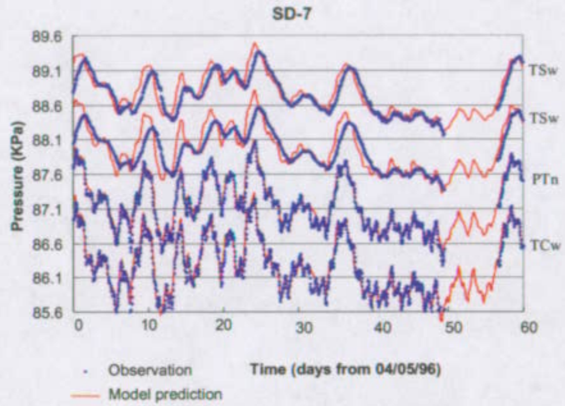
Process for UZ Transport

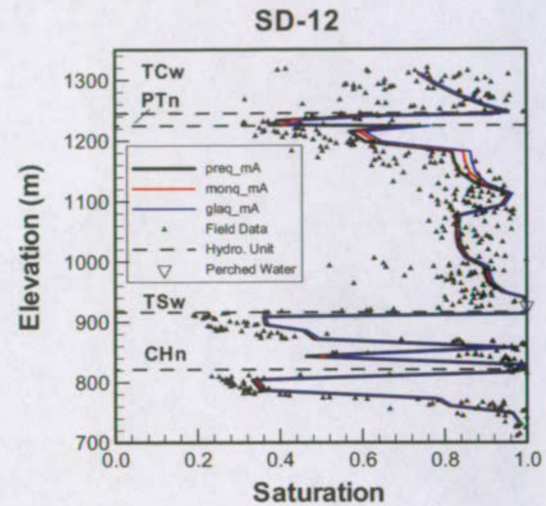
- All processes pertaining to flow are important to transport
- Sorption
- Matrix diffusion
  - Active fracture model
- Daughter products of radioactive decay
- Colloidal transport

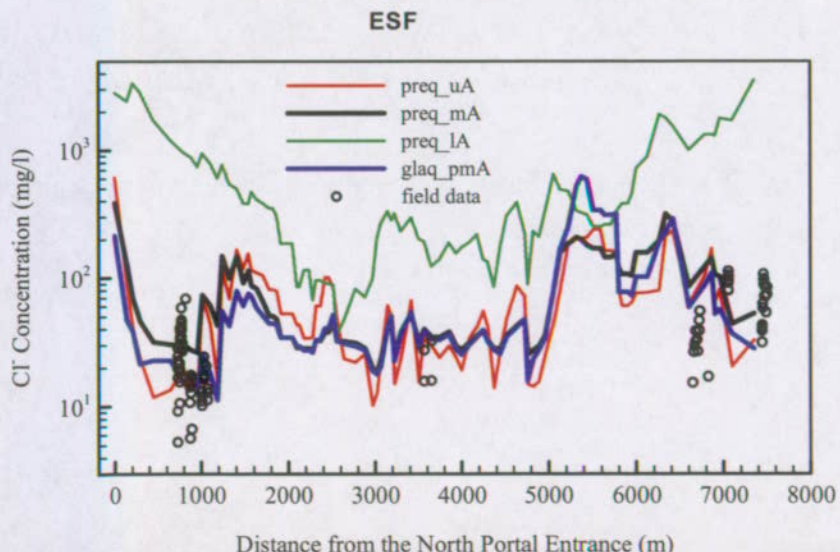


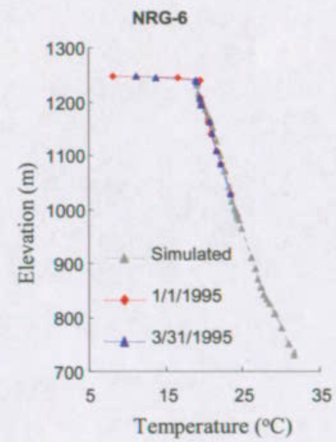
Data Inputs & Calibration Examples

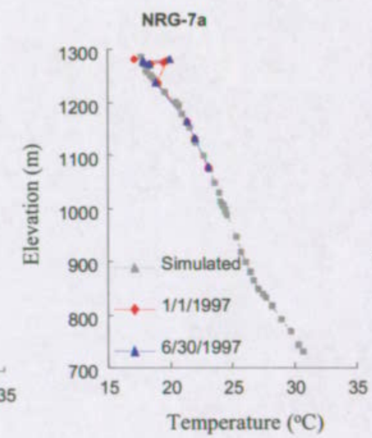
- Pneumatic Pressure
- Liquid Saturation and Water Potential
- Temperature
- Chloride along ESF and other Geochemical Data

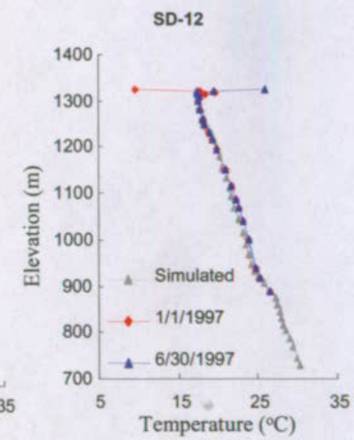






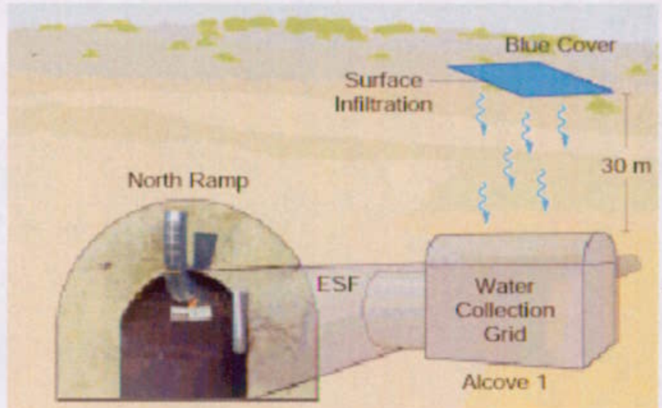


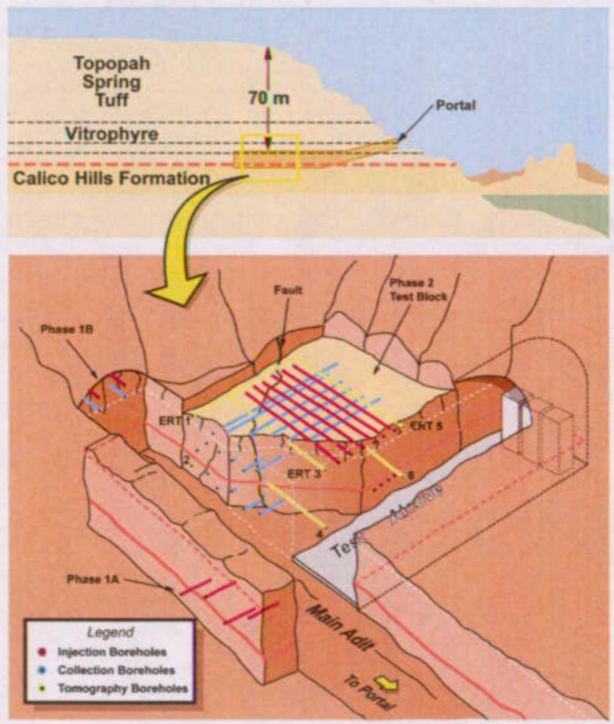


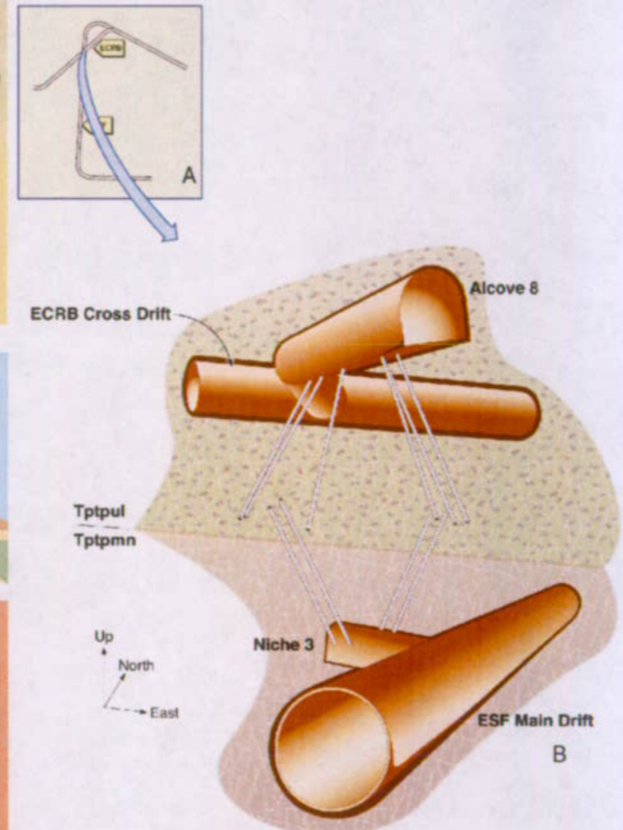


In Situ Field Testing for Transport

- **Alcove 1 in ESF - TCw**
- **Alcove 8 ECRB / Niche 3 ESF – lithophysal to non-lithophysal in TSw**
- **Busted Butte - CHnv**

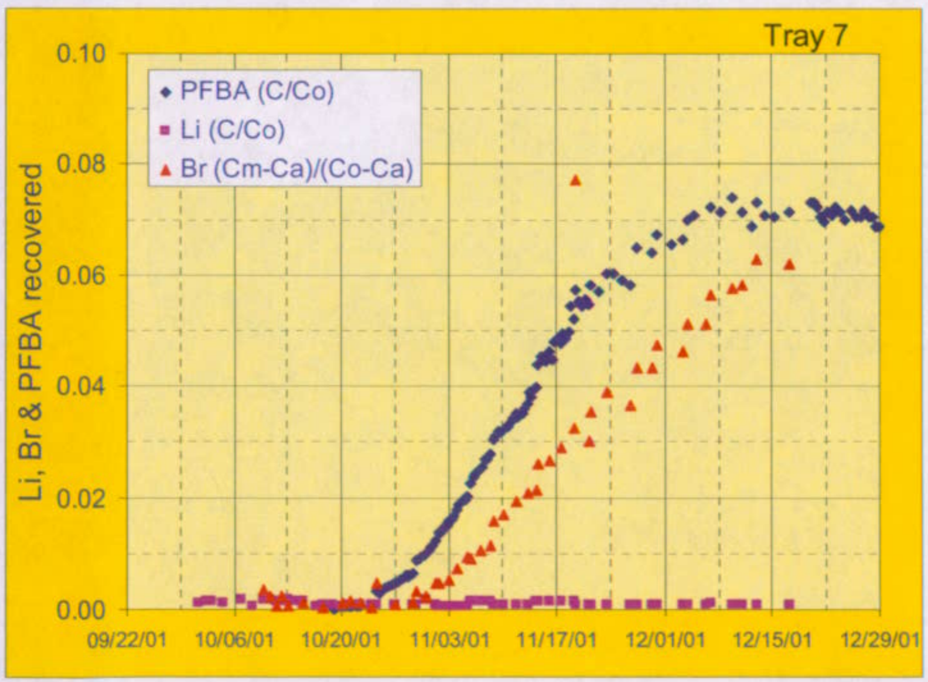


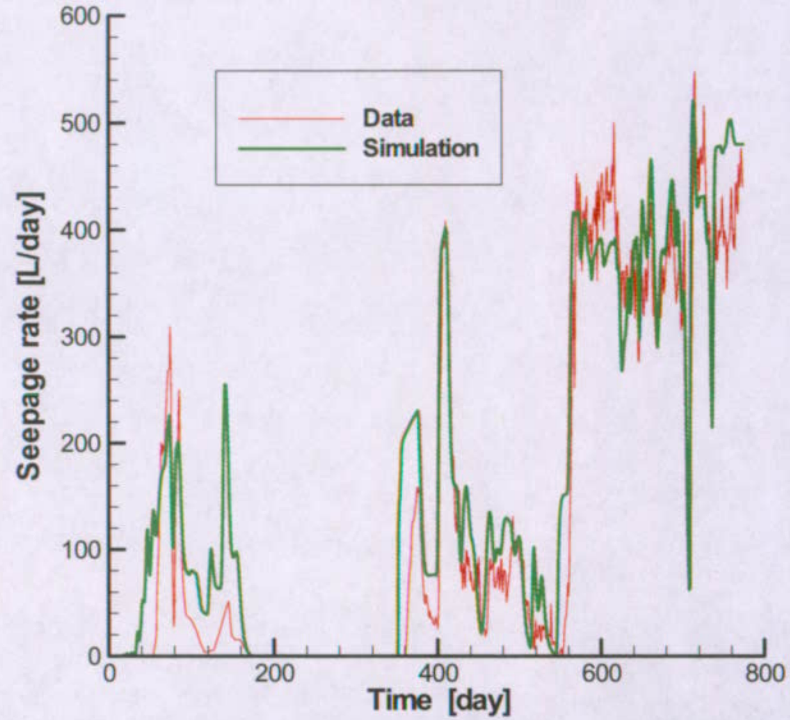


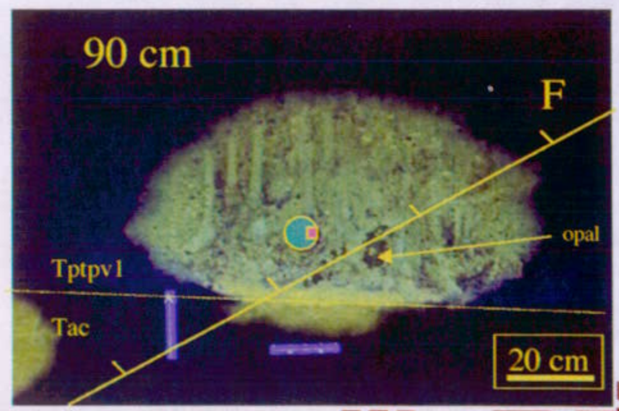


Transport Data for Model Validation

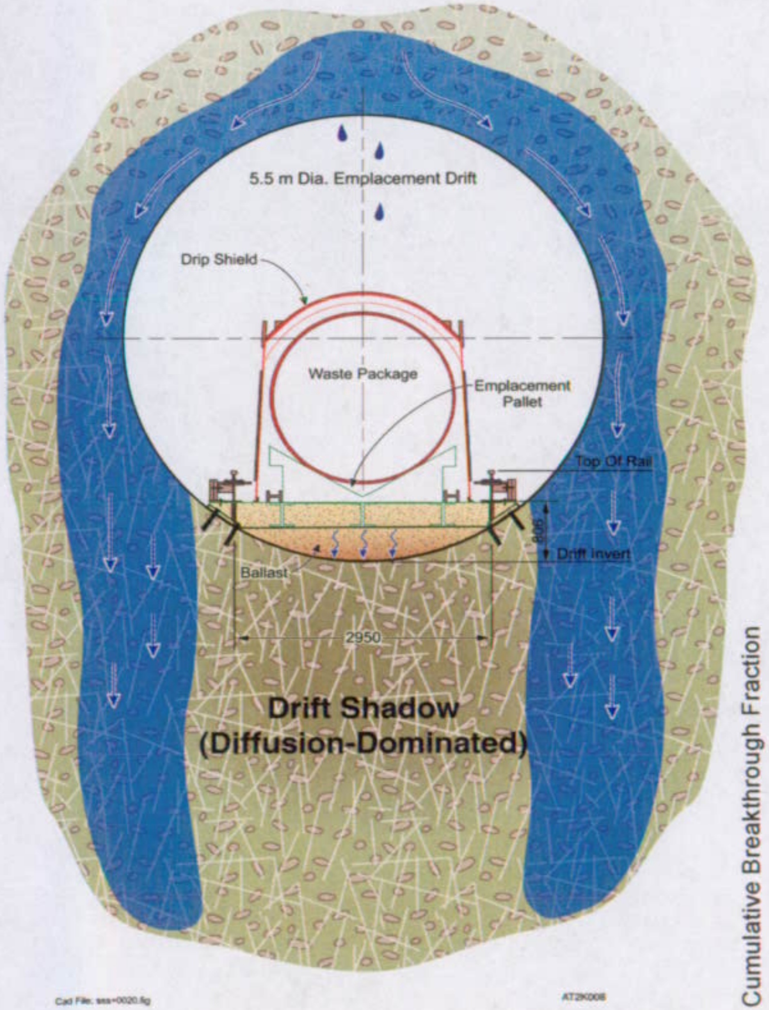
- Infiltration and Seepage Rates
- Breakthrough Curves of Tracers
- Plume Configurations

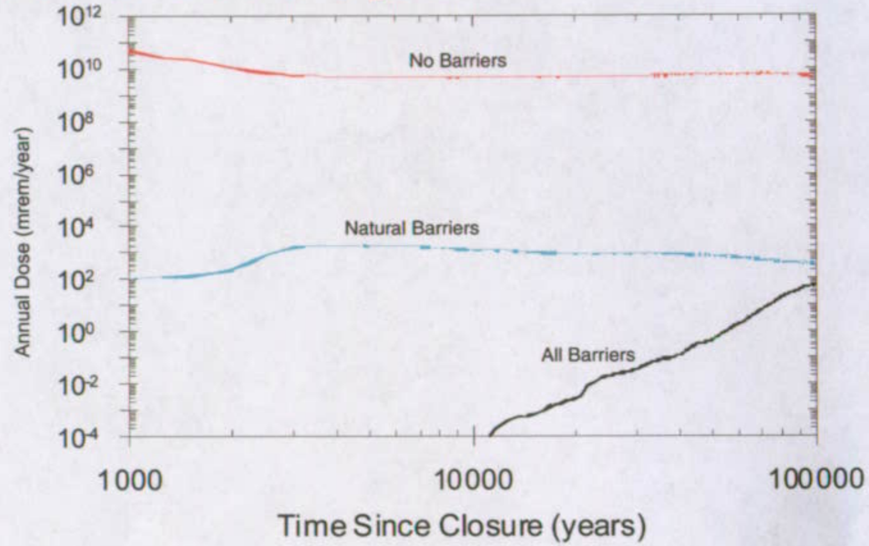


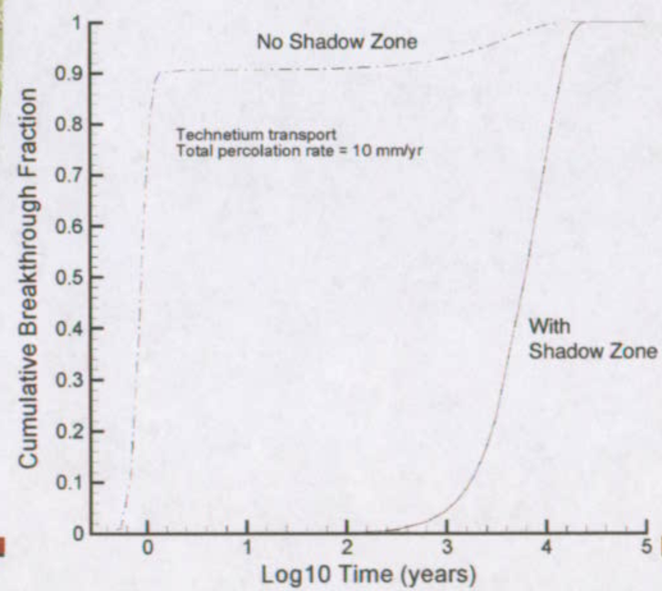




Radionuclide Source Term: *Drift Shadow Concept*

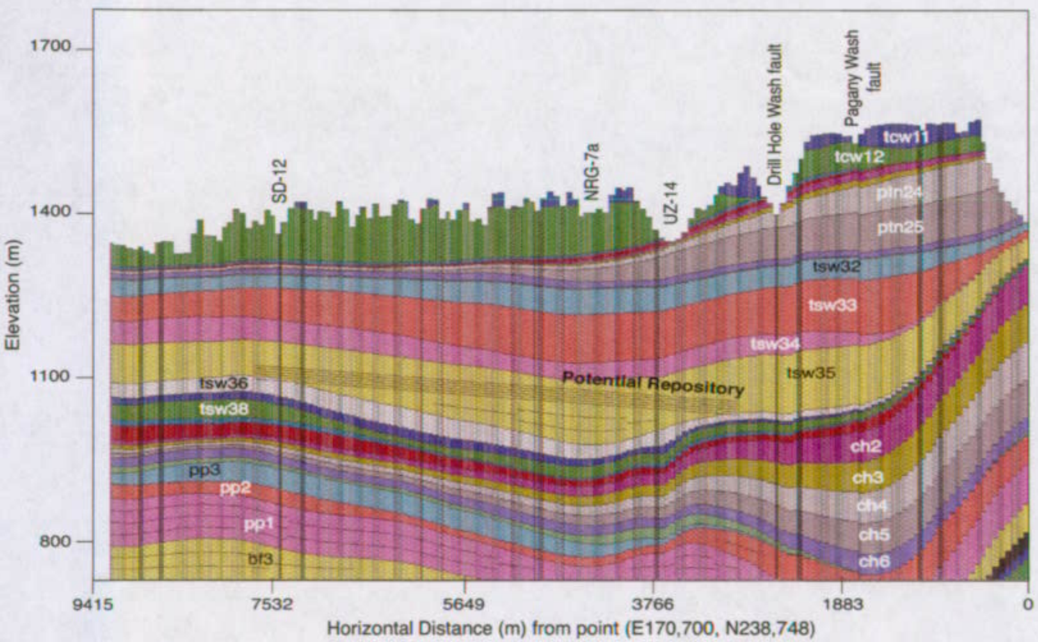


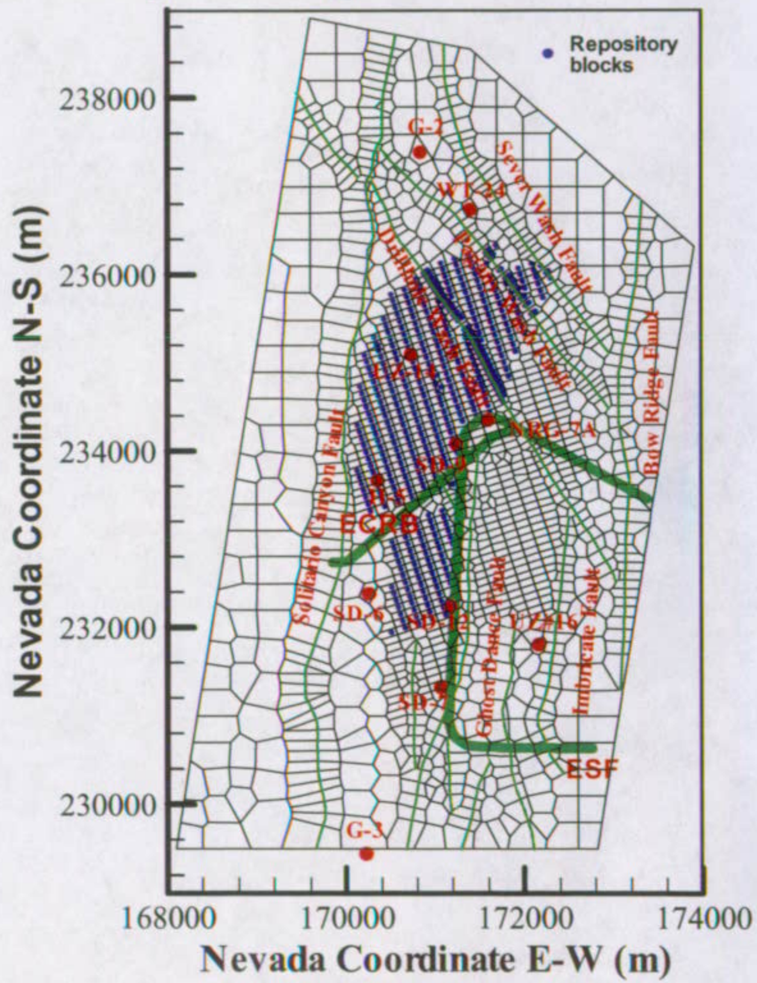




Matrix Release into Drift Shadow can Delay Transport for Thousands of Years

Yucca Mountain Unsaturated Zone Cross Section and Repository Layout

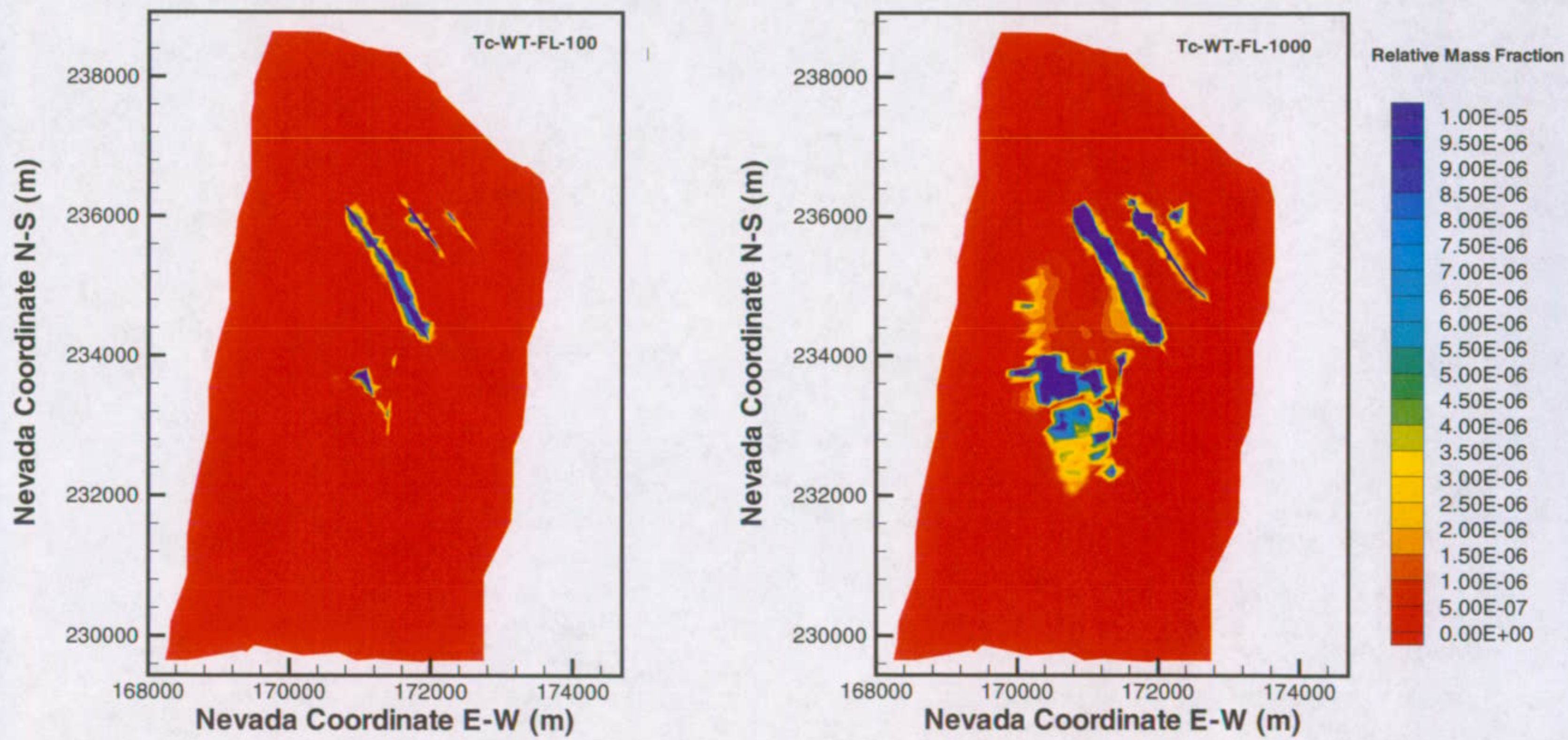




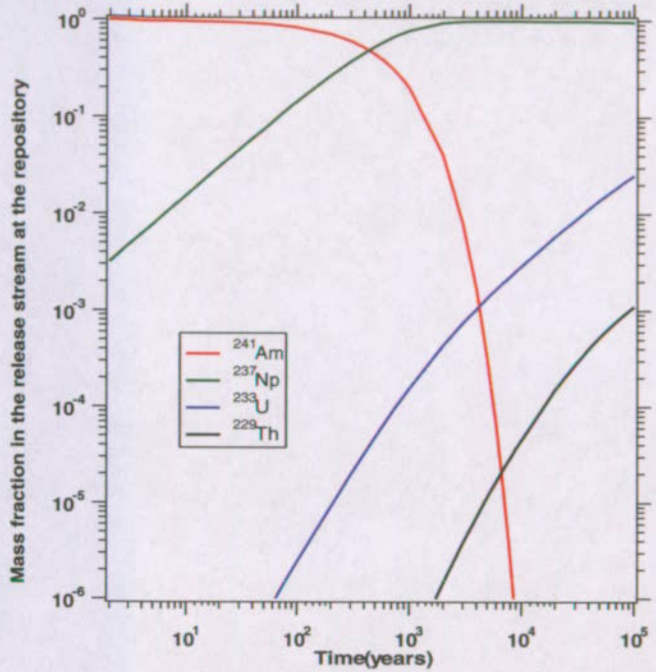
Non-sorbing Radionuclide: *Relative Mass Fraction of ^{99}Tc in the Fractures Immediately above the Water Table*

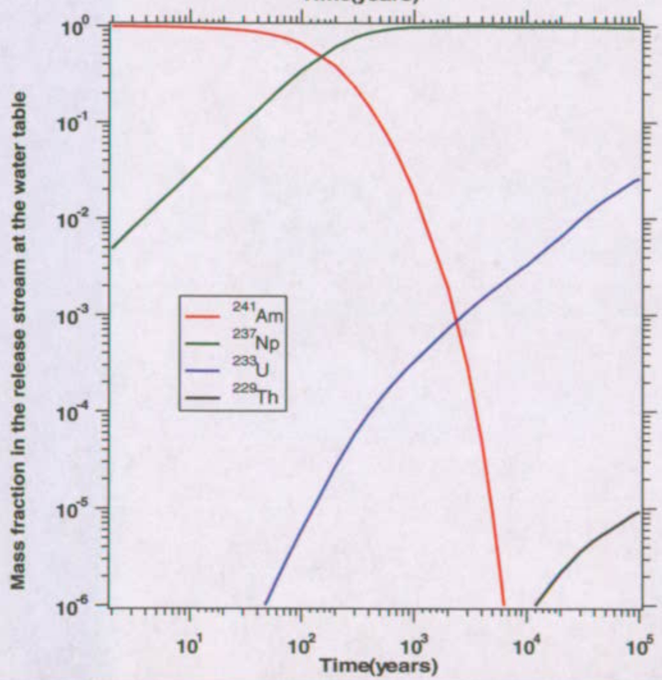
100 years

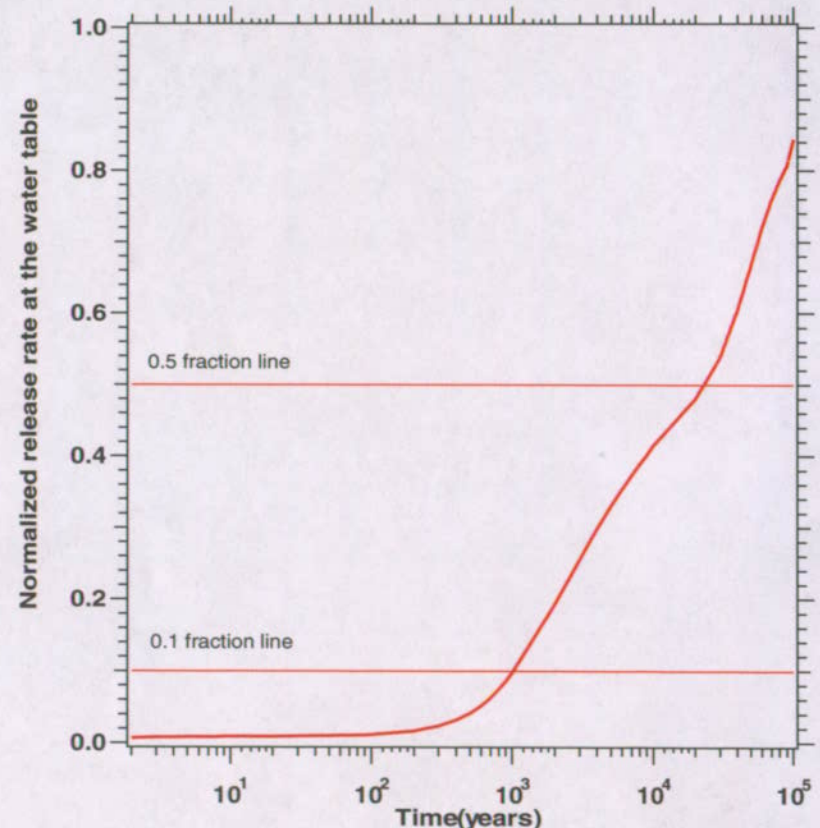
1000 years



Parent-Daughter Decay Transport: *Mass Fractions of Each Member of the ^{240}Am Chain*

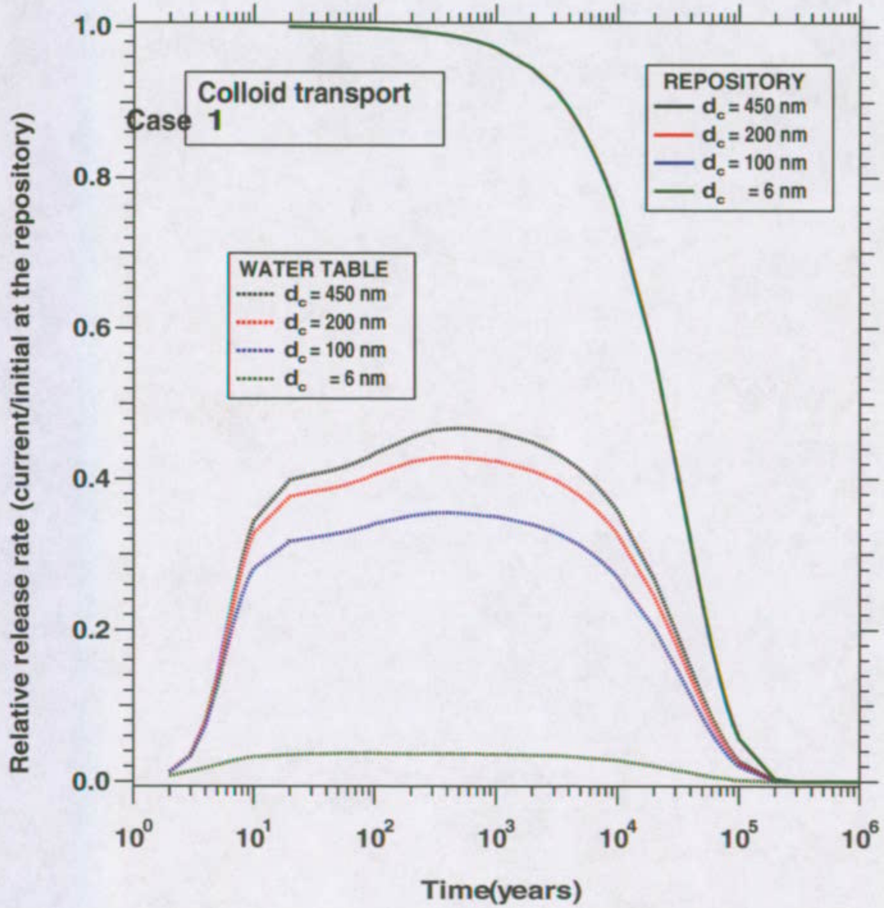


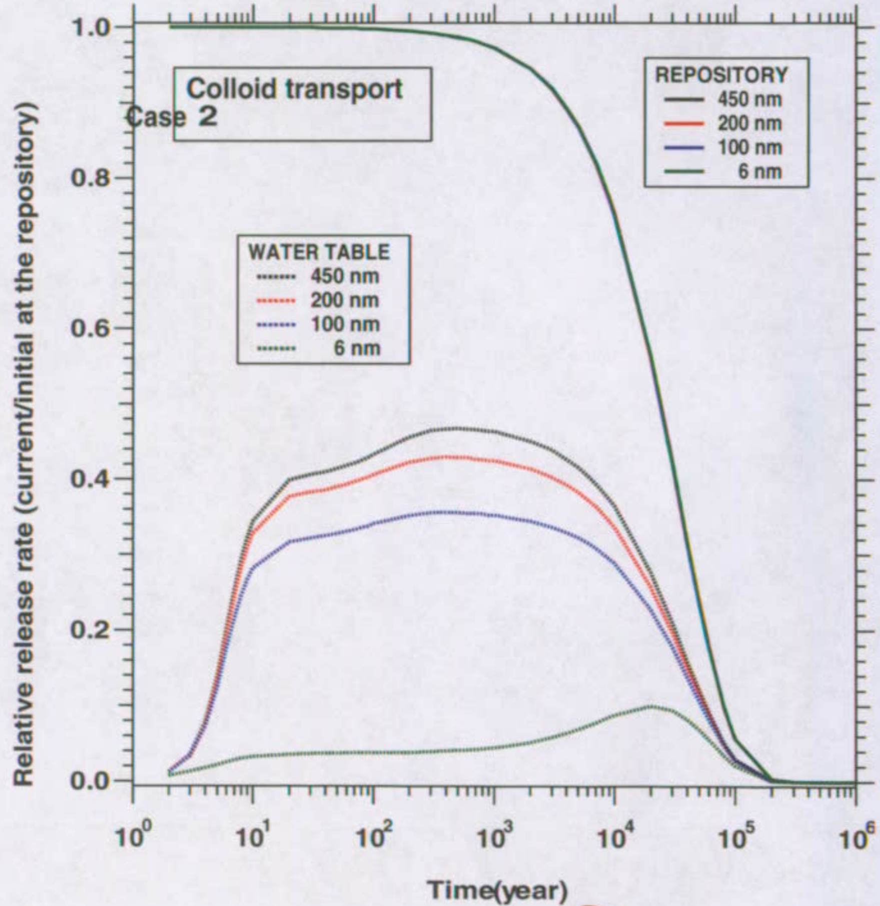




Colloidal Transport Declogging Models

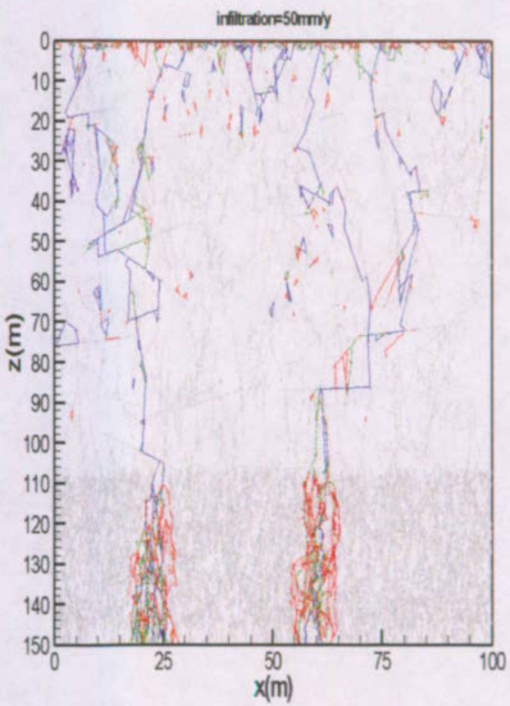
Similarity of Normalized Release at the Water Table for Case 1 - No Declogging, and Case 2 - Strong Kinetic Declogging Indicates Dominant Role of the Fractures



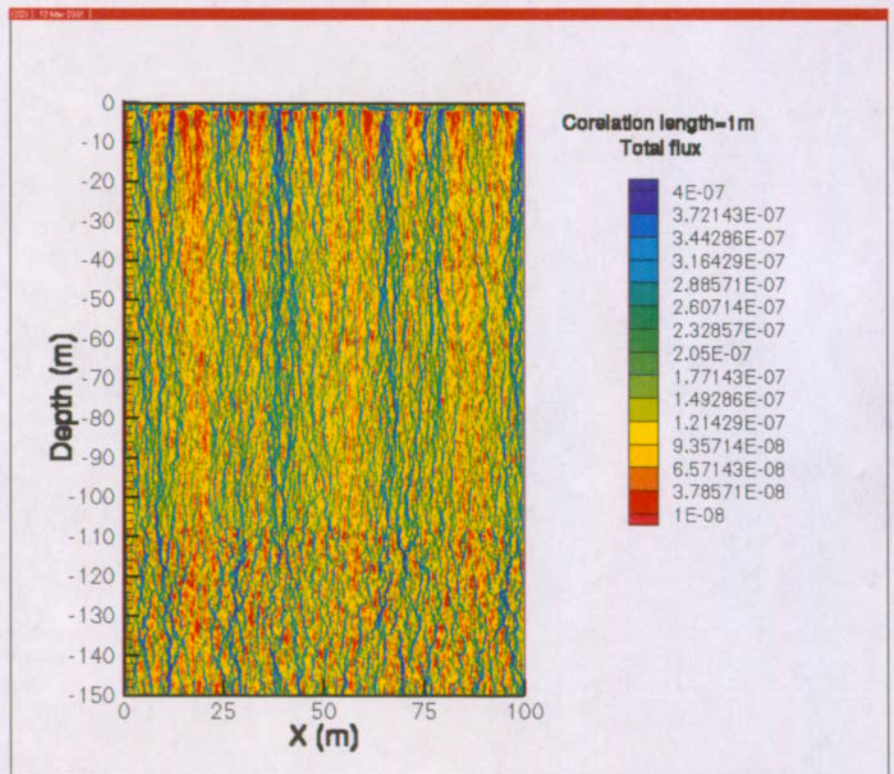


Uncertainty in Flow Focusing with Different Flow Path Developments (in 100-m wide domain)

2D Discrete Fracture Network => 2 paths



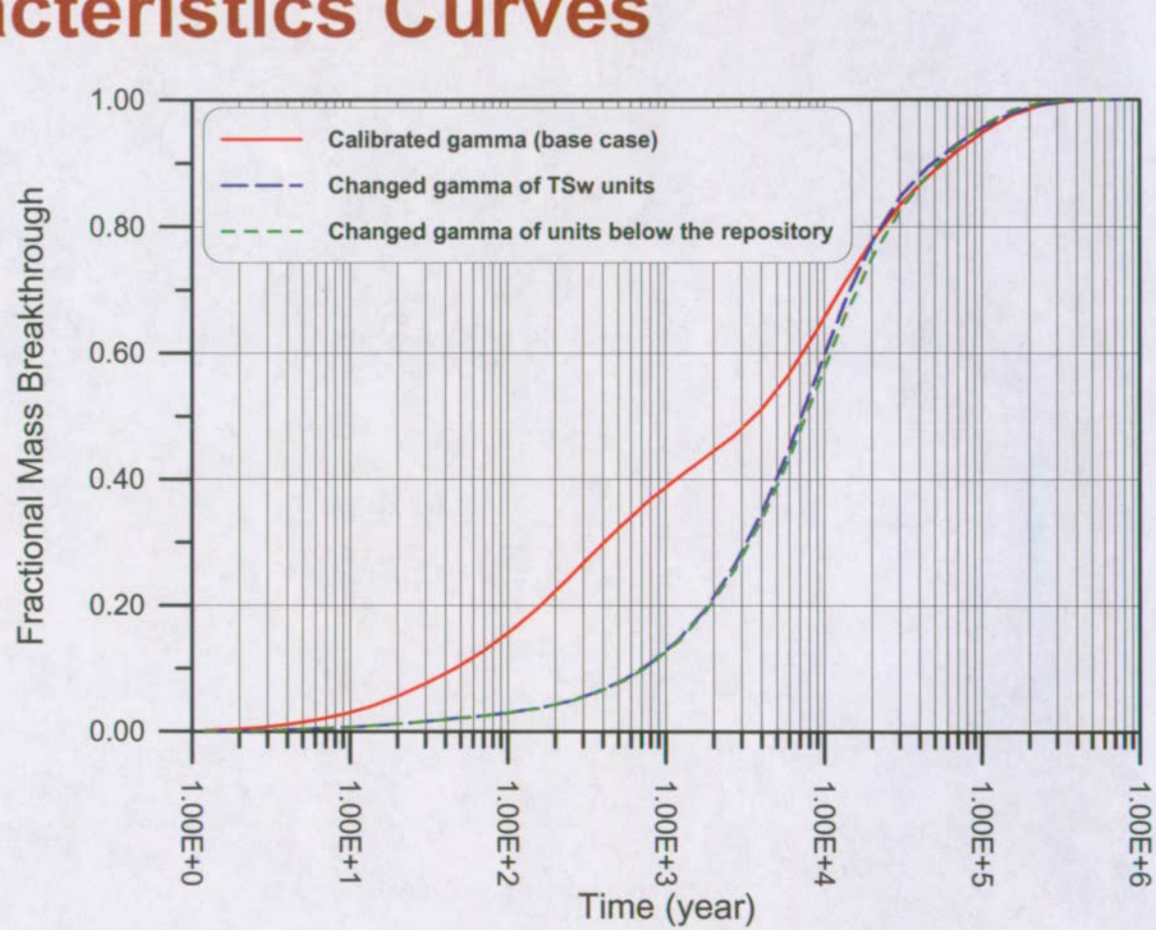
2D Fracture Continua => approx. 10 flow paths (less in 3D)



Alternative model predictions

Uncertainty in Basic Fracture Characteristics Curves

- **van Genuchten model modified to improve matching of infiltration data**
- **Transport model is sensitive to active fracture model**



Breakthrough (transport) is greatly affected by halving the calibrated active fracture model parameter γ

Conclusions – UZ Transport

- On-going and completed tests provide input data that constrain the UZ transport model and allow the Project to take substantial credit for this important barrier
- Tracer tests using Alcove 1 and Alcove 8/Niche 3 provide clear evidence of matrix diffusion and provide essential data for the calibration of the UZ transport model
- Tracer tests conducted in the Busted Butte facility have clearly confirmed the porous medium nature of the vitric Calico Hills and verified sorption values for some important radionuclides
- Colloidal transport is significantly affected by the colloid size, but not much by kinetic declogging (reverse filtering)
- Daughter products of some important radionuclides, such as ^{239}Pu and ^{241}AM must be considered in the UZ transport model
- Greatest uncertainties in the UZ transport model relate to the detailed characteristics of flow, the active fracture model and the efficiency of matrix diffusion. It is expected that significant additional benefits of this barrier can be achieved by full implementation of the shadow zone in the process models and TSPA.

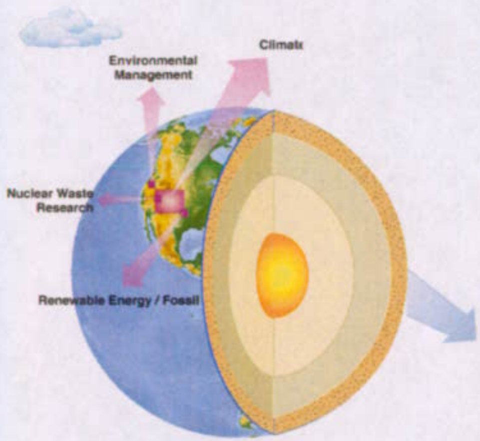
Announcing Initiative:

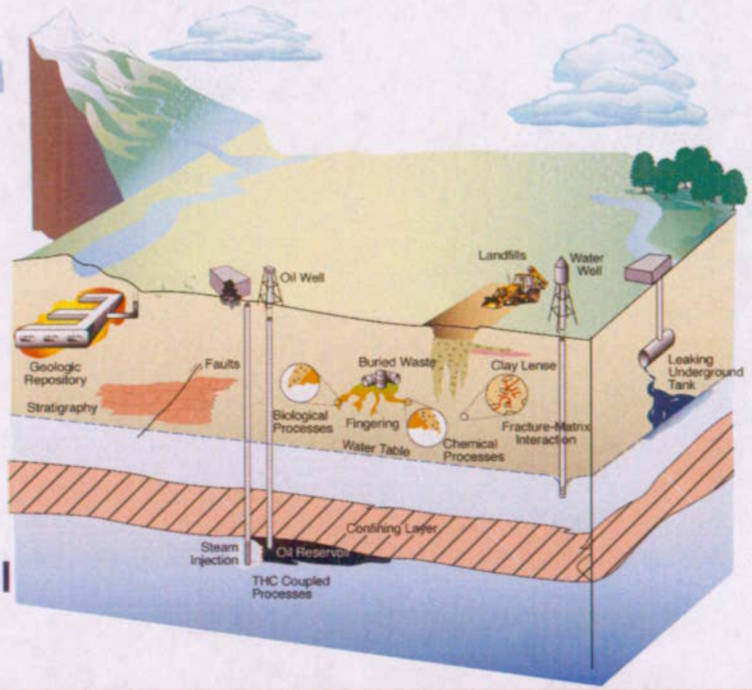
urgent solutions to secure earth's future

SECURE Earth

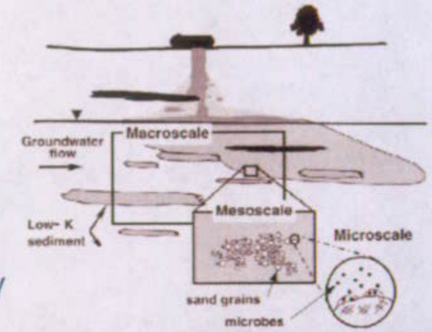
Scientific Environmental/Energy
Cross-Cutting Underground
Research Enterprise

Cross-cutting DOE Geosciences Initiatives

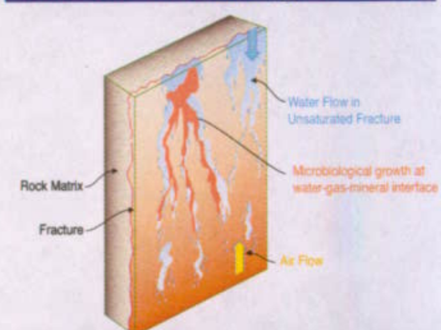




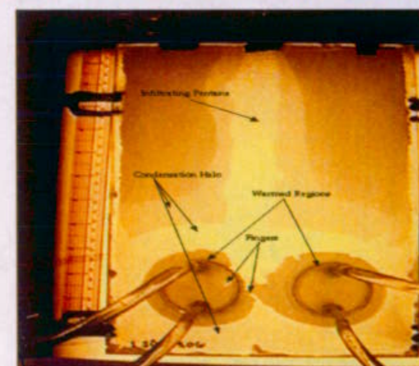
- **sustainable resource development (water, fossil fuels, CO_2 Sequestration)**
- **environmental remediation**
- **climate change prediction**
- **safe nuclear waste disposal**



Scaling



Process Prediction



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