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

Saturated Zone Flow and Transport for TSPA-SR

Presented to:
Nuclear Waste Technical Review Board

Presented by:
Bruce A Robinson
Saturated Zone Department
Civilian Radioactive Waste Management System
Management & Operating Contractor

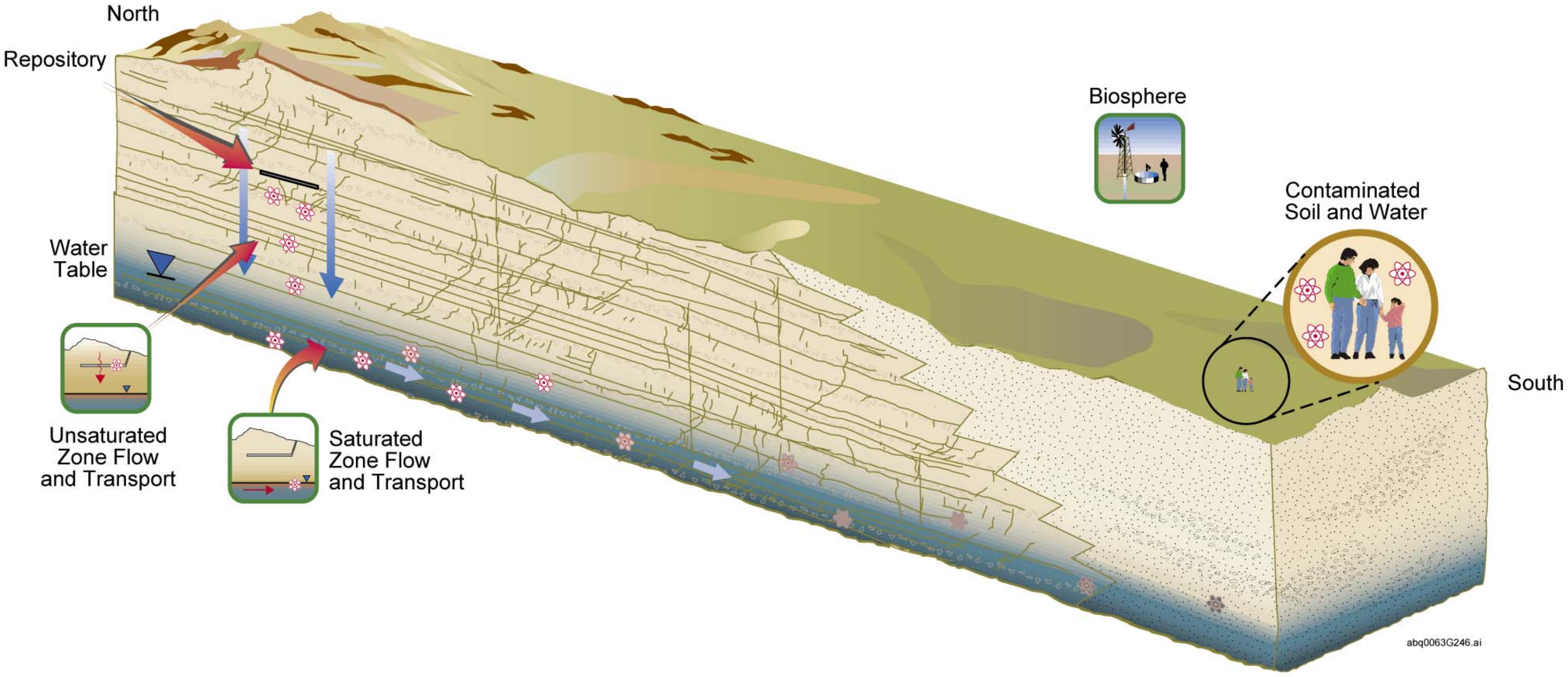
August 2, 2000

YUCCA MOUNTAIN PROJECT

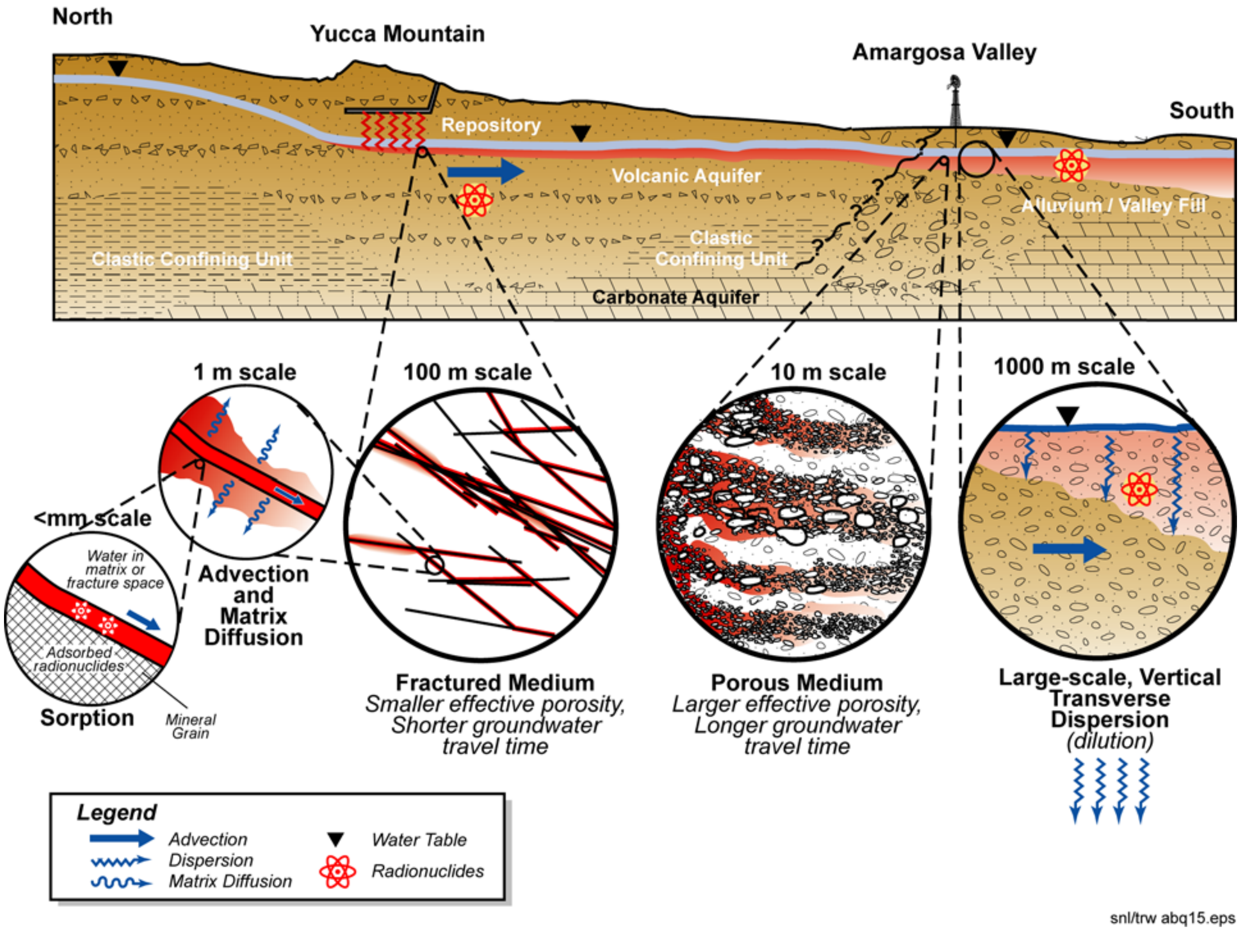
Process Model Factors Affecting Radionuclide Transport Away from Engineered Barriers

Key Attributes of Performance	Process Model Factor	TSPA-SR Input Parameters
Transport Away from the Engineered Barrier System	UZ Radionuclide Transport	• Fracture aperture and spacing in different units • Flow fields for different infiltration scenarios and climate states • K_d for all elements included in TSPA • Matrix diffusion coefficients – f (isotopes, units) • K_c and/or kinetic colloid parameters for Pu , Am, Th etc. • Colloid filtration factor
	SZ Radionuclide Transport	• Breakthrough curves – f (radionuclide, region) • Climate change flux multiplication factor • Capture zones and release locations within each zone. • Flow fields • Flowing interval spacing • Effective porosity for all units except the volcanic units • Dispersivity (longitudinal, horizontal transverse, vertical transverse) • Boundary definition of the alluvium • K_d for isotopes included in TSPA • Flowing interval porosity • Matrix porosity • Effective diffusion coefficient • K_c colloid parameters • Colloid filtration factor
	Wellhead dilution	• Annual groundwater usage
	Biosphere Dose Conversion Factor	• Biosphere dose conversion factor – f (radionuclide, irrigation time)

Radionuclide Migration in the Saturated Zone (SZ)



Conceptual Model of Radionuclide Transport Processes in the SZ



General Approach to SZ Flow and Transport Abstraction in TSPA-SR

- **SZ site-scale flow and transport model used to simulate radionuclide mass transport to 20 km distance from a point mass source (4 source regions below the repository)**
- **Particle tracking is used to generate transport breakthrough curves**
- **Convolution integral method used to couple radionuclide source term from the UZ with the SZ transport**
- **Radionuclide concentration in groundwater source to the biosphere calculated by dividing radionuclide mass crossing the 20 km "fence" by the average annual groundwater usage of the hypothetical farming community**
- **Climate change incorporated by scaling radionuclide mass breakthrough curves in proportion to SZ flux changes**
- **Abstracted 1-D transport model used for some radioactive decay chains**

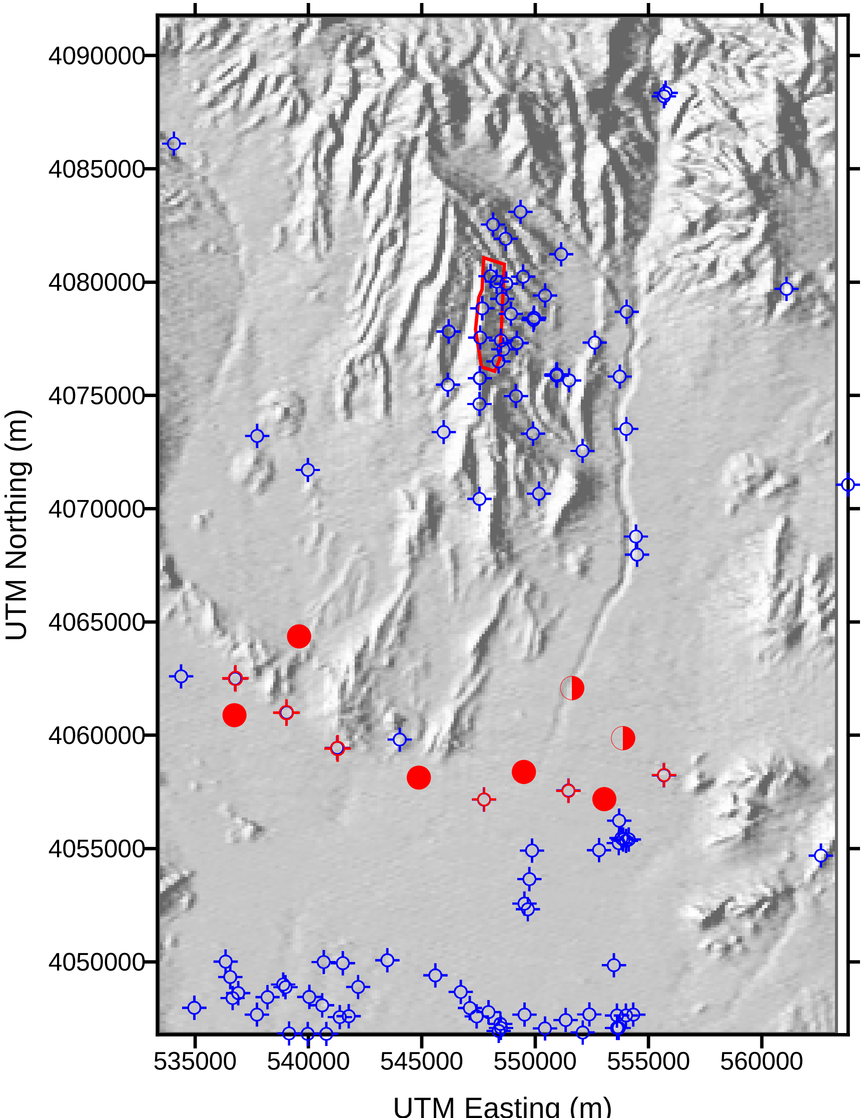
Changes in Approach from TSPA-VA

- The 3-D SZ site-scale flow and transport model is used to simulate radionuclide transport in TSPA-SR (vs. the streamtube approach in TSPA-VA)
- Radionuclide concentrations are calculated in the water supply of the hypothetical farming community in TSPA-SR (vs. concentration in the SZ, as in TSPA-VA)
- Matrix diffusion is explicitly simulated in the SZ site-scale model for TSPA-SR (vs. use of the effective porosity approach for transport in fractured media used in TSPA-VA)
- Particle tracking method used for radionuclide transport in the SZ site-scale model for TSPA-SR (vs. finite element transport method used in streamtubes for TSPA-VA)
- Minor sorption of Tc and I in alluvium for TSPA-SR (vs. no sorption in TSPA-VA)

SZ Site-Scale Flow and Transport Model

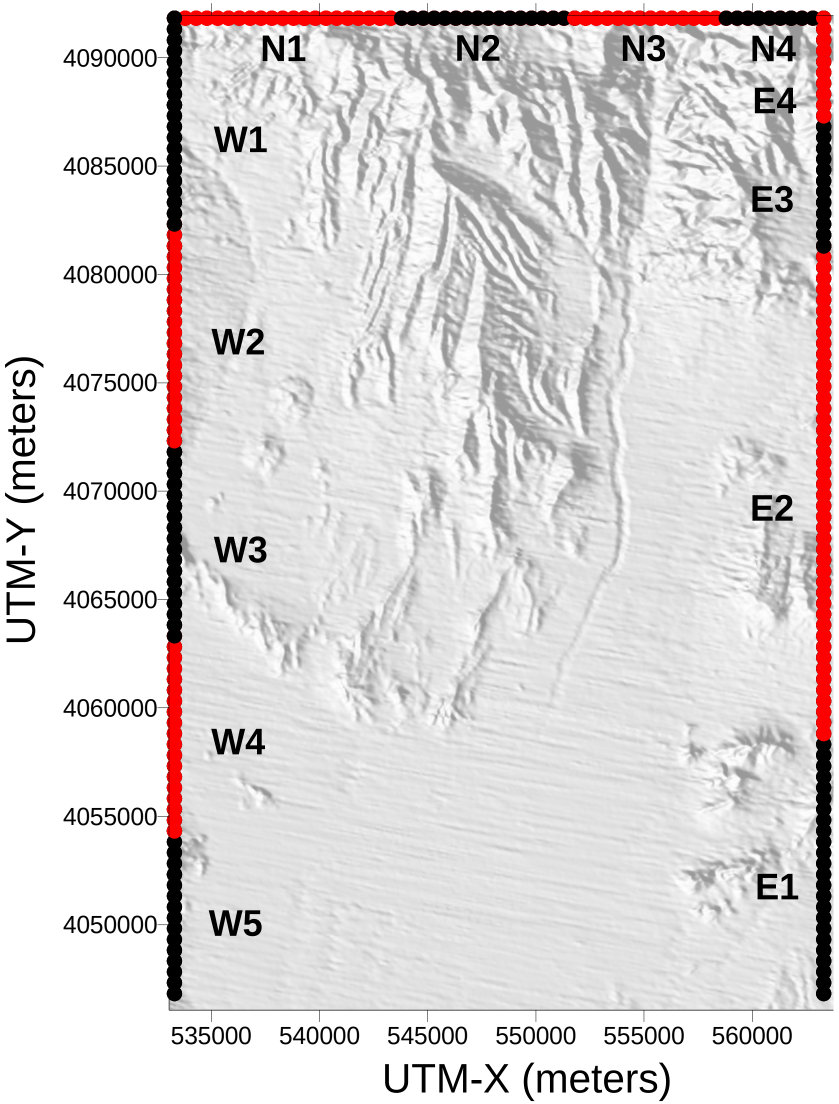
- **3-D model implemented with FEHM software code has domain 30 km x 45 km x 2750 m below water table**
- **Hydrogeologic framework model contains 19 units**
- **Orthogonal grid with 500 m horizontal spacing and variable resolution in the vertical direction**
- **Flow model calibration used automated inversion**
- **Model calibration and validation uses data including:**
  - **Water level measurements in wells**
  - **Simulated groundwater fluxes at lateral boundaries**
  - **Inferred flow paths from hydrochemical data**
  - **Upward hydraulic gradient from carbonate aquifer**
  - **Ranges of measured permeability**
  - **Average specific discharge in volcanic aquifer**

SZ Well Data Used in the SZ Site-Scale Flow and Transport Model



- **115 water-level measurements used in calibration of the SZ site-scale model for TSPA-SR**
- **Water-level measurements at 6 locations from the Nye County drilling program were used**
- **Batch sorption tests of alluvium samples from 3 Nye County wells were performed for sorption of Np, Tc, and I**
- **Ongoing work of the Nye County drilling program includes wells at 7 locations for FY00, including alluvial tracer complex.**

Groundwater Fluxes at the Model Boundaries

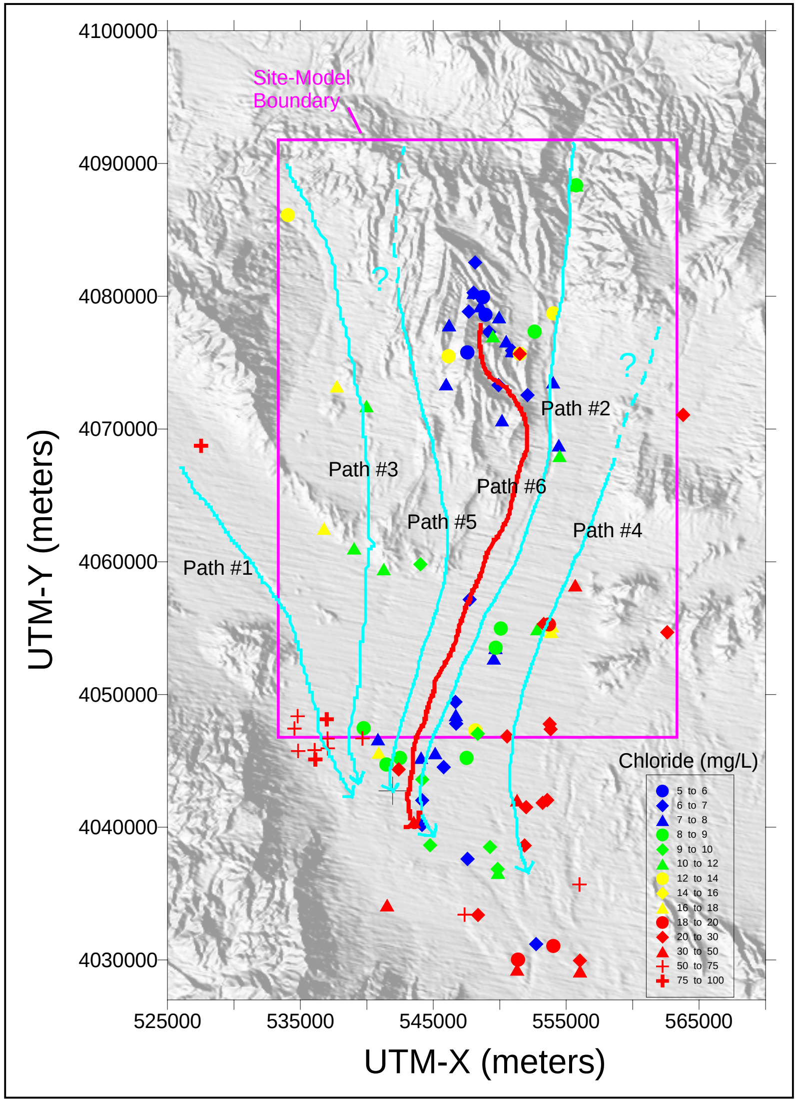


Boundary Zone	Regional Flux (kg/s)	Site-Scale Flux (kg/s)
N1	–101.24	–60.0
N2	–16.48	–33.4
N3	–53.05282	–30.6
N4	–18.41	–44.8
W1	3.45	4.17
W2	–71	–0.00719
W3	–6.9	–0.0000078
W4	2.73	–0.0000223
W5	–46.99	–6.85
E1	–555.45	–553.9
E2	–5.46	3.53
E3	2.65	16.50
E4	–3.07	16.8
S	918	724

Source: D'Agnese et al. (1997); DTN: LA9911GZ12213S.001.

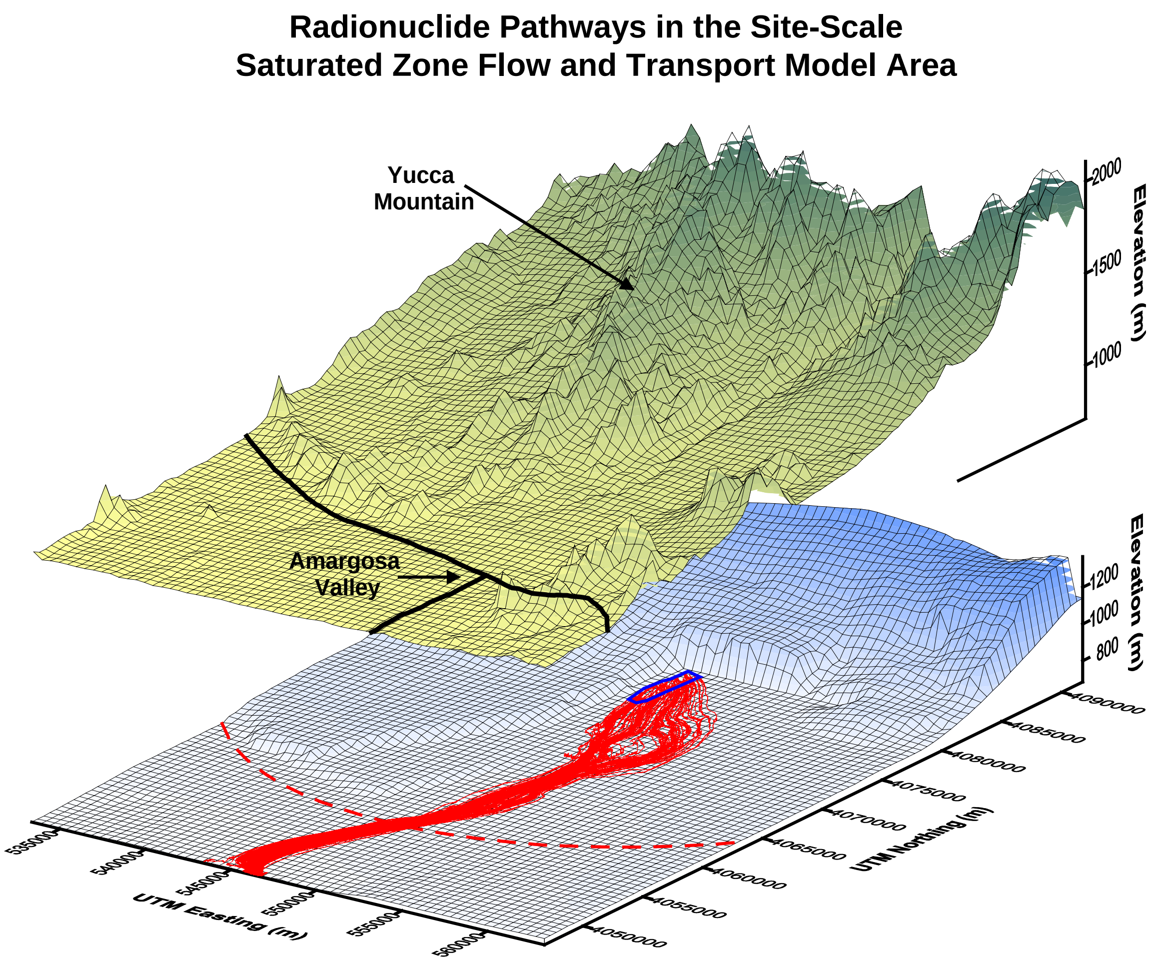
Fluxes computed from the site scale model boundaries agree with the regional model results to within the accuracy warranted by such a comparison

Use of Hydrochemistry to Constrain Flow Model



- **Assumption - trends in the chemical data can be used to delineate large-scale features of the groundwater flow patterns**
- **Multiple chemical and isotopic species were used to constrain the flow model (δ^2H, $\delta^{18}O$, Cl^-, SO_4^{2-}, Na^+, Ca^+)**
- **Flow model results using particle tracking are consistent with the flow patterns deduced from the hydrochemical data**

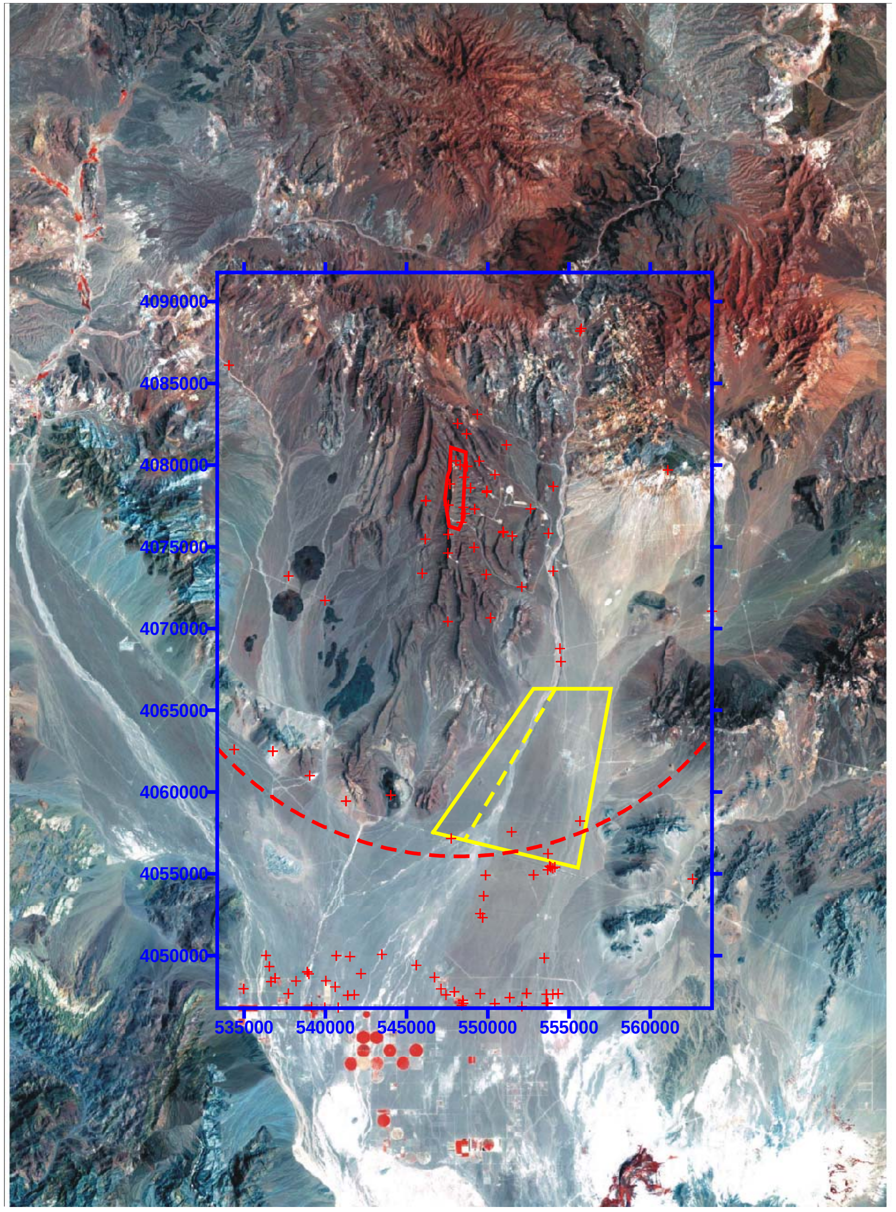
SZ Site-Scale Flow and Transport Model



- **Particle tracking method includes radionuclide transport processes of advection, dispersion, matrix diffusion in fractured volcanic units, and sorption**
- **Simulated flow paths from the repository occur in the upper few hundred meters of the SZ**
- **Simulated flow paths cross the 20 km “fence” approximately 5 km west of the town of Amargosa Valley**

Uncertainty in SZ Flow and Transport

- Three discrete cases (low, medium, and high) of SZ groundwater flux are used. Probabilities for each case are based on expert elicitation results
- Two discrete cases (isotropic and 5:1 anisotropic) of horizontal anisotropy in permeability of volcanic units are used
- Alluvial uncertainty zone defined to account for uncertainty in the location of the tuff/alluvium contact along the flow path
- Stochastic parameters relevant to matrix diffusion used in TSPA are flowing interval spacing, effective diffusion coefficient, and flowing interval porosity (for fractured volcanic units)
- Other stochastic parameters are effective porosity in alluvium, dispersivity, K_ds, colloid retardation factor, source location, and K_c
- Colloid-facilitated radionuclide transport occurs by two modes: 1) irreversible attachment to colloids and 2) reversible, equilibrium attachment to colloids (K_c model)

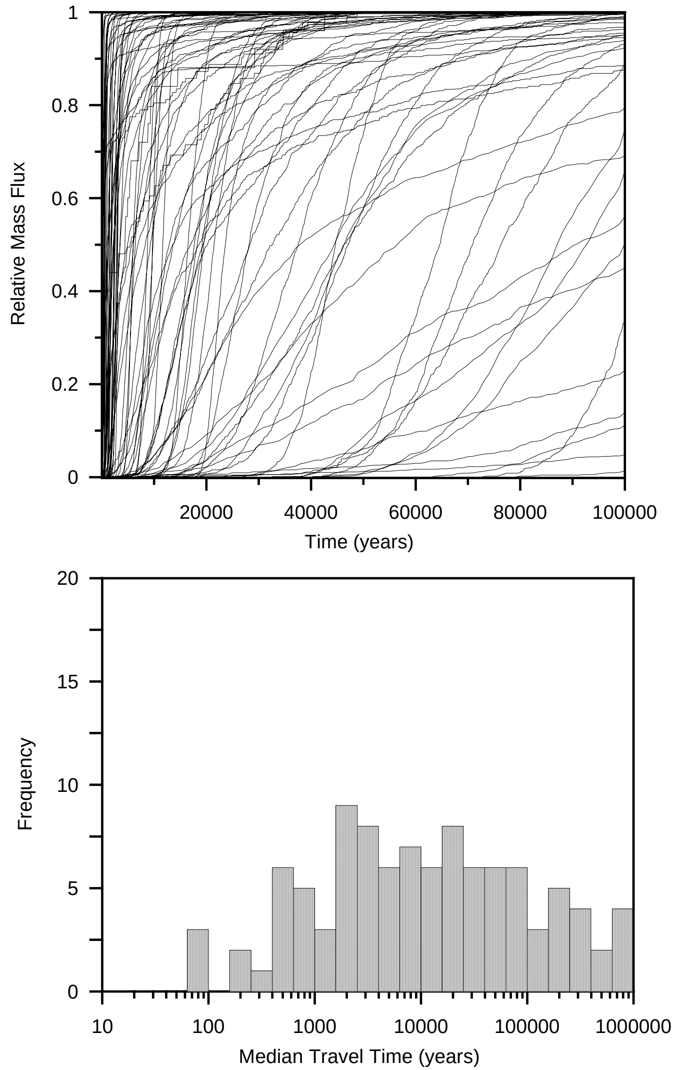


Alluvial Uncertainty Zone

- Northern boundary of the alluvium varies across the entire uncertainty zone
- Western boundary of the alluvium varies approximately from the Fortymile Wash channel to the tuff outcrops to the west
- Flow path length in the alluvium varies from about 1 up to 9 km

SZ Site-Scale Transport Results - ^{237}Np

Simulated Unit Breakthrough Curves and Histogram of
Median Travel Times of Mass Flux for Neptunium, Present Climate

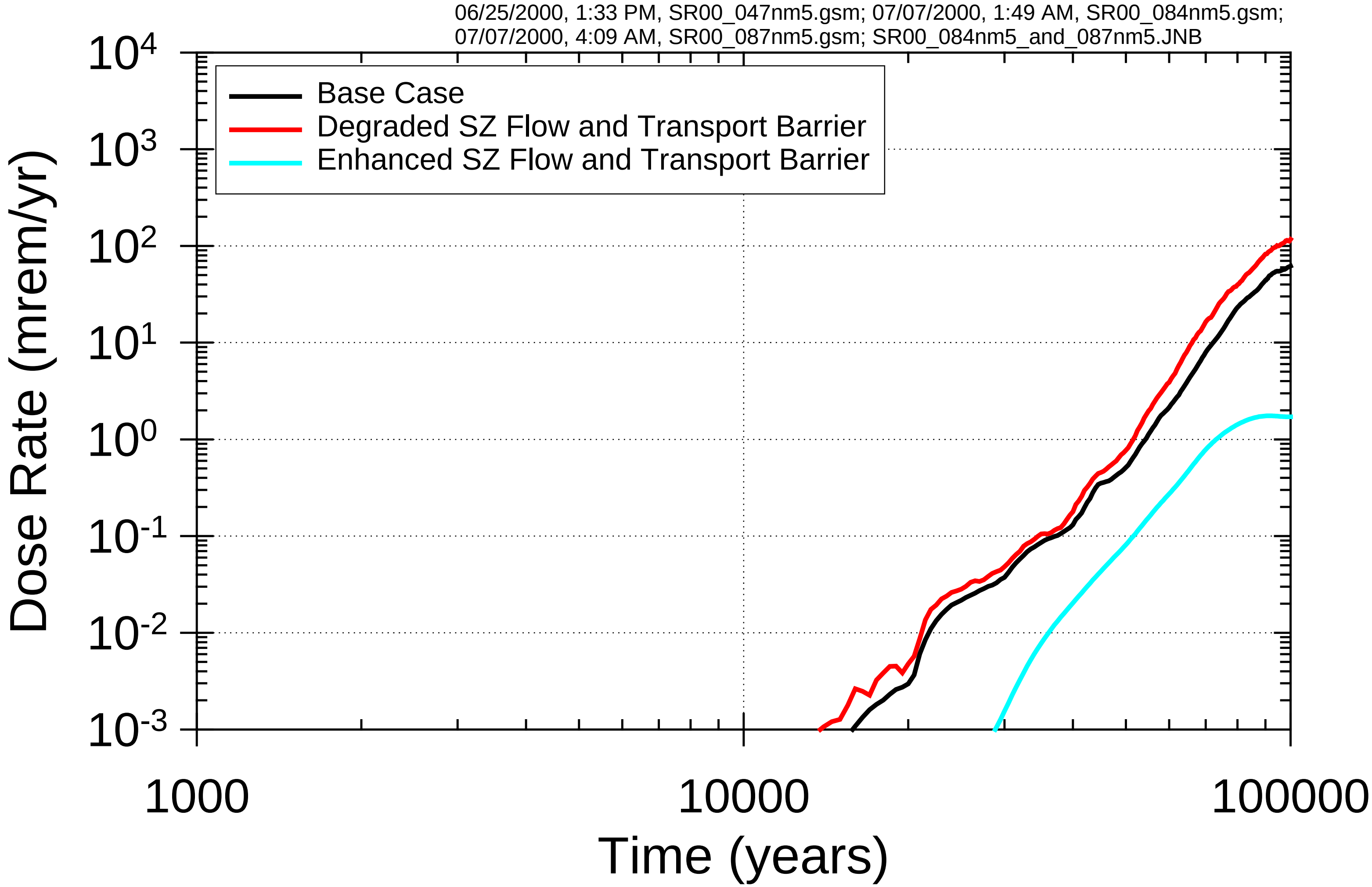


- **Variability in travel times among realizations for transport of ^{237}Np extends from less than 1000 years to 1,000,000 years**
- **Sorption and retardation for ^{237}Np is generally moderate in alluvium and minor in the matrix of fractured volcanic units**
- **Approximately half of the realizations exhibit median travel times of greater than 10,000 years in the SZ**

SZ Flow and Transport Barrier Sensitivity

- **Degraded Barrier**
  - **95th %tile for all SZ Flow and Transport parameters**
- **Enhanced Barrier**
  - **5th %tile for all SZ Flow and Transport parameters**

Preliminary
SZ Flow and Transport Barrier Sensitivity



This information was prepared for the 8/00 NWTRB meeting for illustrative purposes only and is subject to revision; not appropriate for assessing regulatory compliance.

Summary

- **3-D SZ site-scale flow and transport model is used for radionuclide mass transport simulations in TSPA-SR**
- **Matrix diffusion, dispersion, and sorption are explicitly simulated by the particle tracking method in the SZ site-scale model**
- **SZ model is calibrated to water level measurements, and is consistent with hydrochemical data, permeability measurements, and regional groundwater modeling**
- **Transport model uncertainties result in significant overall uncertainty in radionuclide breakthrough curves**
- **Base case performance yields dose curve close to that of the degraded SZ barrier behavior, whereas the enhanced barrier curve yields signifcantly better performance (longer times, lower doses)**