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

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Conceptual Model of Saturated Zone Flow and Transport and Independent Lines of Evidence for Evaluating the Saturated Zone Model Calculations

Presented to:
U.S. Nuclear Waste Technical Review Board Panel On the Natural System

Presented by:
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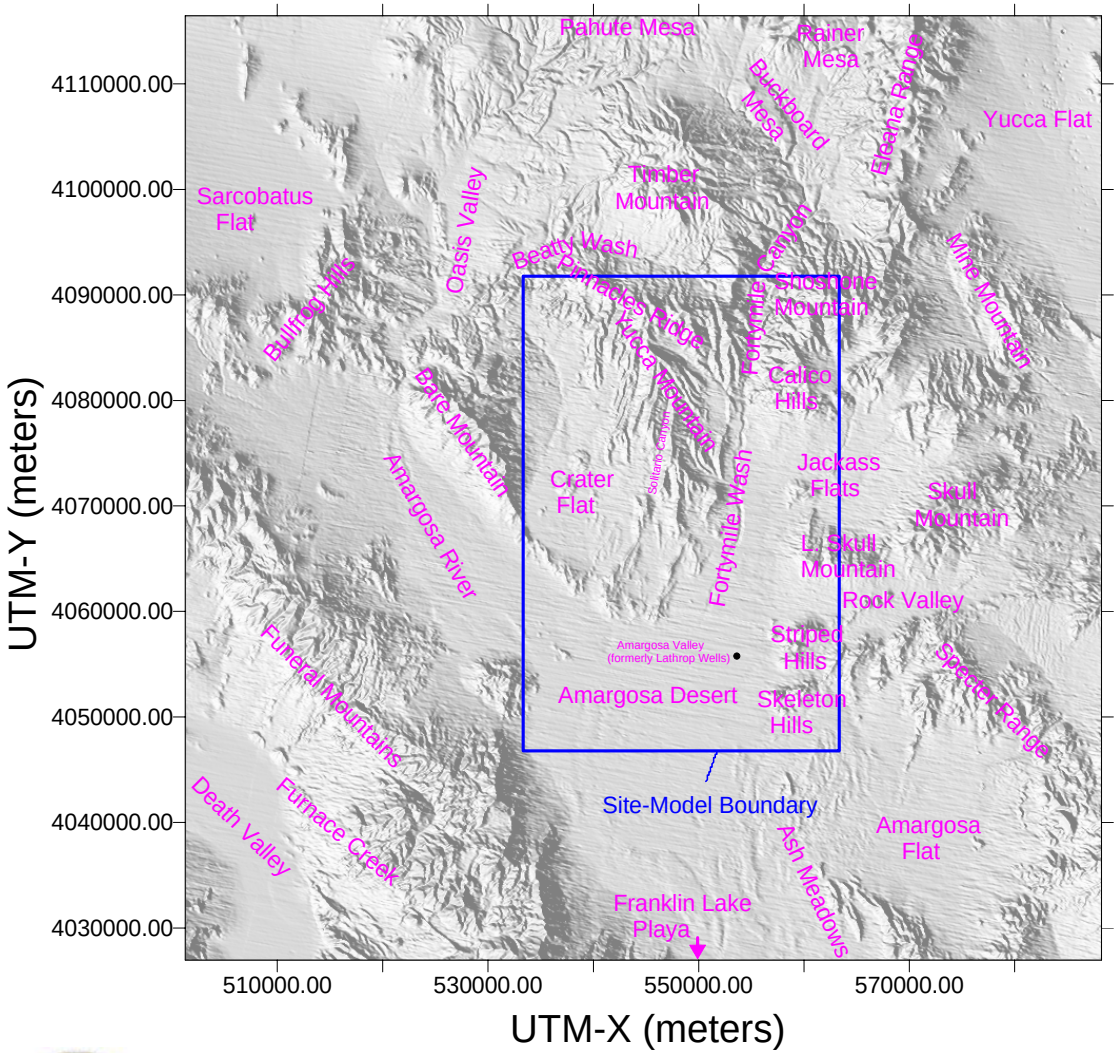
Outline

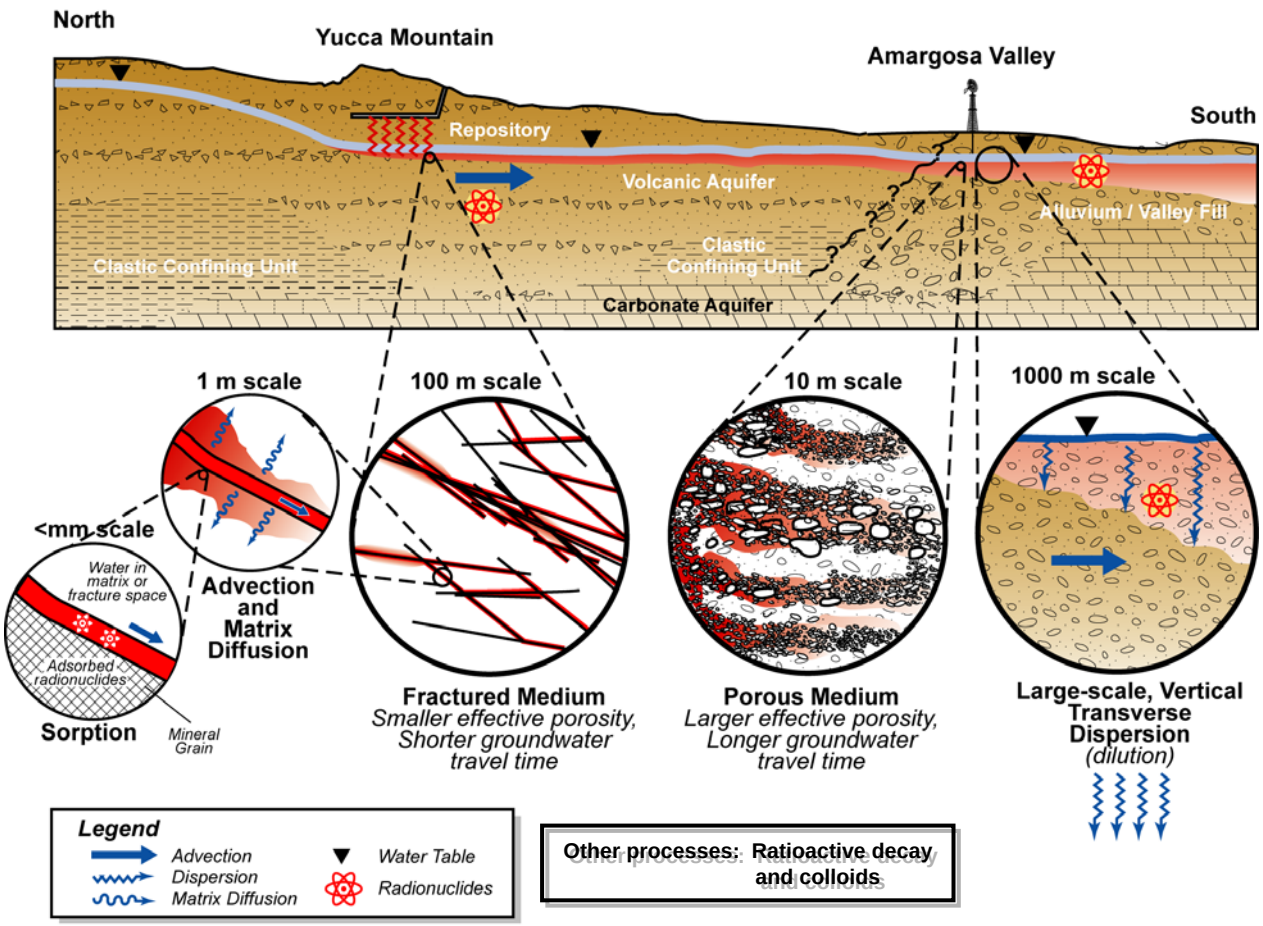
- **Conceptual models of groundwater flow and radionuclide transport**
- **Site scale flow and transport model calculations**
- **Independent lines of evidence to support the model predictions**

Conceptual Model of Saturated Zone Flow

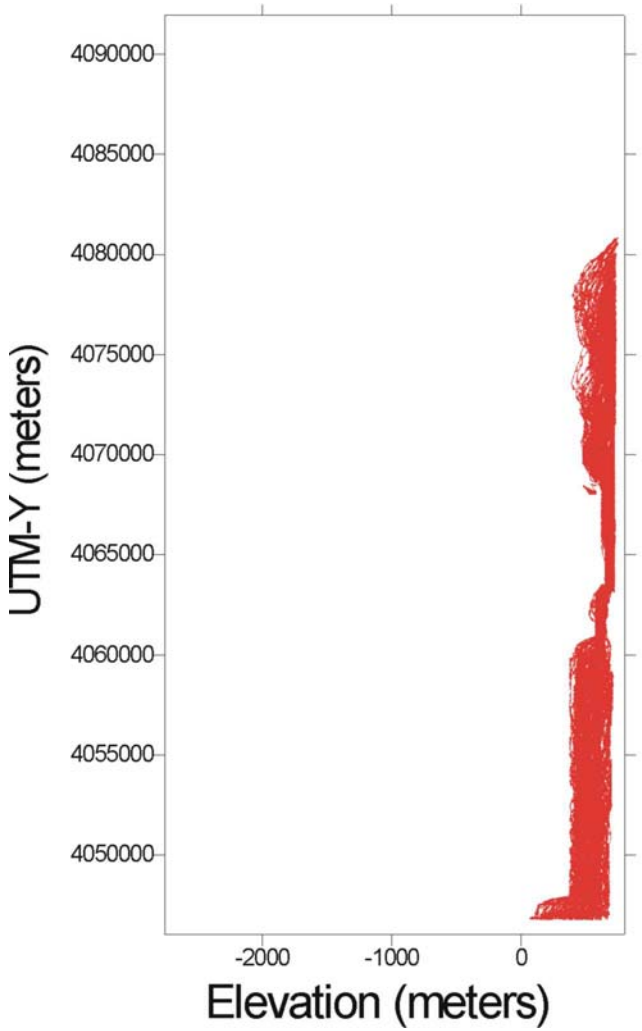


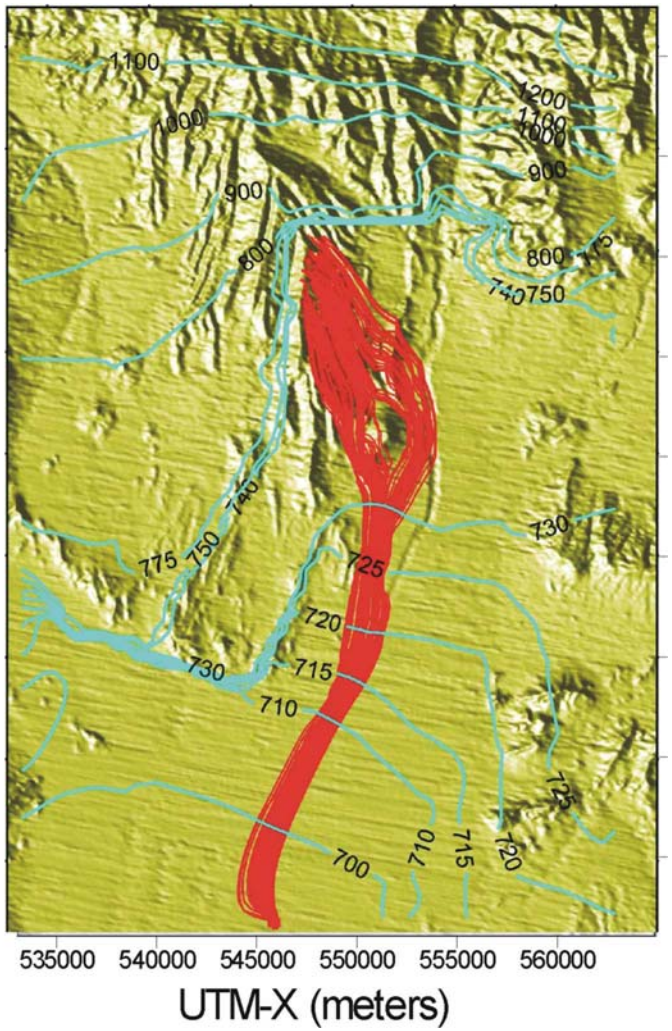
- **Key Controls on Flow**
  - **Geologic formations**
    - **Spatial location**
    - **Properties**
    - **Major faults**
  - **Death Valley Regional Groundwater Flow System**
    - **Recharge and discharge that define the large scale flow system**
  - **Local recharge, Fortymile Wash, pumpage**

Conceptual Model of Radionuclide Transport Along the Groundwater Flow Path



Flow Model Calculations
Water Level and Pathline Calculations

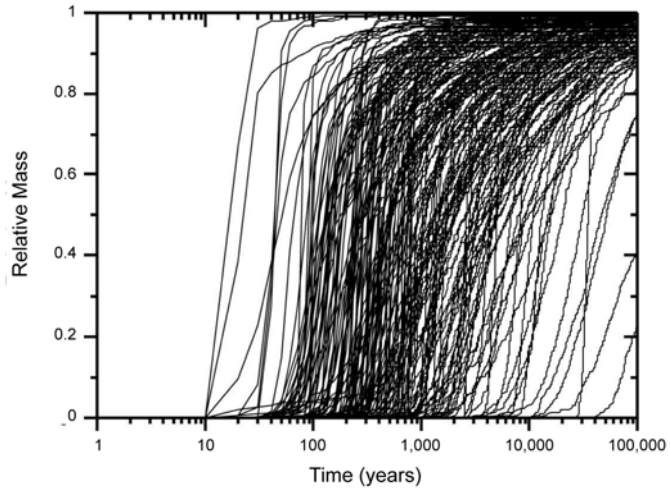




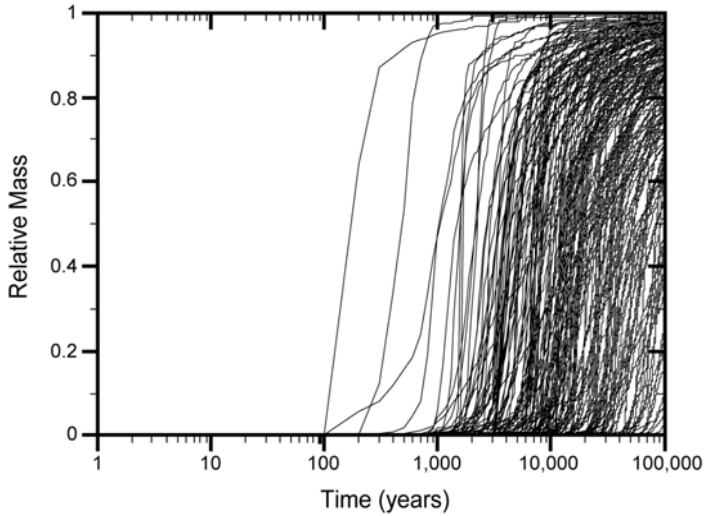
Transport Model Results

Breakthrough curves of radionuclides at the accessible environment after release at the water table beneath the proposed repository

Carbon, Technetium, Iodine



Neptunium



The data shown in this figure are based on a model that is appropriately conservative for TSPA analyses and not intended to represent expected breakthrough of radionuclides or groundwater travel time for saturated zone portion of the Yucca Mountain flow system.

Independent Lines of Evidence to Support the Model Calculations

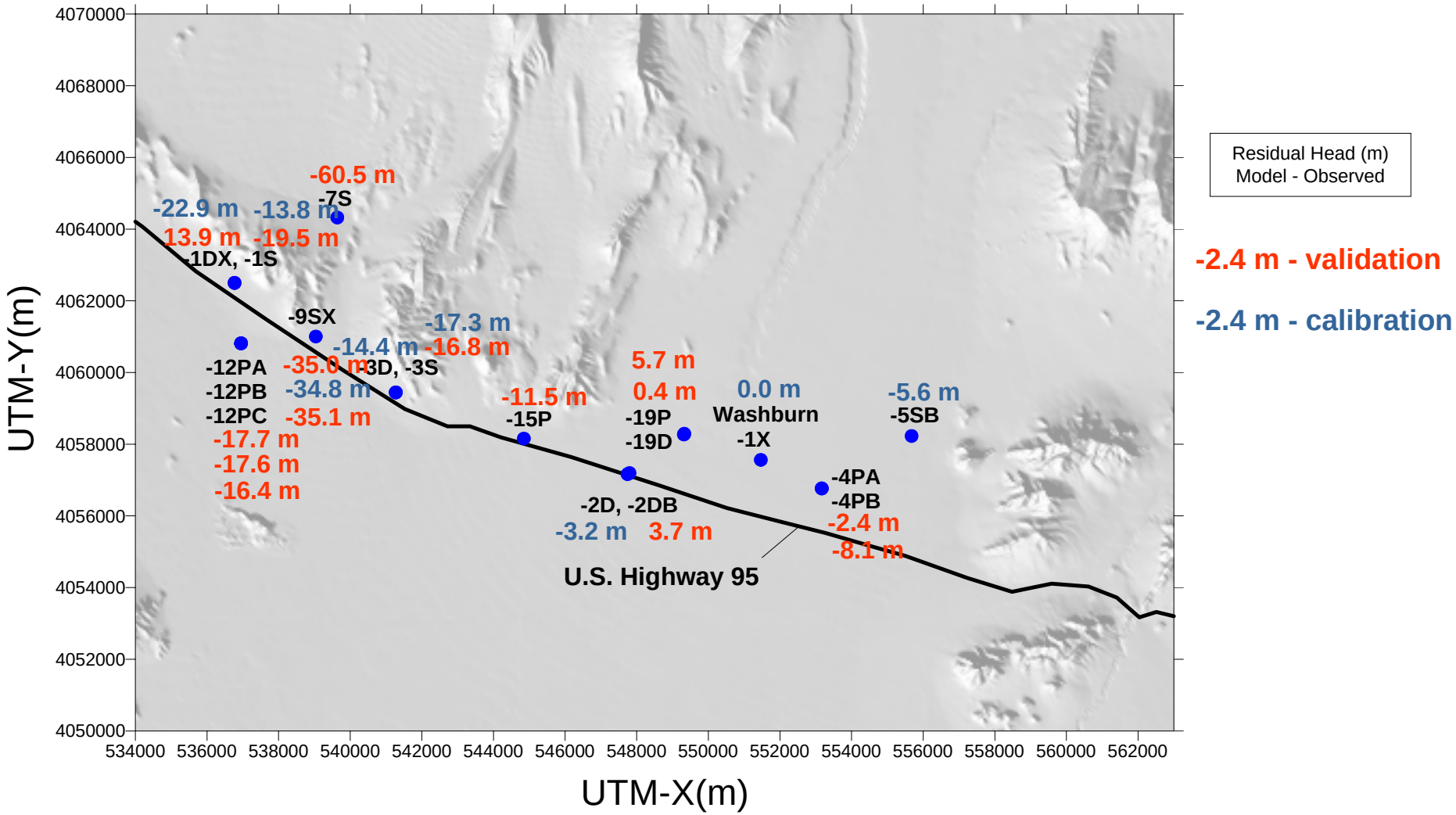
- **Correspondence to measured data (calibration/validation)**
  - **Calibration data**
    - **Potentiometric levels/hydraulic conductivity**
  - **Validation data**
    - **Water levels in Nye County wells/Alluvial Testing Complex cross-hole pumping test**
  - **Hydraulic parameters**
    - **Calibrated K values/validation to new Alluvial Testing Complex cross-hole pumping test data**
- **Correspondence to regional scale observations**
  - **Flow directions and boundary fluxes from the 1997 regional model**

Independent Lines of Evidence to Support the Model Calculations

(Continued)

- **Corroboration with hydrochemistry**
  - **Chemical evolution (or lack thereof) as an indicator of flow paths**
  - **Mixing of different water types**
  - **Groundwater age (or relative age)**
- **Groundwater temperature**
  - **Validation simulations**

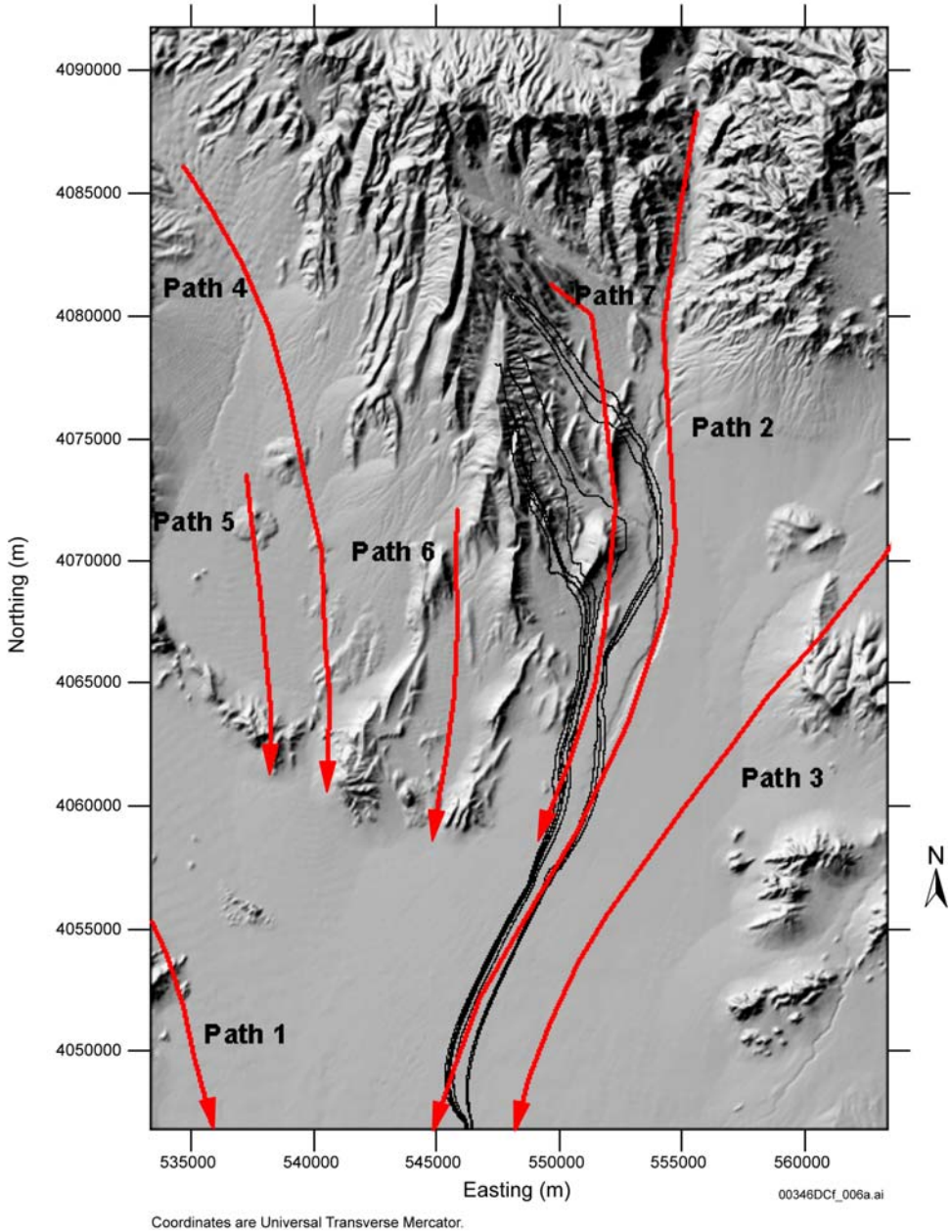
New Water Levels Comparison to Nye County Data



Validation of Alluvium Hydraulic Conductivity and Specific Discharge with New Data from the Alluvial Testing Complex

- **Data from cross-hole testing at the Alluvial Testing Complex provided an intrinsic permeability value of 2.7×10^{-12} m^2. The calibrated value of 3.2×10^{-12} m^2 is 19 percent larger than the measured value**
- **Using new water levels at the Alluvial Testing Complex to calculate the hydraulic gradient and the new aquifer test results, the modeled specific discharge is 27 percent larger than obtained from measured data and Darcy's Law**

Corraboration of Flow Paths with Hydrochemical and Isotopic Data



Flow path based on hydrochemical data interpretation

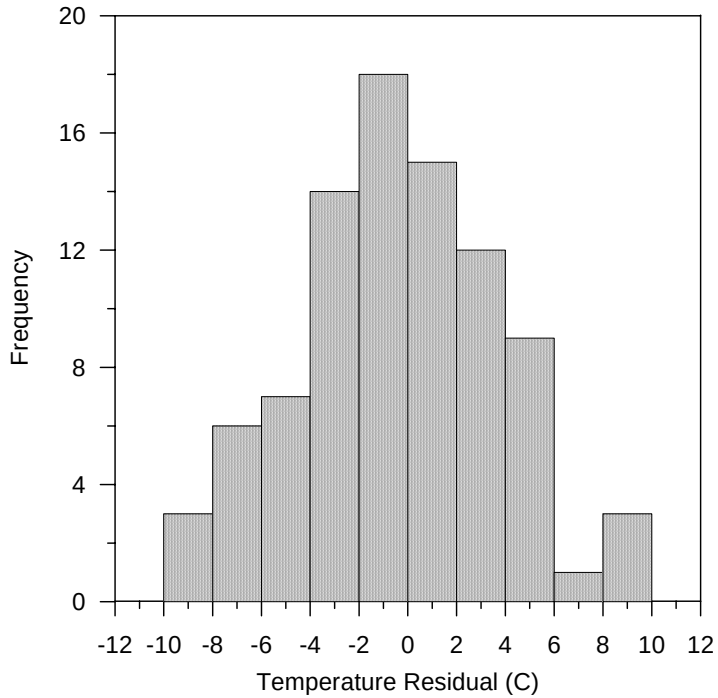
Flow path based on flow model

Magnitude of Recharge

- **Using a chloride mass balance approach, the recharge rate is estimated to be between 7 and 14 mm/yr**
- **From the unsaturated zone studies, the average present-day net infiltration ranges from approximately 1 to 11 mm/yr., with an expected value of 4 mm/yr**
- **Note that recharge in the entire site-scale model is less than 5 percent of the total flow through the system based on flow out the southern boundary versus the total inflows from the other 3 boundaries**

Validation - Thermal Modeling

- **Modeling the distribution of temperature in the saturated zone assuming both conduction via the natural geothermal gradient and convection caused by groundwater movement**
  - **94 observations of temperature in 35 wells that span a range of values from 21.7 to 62.1 degrees celsius**
  - **80 percent of variability in temperature is accounted for by conduction alone**



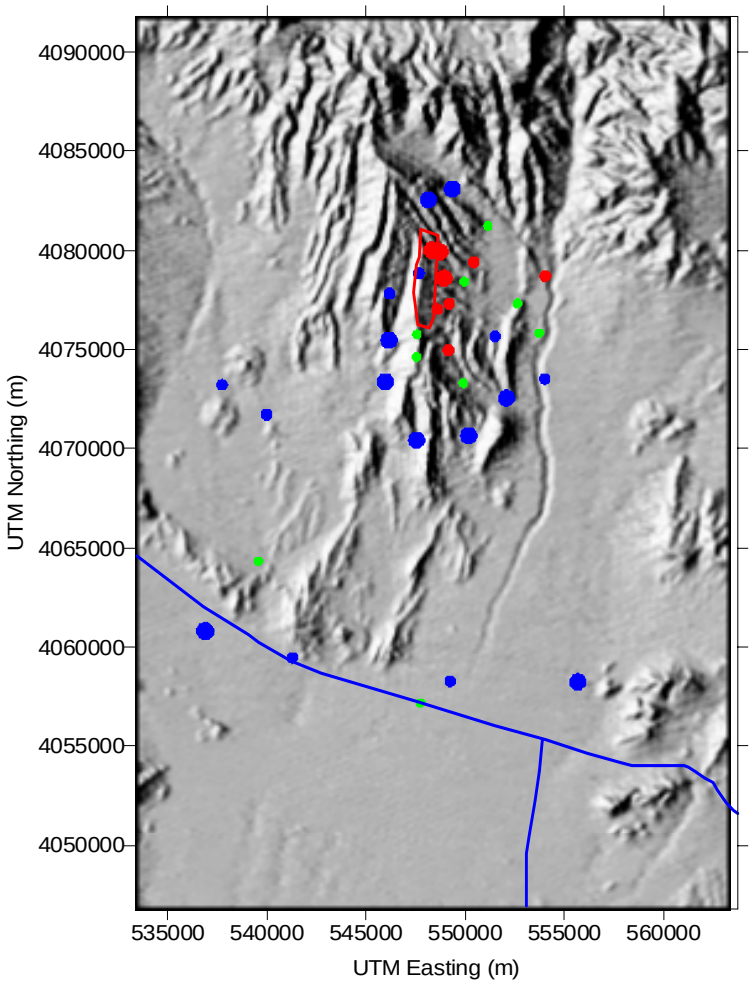
Histogram of temperature residuals for the thermal conduction model

Validation - Thermal Modeling

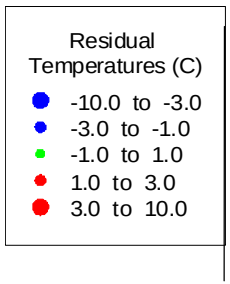
(Continued)

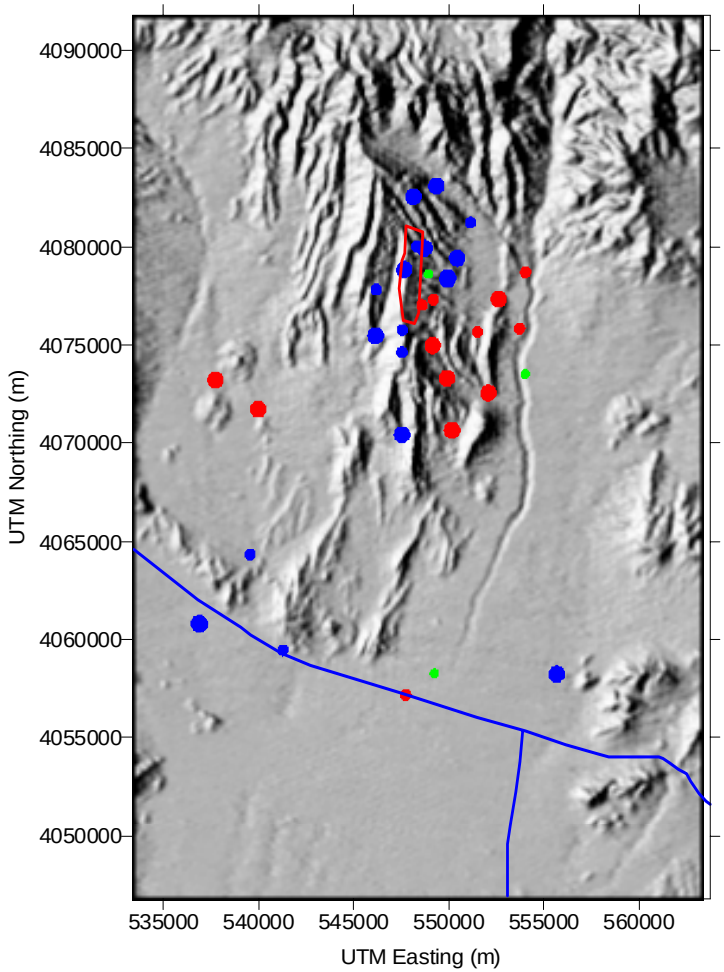
- **Combined conduction/convection case**
  - **Calibrated isothermal flow and calibrated conduction only heat were used to define specified pressure and temperature at boundary**
  - **Coupled heat and flow model was run to steady state, but no joint calibration of temperature and flow was attempted. Yet 85 of 94 observations were matched within 10 degrees**

Residual Temperatures for the Combined Conduction and Convection Case



Conduction Model





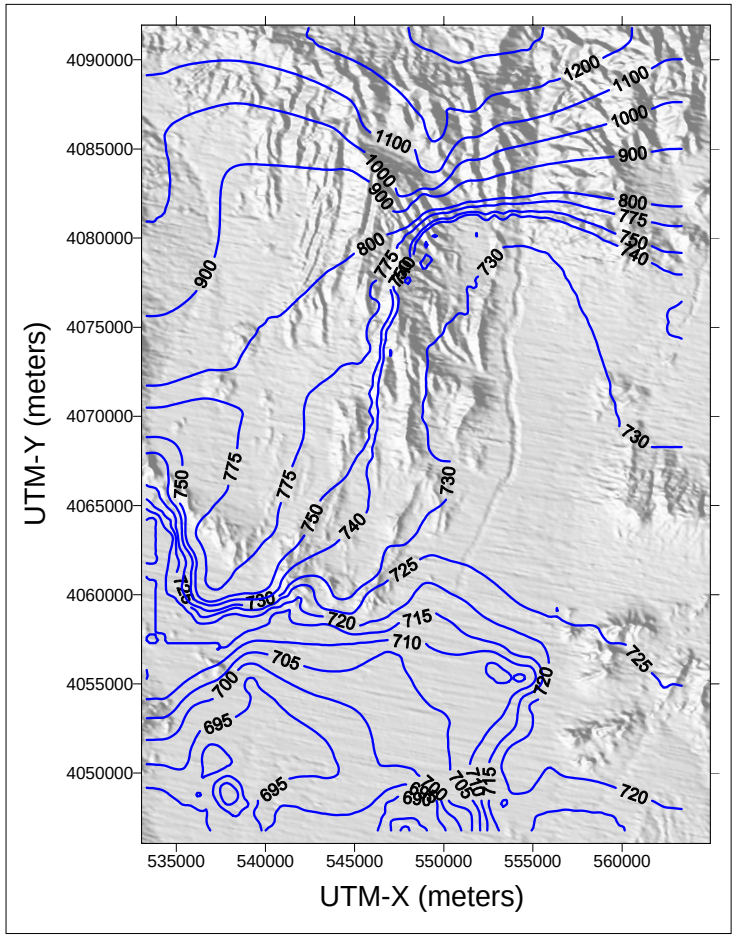
Conduction and Convection Model

Summary

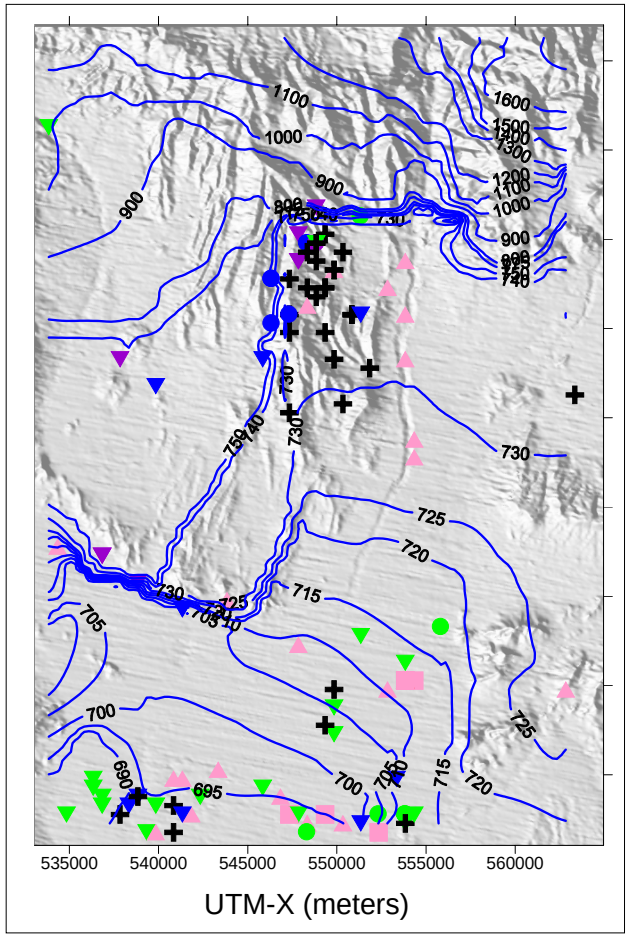
- **Multiple independent lines of evidence corroborate the calculations of the site scale models and increase confidence in the model results**
  - **Calibrated data and parameters**
    - **water levels**
    - **hydraulic conductivity**
    - **boundary fluxes**
  - **Validation data**
    - **Nye County wells water levels**
    - **Alluvial Testing Complex hydraulic conductivity**
  - **Hydrochemistry**
  - **Thermal modeling**

Backup

Water Levels
Calibration to Observed Values



Contours of Observed Heads

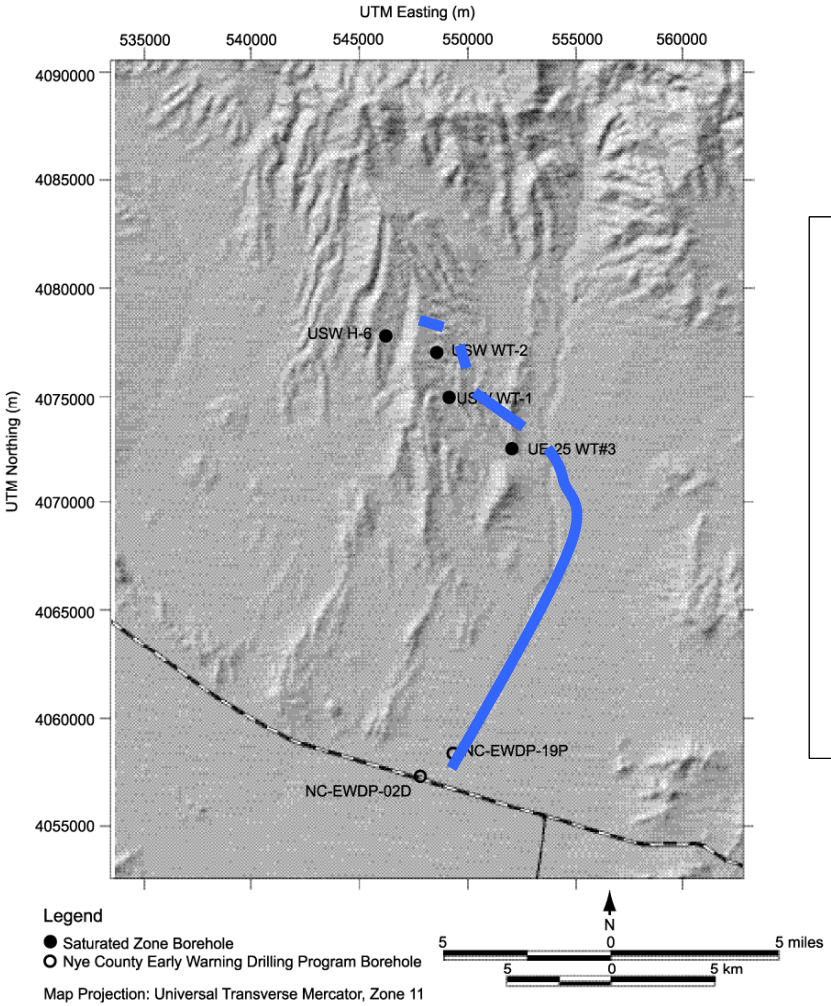


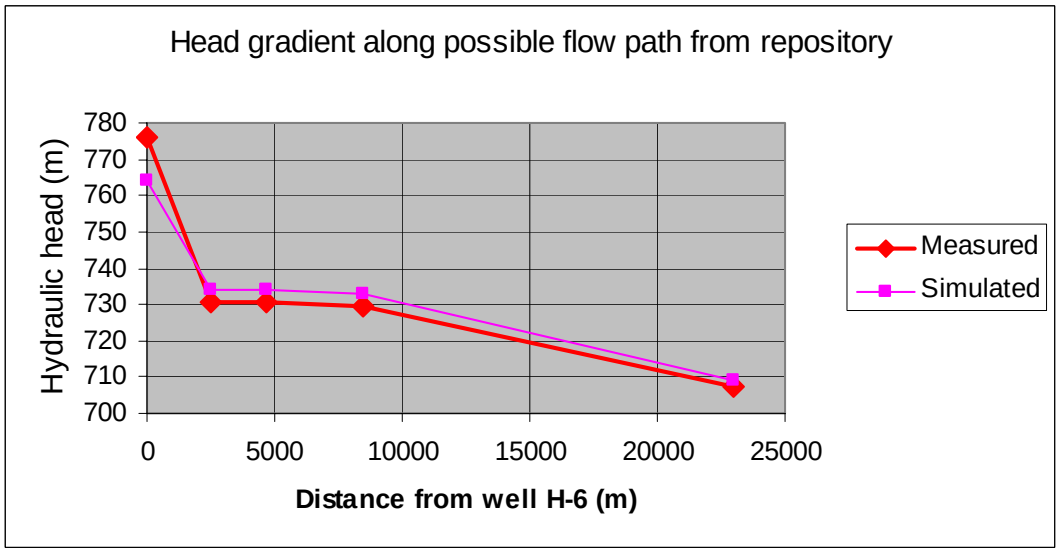
Contours of Model Heads

Residual Head (m)
Model - Observed

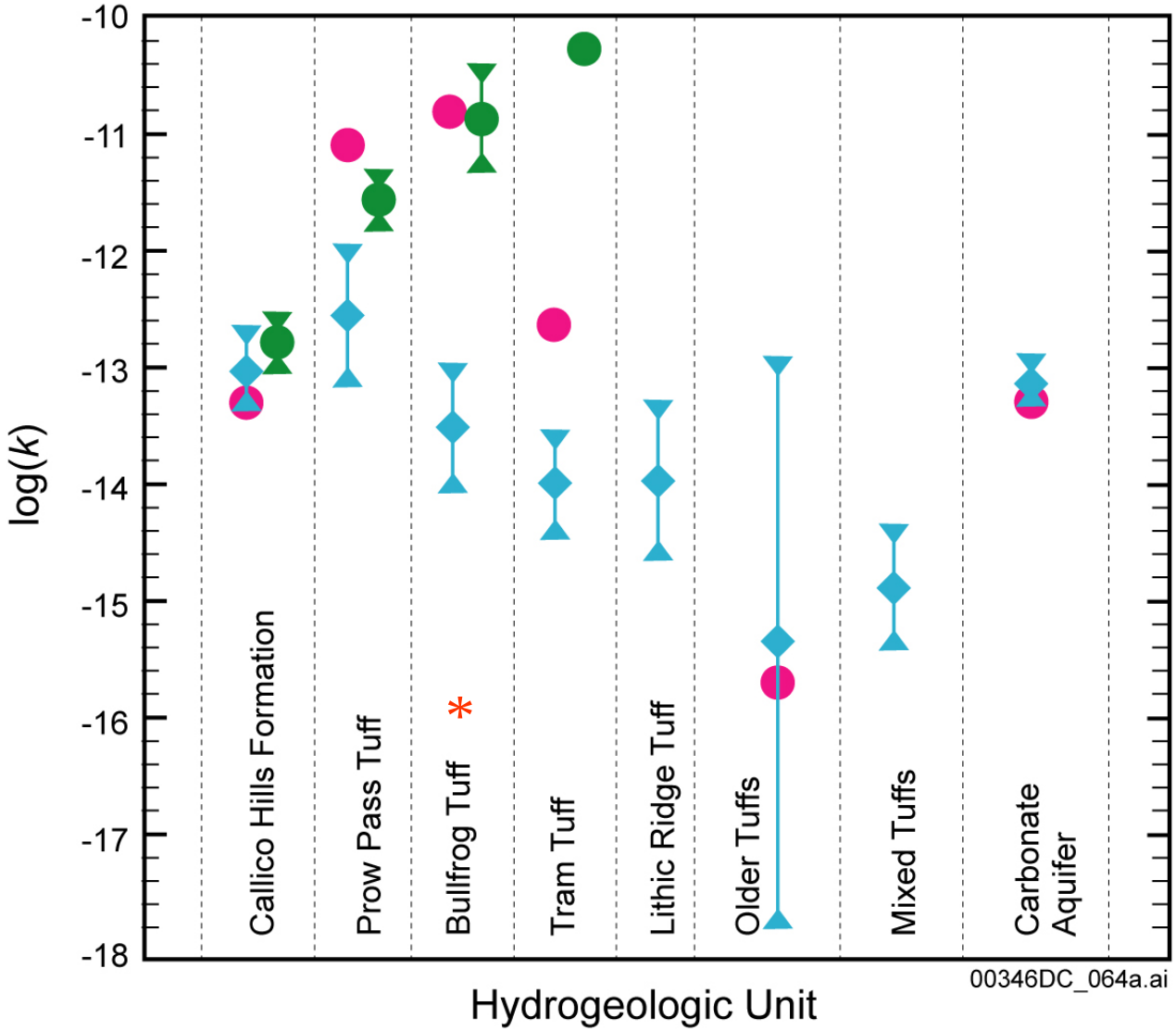
- -89.26 to -50.00
- -50.00 to -30.00
- -30.00 to -20.00
- -20.00 to -10.00
- -10.00 to -5.00
- -5.00 to -1.00
- -1.00 to 1.00
- 1.00 to 5.00
- 5.00 to 10.00
- 10.00 to 20.00
- 20.00 to 30.00
- 30.00 to 40.00
- 40.00 to 50.70

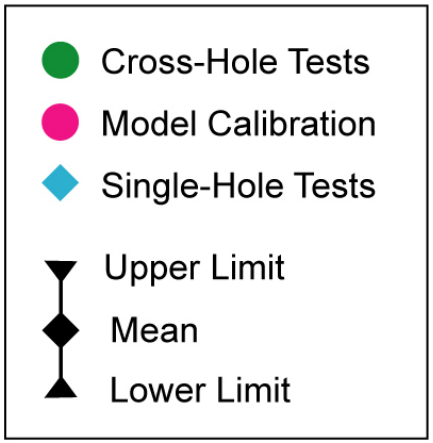
Simulated and Observed Head Gradient Along a Flow Path





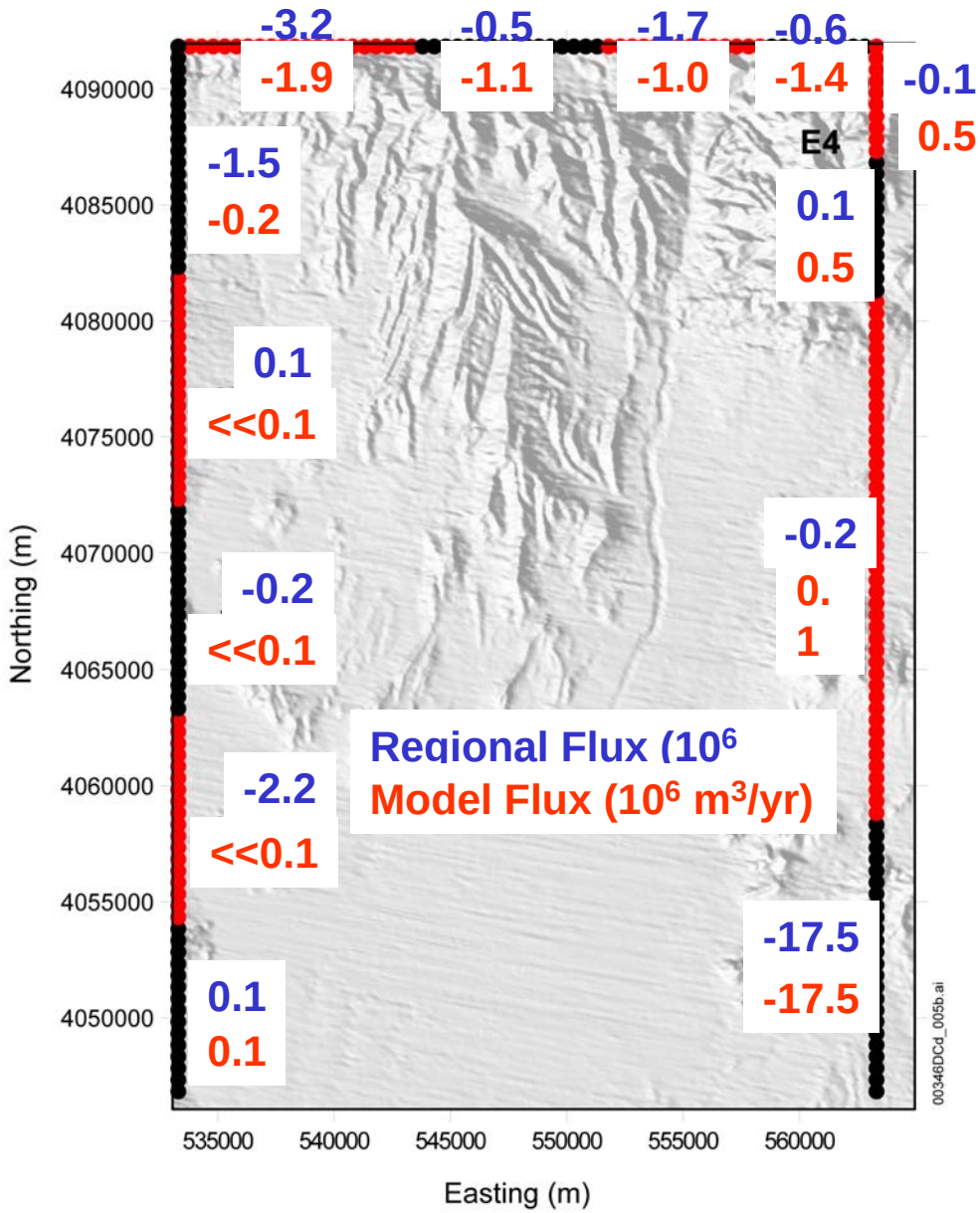
Hydraulic Properties - Yucca Mountain





* **Most important to prediction because most pathlines flow through this unit**

Correspondence to Regional Flow



Boundary Zone	Regional Flux (10^6 m^3/yr)	Model Flux (10^6 m^3/yr)
Northern Boundary	-6.1	-5.4
Western Boundary	-3.7	-0.1
Eastern Boundary	-17.7	-16.4
Southern Boundary	28.9	22.8

Based on 1997 regional model fluxes