YUCCA
MOUNTAIN
PROJECT

Studies

Seepage and Thermal Hydrology for TSPA-VA

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Seepage Into Drifts

Introduction

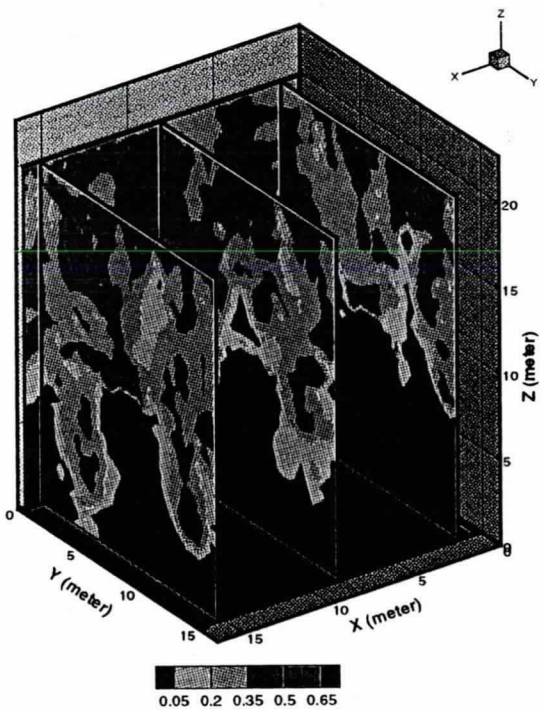
- "Seepage" is the liquid water that enters the emplacement drifts.
- Seepage enhances waste-package corrosion, mobilization of radionuclides from the waste form, and transport of radionuclides within the EBS.
- The final results (i.e., doses to individuals) are strongly affected by seepage.
- We parameterize seepage with two quantities:
  - the seepage fraction, or fraction of waste packages contacted by seeps
  - the seep flow rate, or flow rate of water onto those packages that are contacted by seeps
- Seepage is calculated for six repository regions.

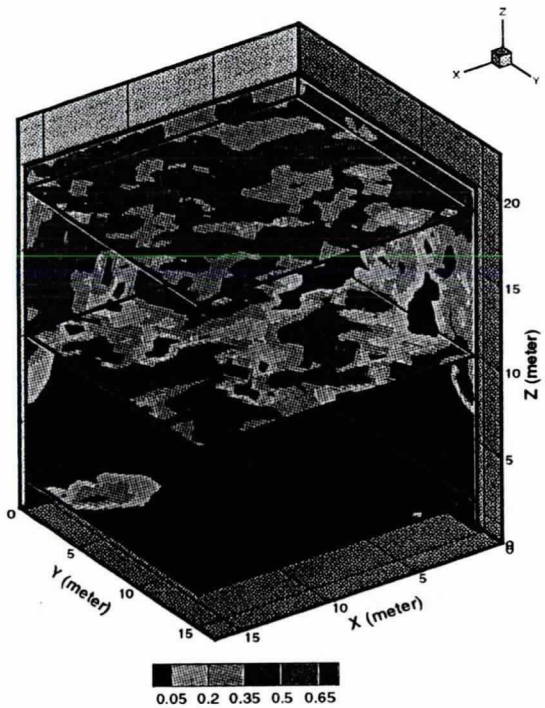
Conceptual Model

- Drifts in unsaturated media can act as capillary barriers, diverting water around them.
- Seepage occurs if rock at the drift wall becomes locally saturated
  - because of disturbance to the flow field caused by the drift opening
  - because of heterogeneities in the permeability field, giving rise to channelized flow and local ponding
- This capillary-barrier effect is confirmed by the ESF niche test.

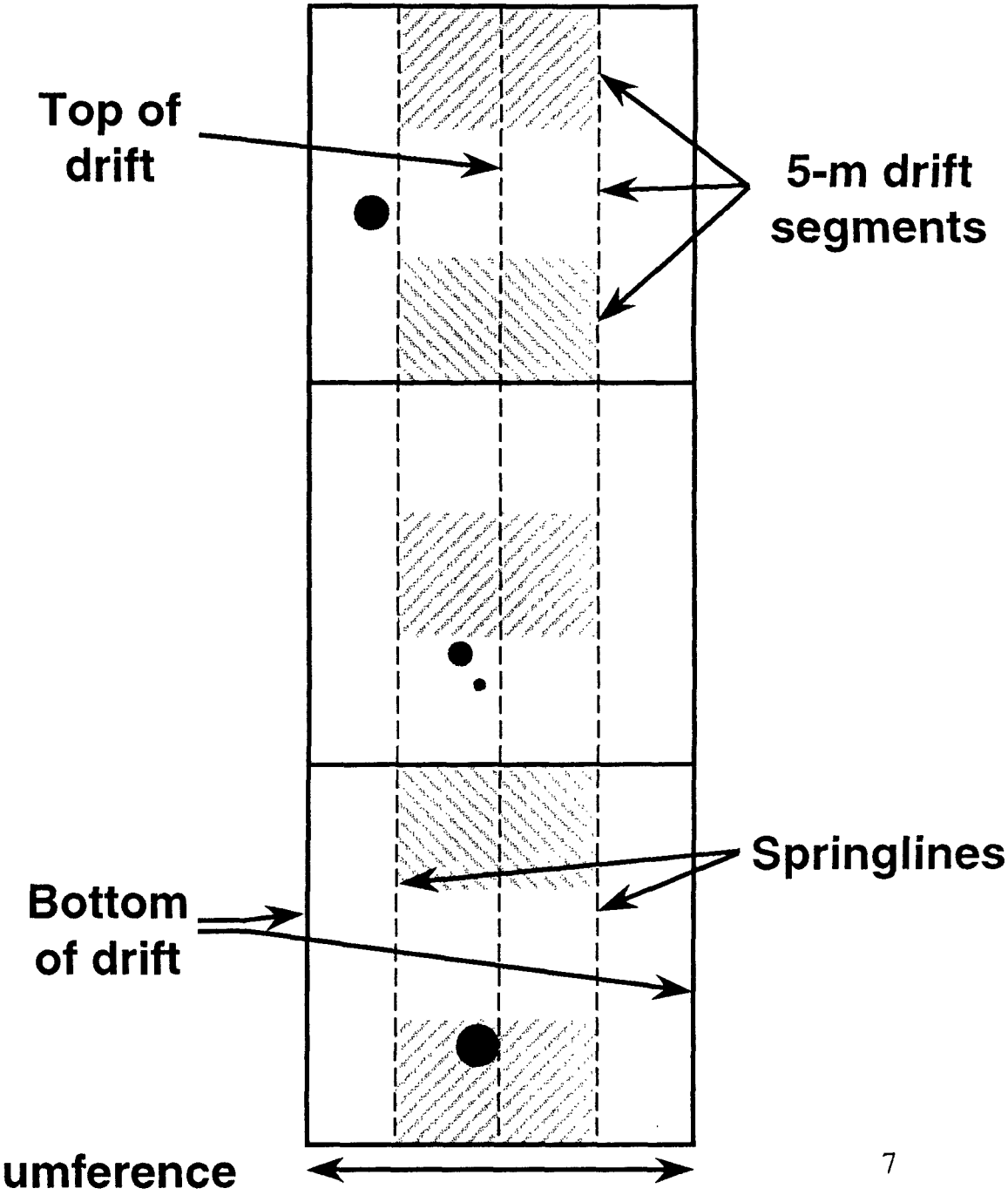
Process Model

- 3-D drift-scale flow model (LBNL)
  - steady state, isothermal
  - no matrix imbibition (fracture continuum only)
  - heterogeneous fracture continuum with 0.5-m grid blocks
  - mechanical, chemical, and thermal alterations assumed to be offsetting or insignificant



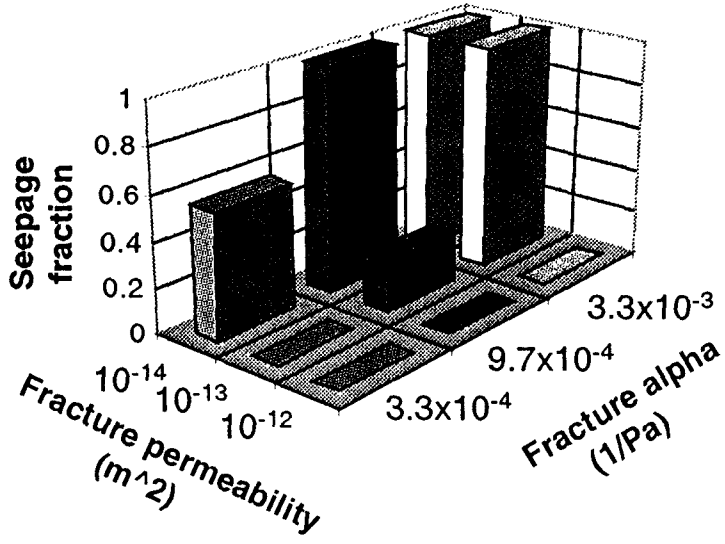


Distribution of Seeps on Drift Wall From 3-D Model

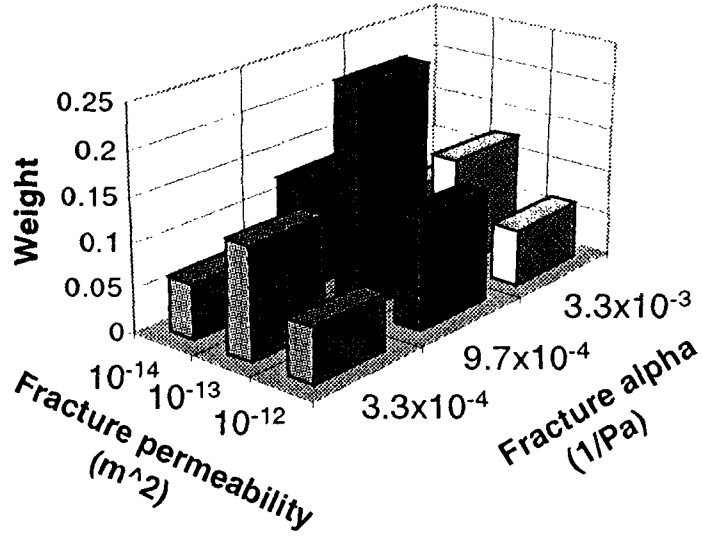


Development of Probability Distribution

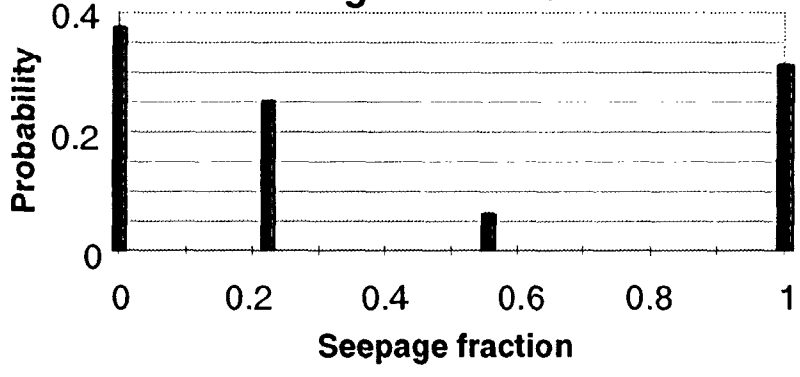
Model results (percolation = 73 mm/yr)



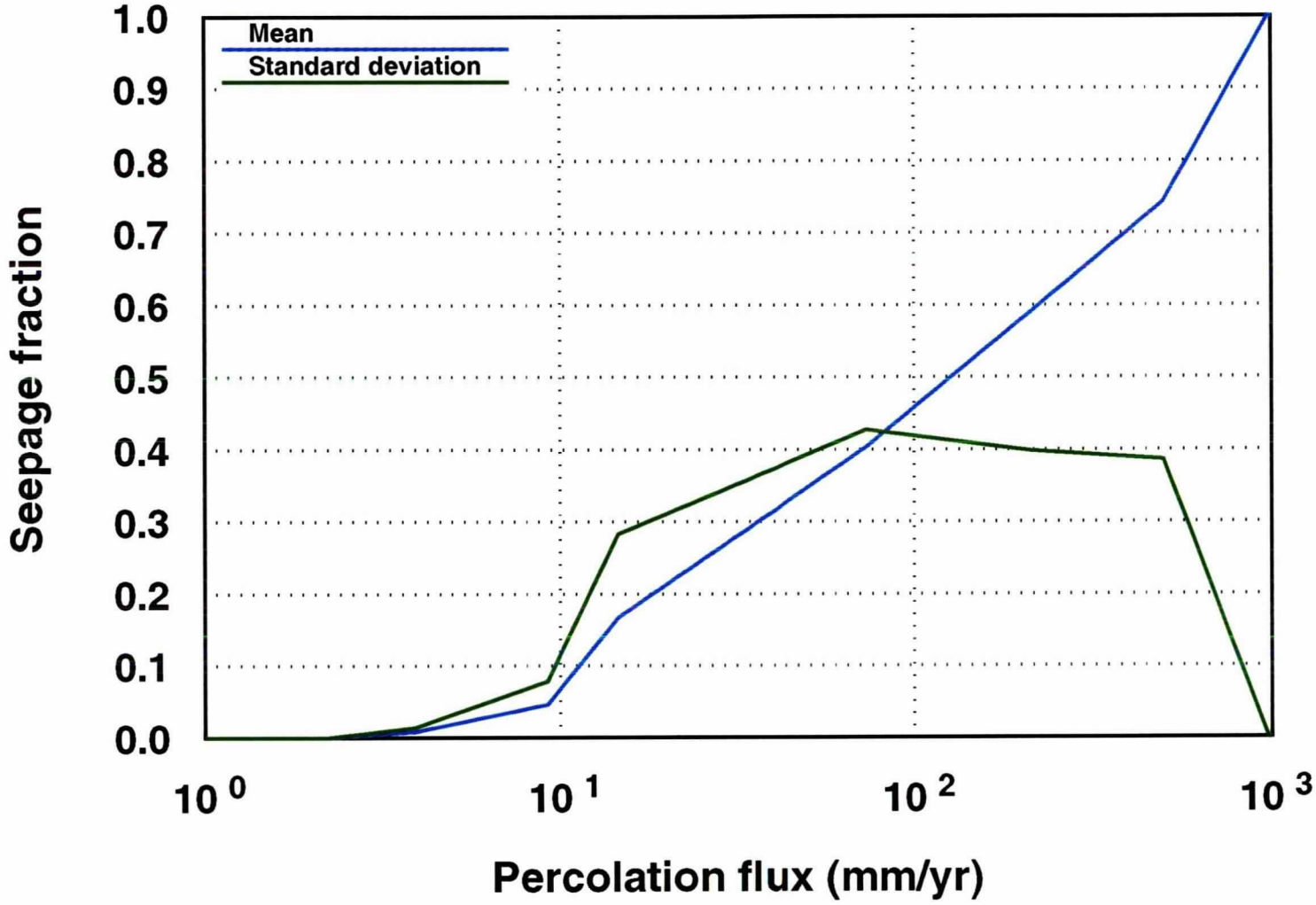
Weights applied to the cases



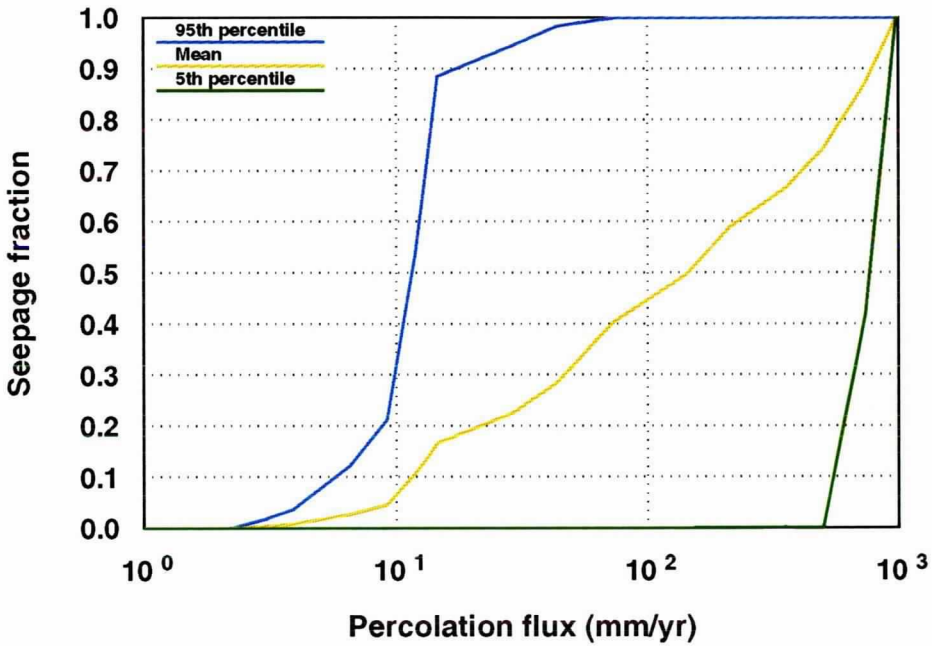
Histogram of results

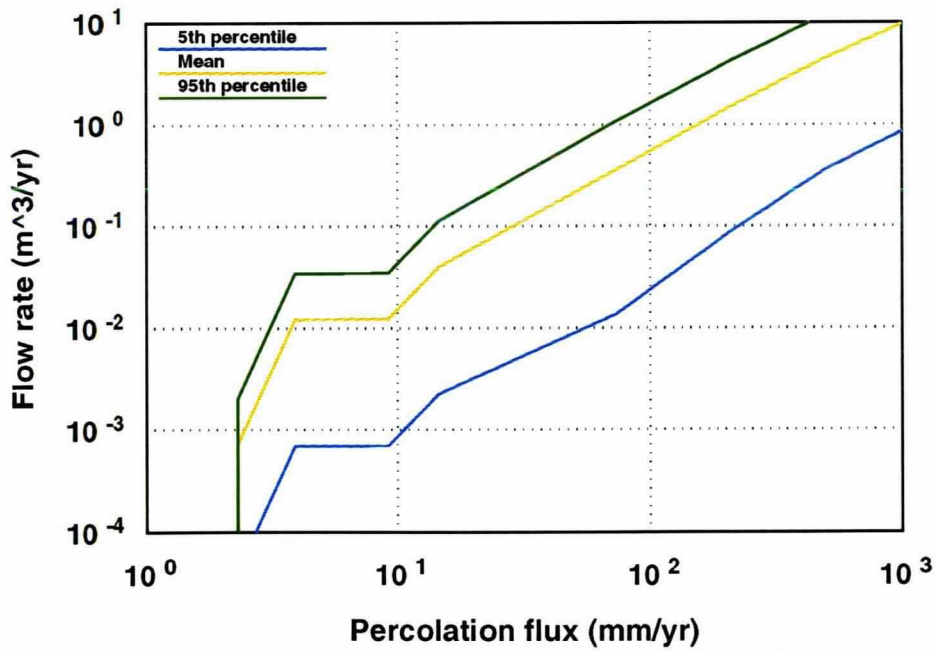


Seepage-Fraction Statistics

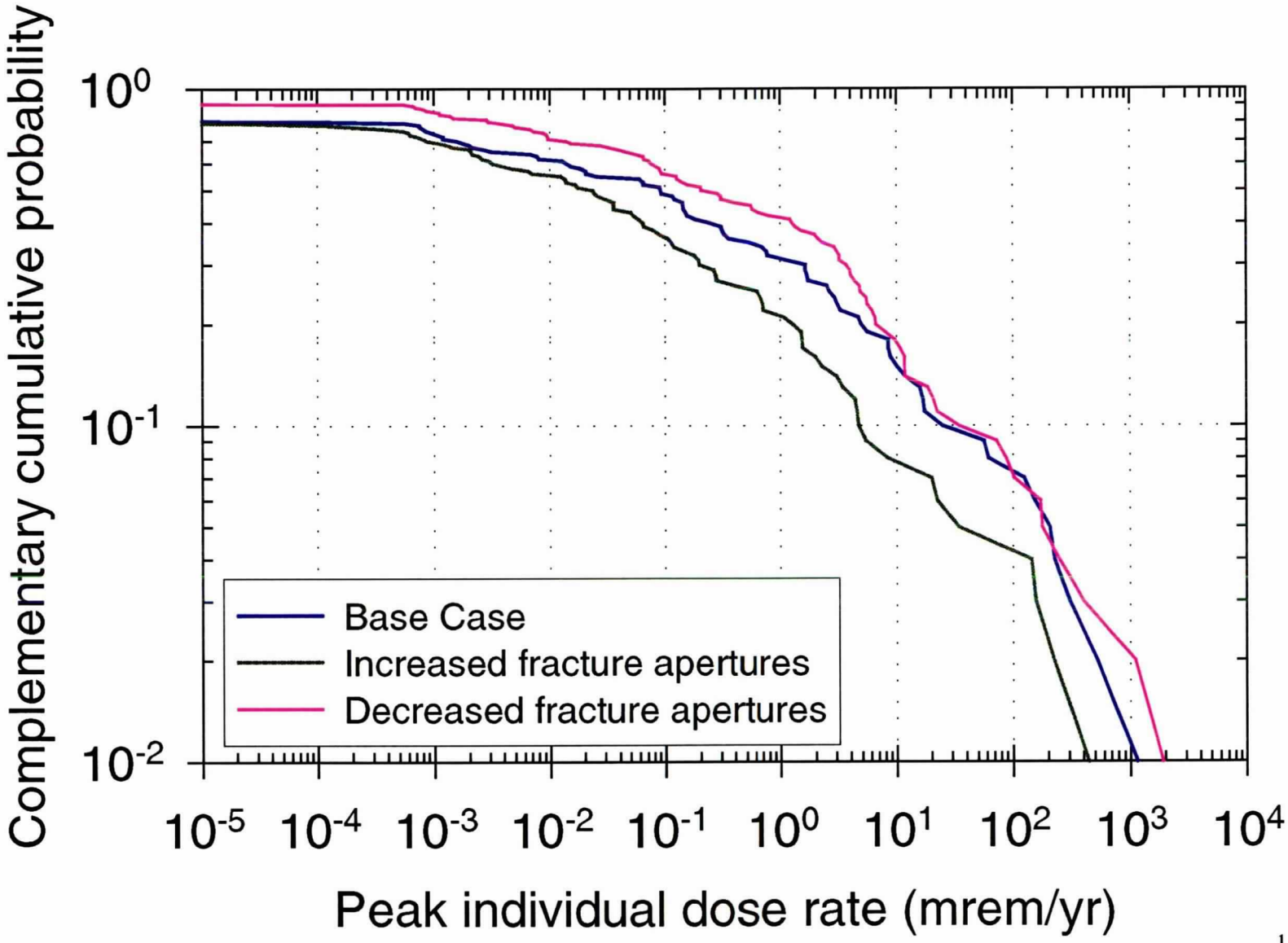


Seepage vs. Percolation Rate





Sensitivity to Fracture-Property Weights



Summary

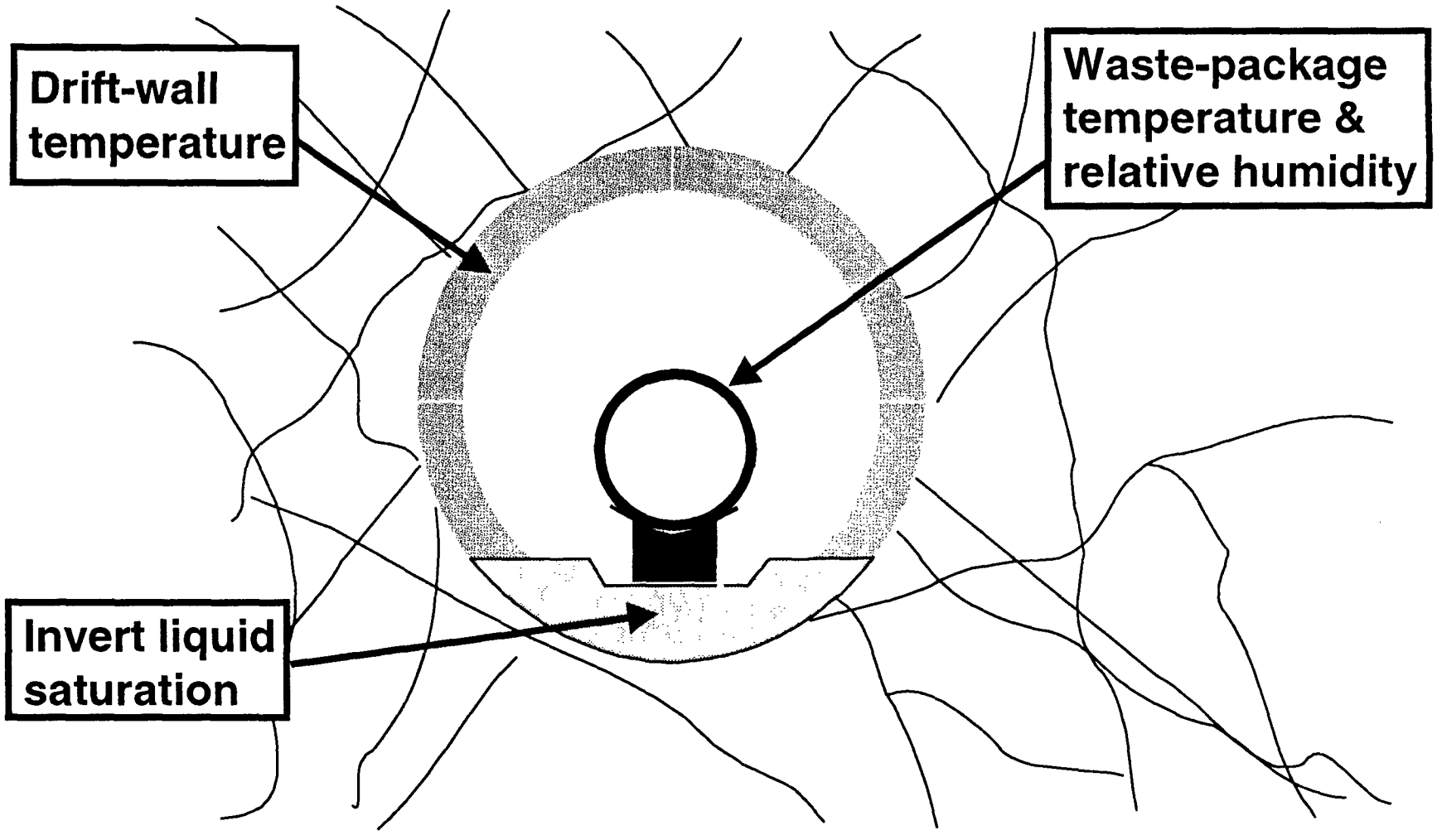
- Seepage for TSPA-VA is based on a 3-D heterogeneous drift-scale flow model.
- Initial comparisons with the ESF niche test are favorable.
- Results from nine sets of fracture hydrologic properties are weighted to arrive at the final abstracted model.
- Modeled <u>average</u> seepage fraction for present climate is about 3%, for LTA climate is about 25%, and for SP climate is about 40%, with wide uncertainty bands.
- For comparison, UZFMEE estimates ranged from less than 1% up to 10% (under present conditions).
- Modeled <u>average</u> seep flow rates range from about 20 liters/year (present climate; roughly a drip every couple of minutes) to about 700 liters/year (SP climate; roughly a drip every few seconds).

Thermal Hydrology

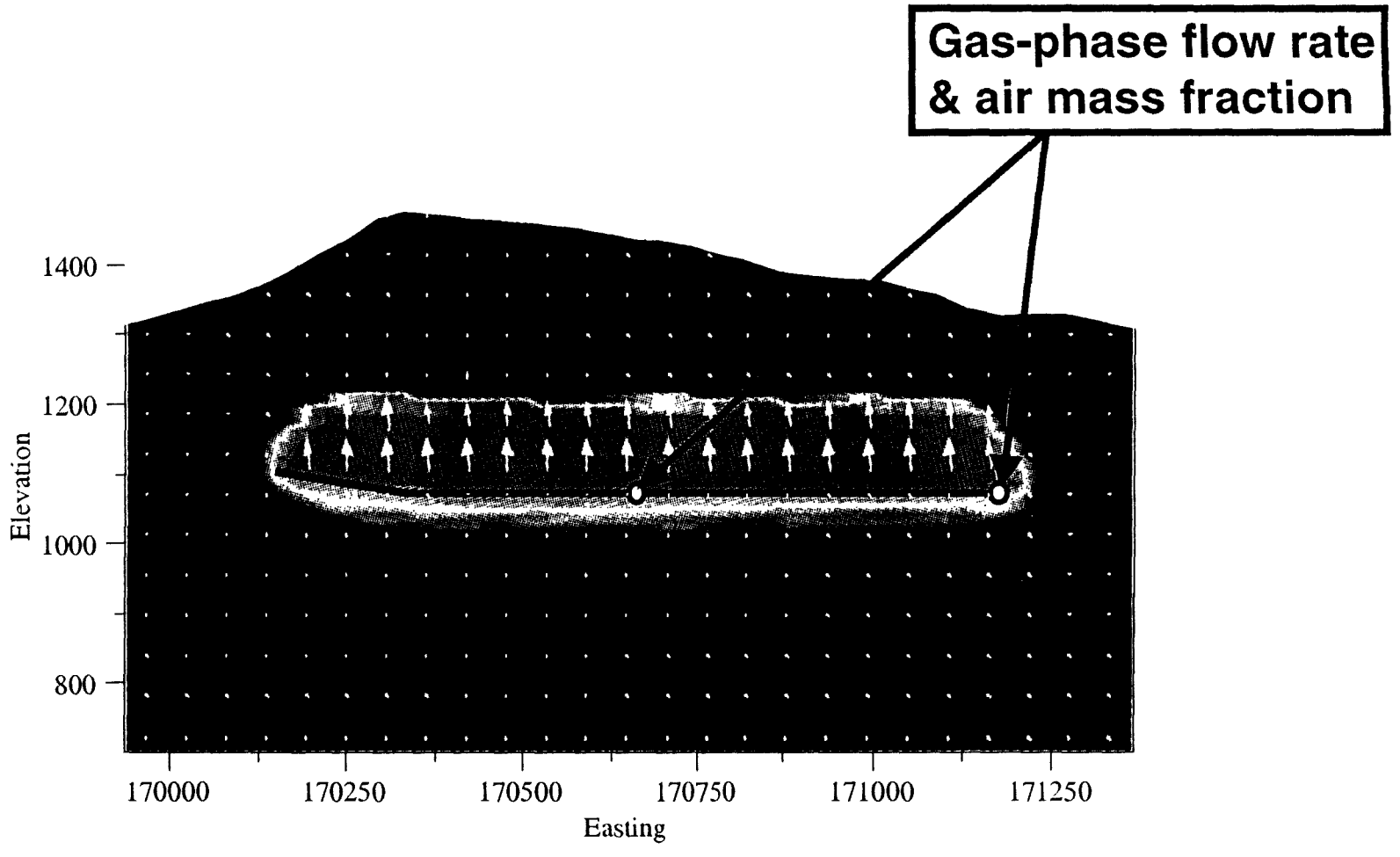
Introduction

- Drift-scale thermal hydrologic calculations are used to determine the thermodynamic environment (hot, dry, humid, etc.) within emplacement drifts and at waste-package surfaces after the emplacement of heat-generating waste.
- Mountain-scale thermal hydrologic calculations are used to determine the impact of repository heat on large-scale movement of gas and liquid in the mountain.
- Drift-scale calculations must be linked to mountain-scale calculations in order to properly account for dissipation of heat away from the repository.

Quantities From Drift-Scale Model



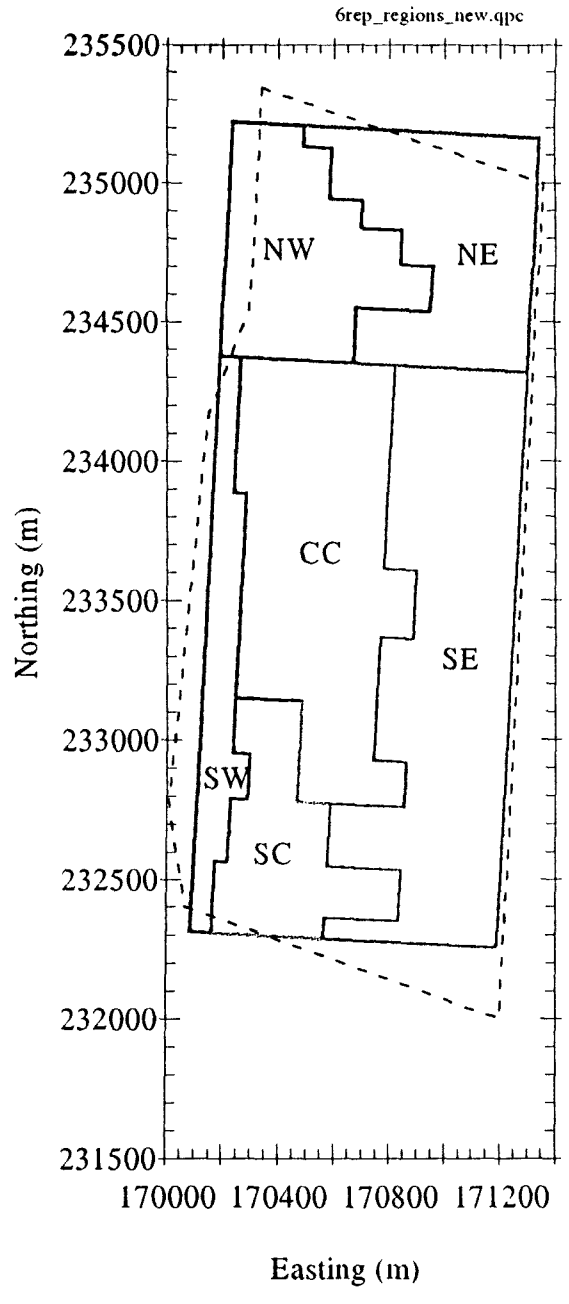
Quantities From Mountain-Scale Model



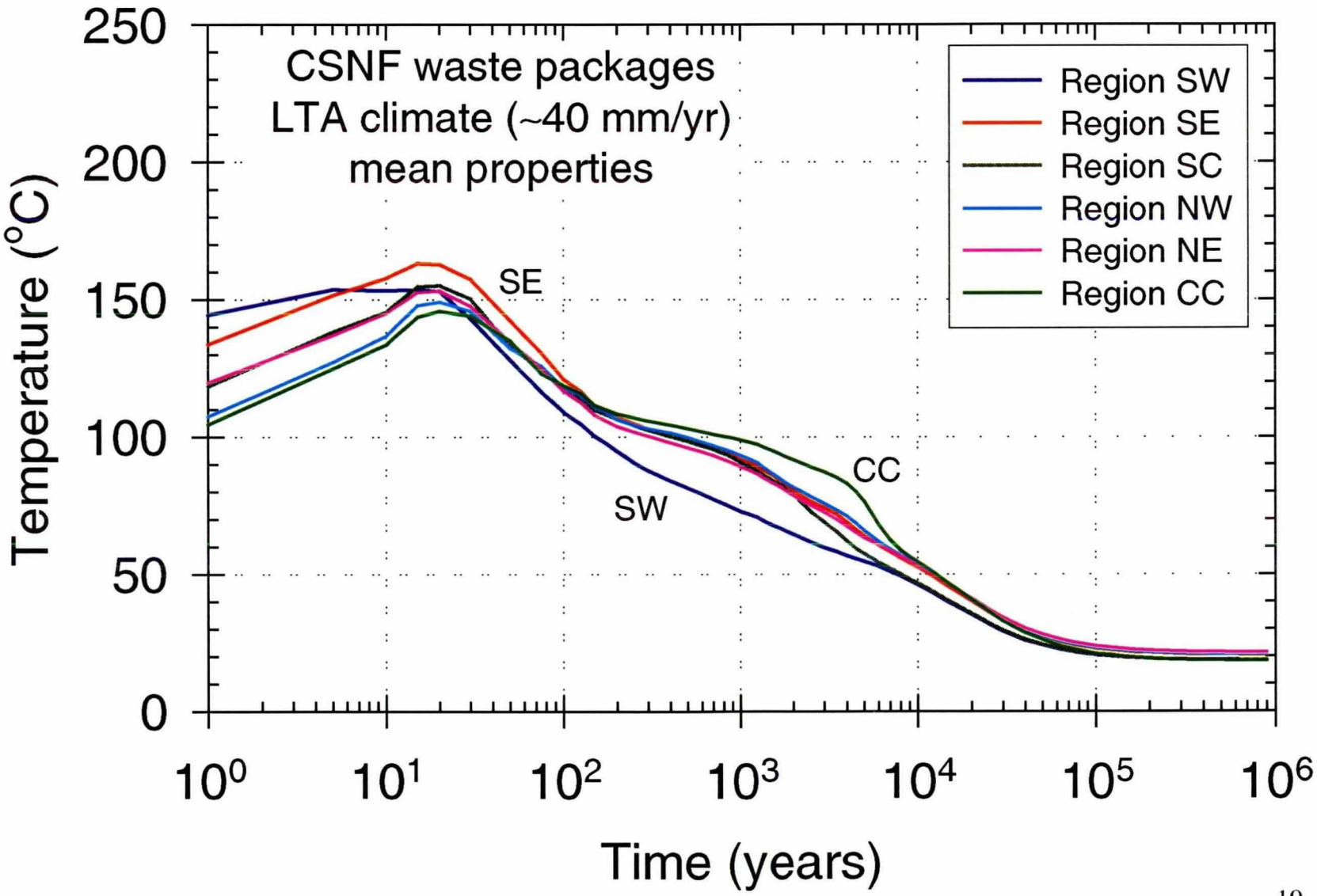
Modeling Approach

- Drift-scale T-H models
  - A drift segment with eight waste packages is modeled, to account for variability in WP heat output.
  - The dual-permeability flow model is used.
  - Radiative heat transfer is modeled for open drifts.
  - A series of linked models from mountain scale down to drift scale is used to approximate important dimensional and thermal hydrological effects.
  - An alternative method of linking mountain-scale and drift-scale models is used as a check.
- Mountain-scale T-H models
  - A two-dimensional east-west cross section is used.
  - The equivalent-continuum flow model is used, with reduced matrix satiation to allow greater fracture flow.
- The models include layering and property sets based on the LBNL site-scale unsaturated-zone flow model

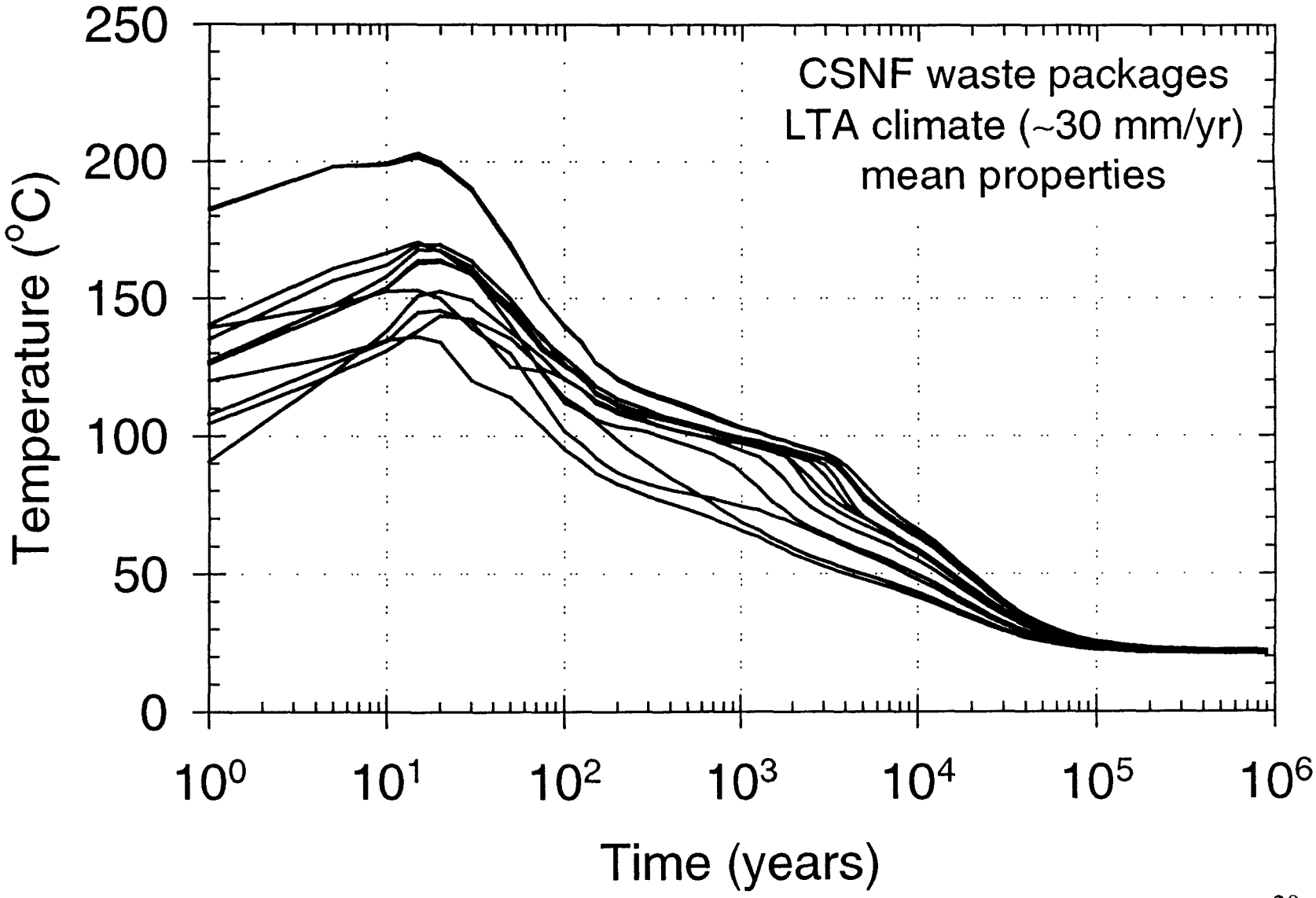
Division of Repository Into Six Regions



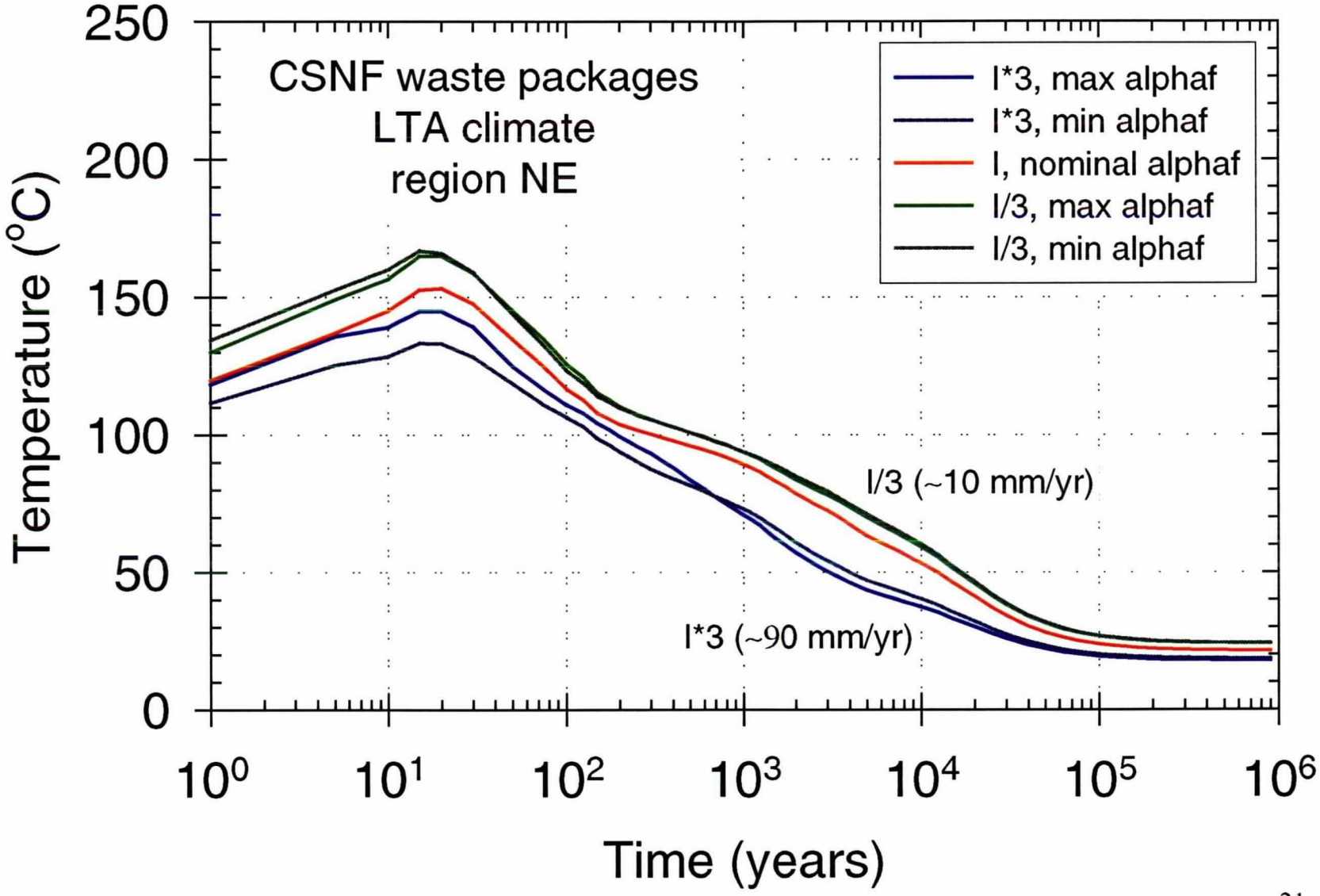
Average Waste-Package Temperature



WP Temperature Variability in Region NE

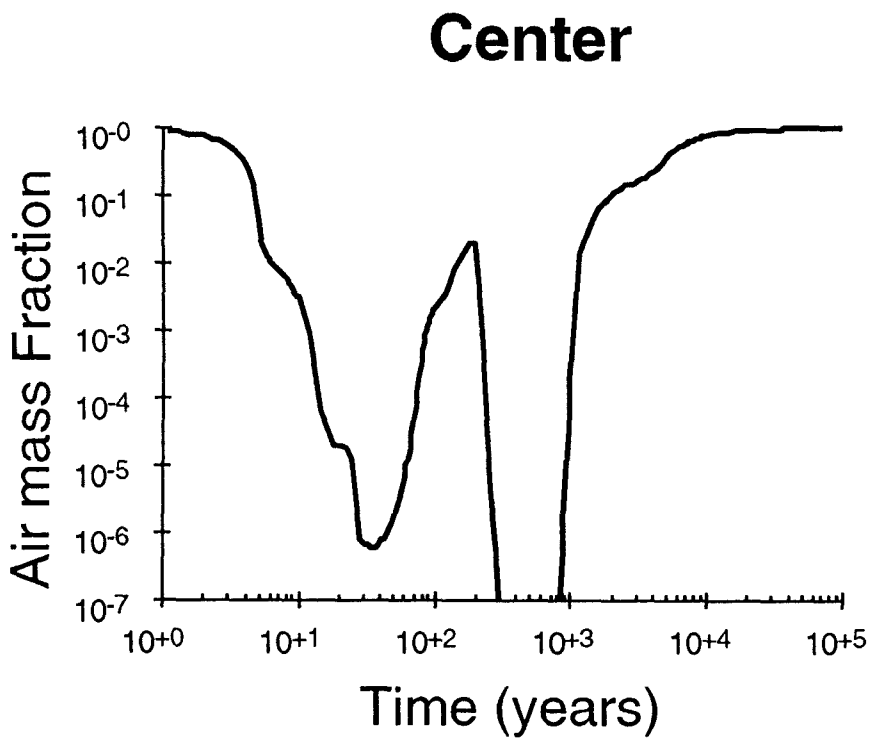


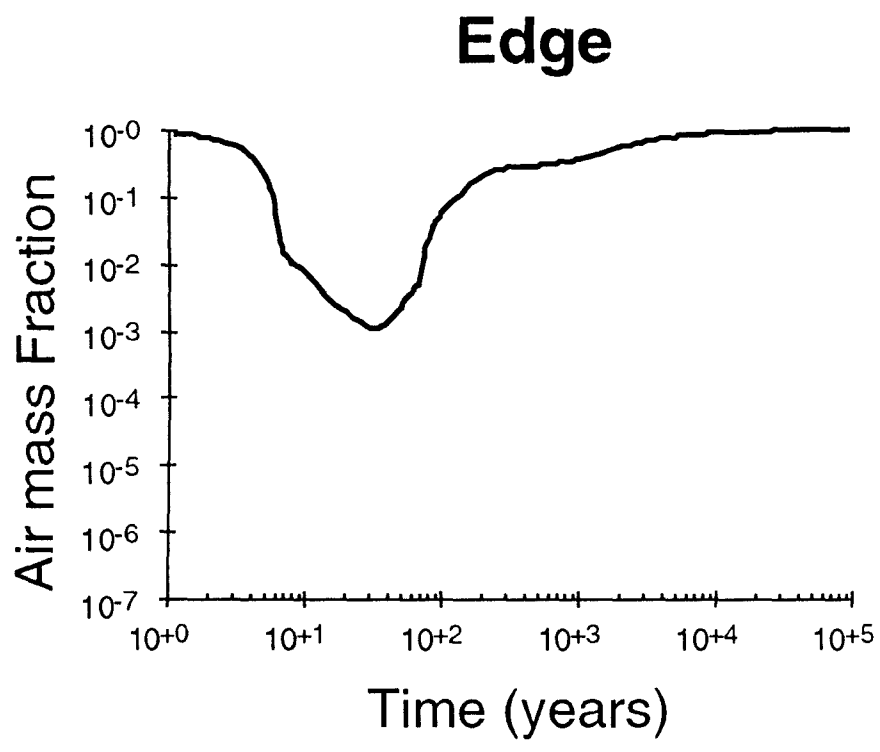
Effect of UZ-Flow Uncertainty



Air Mass Fraction in Repository

present climate (~8 mm/yr)
mean properties





Summary

- Drift-scale T-H quantities are obtained from a multiscale method that accounts for both mountain-scale and drift-scale processes.
- The multiscale modeling approach has been tested against 3-D T-H drift-scale models for repository center and edge locations, with good agreement.
- Gas-phase quantities are obtained from a 2-D mountain-scale T-H model.
- TSPA-VA T-H analyses are performed using conceptual flow models that allow for fracture flow (dual permeability; equivalent continuum with reduced matrix satiation).
- UZ flow/transport and UZ thermal hydrology use consistent hydrologic-property sets.
- Drift seepage is currently calculated within the UZ-flow tasks (i.e., thermal effects on seepage are neglected).