UZ Flow, Transport, and Coupled Processes Model Update

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Nuclear Waste Technical Review Board

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Outline

- Role of process modeling
- Unsaturated Zone (UZ) issues considered in this presentation
- Progress on resolution of issues
- Concluding remarks
Role of Process Modeling in Yucca Mountain Project

- Process understanding
- Test design
- Data analysis/site characterization
- Predictive modeling
- Sensitivity analysis/uncertainty analysis
- Basis for abstraction
- Basis for Total System Performance Assessment
UZ Issues Considered in this Presentation

- Moisture condensation in the Enhanced Characterization of the Repository Block (ECRB)

- Model validation issues
  - Radon data for property validation
  - Seepage in lower lithophysal (Niche 5/Systematic testing)
  - Matrix diffusion (Alcove 8/Niche 3)

- Radionuclide transport issues
  - DCPT/FEHM particle transport
  - Radionuclide transport below the drifts (shadow zone)

- Coupled Processes Issues
  - Drift-Scale Test (DST) cool-down started
  - Thermal/Hydrologic/Chemical (THC) effects on fracture sealing
ECRB Moisture Condensation

- **Modeling Approach**
  - Ventilation induced drying to match borehole data
  - Moisture flux from the rock to interpret the humidity rise after bulkhead closure
  - Cross Drift simulations to determine condensate origin

- **Results**
  - Water potential data matched
  - Moisture condensation from hot to cold regions identified as the likely mechanism
  - Geothermal feed zones identified as analogs for moist-air in-flow along drifts
  - Drifts along temperature isotherms suggested
Calibration Against Radon and Pressure Data

- **Modeling Approach**
  - Developed gas flow and radon transport model
  - Performed joint inversion of pressure and radon concentration data

- **Results**
  - Estimated formation parameters and initial and boundary conditions
  - Model accurately reproduces and predicts radon concentrations along Exploratory Studies Facility
Seepage/Evaporation Analysis

- **Analysis Approach**
  - Partition of flow paths by travel times and volumes in series of seepage tests
  - Evaporation estimates by pan measurements
  - Wetted area evolution on the drift/niche ceiling

- **Results**
  - Evaporation alone cannot account for the difference between injection and seepage, further validating the threshold concept
  - Lower lithophysal tuff has large storage capacities to suppress seepage and enhance seepage threshold, based on Niche 5 and systematic testing results to be used in Seepage Calibration model
Alcove 8 / Niche 3 Matrix Diffusion

- Modeling Approach
  - Dual-permeability models for the fault connected to fracture network (Model #1) or with fracture network ignored (Model #2)

- Results
  - Models matched the seepage data well
  - Different predictions were made for tracer breakthroughs from two models, due to differences in the matrix diffusion contributions of the fracture network
DCPT/FEHM Particle Transport

- **Modeling Approach**
  - FEHM uses dual-porosity matrix-diffusion model
  - DCPT uses random-walk particle method for a dual-continuum-particle-tracker

- **Results**
  - FEHM may be non-conservative at early- and late-times, conservative at mid-breakthroughs
  - DCPT matched T2R3D dual-K results (Water Resources Res. accepted 2002)
  - Currently we are evaluating a path forward with a realistic transport model for Performance Assessment
Radionuclide Transport from the Emplacement Drifts (Shadow Zone)

- Drift shadow zone formed by seepage diversion
- Matrix flow below drift for seepage-free drifts
- Delays transport by 10,000 years or more from base case
- This performance enhancement needs verification
Drift Scale Test Cool-Down

- **Modeling Approach**
  - DST model calibrated with four-year heating phase data
  - Predictions will be compared during the cool-down phase

- **Results**
  - **Temperature Decline**
    - After one year of cooling, drift surface temperature drops by 120°C, after two years the drop is 140°C.

  - **Fracture Liquid Saturations During Cooling**
    - 48 (Top Left), 51 (Top Right), 54 (Bottom Left) and 60 m (Bottom Right)

  - **Matrix saturations (geophysical measurements)** are predicted to remain almost unchanged through the cooling cycle (4 years)
High- and Low-Temperature (T) Comparison

- **Modeling Approach**
  - Detailed THC model for seepage chemistry and in-drift Waste Package/Engineered Barrier System conditions

- **Results**
  - Both high-T and low-T cases have no extreme pH or salinity values, and small porosity changes
  - High-T has low probability of seepage during thermal period
  - Low-T has less thermal-hydrologic, THC uncertainties, higher probability of seepage, and needs larger repository footprint
  - THC sealing in multiple fractures is uncertain
Concluding Remarks

- The approach of testing and associated modeling is key element in realistically assessing the Yucca Mountain performance
- Moisture redistribution by temperature variation is shown to be an important process affecting drift conditions
- Radon evolution by barometric pumping validates bulk k estimate
- Seepage suppression by ventilation is being quantified for testing in lower lithophysal unit
- Matrix diffusion, matrix-matrix interaction, and drift shadow greatly delay transport through the UZ
- Coupled processes continue to be evaluated with the DST; THC sealing effects will be evaluated for multiple fractures