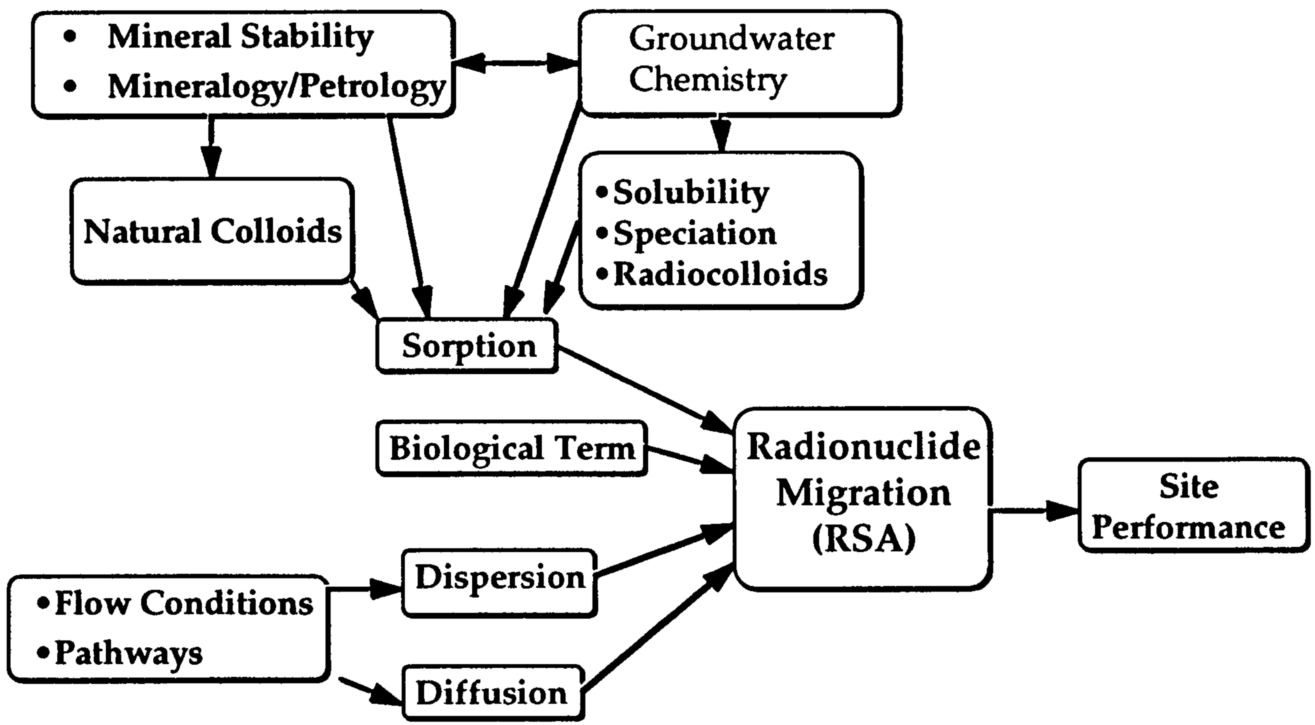
Unsaturated Zone Flow and Transport at Yucca Mountain

- George Zyvoloski
- Los Alamos National Laboratory

- NWTRB Board Meeting
- July 11-13,1994

Los Alamos Radionuclide Migration Program



Retardation Sensitivity Analysis

- **Flow**
  - Fractures
  - Faults
  - Infiltration
  - Thermal Load
- **Sorption**
  - Min/Pet
  - Geochemistry
- **Numerical**
  - Geometric Realization
  - Numerical Diffusion

Outline of Talk

- Technical Challenges
- Solution Approaches
- Applications
- Concerns
- Future Developments

Technical Challenges

- Very Long Time Frame
- Complex Geologic Setting
- Complex Flow and Transport Mechanisms

Complex Geologic Setting

- 20 Defined Hydrogeologic Units
- More Units needed for Transport (Zeolite Zones)
- Topography Affects Infiltration and Gas Flow

20 Defined Hydrogeologic Units

- Stratigraphy/Topography Data from Project Databases
  - Sandia
  - USGS/LBL
- Other Data Includes
  - Intrinsic Permeability
  - Relative Permeability and Capillary Data
  - Fracture Volumes and Spacing
  - Faulting

Complex Flow and Transport Mechanisms

- Air/Water Vapor/Water/Heat
- Fracture Flow
- Dry Unsaturated Media
- Complicated Sorption and Diffusion
- Coupled Flow and Geochemistry

Complicated Sorption and Diffusion

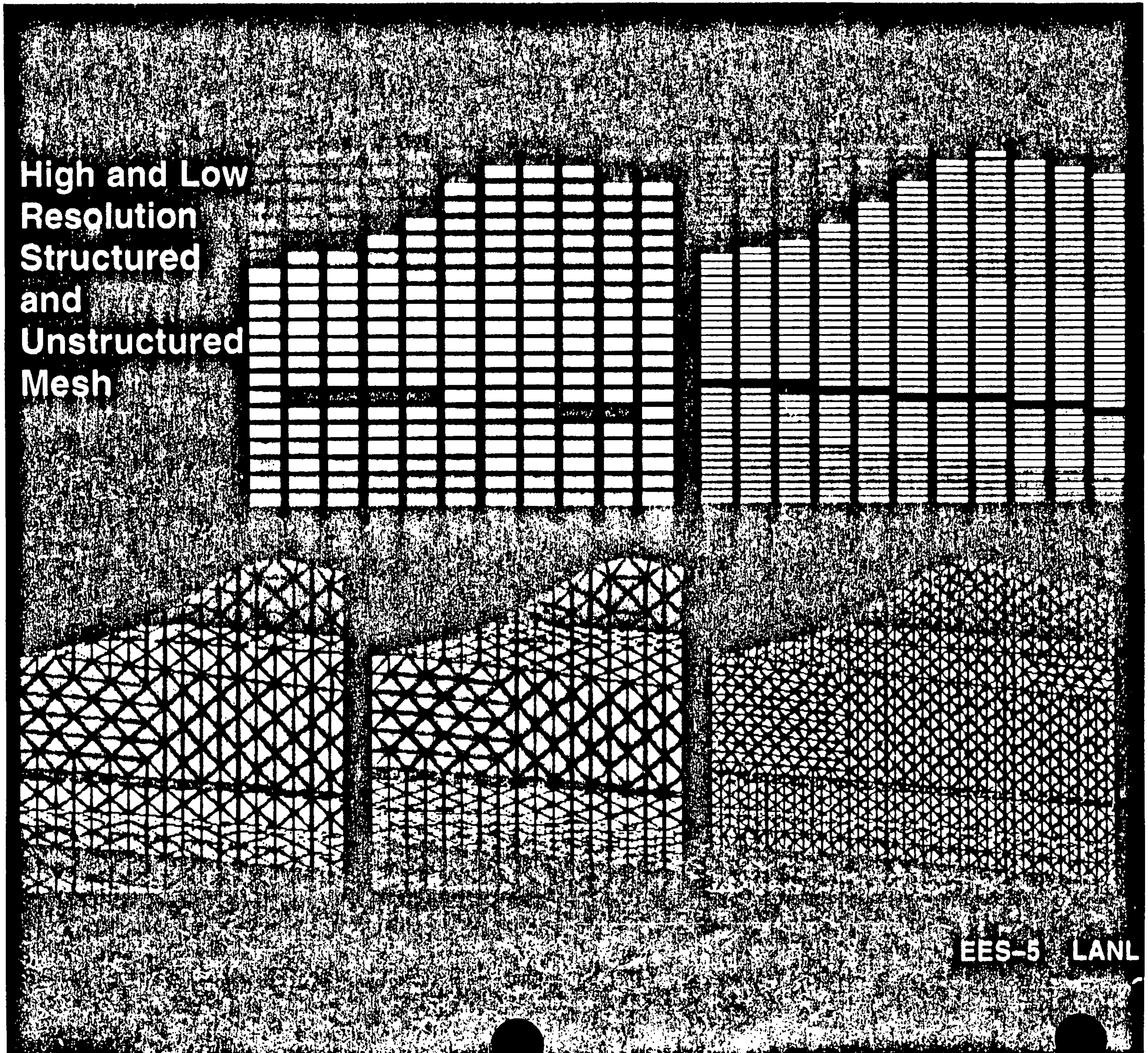
- Retardation Factors Vary with Unit Type and and Zeolitization
  - Data Obtained from Los Alamos Studies
  - Validation Studies are Planned
  - Fracture Data will be Provided
- Diffusion Can Be Important in Fracture Flow
  - Competition Between Fracture Flow and Matrix Diffusion
  - Data Obtained from Los Alamos Studies

Solution Approaches: FEHM Numerical Model

- Fully Coupled Fully Implicit Numerics
- Grid Generation
- Finite Element/Finite Volume Numerics
- Nonisothermal Multiphase
- Dual Porosity/Dual Permeability Module
- Comprehensive Transport/Geochemistry Module

Applications

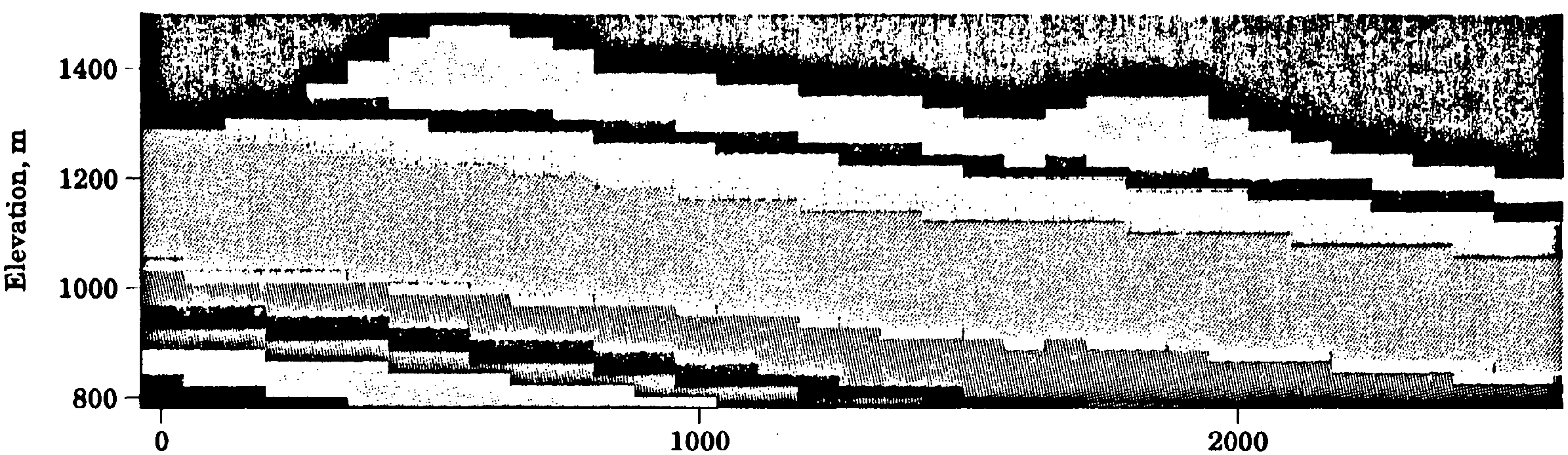
- Grids
- Transport Studies
- 3-d Flow and Transport (Conservative Tracer)


High and Low Resolution Structured and Unstructured Mesh
EES-5
LANL

Transport Studies

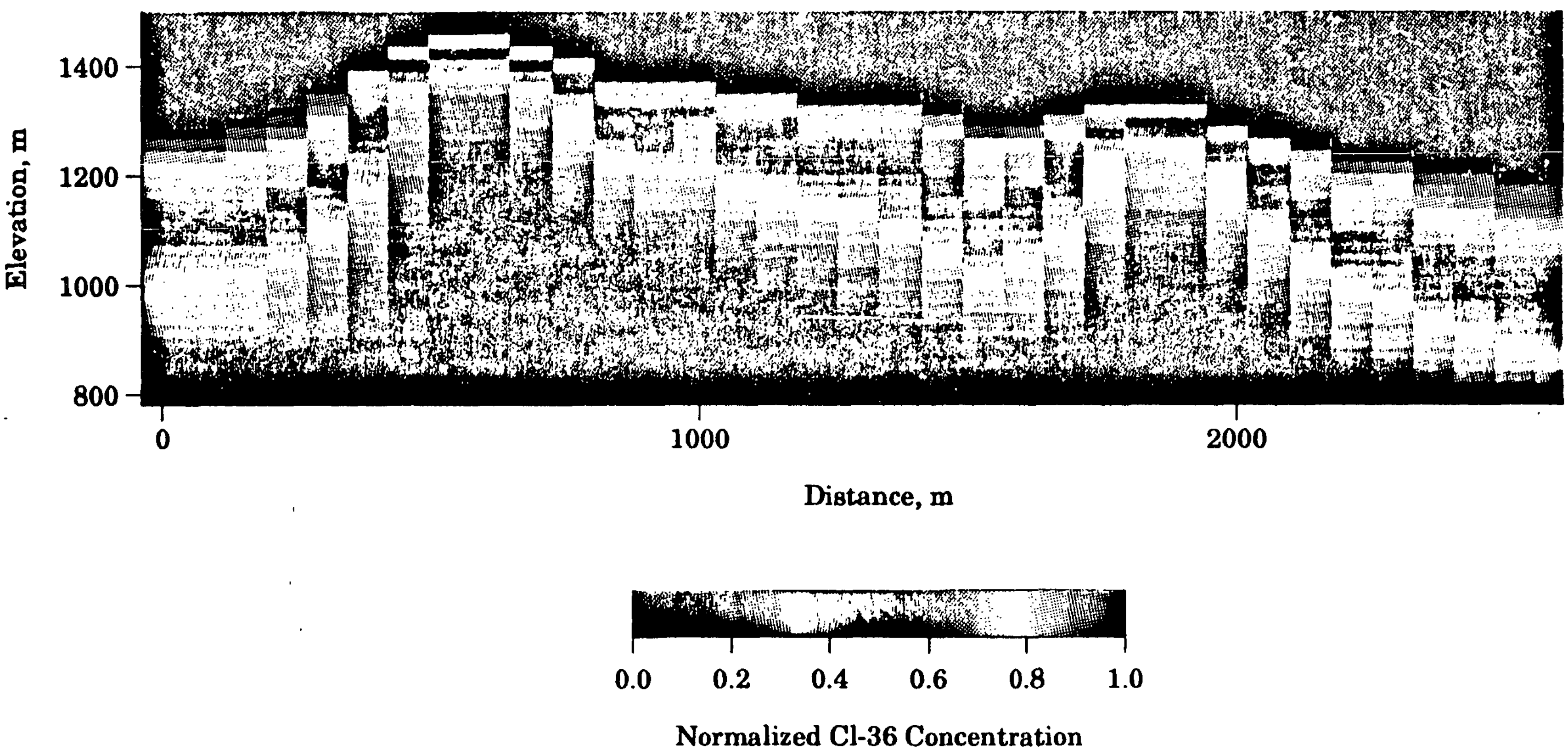
- ^{36}Cl- Residence Time Indicator
- Np
- Dissolution/Precipitation with Repository Heat

Antler Ridge Cross Section, Yucca Mountain

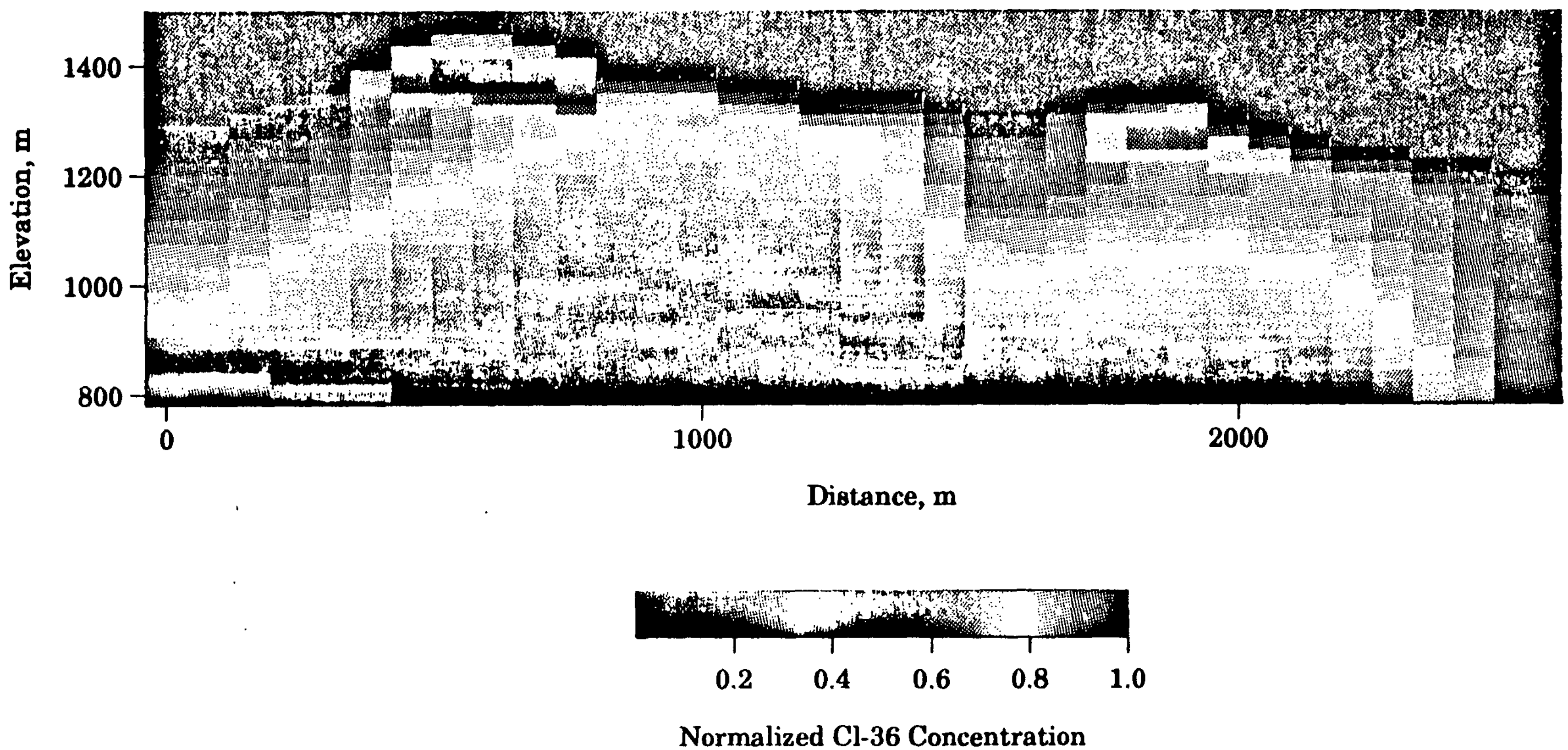


Colors Denote Different Stratigraphic Units

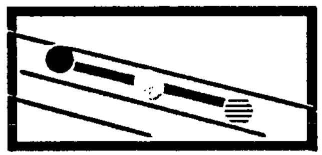
Cl-36 Distribution, Low Infiltration Rate



Cl-36 Distribution, High Infiltration Rate



FEHM Np Transport Time Simulations (Continuum Model)

	Np Transport Time* (million yr)	
	Infil. Rate = 0.0365 mm/yr	Infil. Rate = 0.365 mm/yr
Bottom	2.3	0.25
Middle	6.4	1.1
Top ●	∞	2.0
Entire Repository	4.8	0.45

* time for 1% of Np to reach the water table

^{237}Np: $t_{1/2} = 2.14 \times 10^6$ yr

K_d: 4 g/cc in CHn1 and CHn2, 0.5 g/cc elsewhere

FEHM Np Transport Time Simulations (Dual Porosity/ Dual Permeability Model)

Assumptions

- Total repository breach
- Fracture spacing = 10 m
- Infiltration rate = 0.0225 mm/yr
- $K_{d,frac} = 0$; $K_{d,matrix} = 0.5 - 4$ g/cc

Results

Case 1: $D_{mol} = 0$
Transport time = 25,000 yr

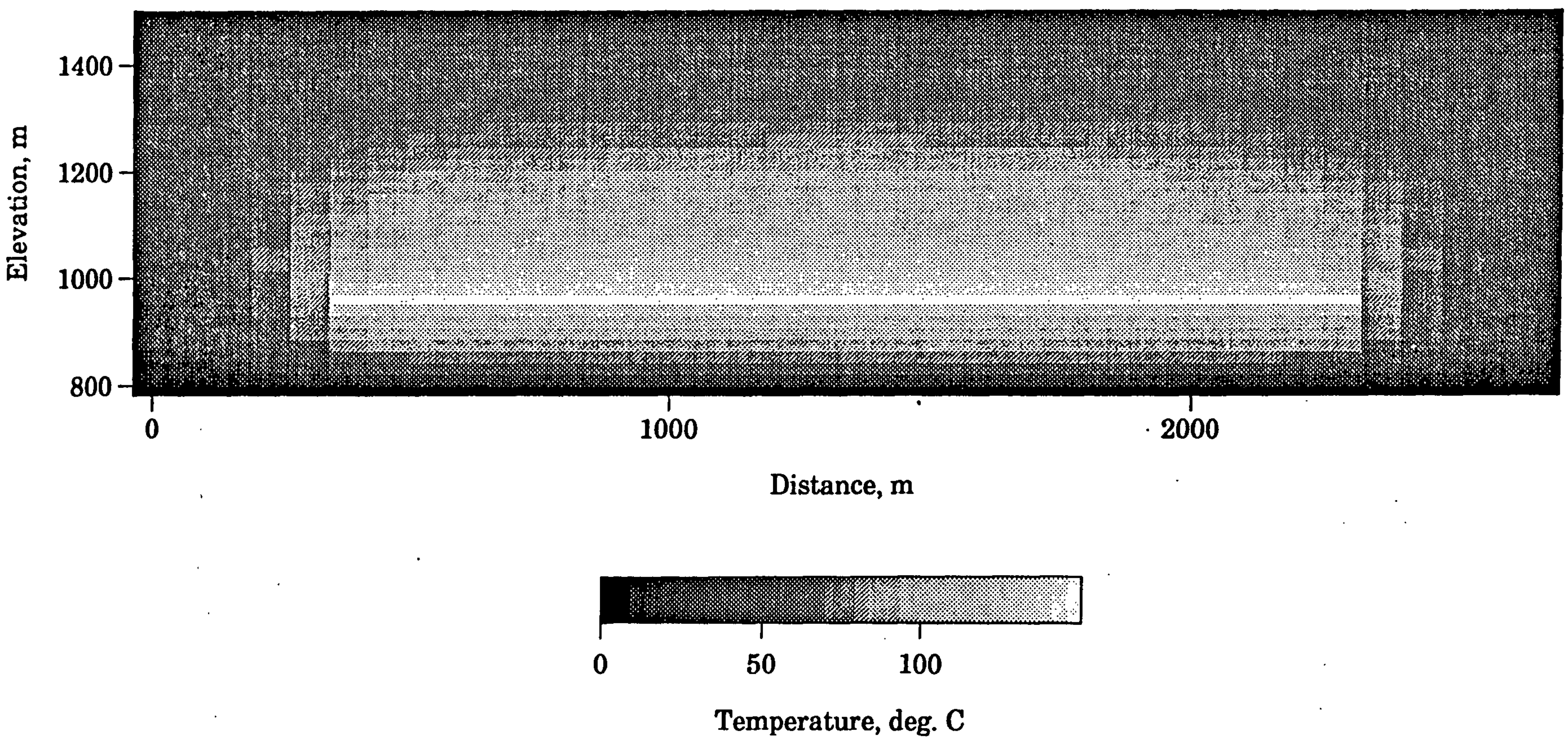
Case 2: $D_{mol} = 1 \times 10^{-11}\ m^2/s$
Transport time =240,000 yr

Conclusion: Transport time increases significantly if credit can be taken for matrix diffusion and/or sorption on fracture surfaces.

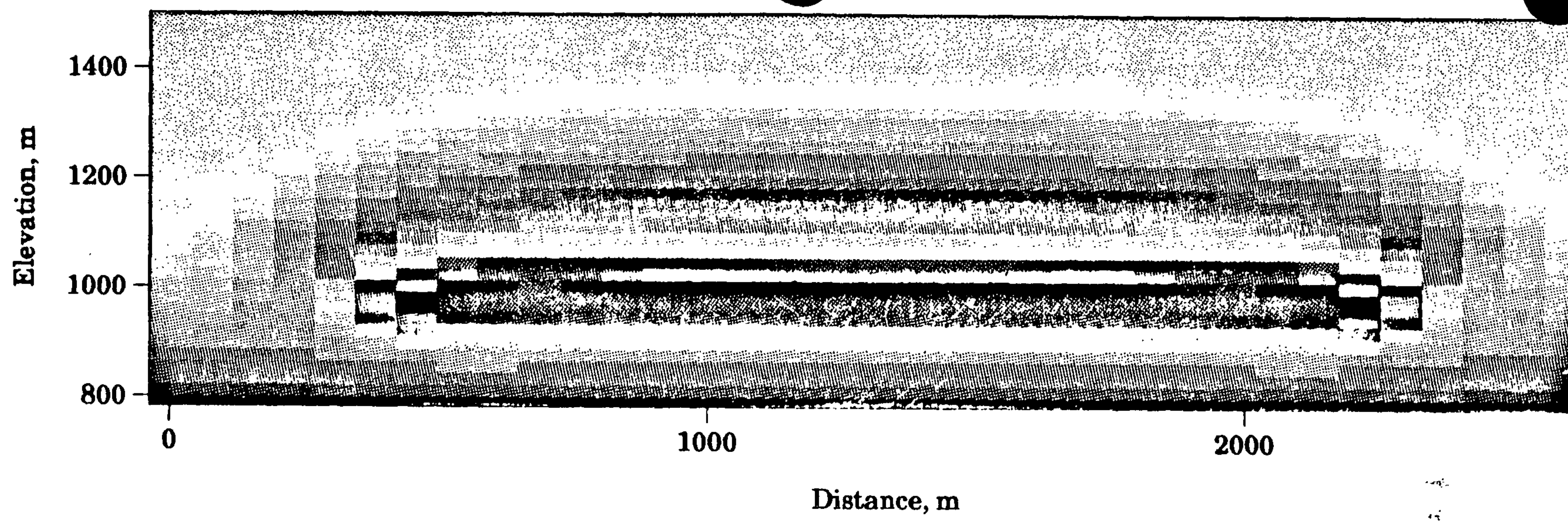
Dissolution/ Precipitation with Repository Heat

- Explore Reactions with EQ3/6
- Download Small Set(5-10 Reactions) to FEHM
- Simulate Coupled Flow and Geochemistry

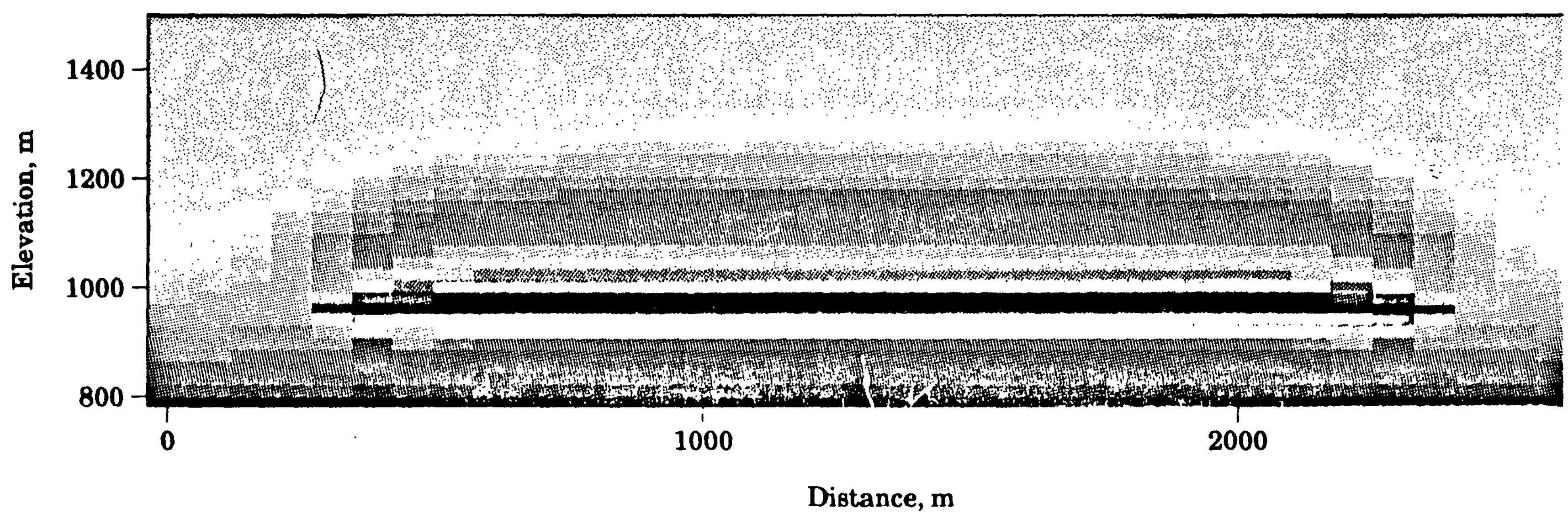
Temperature at 10000 Years

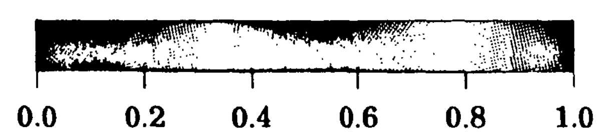


Saturation at 10000 Years, Strong Geochemical Effect on Permeability

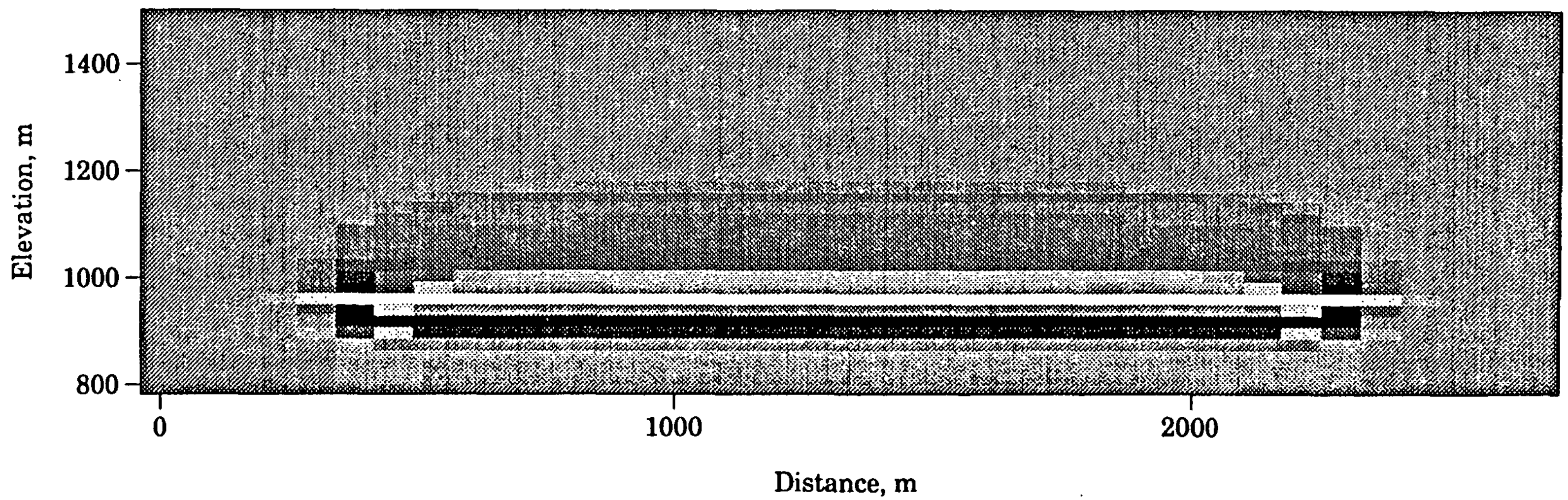


Saturation at 10000 Years

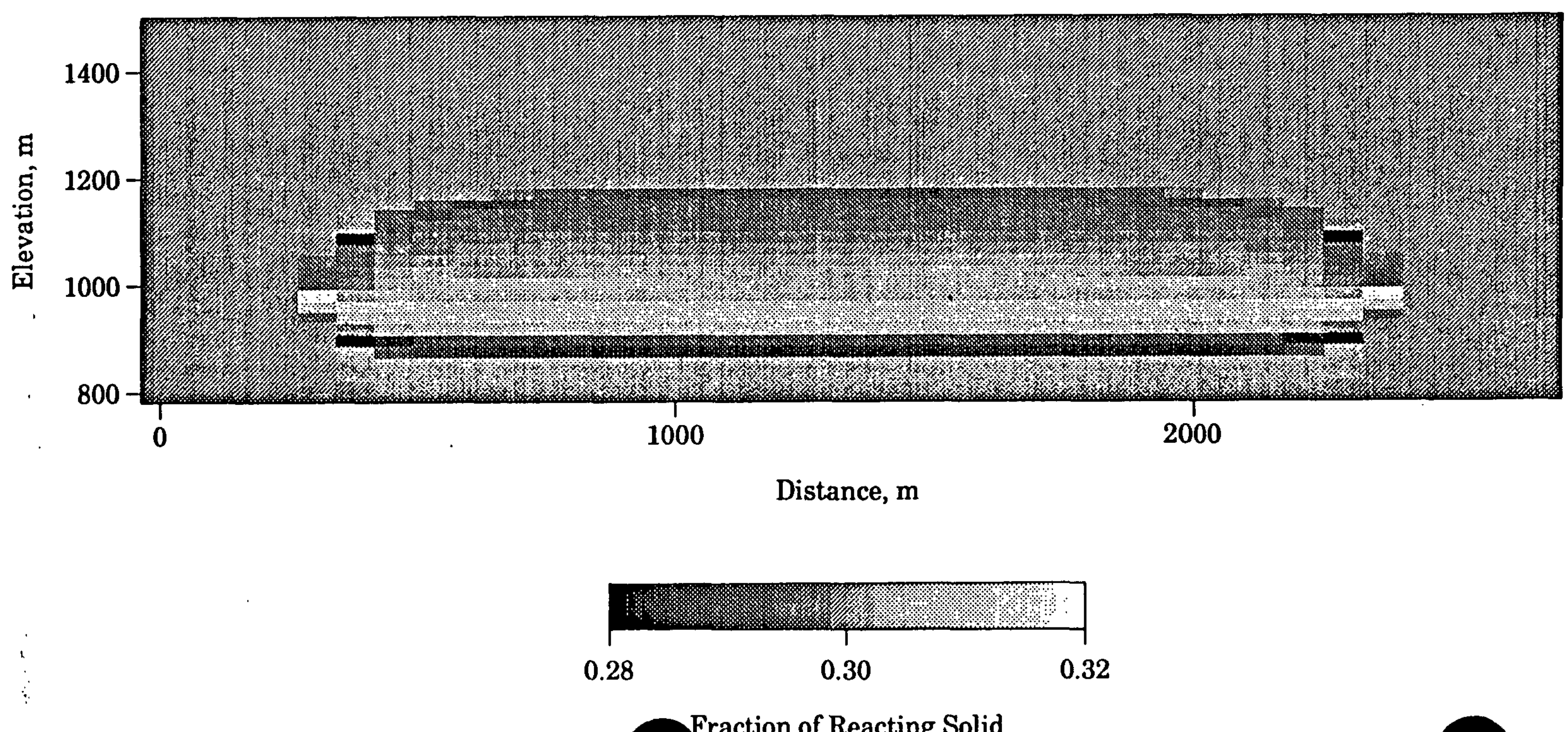




Distribution of Reacting Solid at 10000 Years



Distribution of Reacting Solid at 10000 Years, Strong Geochemical Effects on Permeability



Concerns

- Availability of Data
  - Geology
  - Flow Parameters
- Computing Power for Fine Grid Simulations
- Geostatistics(Multiple Realizations)
- Validation or Confidence Building

Where we need to be

- 1,000,000 nodes
- Air/Water/Water Vapor/Heat Physics
- Dual Permeability
- Geochemistry

Future Work

- Fine Grid-Minimum K_d
- Parallel Computation
- GUI Interfaces
- Stratigraphic Interfaces (Faults)
- Particle Tracking

Summary

- **Transport**
  - Complex Flow Requires 3-d Models
  - Need to Incorporate Min/Pet Studies
- **Coupled Flow and Geochemistry**
  - Is Important Near the Repository
  - Technically Feasable
- **^{36}Cl**
  - Useful in Residence Time Studies
  - Can Indicate Fast Flow Paths Where More Resolution Is Required
- **Np**
  - Significant retardation of Np in Calico Hills Units
  - If significant fracture flow exists, matrix diffusion or fracture sorption will be required to increase travel times