Column Testing and 1D Reactive Transport Modeling to Evaluate Uranium Plume Persistence Processes

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Motivation for Study

- Natural flushing of contaminants at various U.S. Department of Energy Office of Legacy Management sites is not proceeding as quickly as predicted (plume persistence)

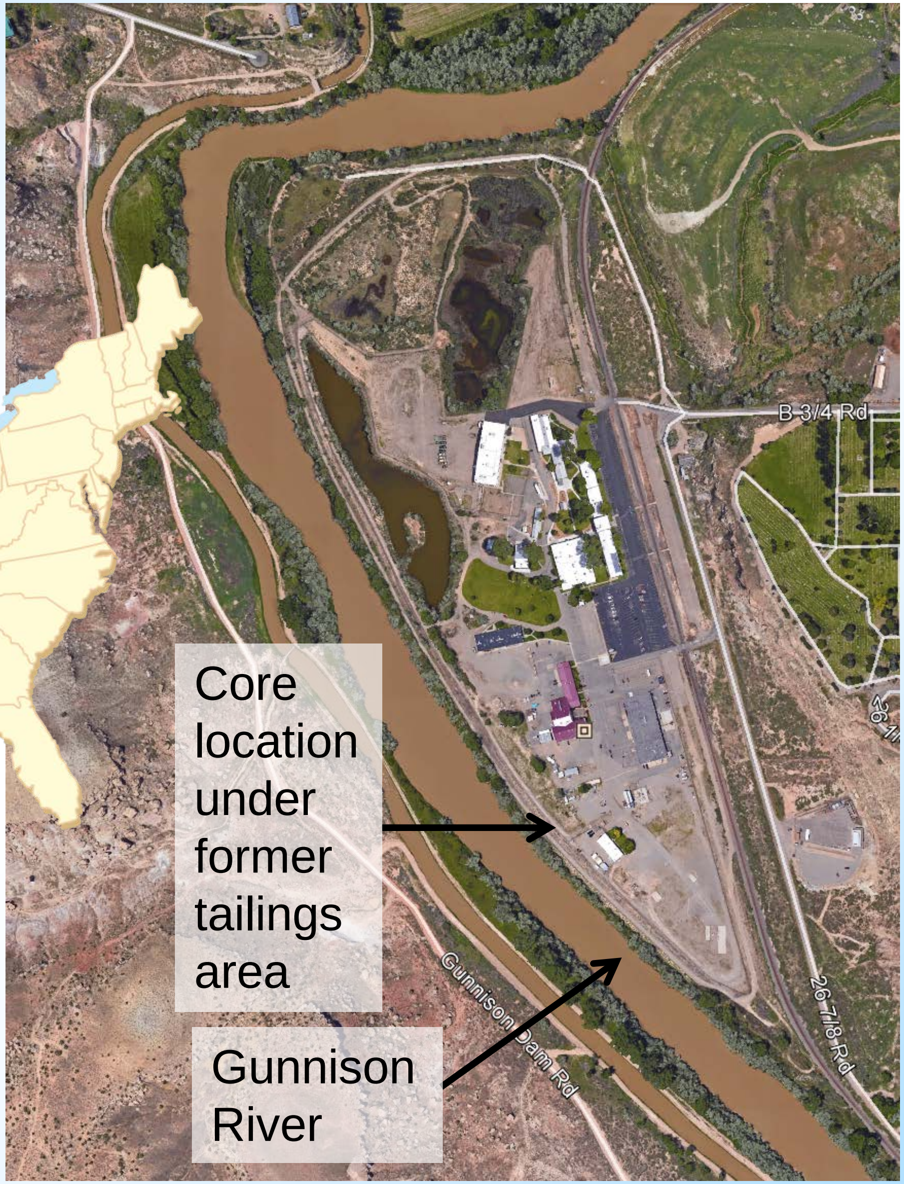
Objectives

- Help determine natural flushing rates using column tests
- Use 1D reactive transport modeling to better understand the major processes that are creating plume persistence

Approach

- Core samples from under a former mill tailings area
  - Tailings have been removed
- Column leaching using lab-prepared water similar to nearby Gunnison River water
- 1D reactive transport modeling to evaluate processes

Site Location



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Core Characterization

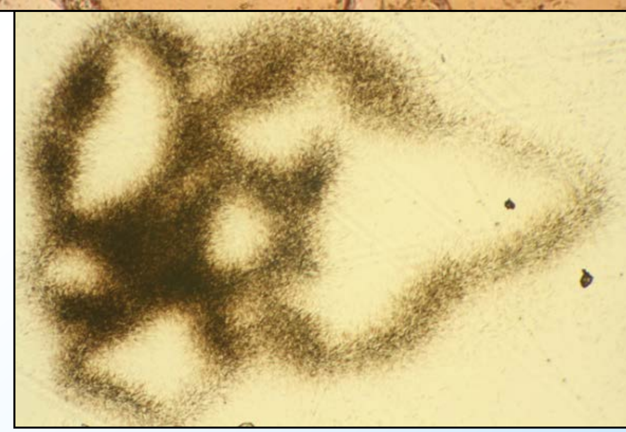
Core used for column testing = 10 mg/kg U

Underlying groundwater plume contains ~ 200 to 700 μg/L U

Background core is < 1 mg/kg U

Fe oxide cements

Dual porosity

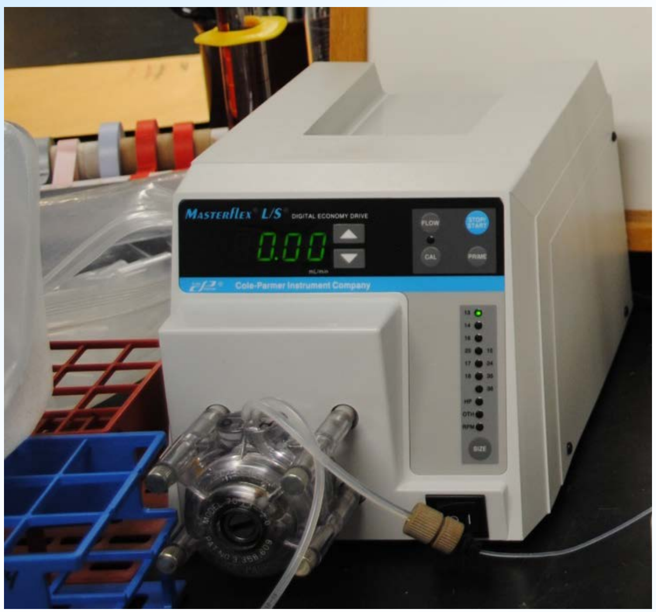


Fission tracks indicate more U

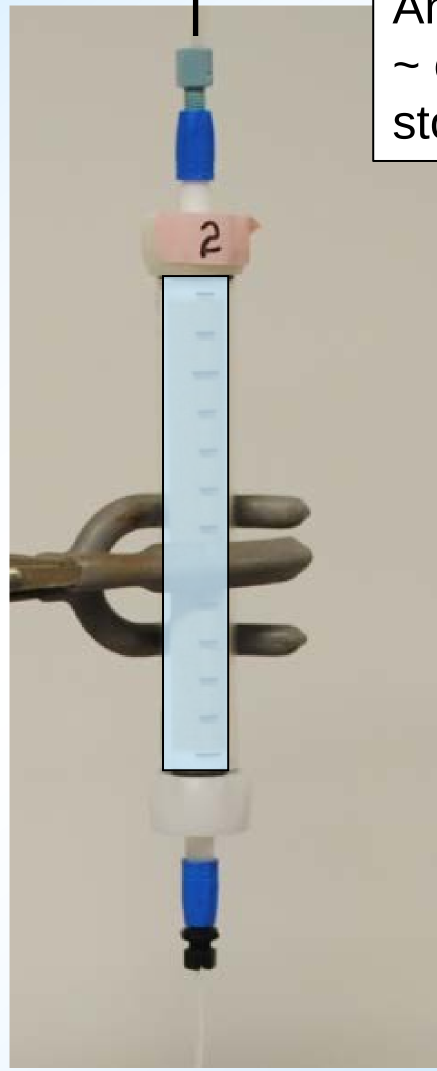
Column Set Up

1 pore volume (PV) = 30 mL with 0.15 mL/min flow rate, equivalent to 1,840 ft/yr

Compared to groundwater flow rate of 3 to 5 ft/yr



Analyze outflow water at ~ every 0.85 PV, stop flow at every 25 PVs

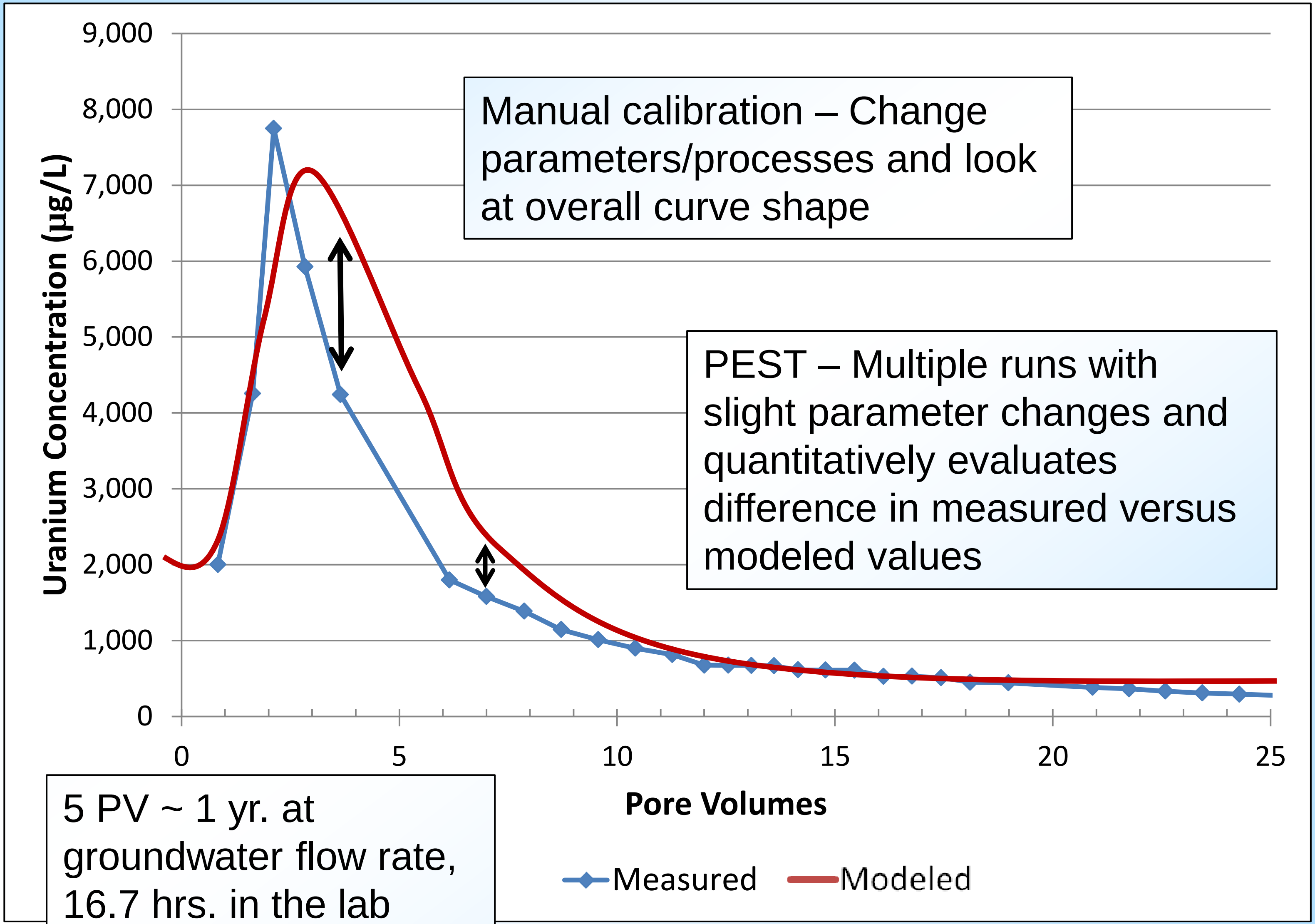


21.3 cm long
by 2.5 cm wide

Modeling Procedure

- Geochemical modeling and 1D reactive transport processes with PHREEQC
- Use updated database for Ca/Mg uranyl carbonate complexes and U thermodynamics
- Manual calibration using constant flow rates
- Then PEST (automated calibration) with stop flow was final calibration
- Look at curve fits with <u>different processes, one at a time and in combination</u>

Results and Calibration Process



Manual calibration – Change parameters/processes and look at overall curve shape

PEST – Multiple runs with slight parameter changes and quantitatively evaluates difference in measured versus modeled values

5 PV ~ 1 yr. at groundwater flow rate, 16.7 hrs. in the lab

Use First Sample for Column Equilibration

Analyte	Inflow Water	"Equilibrated" Water (0.83PV)
pH	7.0	7.6
Alkalinity (mg/L)	313	101
Calcium (mg/L)	192	530
Sulfate (mgL)	918	4,180
Uranium (µg/L)	0.00	2,000

Continued inflow

Use as 0 PV water equilibrated with solid phase for modeling

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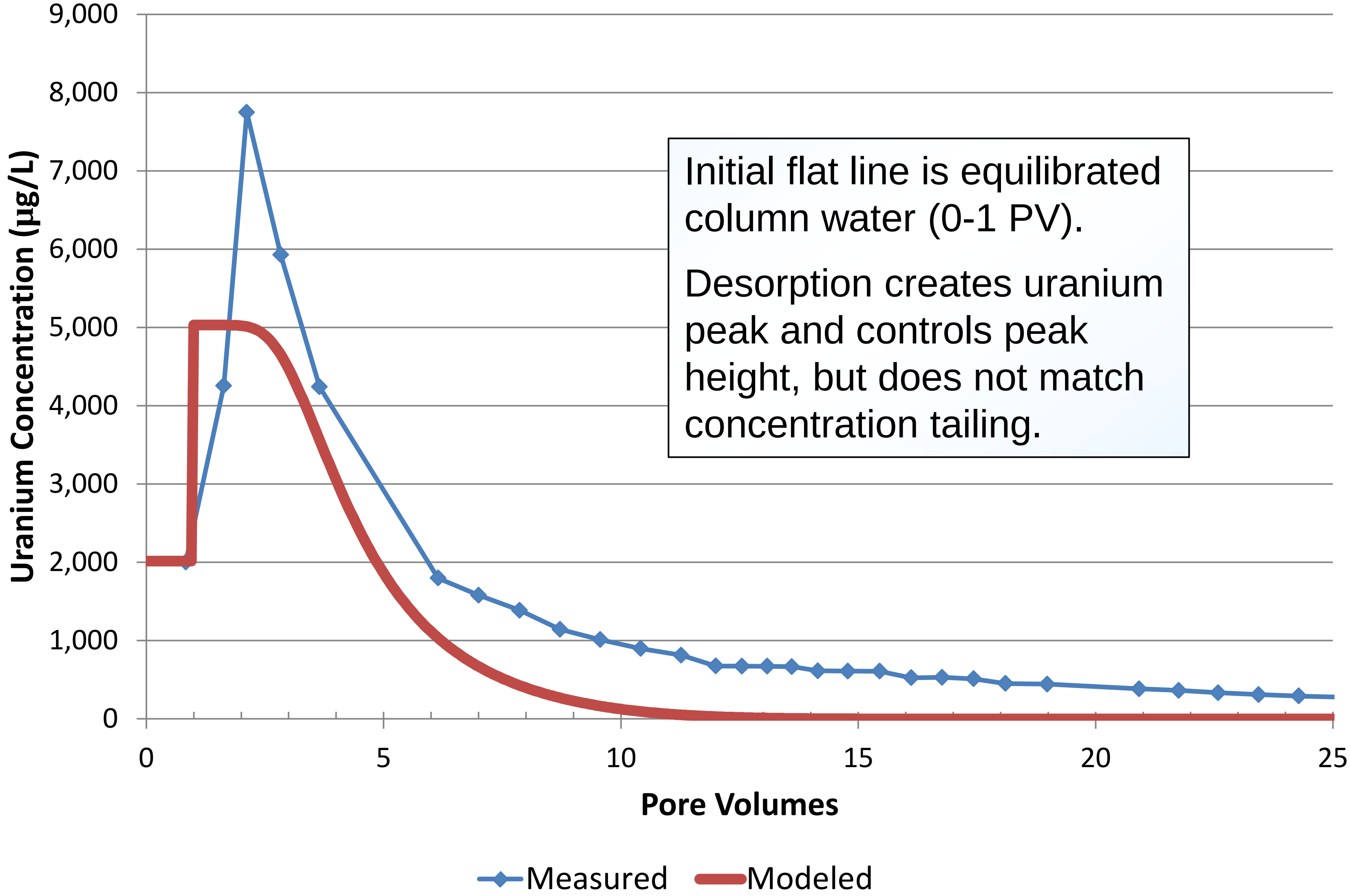
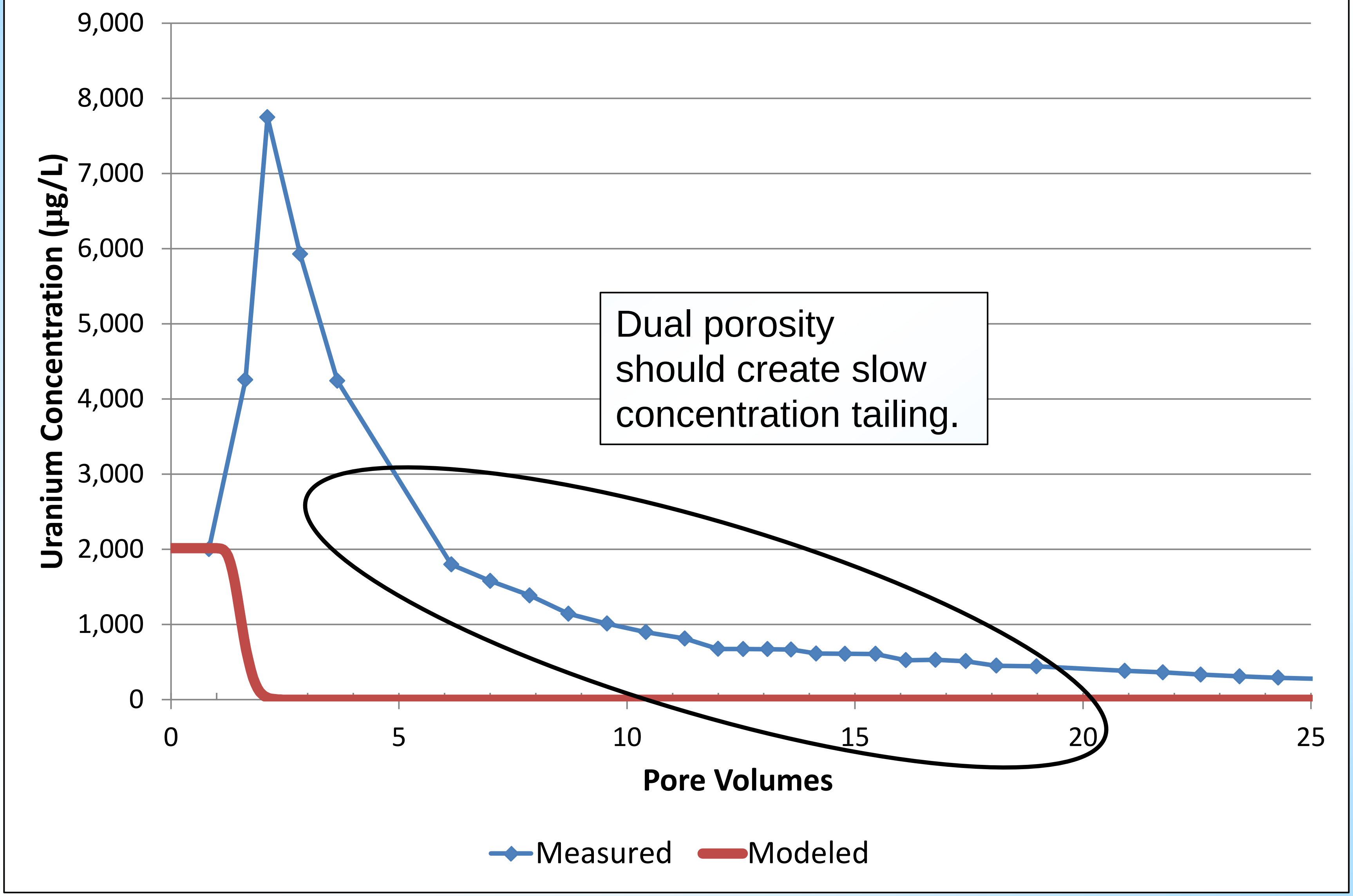
Processes Tested

- Sorption
- Dual porosity
- Mineral dissolution/precipitation (gypsum)
- Dispersion
- Cation exchange

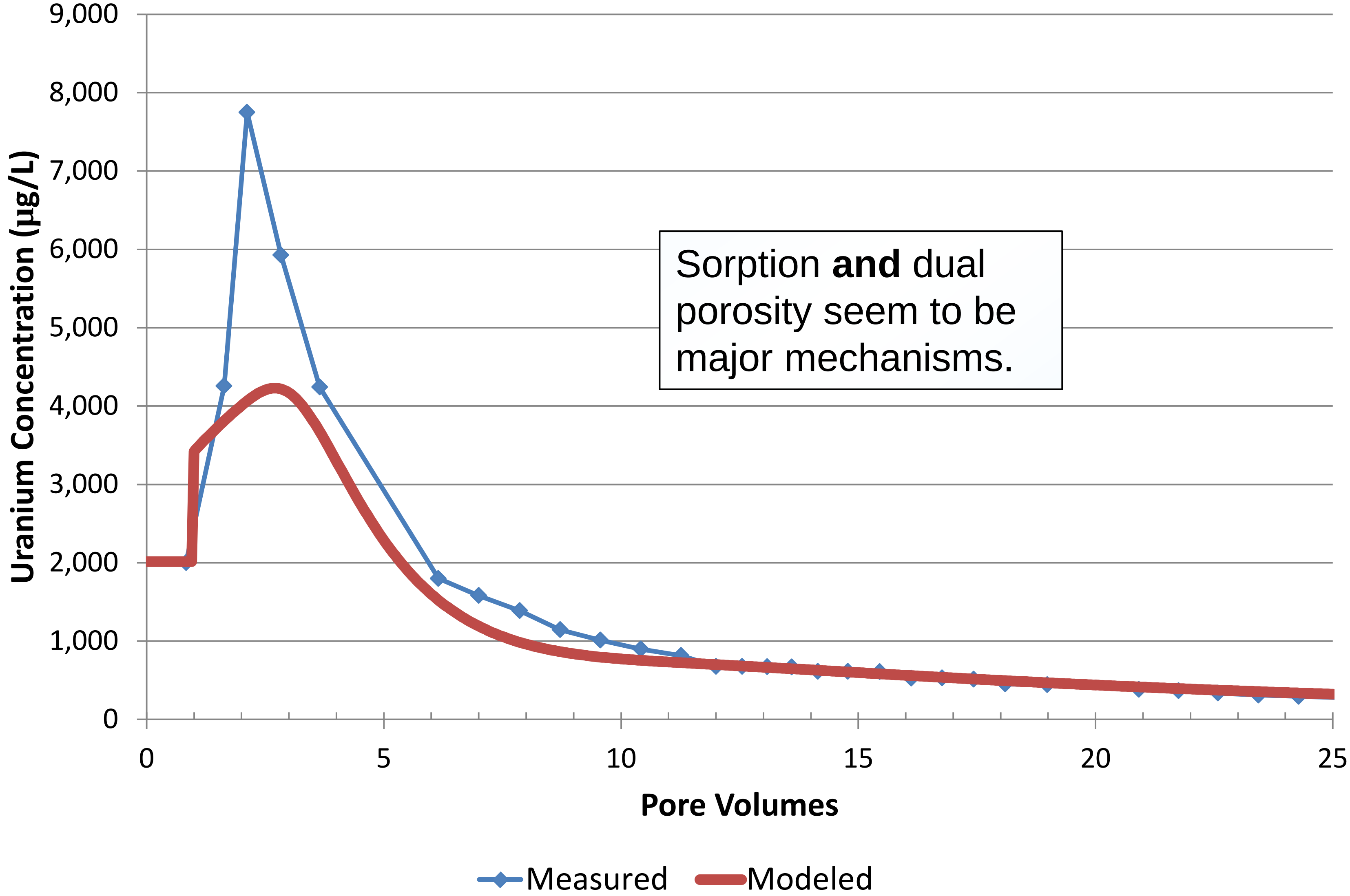
Sorption Only



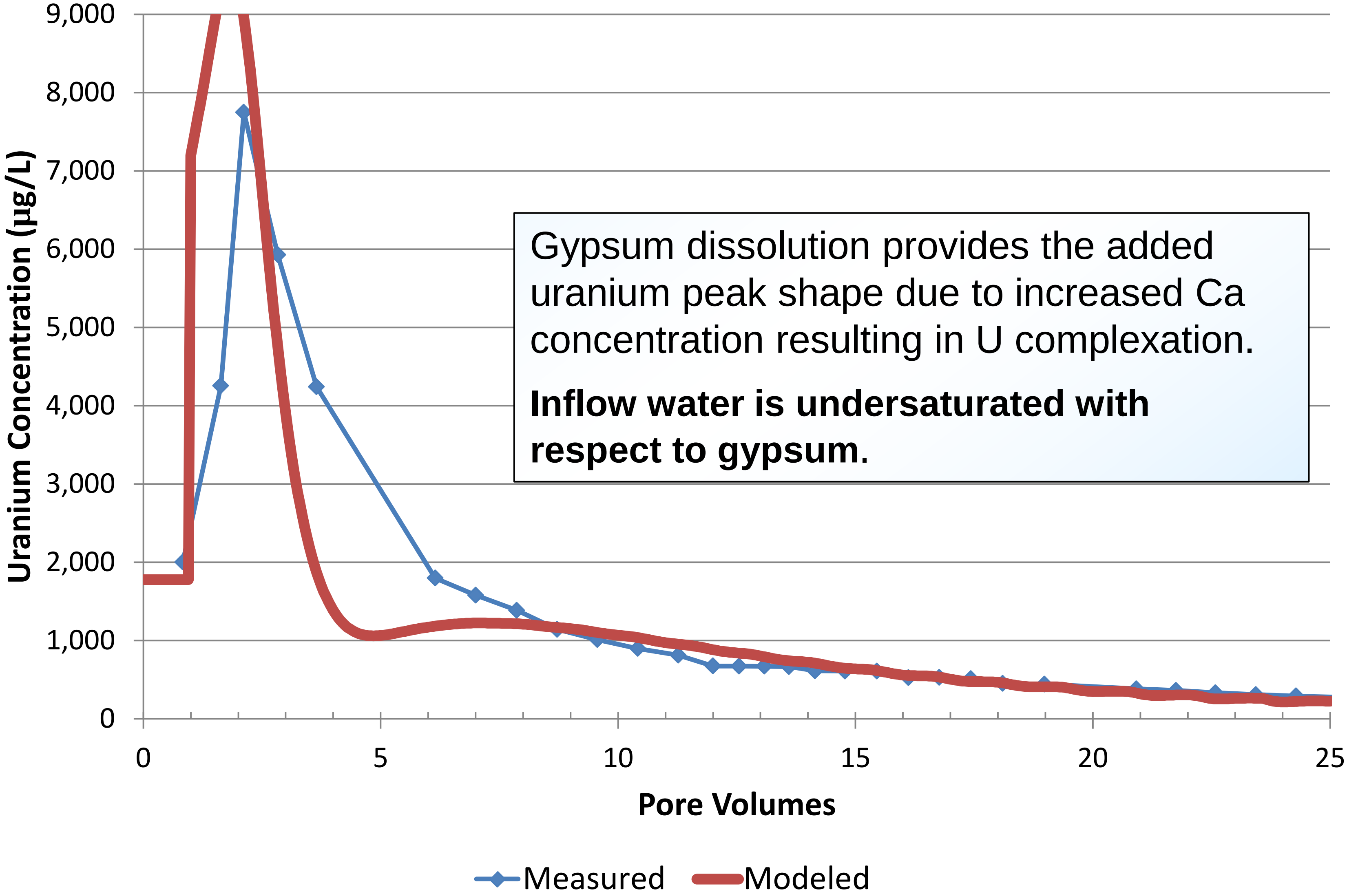
Dual Porosity Only



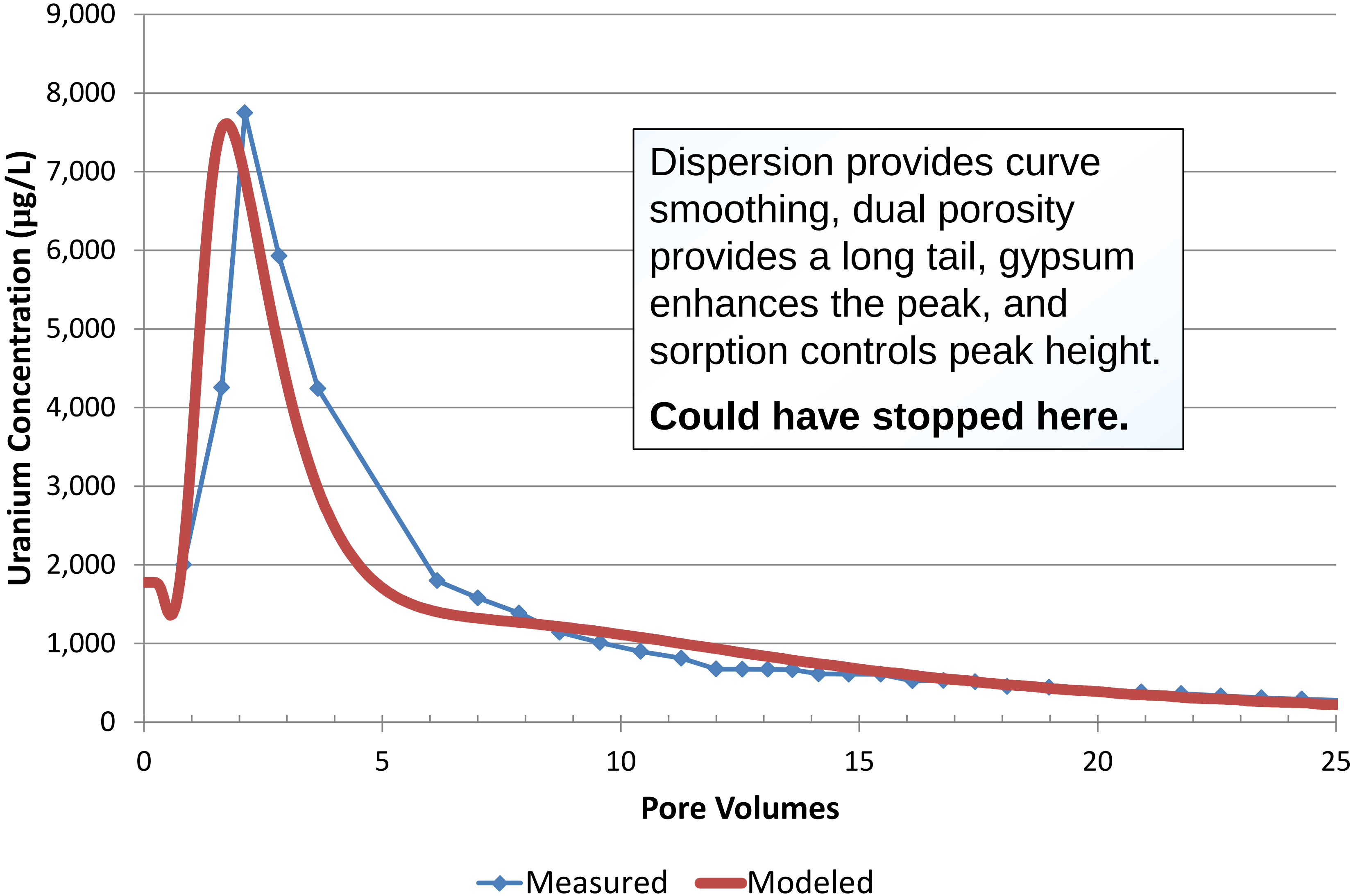
Sorption and Dual Porosity



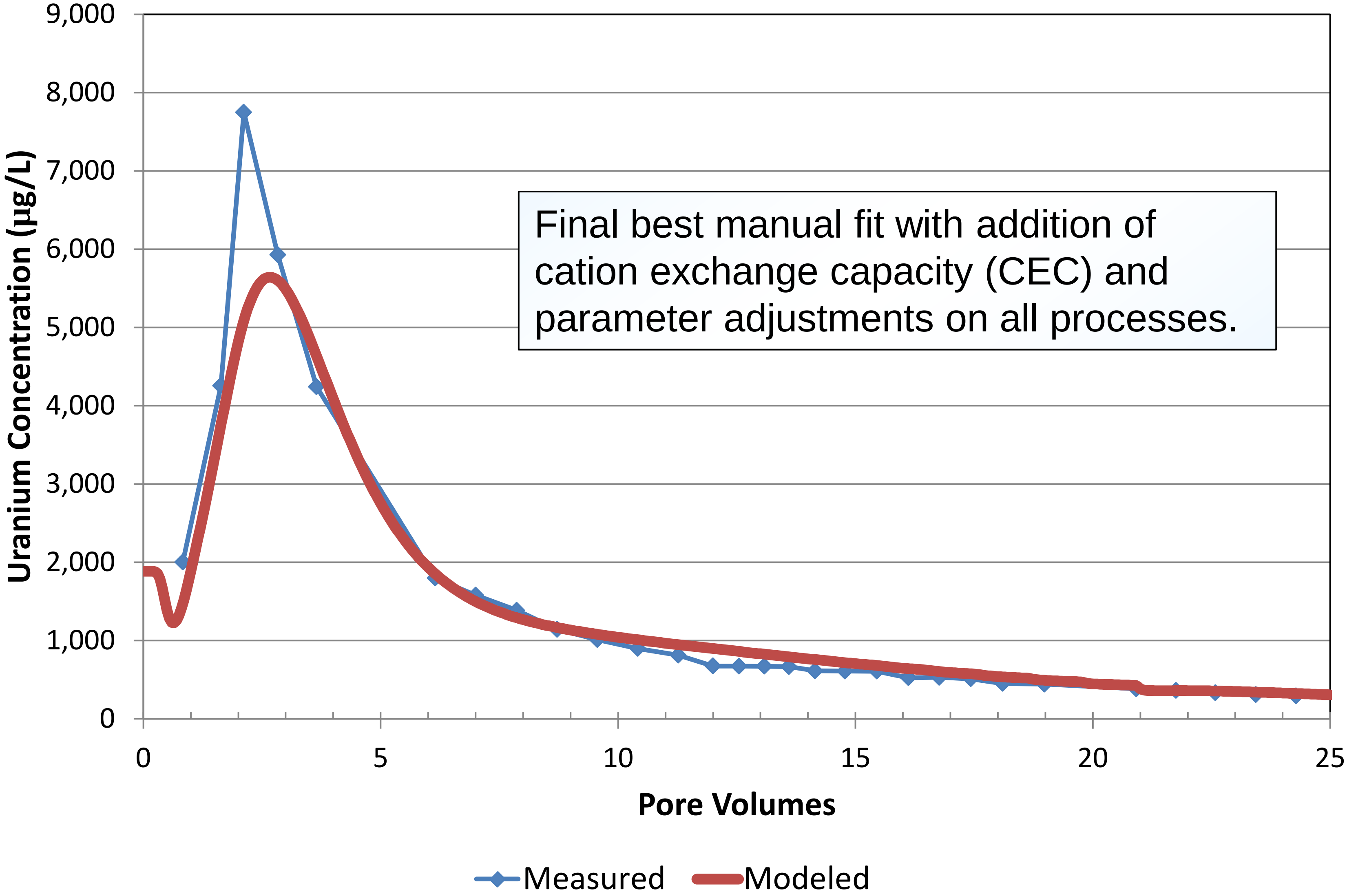
Sorption, Dual Porosity, and Gypsum



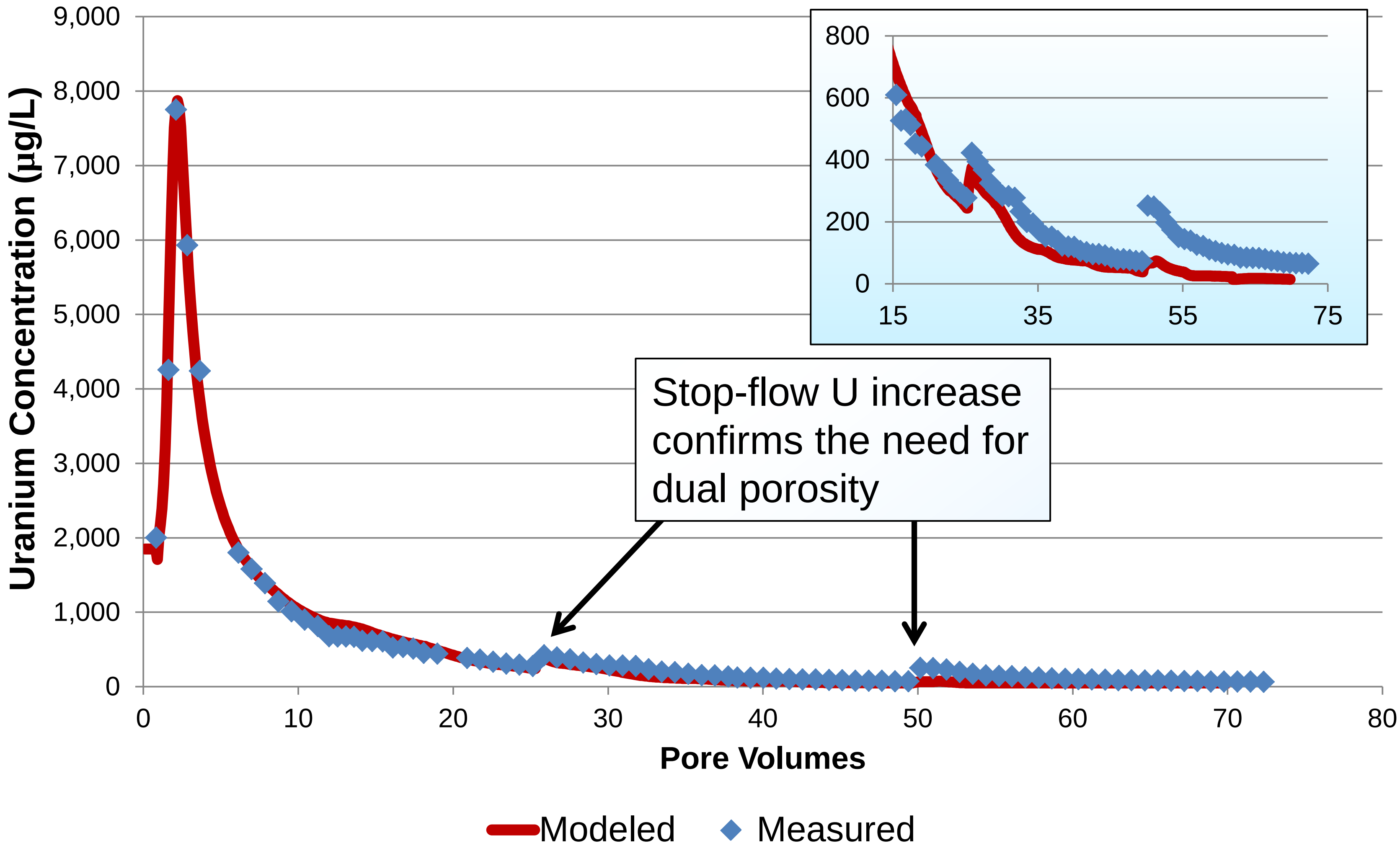
Sorption, Dual, Gypsum, and Dispersion



Sorption, Dual, Gypsum, Dispersion, and CEC



PEST Final Calibration (Sorption, Dual Porosity, Gypsum, Dispersion, CEC)



Lessons Learned

- Allow initial column equilibration
- Slower flow rates would be more realistic
- Sample more frequently at early pore volumes
- Add direct mineral identification (i.e., XRD for gypsum)

Summary

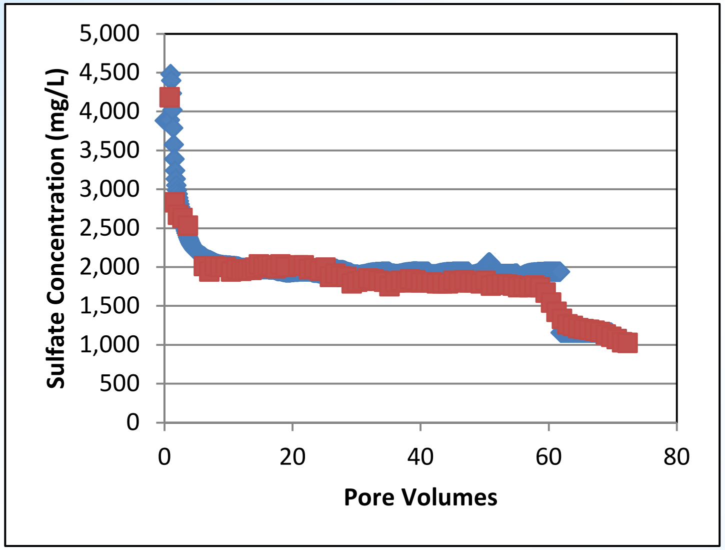
- Column testing confirms long concentration tailing similar to field observed plume persistence
- Reactive transport modeling of the columns provides a useful tool for evaluating processes
- Major processes: sorption, dual porosity, gypsum dissolution
- Less important processes: dispersion and cation exchange

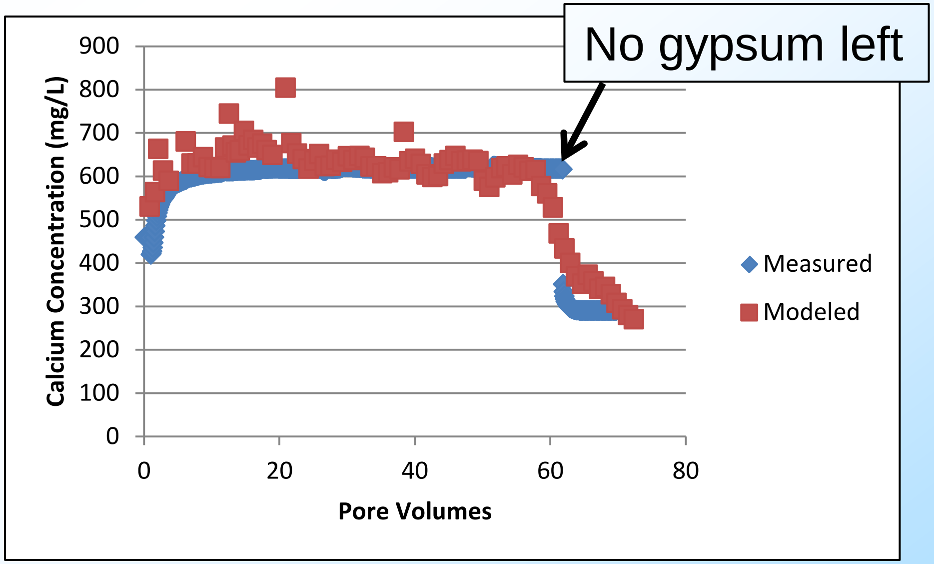
Extra Slides

- Other analytes
- Model with calcite

Other Analytes (Ca, SO_4, Alkalinity, etc.)

- Need full geochemistry for PHREEQC simulations
- Provide additional calibration data
- Overall, looked good with manual calibration
- All other analytes were included in PEST calibrations





Sorption, Dual, Gypsum, Calcite, Dispersion