

# PNNL/Alabama/ORNL Project Activities and Results

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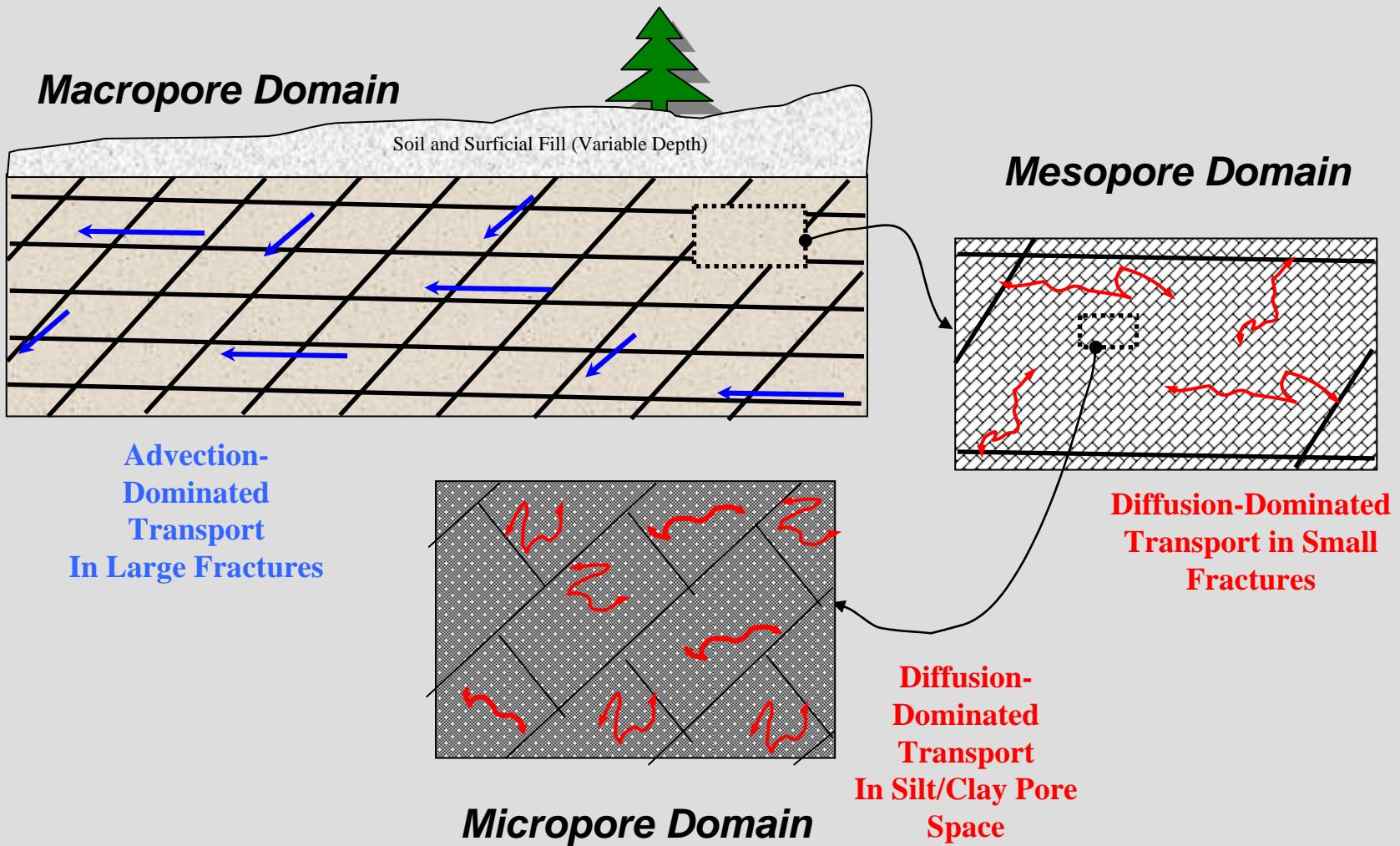
Scott C. Brooks, ORNL

John M. Zachara, PNNL

# Fractured Saprolite



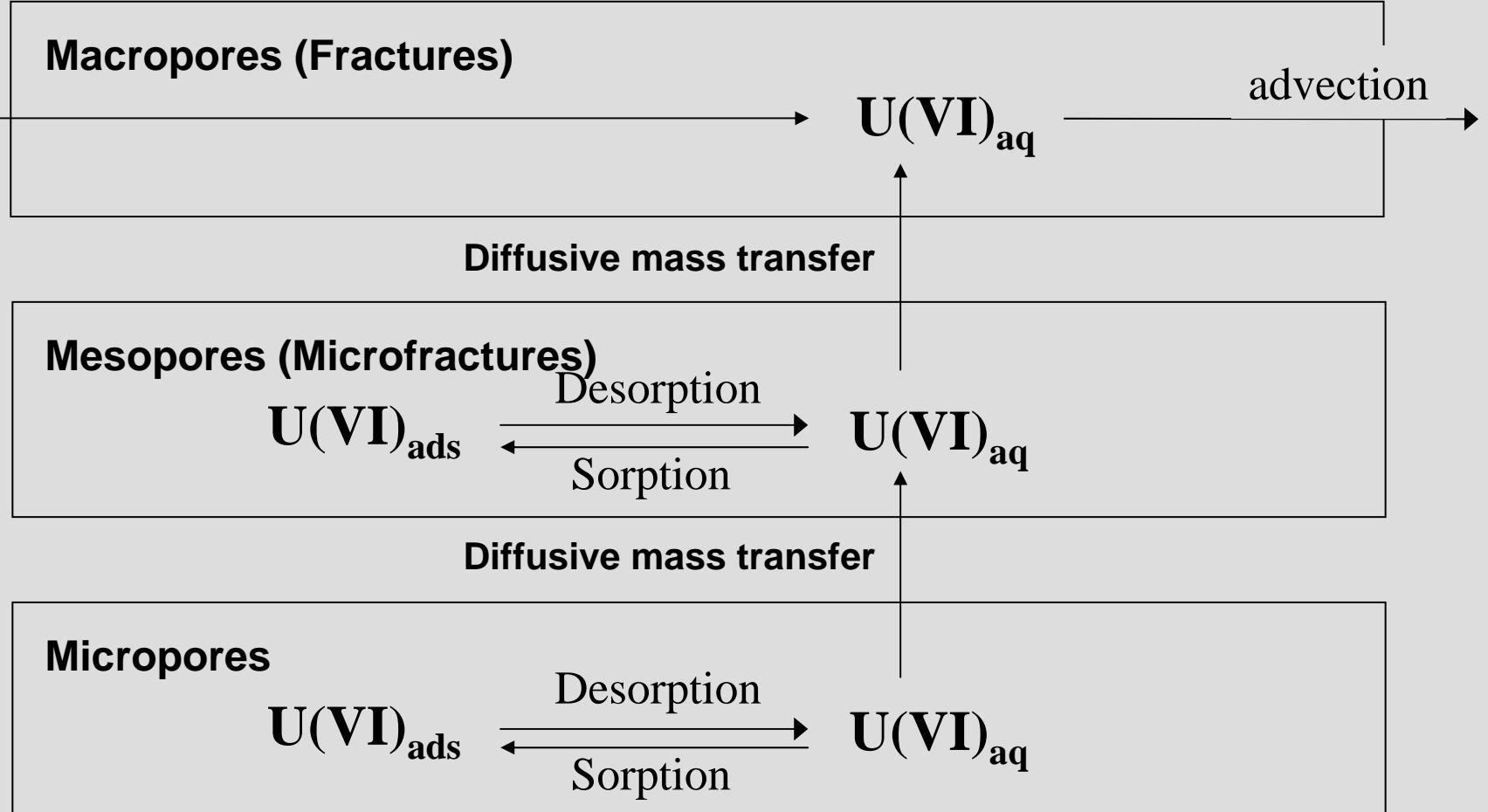
# Structured Porous Media



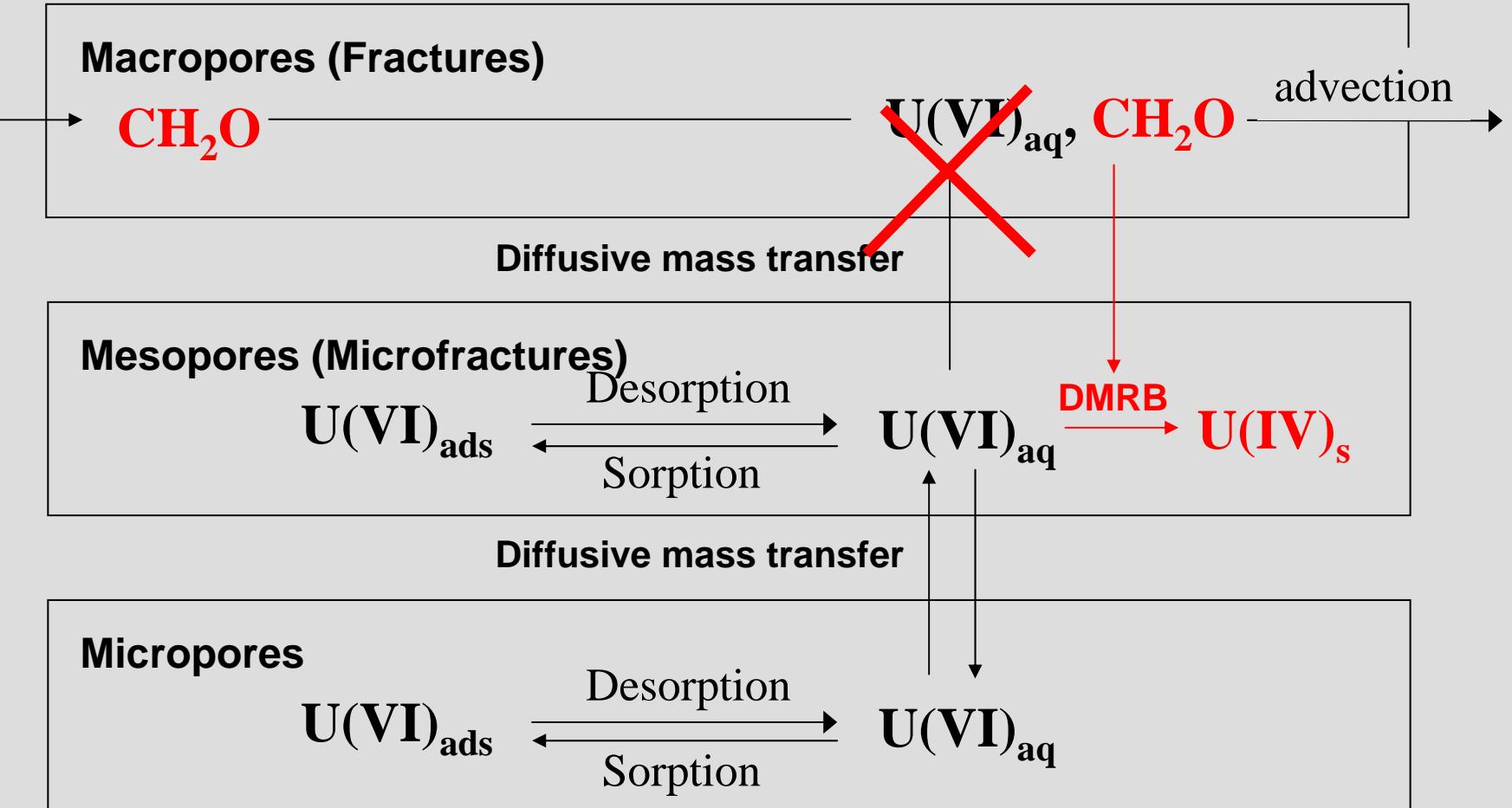
# Hypothesis

- ▶ Mobile radionuclides in low-permeability porous matrix regions of fractured saprolite can be effectively isolated and immobilized by stimulating localized in-situ biological activity in highly-permeable fractured and microfractured zones within the saprolite.

# 1-D Multiple Pore Region Model of Bacterial U(VI) Reduction



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# Multiple Scales of Interest

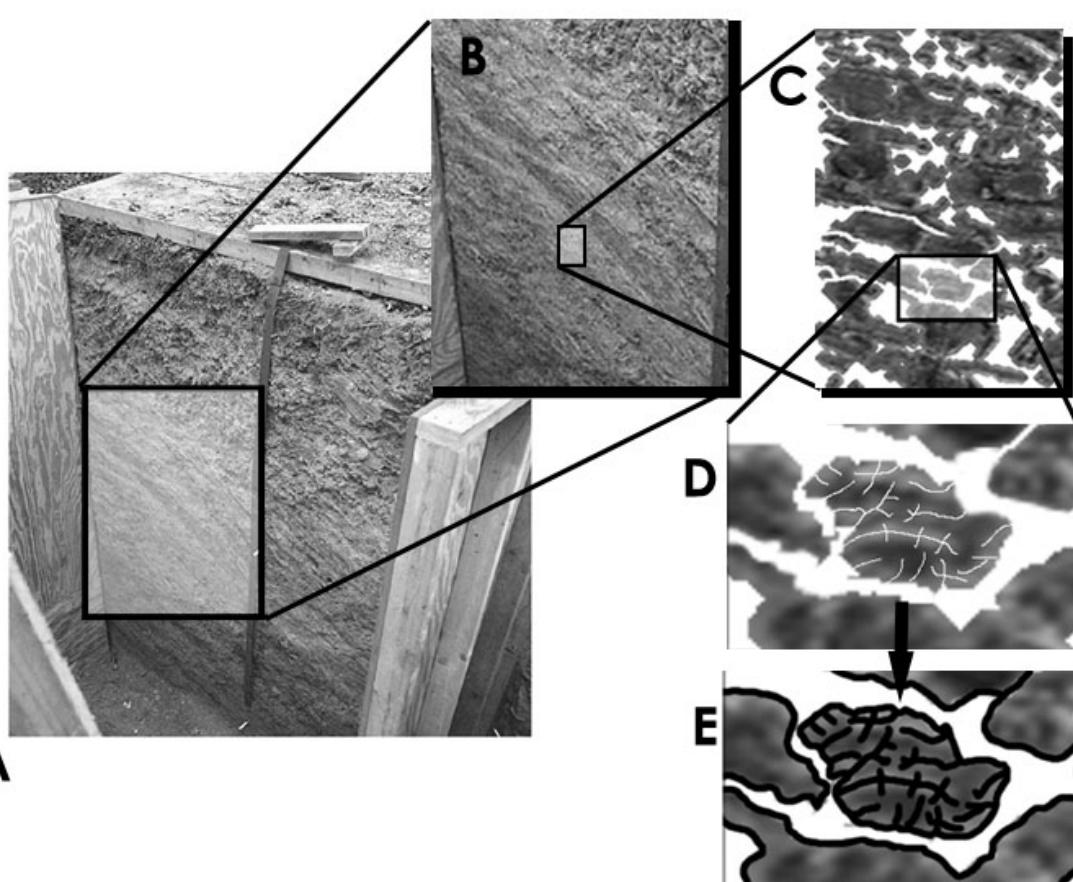


Image A from a trench at the NABIR Field Research Center on the Oak Ridge Reservation (courtesy of David Watson, ORNL, FRC Manager). Images C-E modified manually to conceptually indicate multiple scales of fracturing and localization of biomass development.

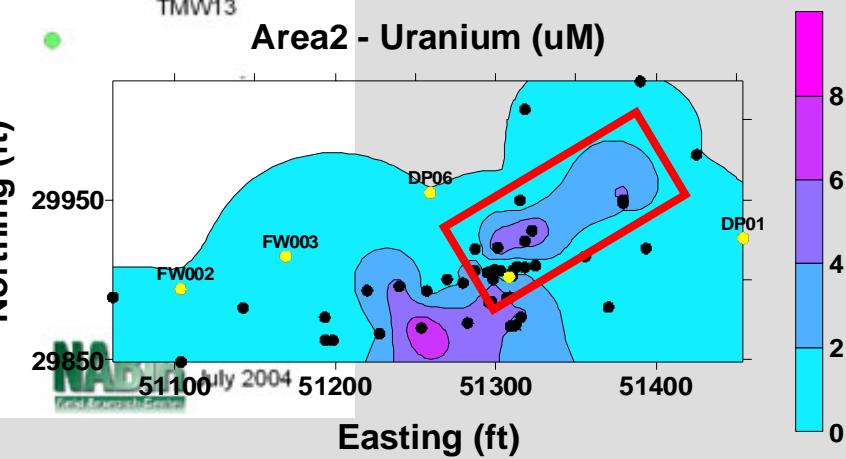
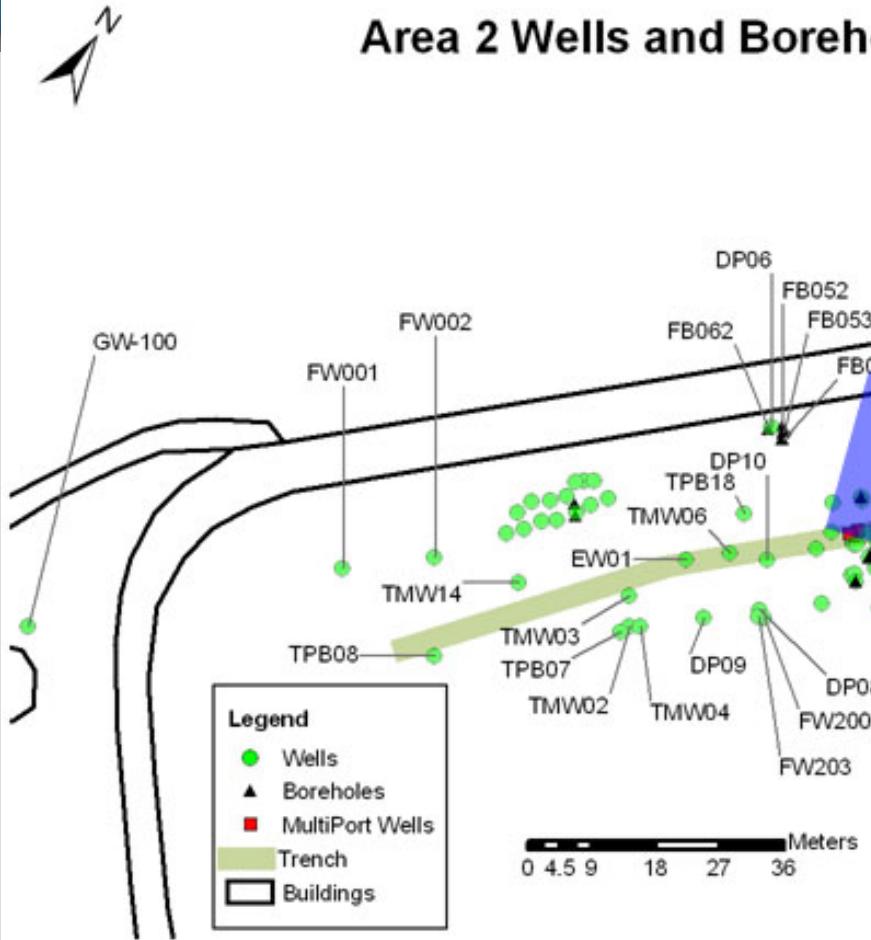
- A. Field scale
- B. Local continuum scale
- C. Local mixed discrete/continuum scale (large fractures and flow paths)
- D. Pore scale (discrete microfractures and continuum porous matrix)
- E. Biofilm development in fractures

# Area 2 Field Site

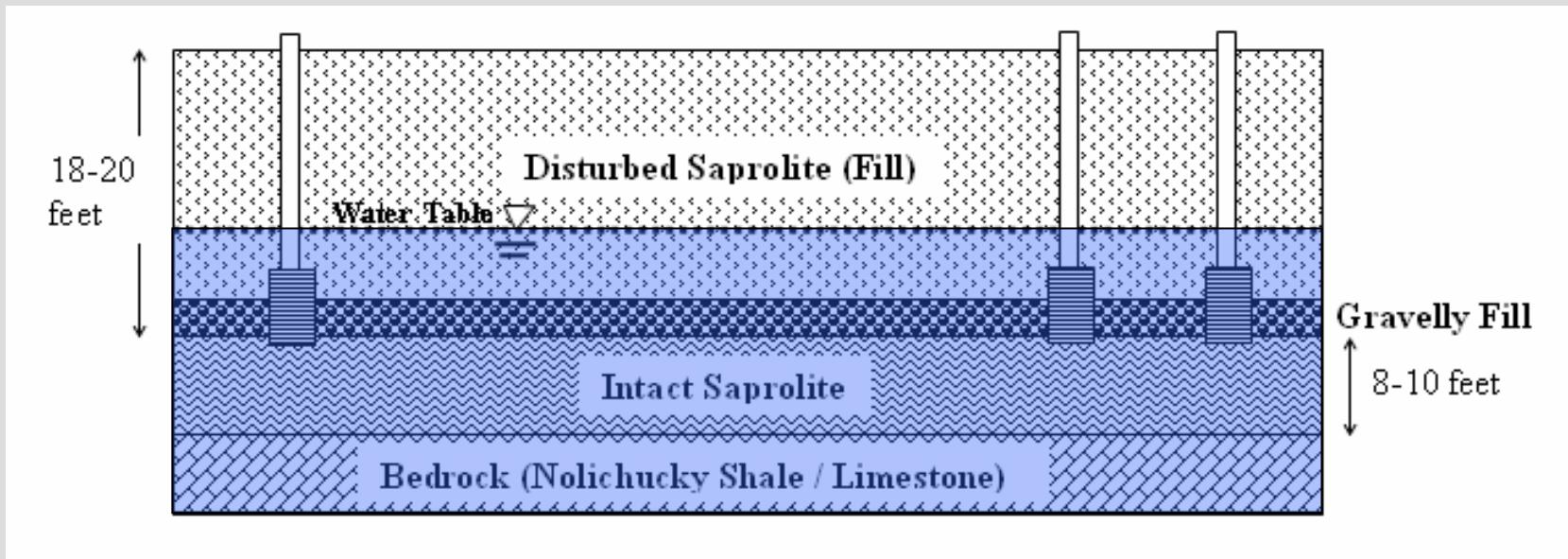


# Area 2 Field Site

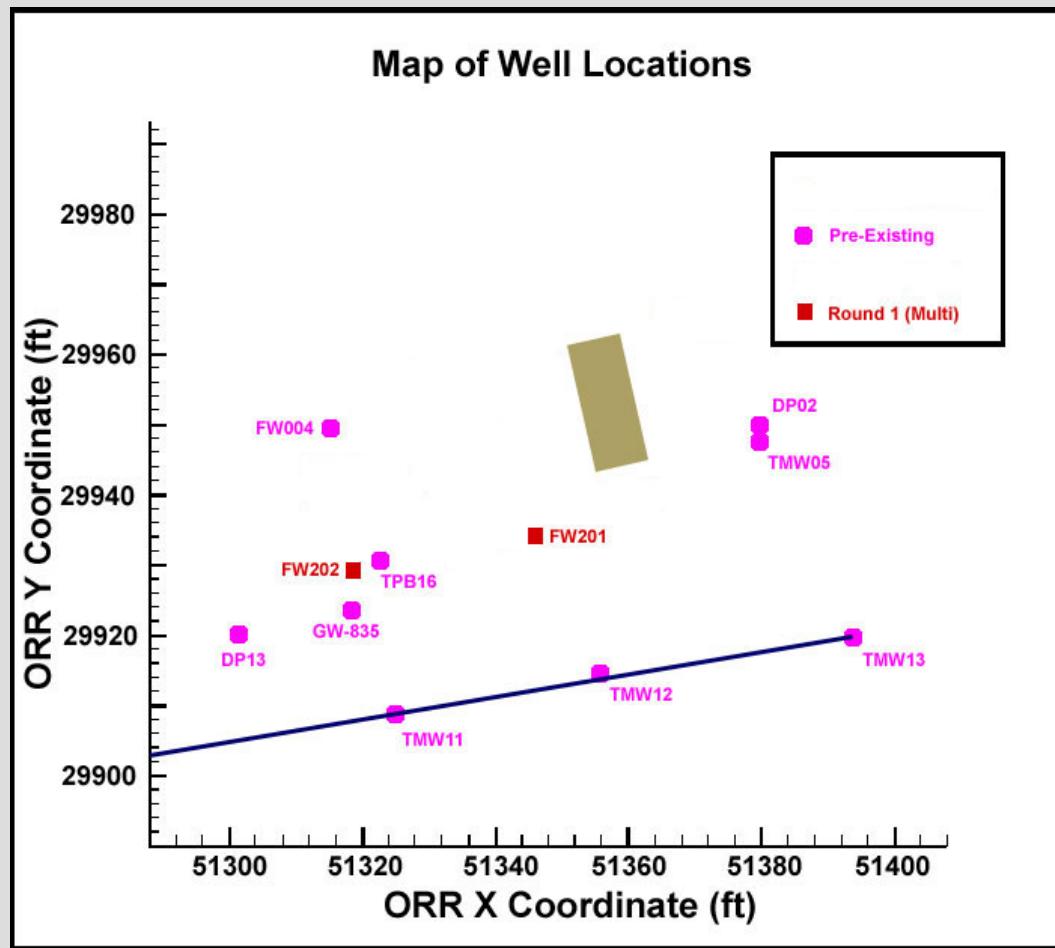
## Area 2 Wells and Boreholes



# Site Stratigraphy

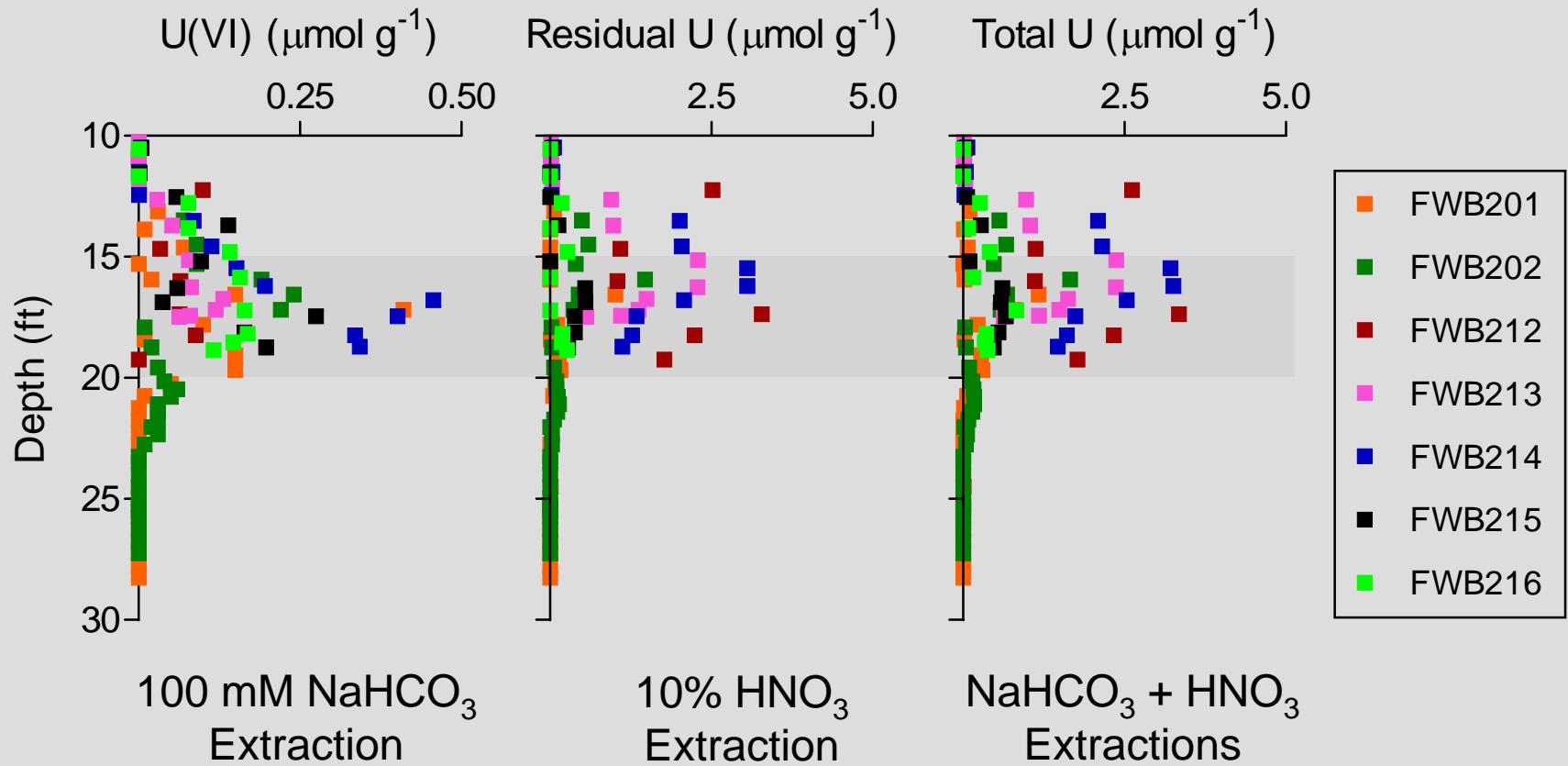


# Site Development – Phase 1

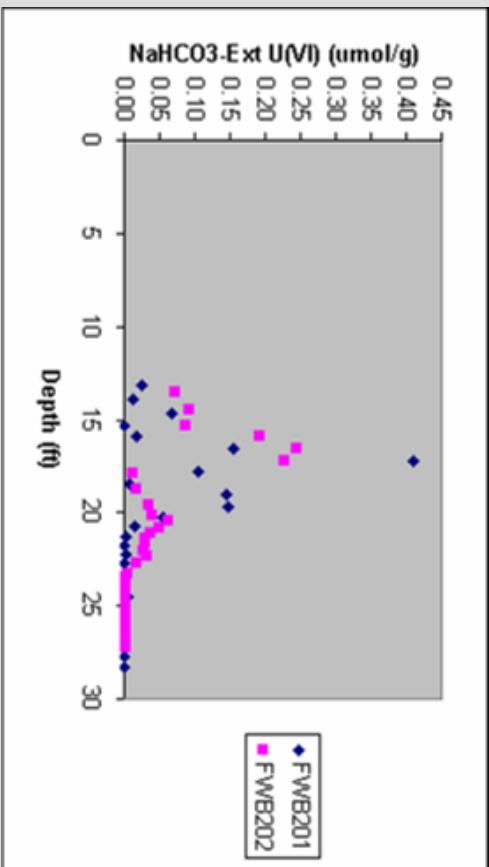




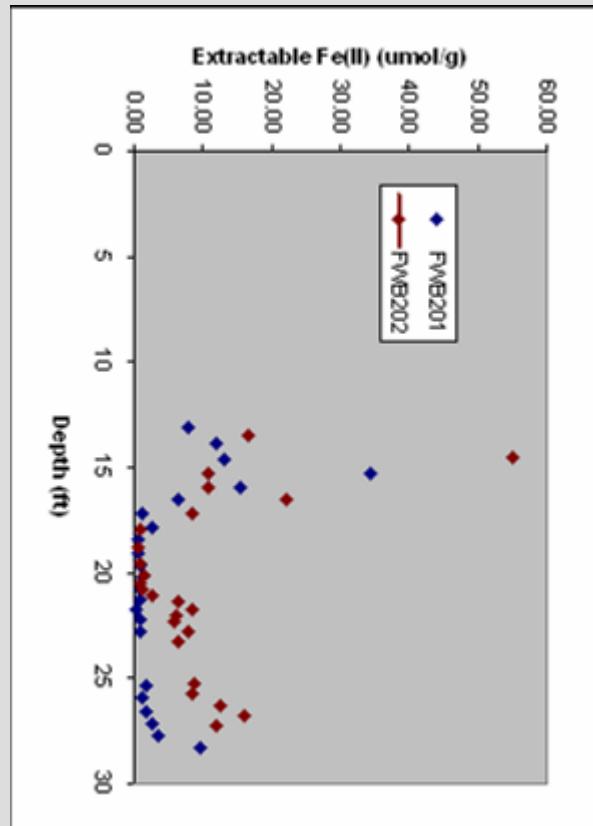
# Uranium Distributions in Area 2 Sediments



# Sediment Extractions



NaHCO<sub>3</sub>-Ext U(VI)



Extractable Fe(III)

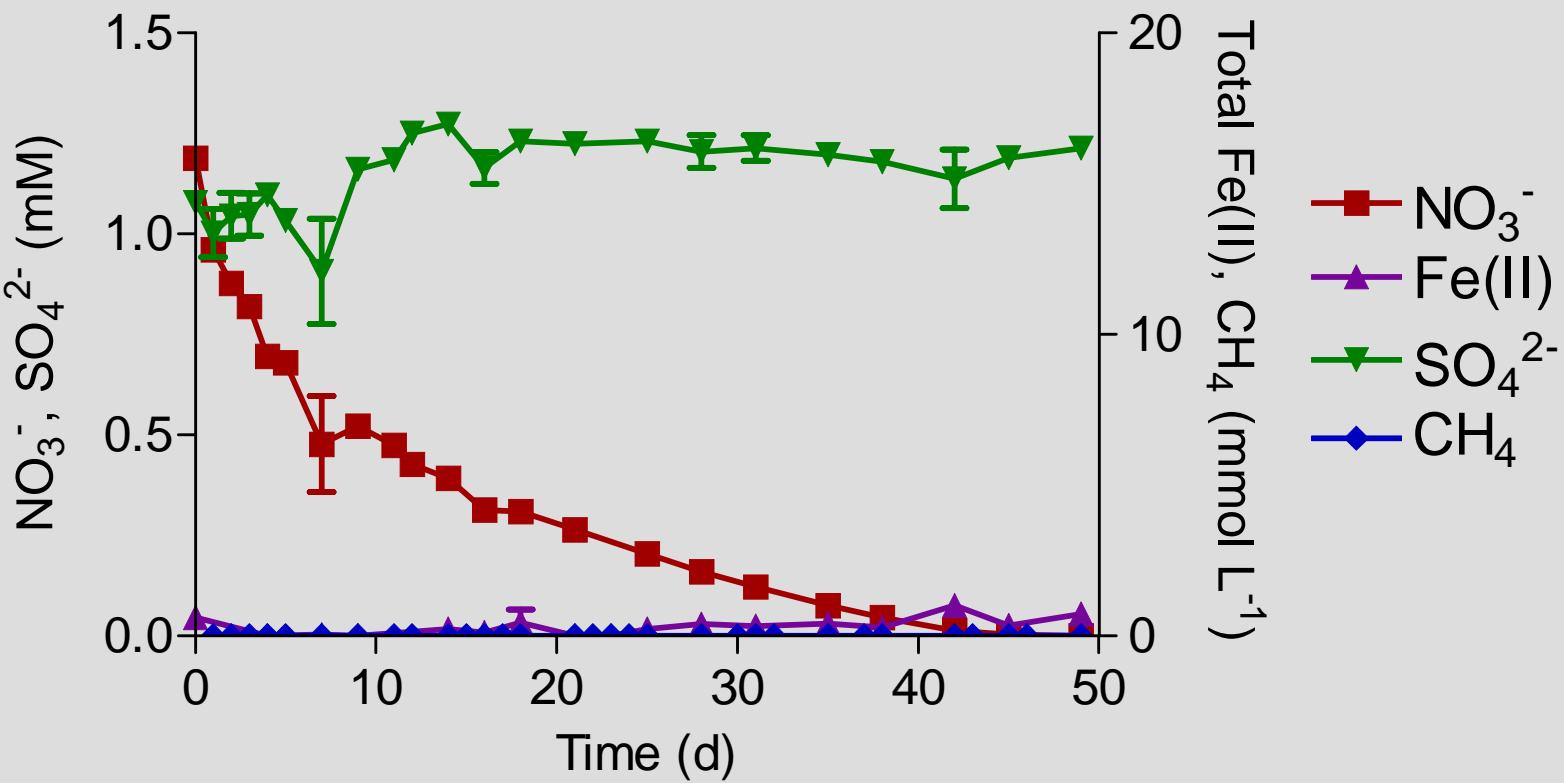
# Reduced vs. Unreduced Area 2 Sediment Slurries



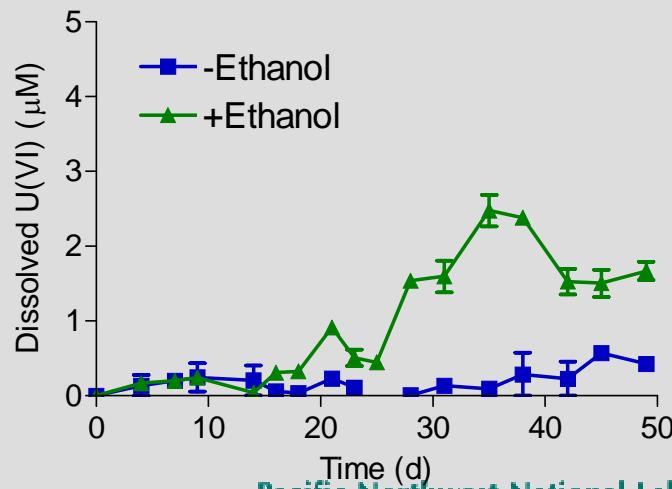
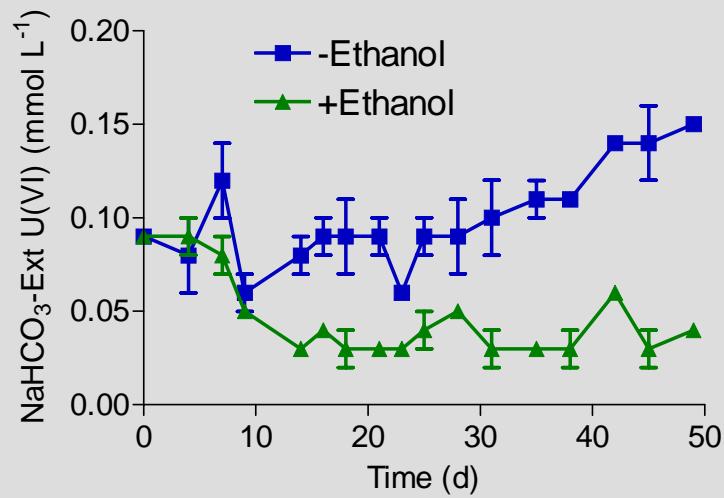
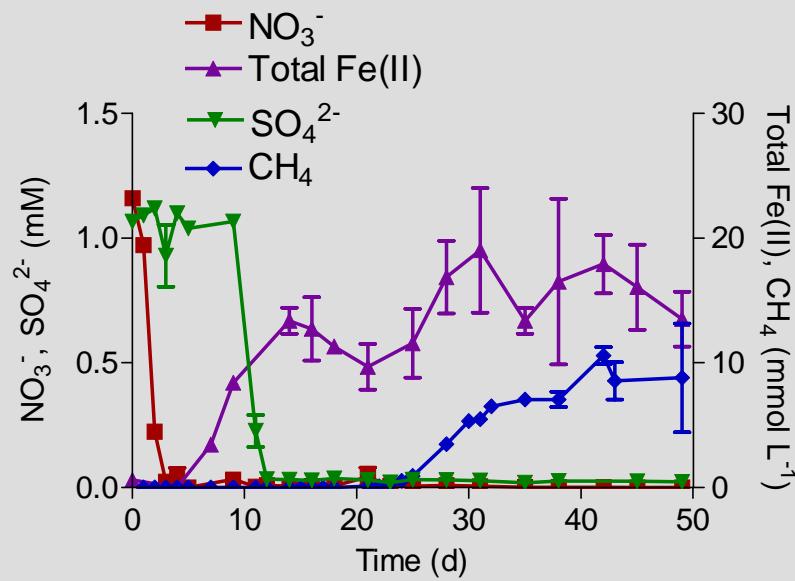
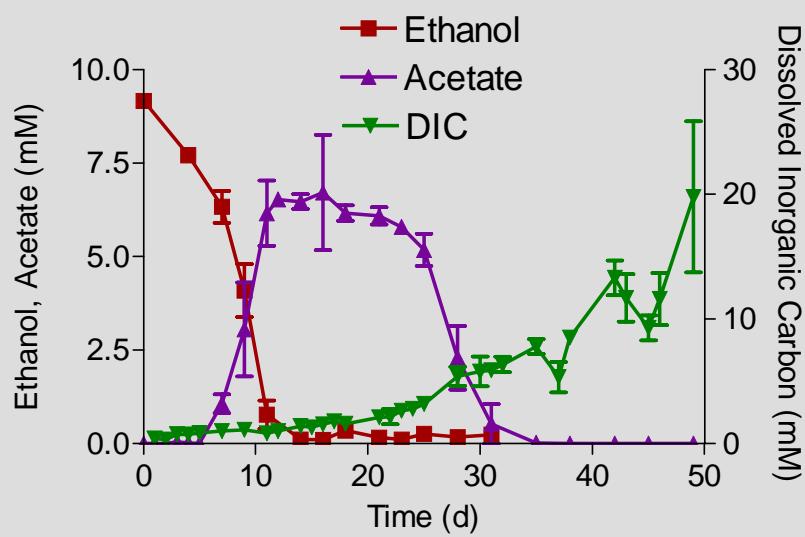
Unreduced  
(-Ethanol)

Reduced  
(+Ethanol)  
Pacific Northwest National Laboratory  
U.S. Department of Energy 15

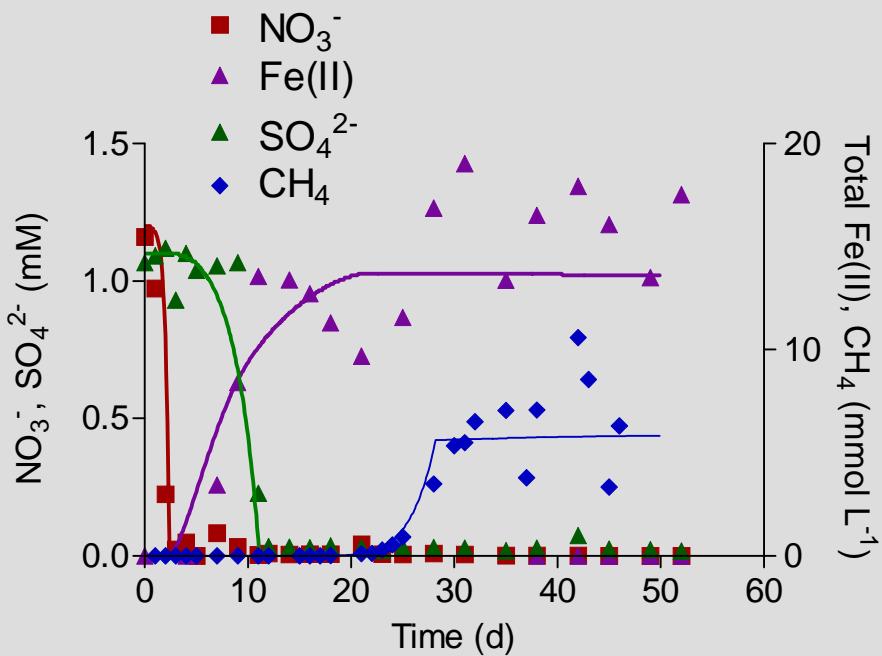
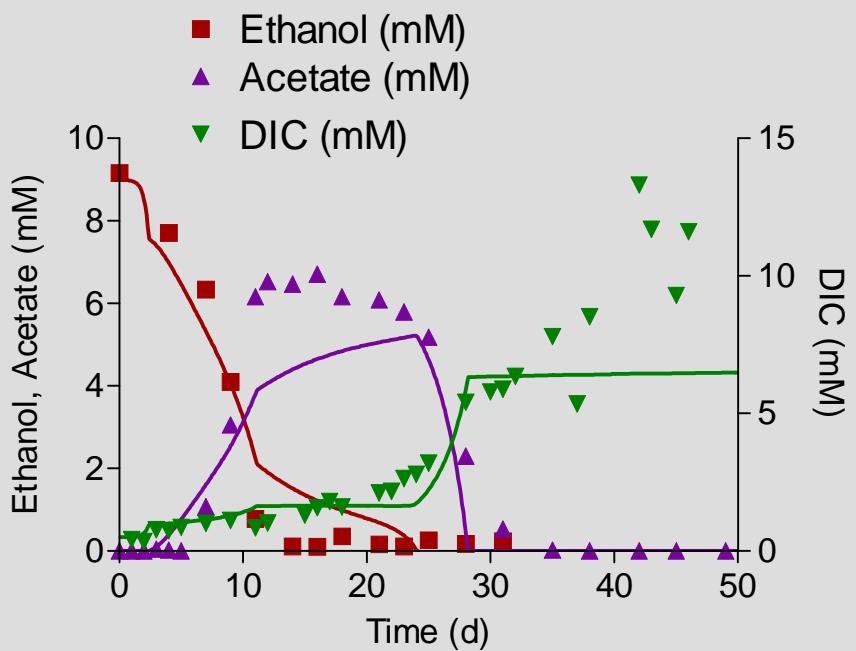
# Unamended Slurry Results



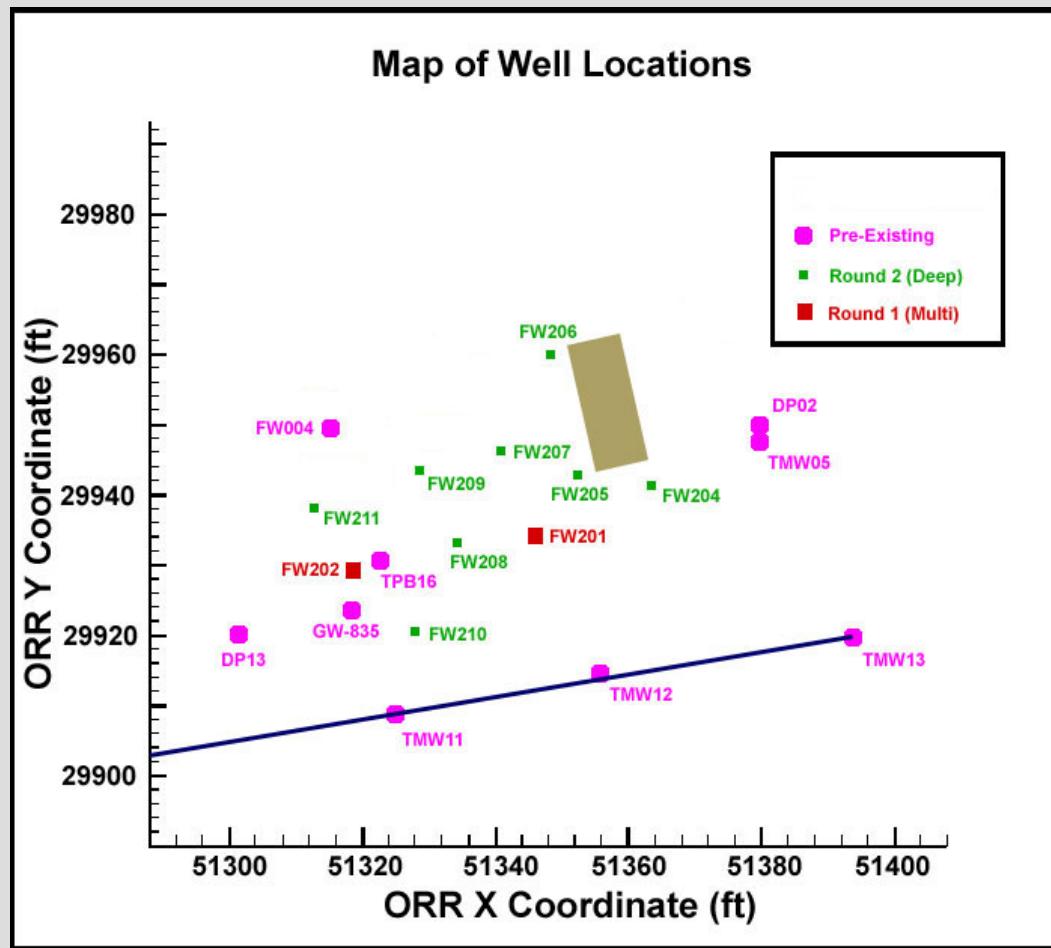
# Area 2 Sediment Slurry Experiment

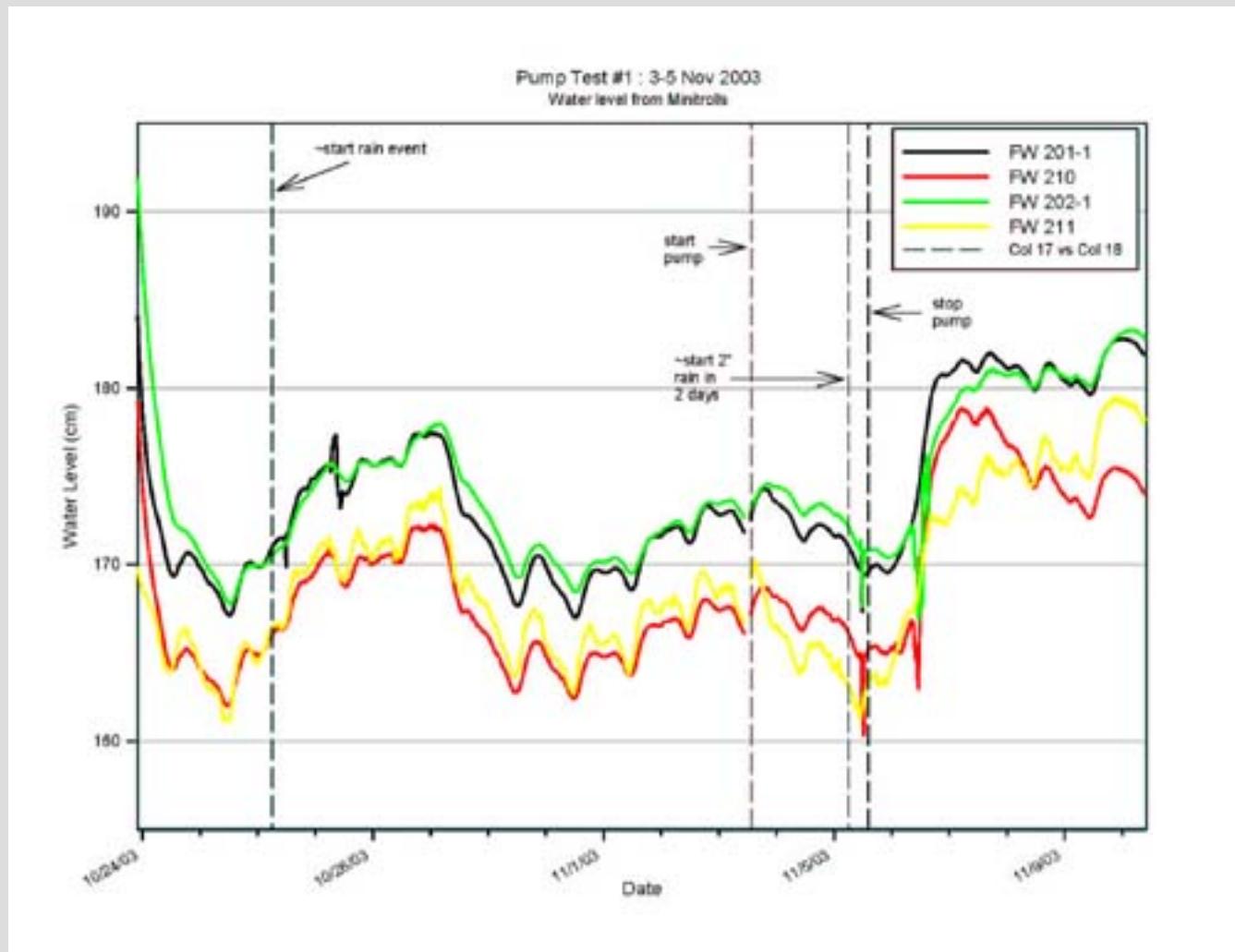


# TEAP Simulation Model Results



# Site Development – Phase 2





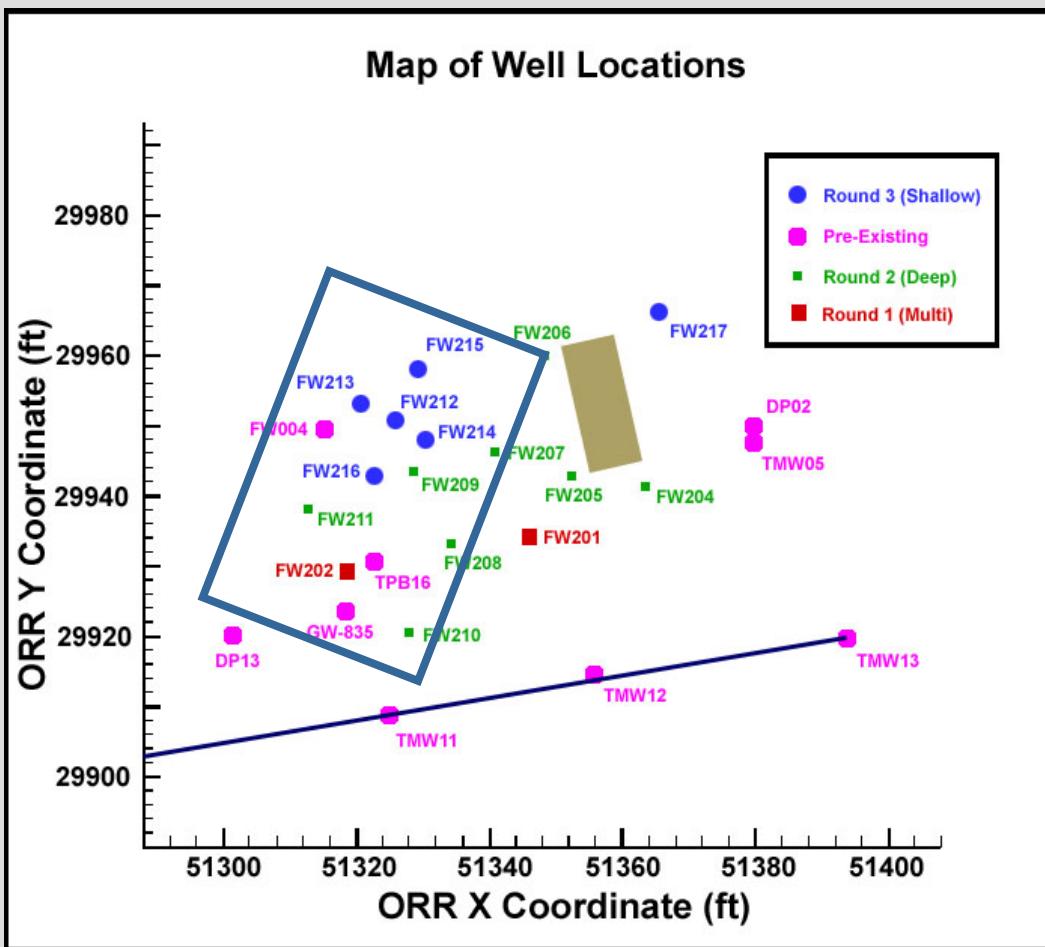
# Saprolite Characterization Results

- ▶ Estimated hydraulic conductivity  $K = 4.1 \times 10^{-7}$  m/s (about 1 cm/day groundwater velocity assuming gradient = 0.03 and advective porosity = 0.1)
- ▶ Chemistry:
  - U in  $\mu\text{M}$  range
  - pH circumneutral
  - Nitrates as high as ~125 mM
  - Sediment-associated U low ( $<< 1 \text{ mmol/g}$ )

Date	Well	pH	NO <sub>3</sub> - (ppm)	SO <sub>4</sub> = (ppm)	U (ppb)
08/26/03	FW204	7.30	237.4	118.6	547.4 441.1
	FW205	6.87	495.0	65.8	77.4 74.1
	FW206	6.59	684.2	34.4	15.7 15.6
	FW207	6.83	368.2	48.9	180.5 150.6
	FW208	5.48	3077.7	11.3	69.3 67.4
	FW209	6.26	1078.2	13.4	239.7 238.8
	FW210	6.36	7719.5	12.0	185.7 117.6
	FW211	6.33	1584.3	62.1	421.8 428.8

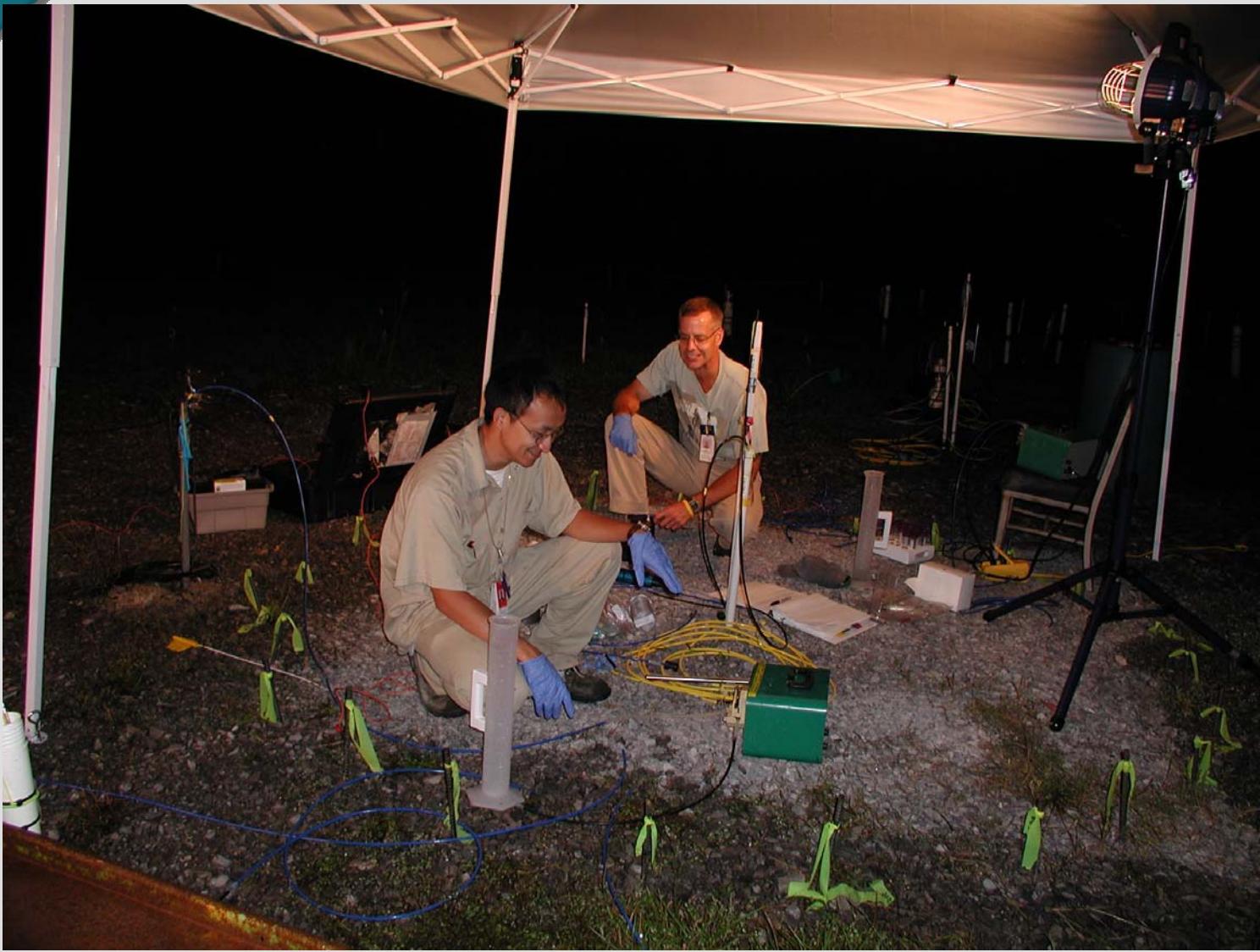
Note: Top number for U is unfiltered; bottom is filtered.

# **Site Development – Phase 3**





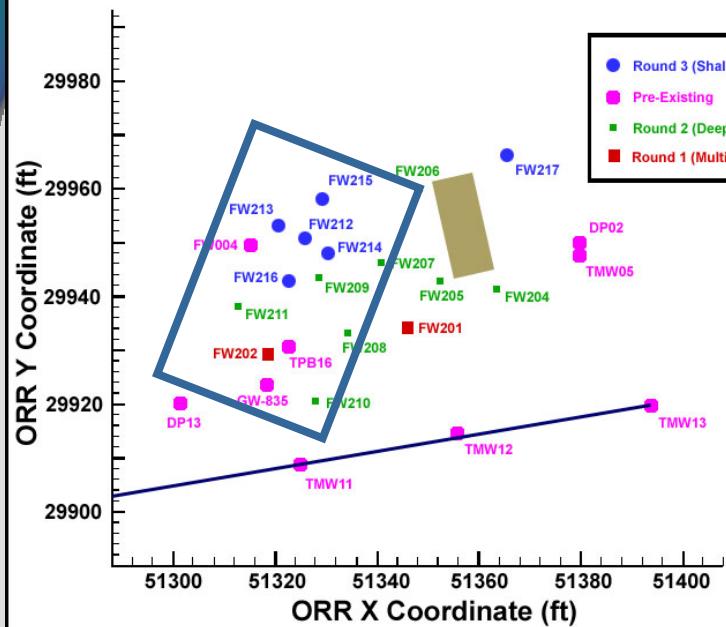




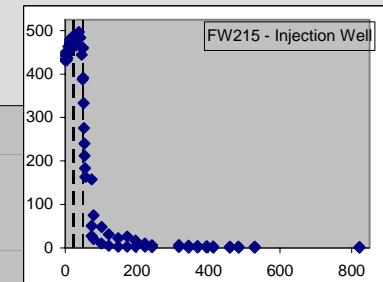
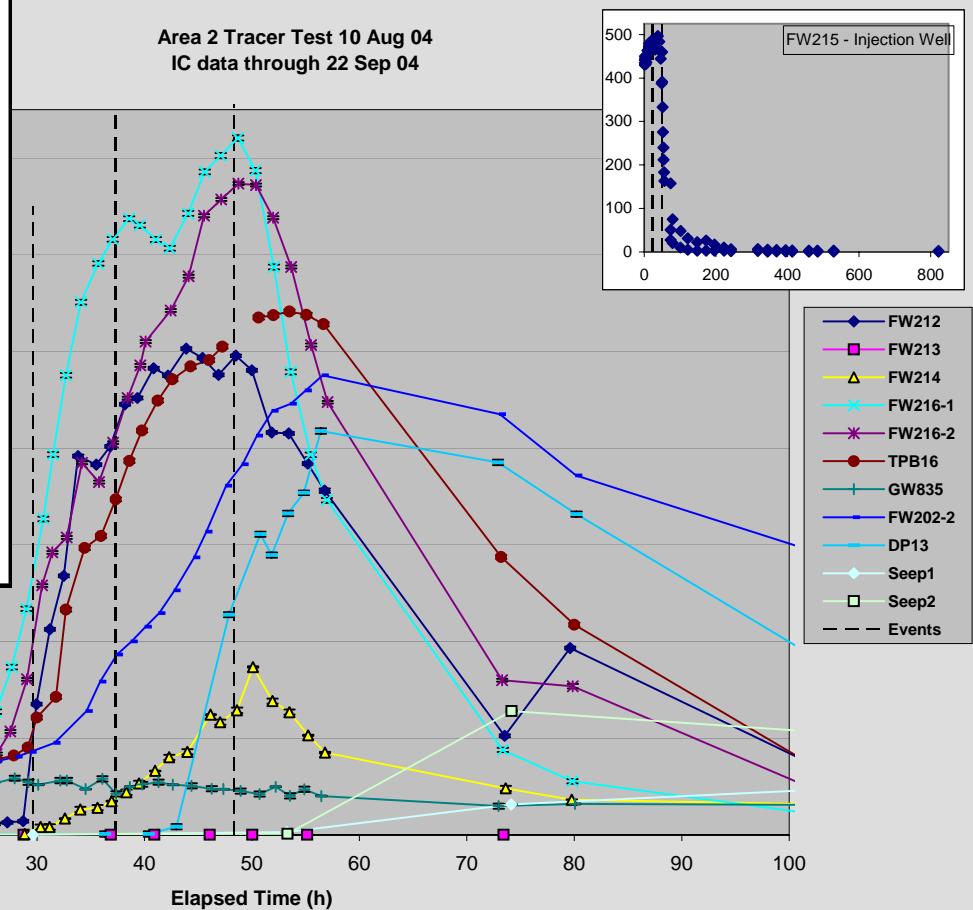


# Tracer Test Results

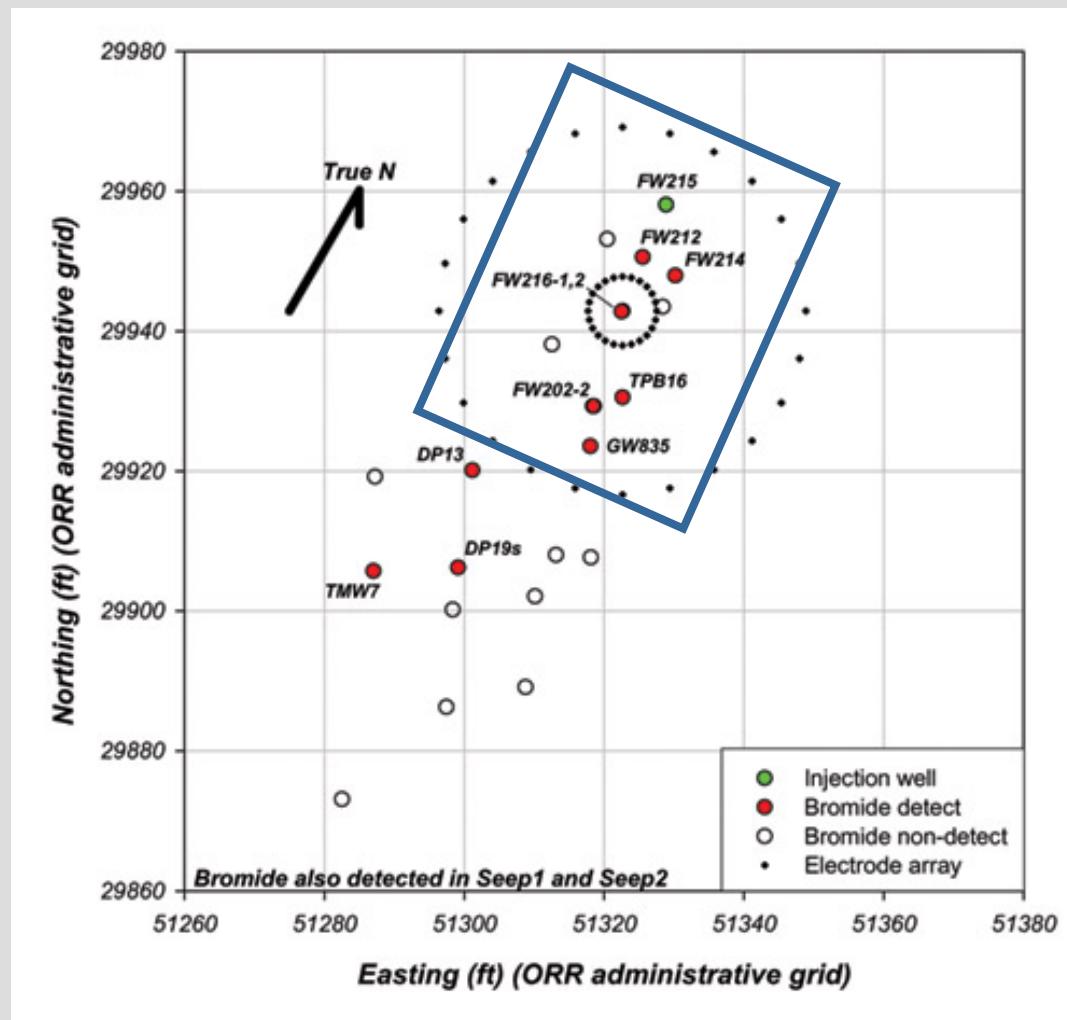
Map of Well Locations



Area 2 Tracer Test 10 Aug 04  
IC data through 22 Sep 04

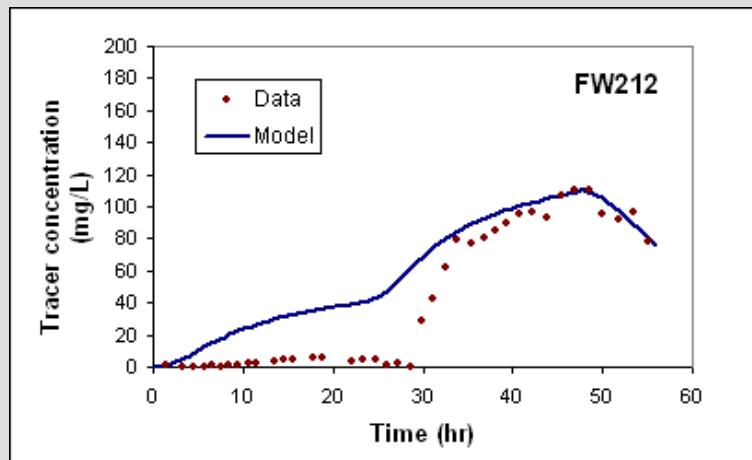
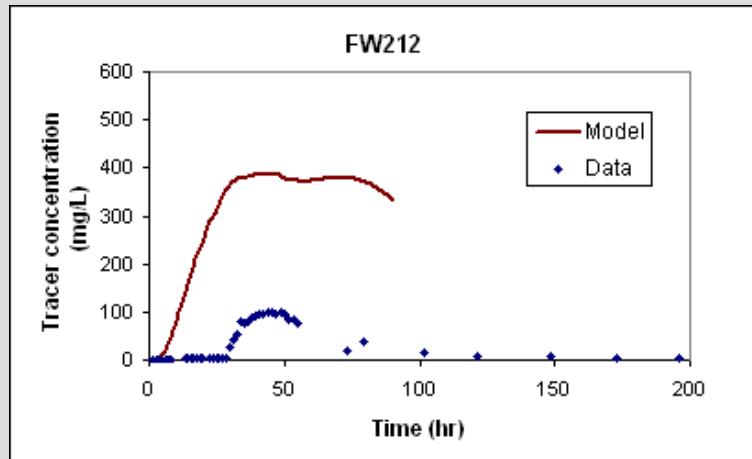
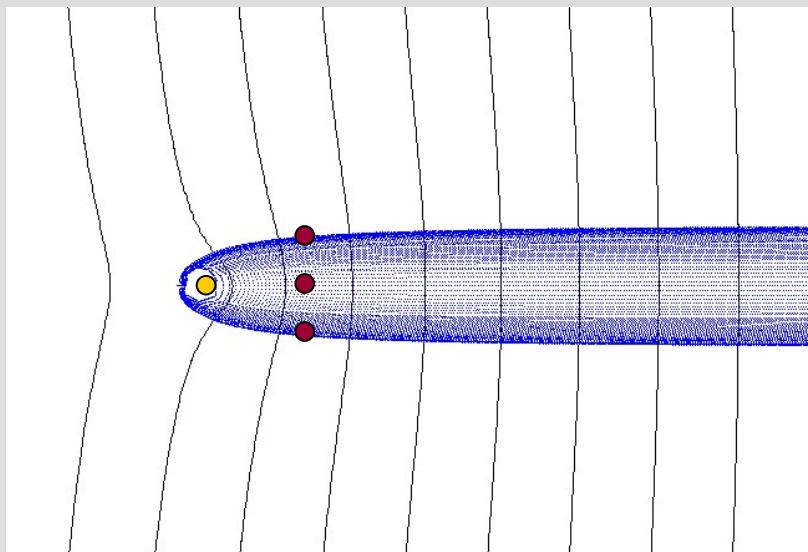


# Tracer Test Results

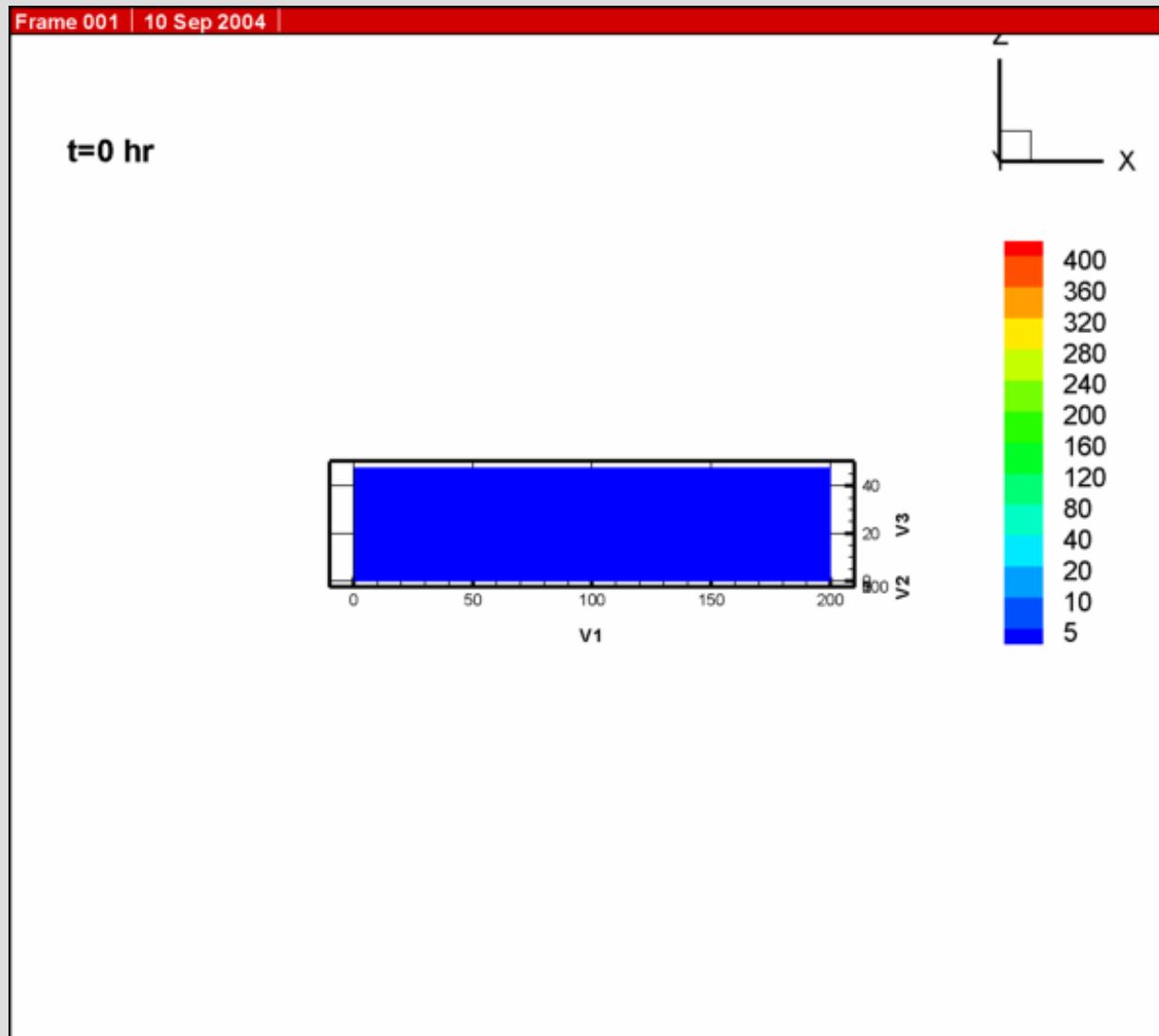


# Tracer Interpretation

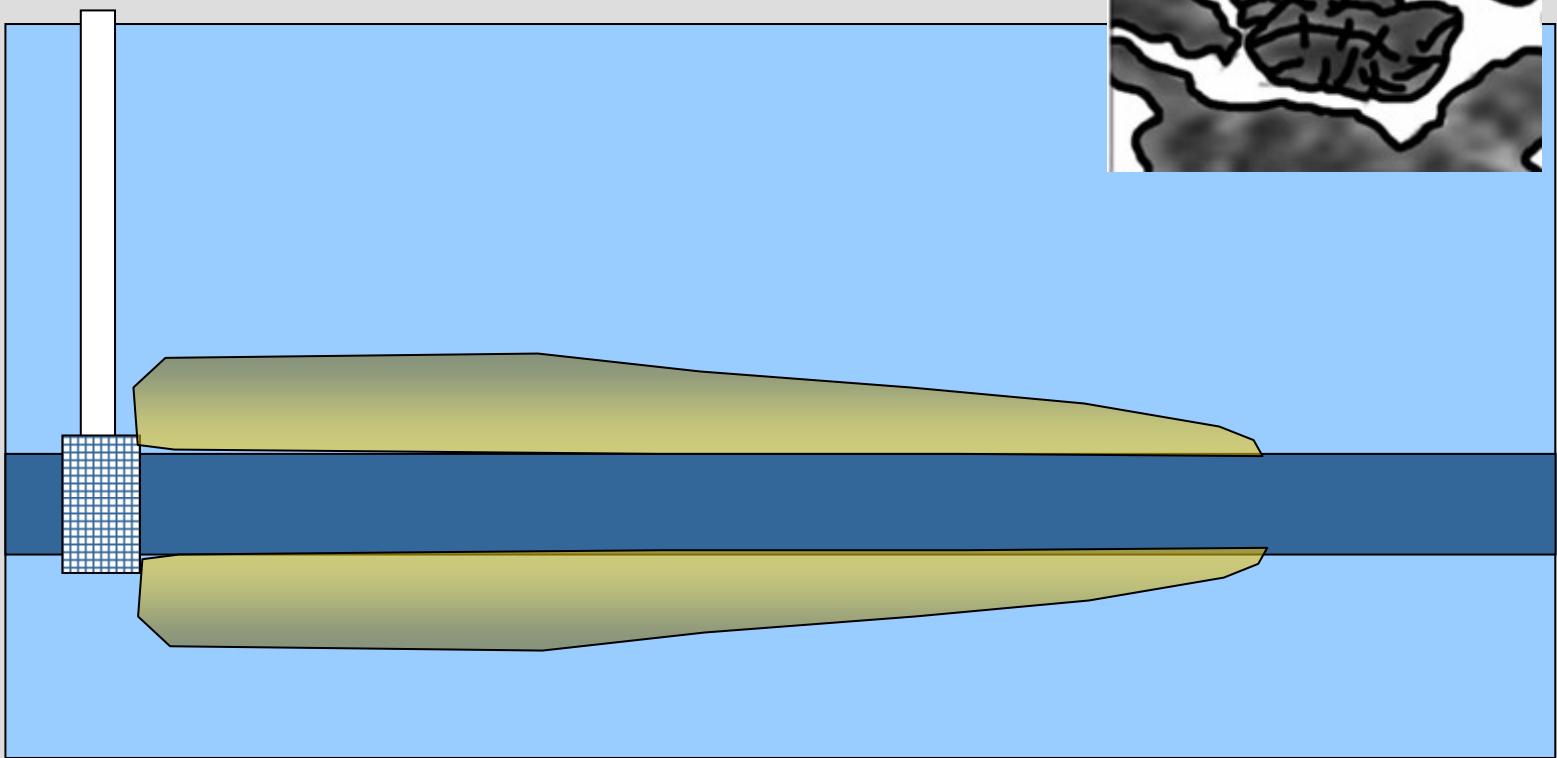
- ▶ Gravel layer dominates flow
- ▶ Mass transfer gravel ↔ fill and gravel ↔ saprolite is a significant process



# Modified Hypothesis



# Modified Hypothesis



# Biostimulation Test

- ▶ Natural gradient flow
- ▶ Intermittent (pulsed) injection of electron donor
- ▶ Geophysical monitoring

