



Hanford 300 A IFC

Hanford 300 Area IFC Breakout Session

Multi-Scale Mass Transfer Processes Controlling Natural Attenuation and Engineered Remediation: An IFC Focused on Hanford's 300 Area Uranium Plume

John M. Zachara and IFC Team

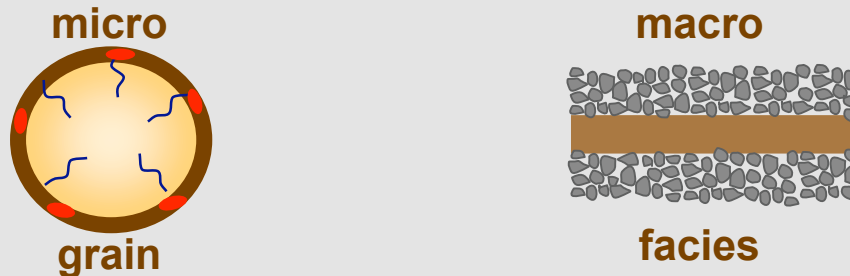
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Other External Participants


- ▶ Roy Haggerty – OSU, mass transfer experiments and modeling
- ▶ Douglas Kent – USGS, field injection experiments, surface complexation processes
- ▶ Alan Konopka – PU, microbial ecology and microbiological heterogeneity
- ▶ Yoram Rubin – UCB, stochastic hydrology and modeling
- ▶ Roloef Versteeg – INL, geophysics and data management
- ▶ Chunmiao Zheng – UA, hydrologic modeling and geostatistics

Hanford IFC


Science Theme ~ *Multiscale mass transfer processes influencing sorbed contaminant migration*



Associated Practical Issues

 Accurate projection of dissipation times for groundwater plumes of sorbing contaminants

- ▶ Sorbing solutes not equal
- ▶ Concentrations at different scales

 Optimal delivery of remediation reactants

- ▶ Access
- ▶ Kinetic formation and reaction
- ▶ Persistence

 Practicality and effectiveness of remediation

Hanford 300 Area in 1962



300 A Waste Streams

- ▶ Sodium aluminate (to ~1956)
 - Dissolved Al cladding from rejected fuel assemblies
 - 15% NaOH, Density of 1.5

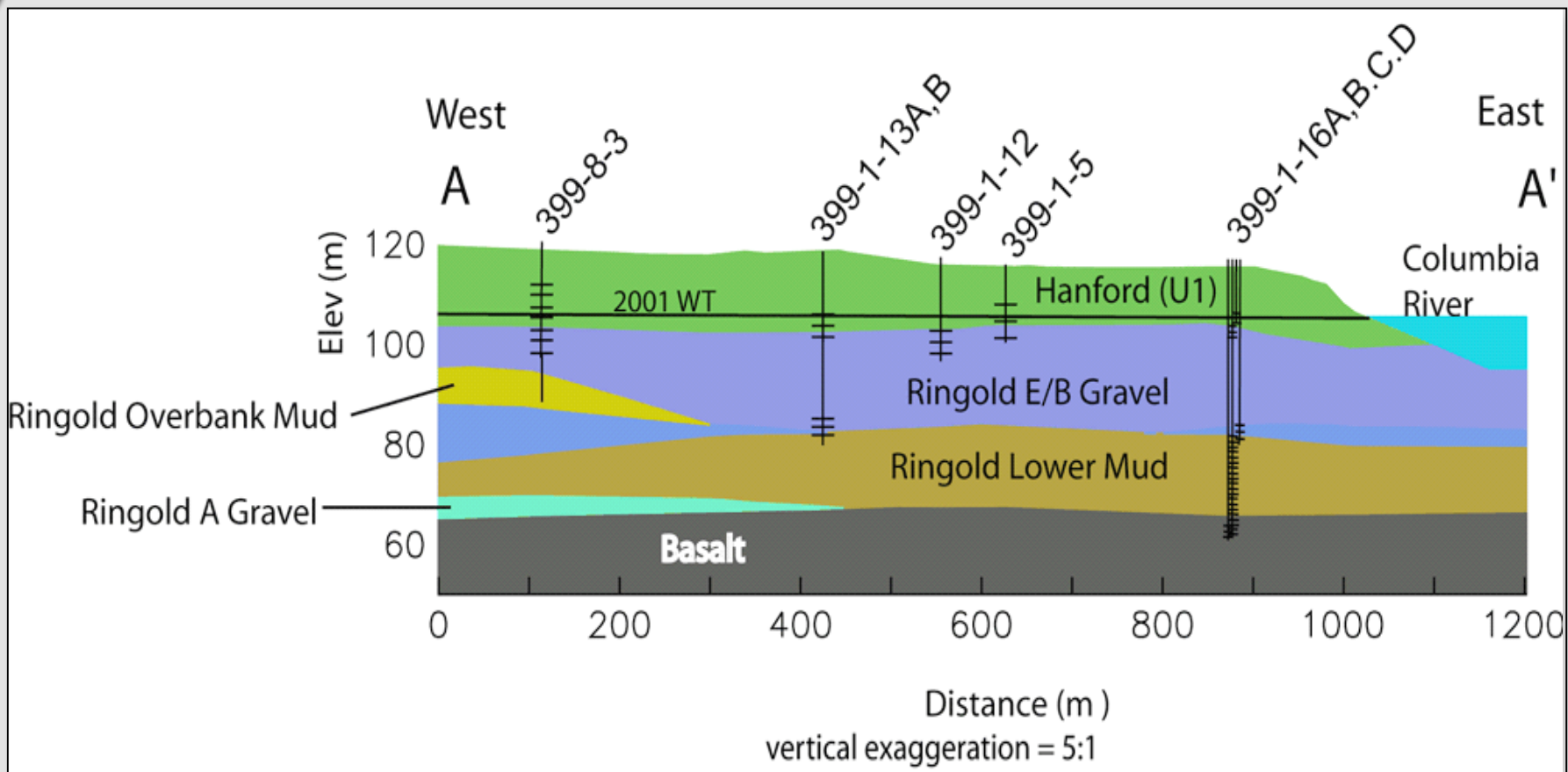
- ▶ Effluents from REDOX and PUREX process development (1944 – 1954)
 - Nitric acid solutions containing uranyl nitrate

- ▶ N-reactor fuels fabrication wastes (1978 – 1986)
 - Nitric acid solutions containing U and Cu

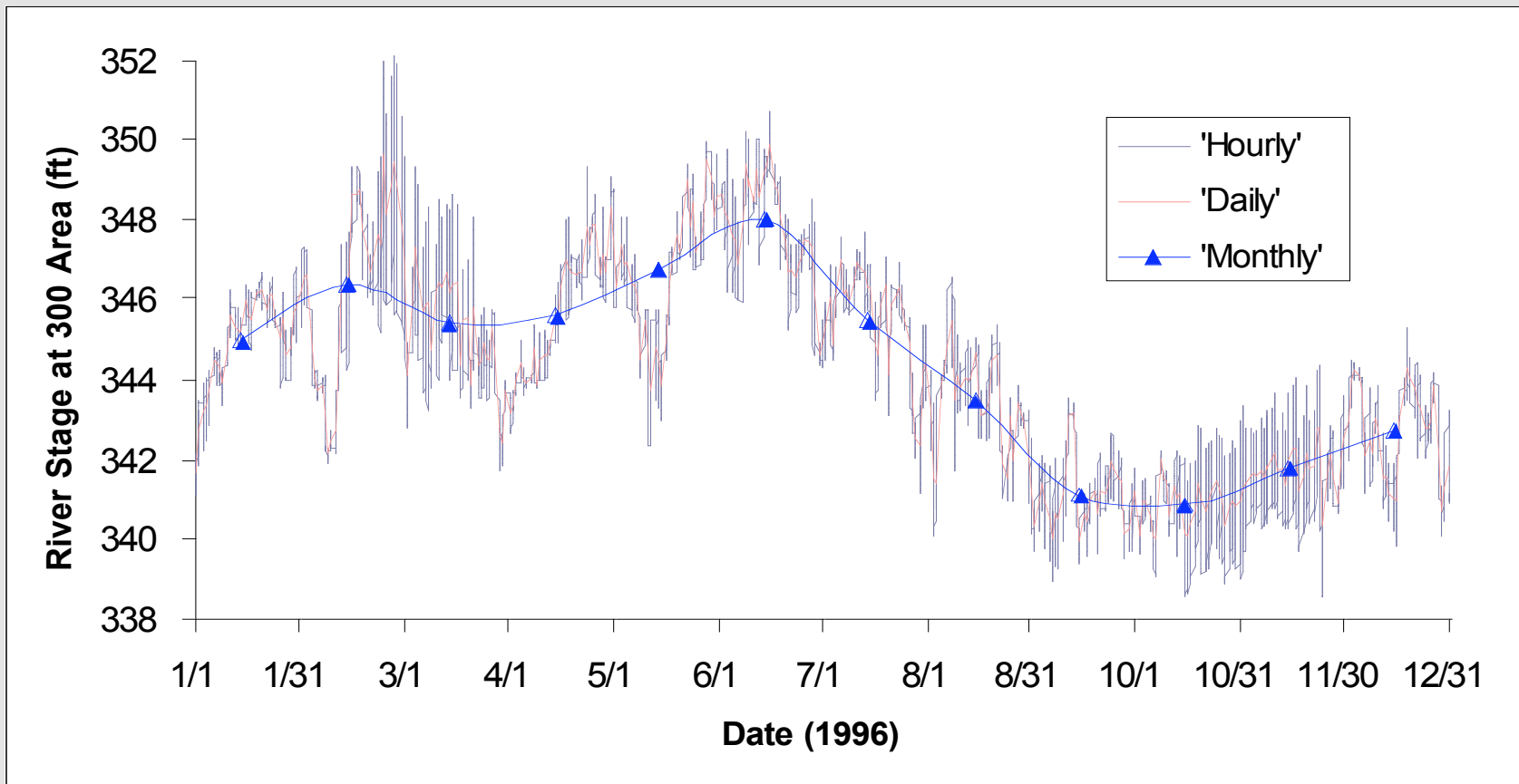
- ▶ Different grades of enriched U as well as natural and depleted U

- ▶ Primary chemical inventory in NPP and SPP
 - 37,000 – 65,000 kg of U; 265,000 kg of Cu

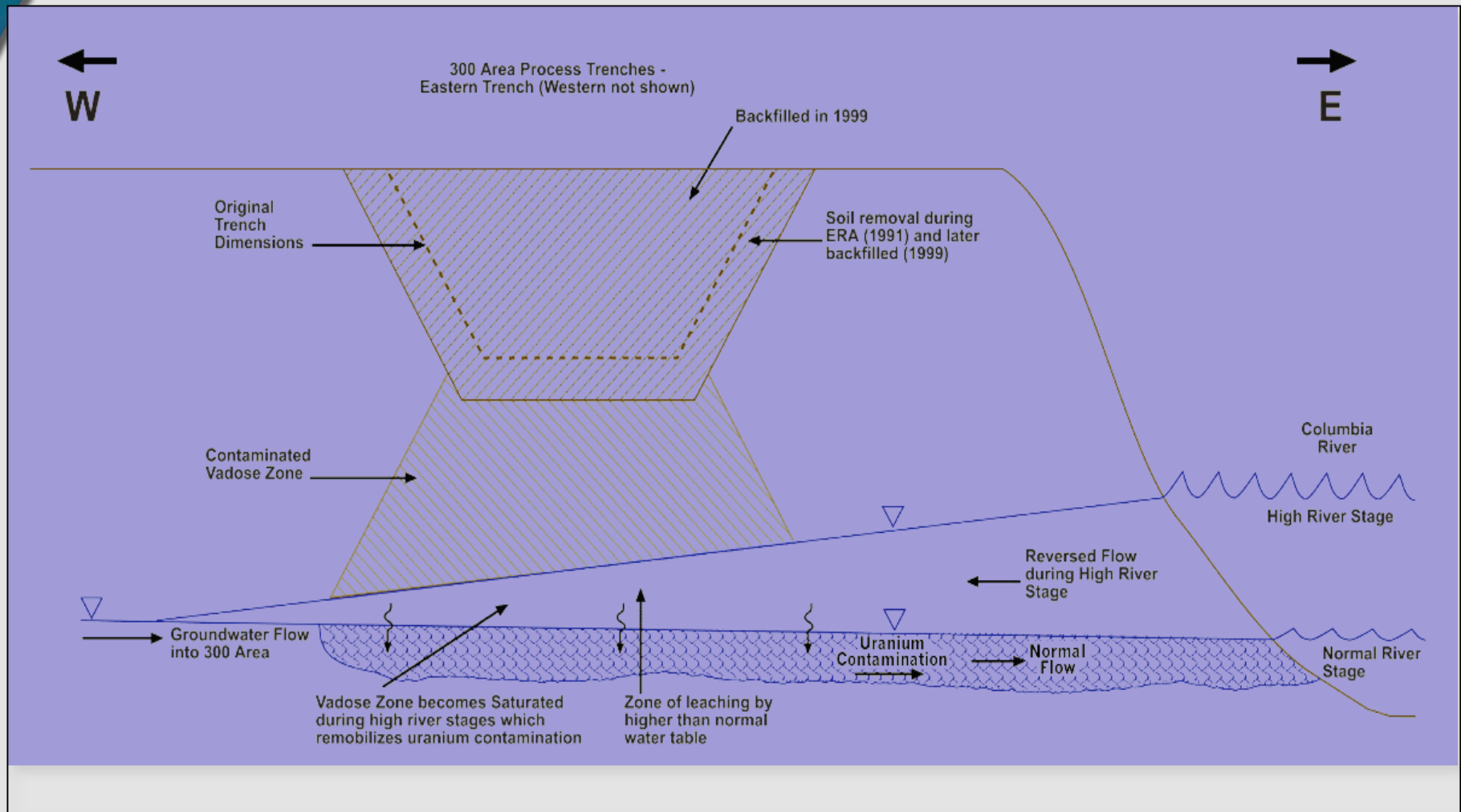
Geological Cross Section



Hourly, Daily Average, and Monthly Average River Stage at the 300 Area in 1996

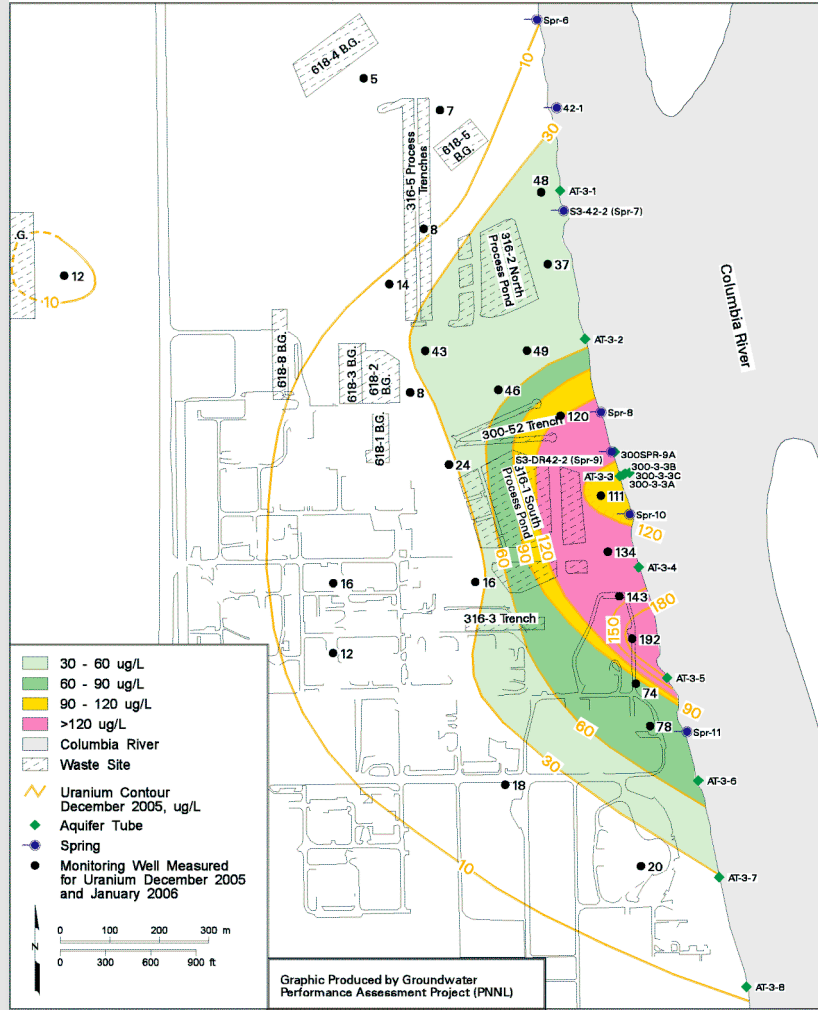


Vadose Zone Release Model

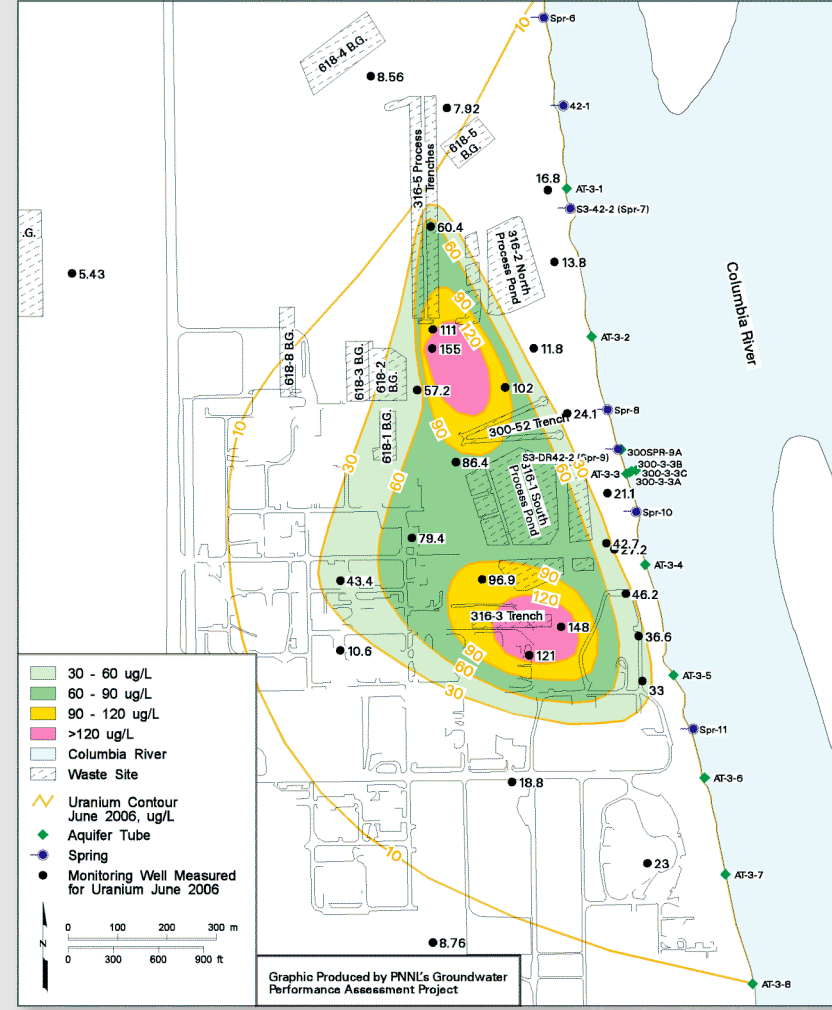


Seasonal Dynamics of 300 A Uranium Plume

300 Area Uranium, December 2005



300 Area Uranium, June 2006

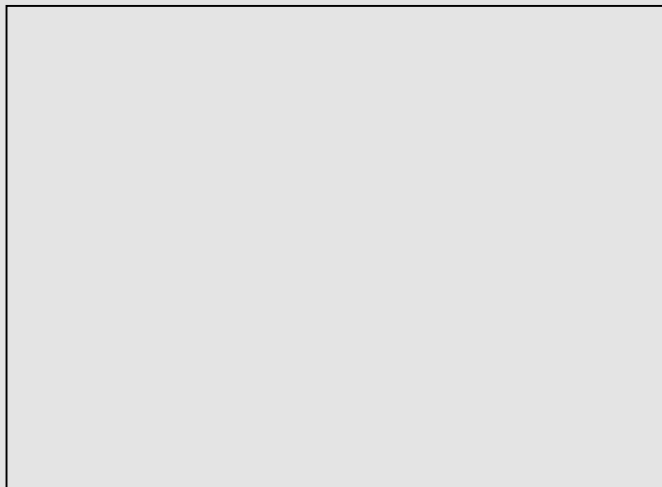


Primary Objectives

- ▶ Quantify the role of mass transfer in controlling U(VI) distribution under various geochemical, hydrologic, and remedial conditions
 - Vadose zone
 - Saturated zone
- ▶ Investigate in-situ microbiologic processes that couple with mass transfer to control phosphate barrier performance and longevity
- ▶ Create enduring field experimental data sets for model and field-scale hypothesis evaluation
- ▶ Test and improve existing models of multi-reaction chemistry and multi-scale mass transfer by comparison to new, robust experimental field data
- ▶ Proactively transfer results to site for decision making and remediation

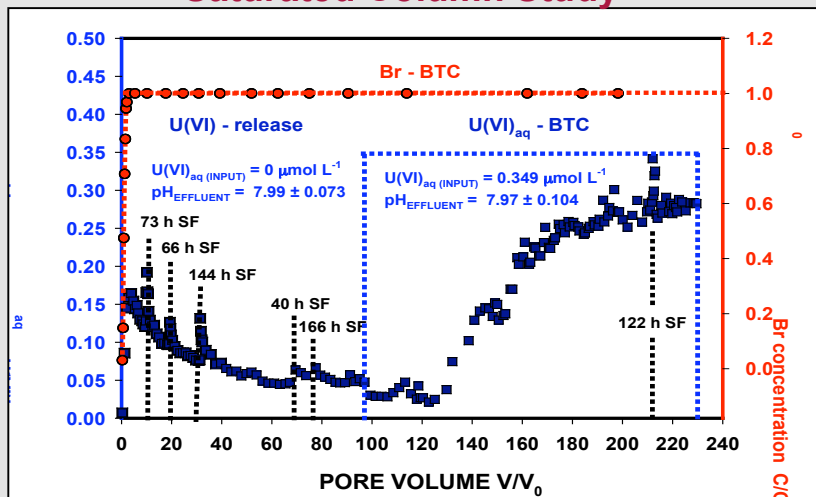
Transport Behavior (Desorption/Sorption) in < 2 mm Sediment is Kinetically Controlled

North Process Pond Pit 1 – 14 ft

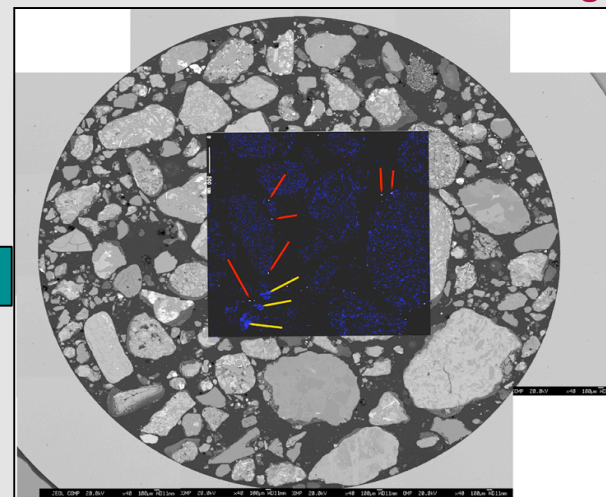


Size Range (mm)	Mass Distribution (%)	U _{Total} (nmol/g)
Cobbles		
> 12.5	74.5	< 22
2.0 - 12.5	17.2	< 19
Sand		
1.0 - 2.0	2.64	26
0.5 - 1.0	2.34	< 18
0.25 - 0.5	0.78	< 21
0.149 - 0.25	0.33	37
0.106 - 0.149	0.19	< 23
0.053 - 0.149	0.20	< 23
Silt + Clay		
< 0.053	1.78	125

Saturated Column Study



Electron Microprobe U Abundance Map on Backscattered Electron Image



The release of sorbed contaminant U(VI) and the adsorption of U(VI) from contaminated groundwater both show strong kinetic behavior

(Qafoku et al., 2005; Liu et al., 2007)

Approaches

- ▶ Robust 3-D geostatistical characterization of the experimental domain
 - Borehole samples and downhole logging
 - Surface and cross-borehole geophysics
 - geo-, hydro-, chemo-, bio-, and U(VI)-facies
 - Correlative transfer functions with process-specific parameters

- ▶ Field experimental campaigns based on 3 hypothesis at an integrated vadose zone-saturated zone site
 - Well field sufficient to sample heterogeneities and plume evolution
 - Infiltration experiments in vadose zone
 - Passive river stage experiments in capillary fringe
 - Injection experiments in saturated zone
 - Collaborative experiments with EM-20

- ▶ Modeling of different types
 - Stochastic-deterministic
 - Various multi-scale models (multi-rate, and multiple continuum)
 - STOMP as the integrative project code

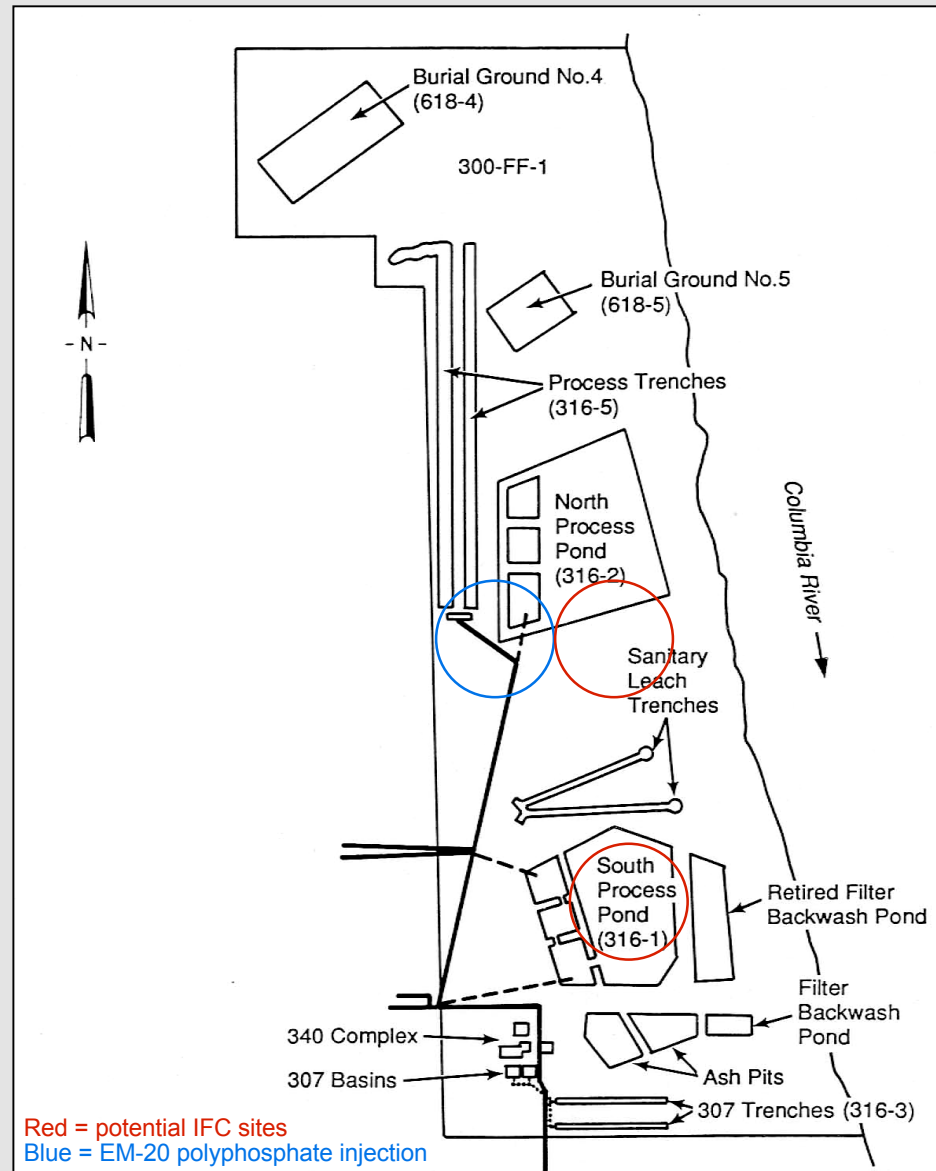
Field Site Design to Exploit Unique Site Attributes

- ▶ Variable U concentrations and speciation through vadose zone, capillary fringe, and vadose zone

- ▶ Seasonal changes in river stage
 - Groundwater composition/U(VI) distribution
 - Hydrologic gradient, porewater velocity, and flow path trajectory
 - Access to sorbed U in the deep vadose zone and capillary fringe
 - Microbial ecology of saturated and vadose zone and capillary fringe

- ▶ Extensive supporting information
 - Geologic, hydrologic, and historic data
 - Lab geochemical information (speciation, kinetics, SCM)
 - Aquifer hydrologic models
 - EM-20 tracer experiments and well field

The 300-FF-1 Operable Unit



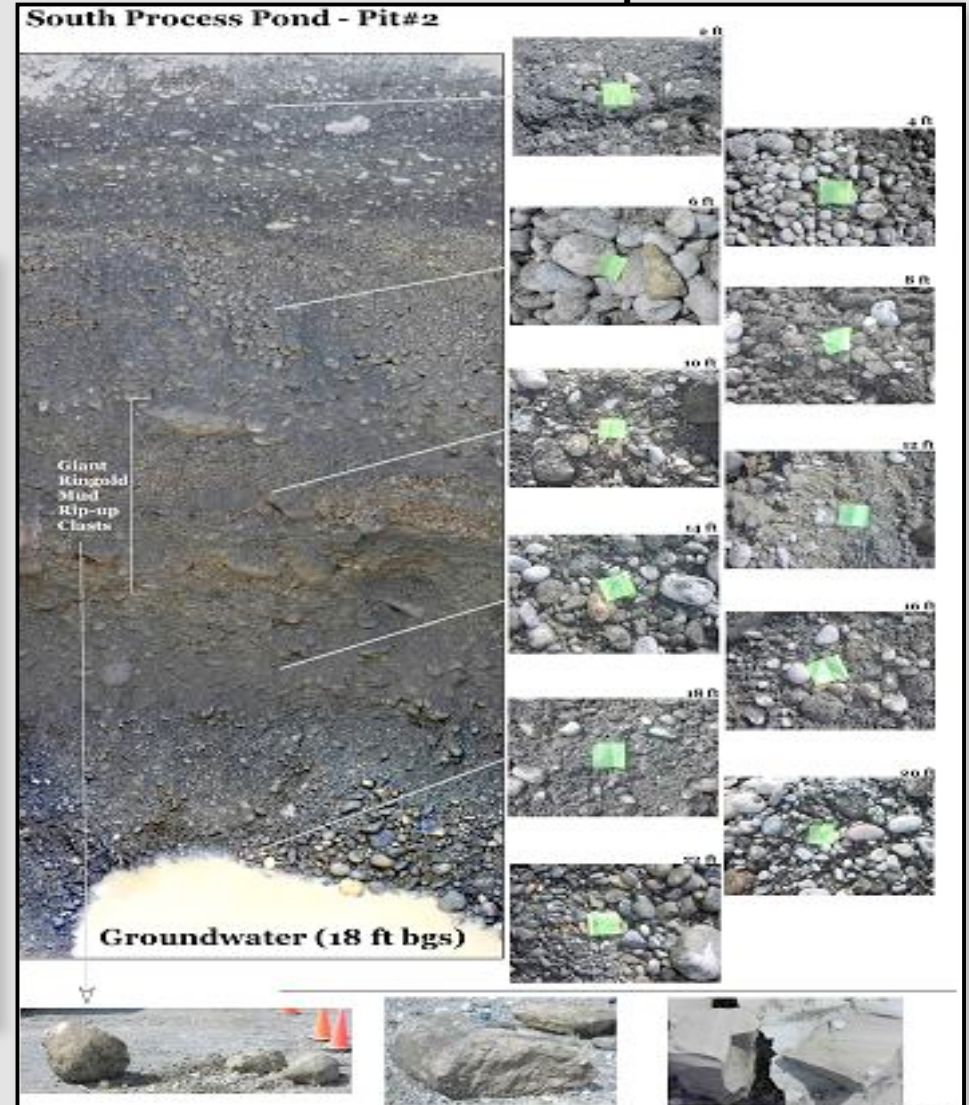
Red = potential IFC sites
Blue = EM-20 polyphosphate injection

North Process Pond and Excavation

The North Process Pond



One of Four Excavations Sampled



Example Opportunities for Collaborative Research

- ▶ In-situ adsorption/desorption experiments of various types
- ▶ Laboratory to field comparisons
- ▶ Evaluation of geophysical methods and inversion techniques
- ▶ Mass transfer processes of different types at different scales
- ▶ Microbiology of linked groundwater-river systems of low to high transmissivity
- ▶ Geologic, hydrologic, geochemical, and biogeochemical modeling of different types
- ▶ Microbiology and geochemistry of phosphate amended systems

Materials Available to External Investigators

- ▶ Historic U(VI)-contaminated source term materials (limited)
- ▶ Contaminated U(VI) vadose zone materials whose geochemical speciation and mass transfer properties have been determined (limited)
- ▶ Uncontaminated vadose zone and aquifer sediments from various locations
- ▶ Circumneutral site groundwaters with variable U(VI), HCO_3^- , and Ca concentrations
- ▶ Core materials from vadose zone and aquifer experimental plots (TBC, limited)
- ▶ Aseptic samples of vadose zone and Hanford and Ringold formation aquifer sediments (TBC, limited)

* TBC = to be collected

Anticipated Outcomes

- ▶ Outstanding, multidisciplinary collaborative effort that significantly advances science
 - Characterization, experiment design, interpretation
 - Basic underpinnings of EM-20 activities
- ▶ Enduring and accessible field experiment data sets for hypothesis and model testing
- ▶ Improved linked multi-scale mass transfer/biogeochemical models for reactive contaminants
- ▶ New conceptual understanding of mass transfer processes at different scales influencing field behavior
 - Desorption, dissolution, dissipation
 - Effective reaction kinetics
 - Contaminant immobilization

Linkage to Site Remediation, Closure and Monitored Natural Attenuation

- ▶ Operational model for infusion of DOE science into site remediation and closure decisions
 - Lab to field
 - Concept to application
 - Evaluation and testing of new models and measurement techniques

- ▶ 300 A site is representative of Hanford River Corridor locations
 - Applicability of conceptual and numeric models to other locations

- ▶ Scientific context for evaluation of remediation strategies and concepts
 - MNA versus active approaches
 - Optimization strategies
 - Expectations for remediation efficiency