Hanford 300 A IFC

Office of Science/Environmental Remediation Sciences Division (ERSD) Supported Research at Hanford: The PNNL Scientific Focus Area (SFA) and Integrated Field Research Challenge (IFRC)

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http://ifchanford.pnl.gov
http://www.pnl.gov/biology/sfa/

River & Plateau Mtg
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Environmental Remediation Sciences

William R. Wiley EMSL
Environmental Molecular Sciences Laboratory

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Environmental Remediation Sciences Division (ERSD)

- Located within Office of Biologic and Environmental Research (OBER) in the Office of Science.
- Focus on fundamental environmental science, fate and transport primarily (i.e., EMSP).
- Seek positive impact on clean-up progress through knowledge generation, process understanding, and advanced measurement/analysis techniques.
- Steward of PNNL's Environmental Molecular Sciences Lab (EMSL) a user facility with budget > $25M.
- Traditional emphasis on environmental microbiology (e.g., NABIR).
- Primary product is peer reviewed publication and scientific insights to solve cleanup challenges.

Hanford Inspired, ERSD Funded Environmental Research at PNNL

	Scientific Focus Area	Integrated Field Research Challenge
Contact	www.pnl.gov/biology/sfa	www.ifchanford.pnl.gov
Funding	6.5M	3.0M
Science Theme	Role of microenvironments and transition zones on U, Tc, and Pu fate & transport	Influence of multi-scale mass transfer on U persistence and migration in groundwater
Scope	Lab based with model systems and Hanford samples. Some use of IFRC and other sites as field laboratories. Strong emphasis on biogeochemistry, coupled reactive transport processes, and molecular-microscopic-macro-scopic interactions	Field-based with emphasis on i.) large scale processes and inter-actions controlling U concentrations in groundwater, ii.) characterizing controlling factors and their variation, iii.) field experiments of different type, and iv.) geostatistical and reactive transport models
Internal Investigators	12	7
External Collaborators	11	7
Origin	Reprogramming of competitively awarded ERSD projects in FY08	FY07 award in response to ERSD competitive proposal solicitation

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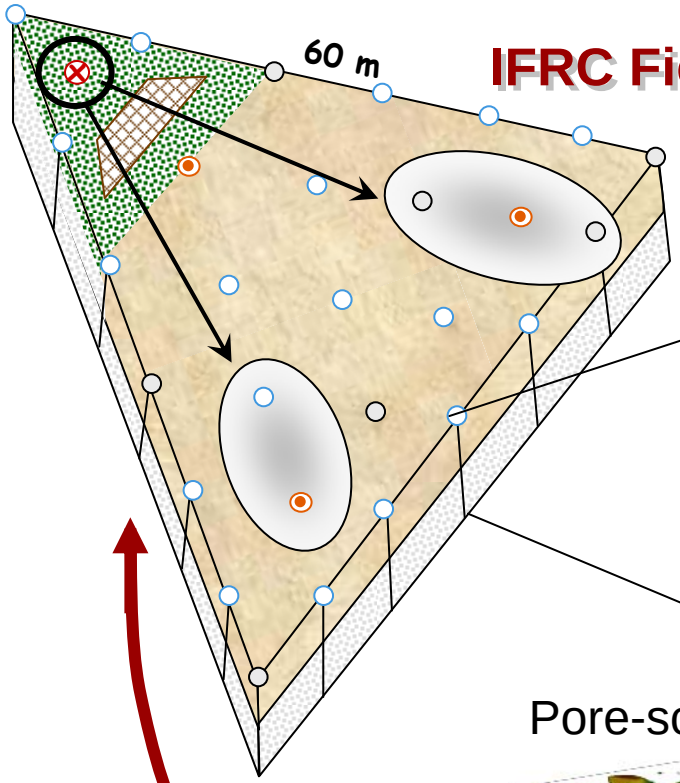
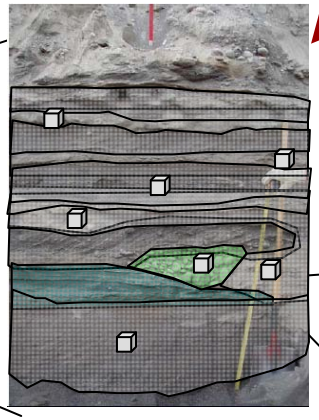
PNNL ERSD Research



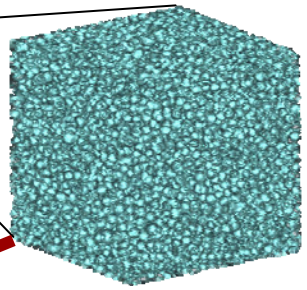
IFRC Field Experiments

(Geophysical, geological, and geostatistical characterization – SFA and IFRC)

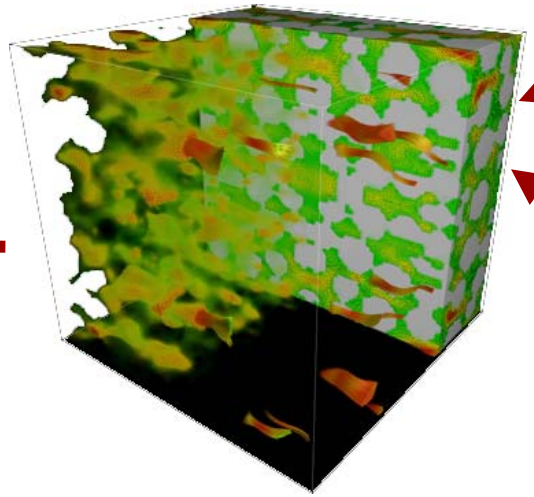
Facies-scale geometry



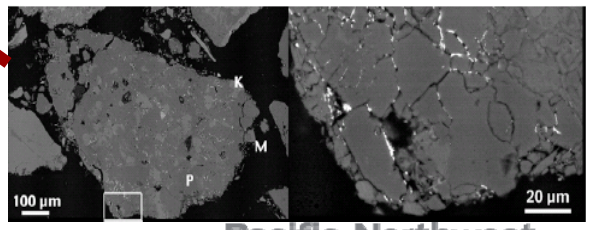
Pore-scale characterization



Pore-scale simulations



SFA Molecular and Pore-Scale Process Research



Upscaled models and parameters

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Scientific Focus Area (SFA) Concept

- Independent, competitively awarded projects (12), reformulated to be collaborative and to address a focused suite of state-of-science issues across different spatial and time scales.
- Guidance provided by BER/ERSD on SFA scope and unique expertise areas.
- Hanford-inspired science theme (microenvironments and transition zones), research topics, and contaminants.
- Close alignment with Hanford 300 Area Integrated Field Research Challenge, use of EMSL and other unique DOE capabilities.
- Team includes those with detailed knowledge of Hanford science issues (over 40 publications with Hanford Site impact).
- Concept allows PNNL to manage research team for maximum collaboration and synergistic impact – funding allocations made by PNNL science PI.
- Research to be sufficiently fundamental for application to other DOE contaminated sites and environmental problems.

SFA Contaminant Emphasis – Hanford Drivers

- Risk drivers on the Hanford site:
  - U, ^{99}Tc, ^{129}I, Cr, and CCl_4 – environmental mobility and persistence
  - $^{239,240,241}Pu$, ^{137}Cs, and ^{90}Sr – lower mobility but high radioactive toxicity

- Initial SFA research focused on U, ^{99}Tc, and Pu
  - Polyvalency with complex biogeochemistry
  - Past releases to soil
    - U = 202,703 kg, ^{99}Tc at 1390 Ci, and Pu at 400 kg
  - Long term concerns and scientific issues
  - Important science opportunities

[Cr investigated by LBNL-SFA; collaborative studies with PNNL SFA on CCl_4 mineral transformations supported by BES]

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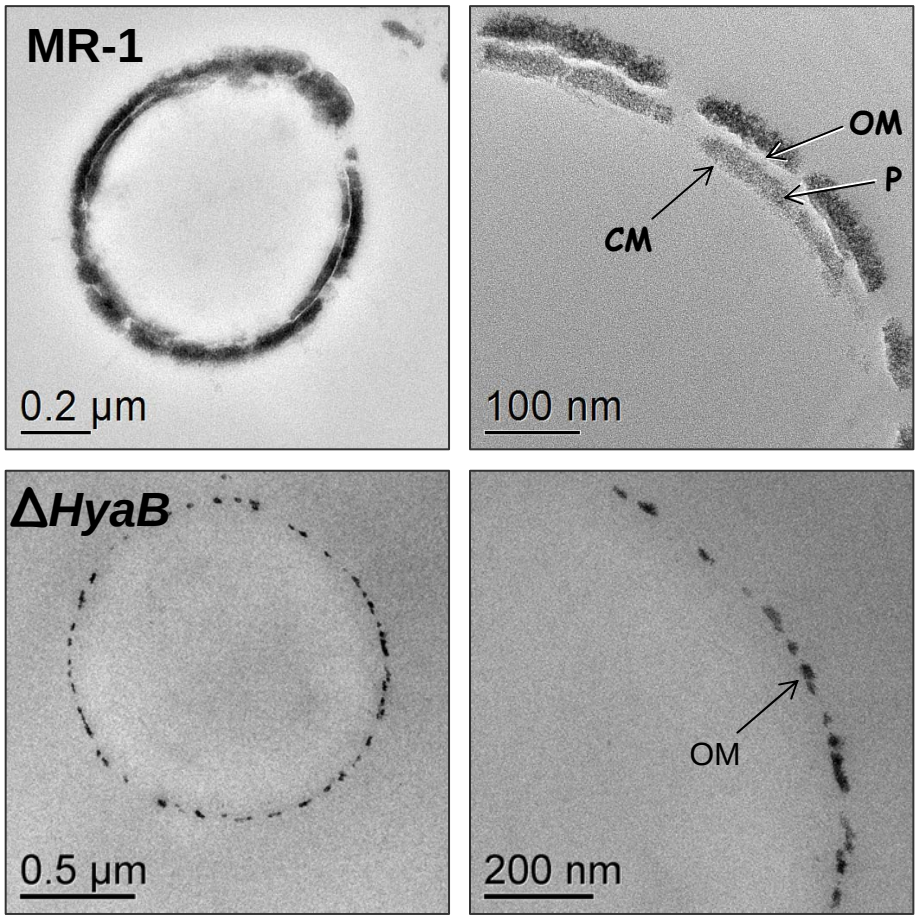
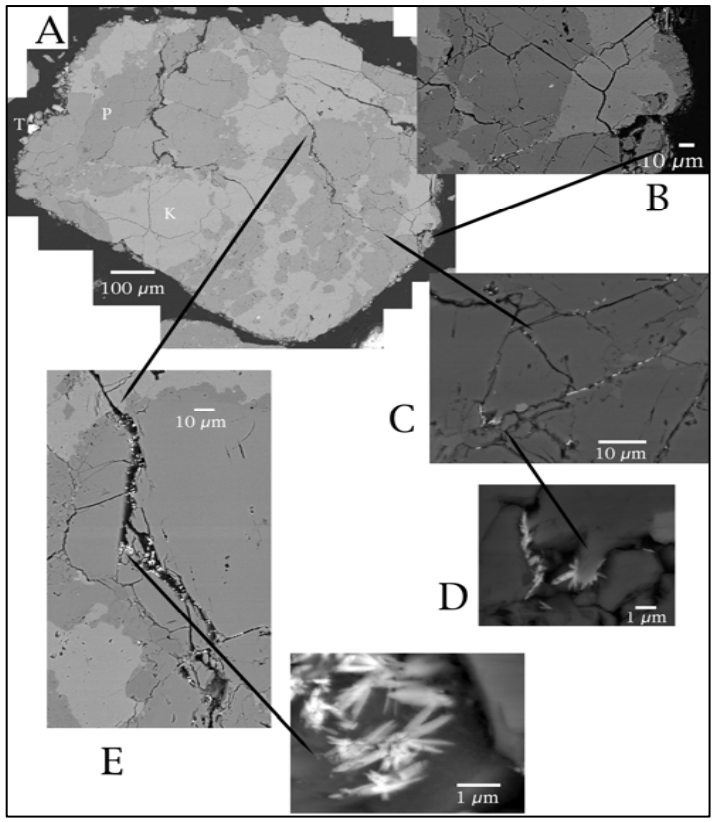
Microenvironments – Disproportionate Influence on Chemistry

Biogenic TcO_2



(Marshall et al. 2008, Environ. Microbiol.)

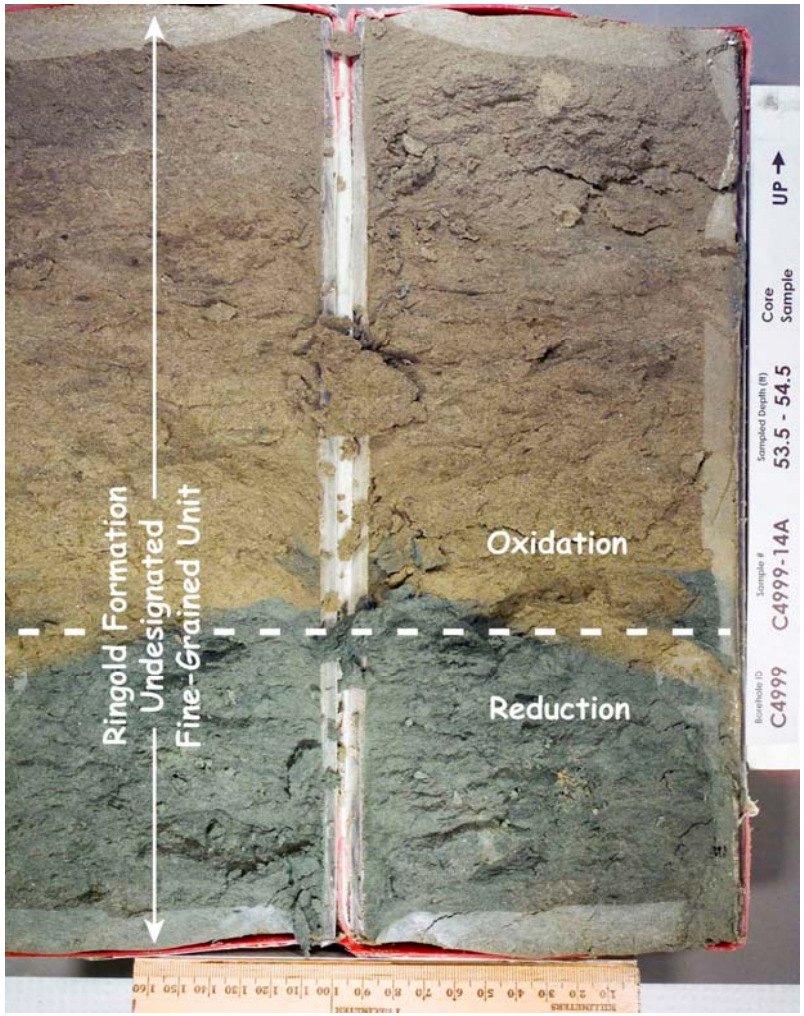
Intragrain U(VI) Precipitates



(McKinley et al. 2006, GCA)

Transition Zones – Exhibit Chem-Phys-Bio Changes Over Short Distances

Ringold Formation Redox Boundary



Columbia River Hyporheic Zone

(Moser et al. 2003, ES&T)

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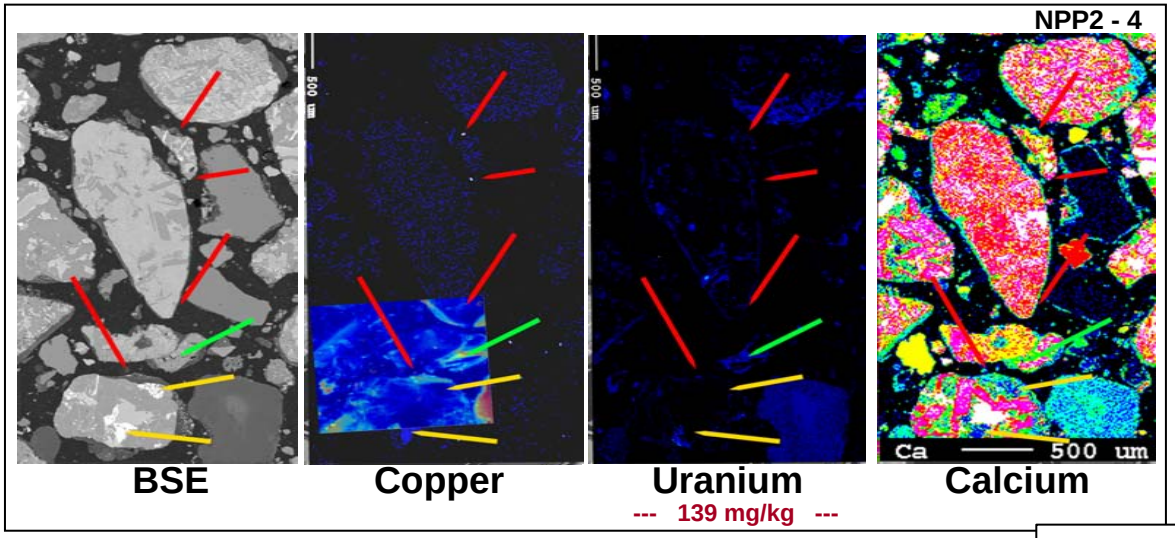
Microscopic Speciation Controls Macroscopic Release Behavior of U

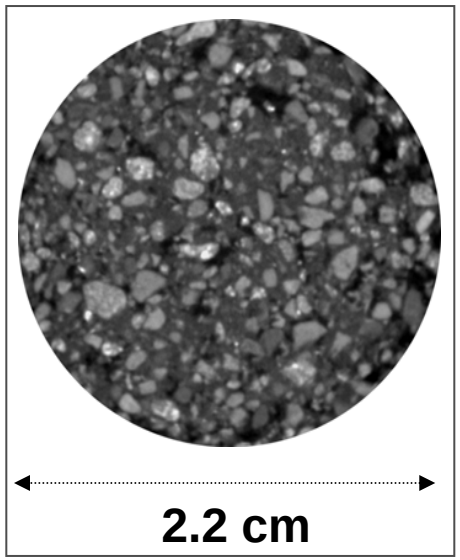
Metatorbernite (uranyl copper phosphate) in 300 A grain coatings

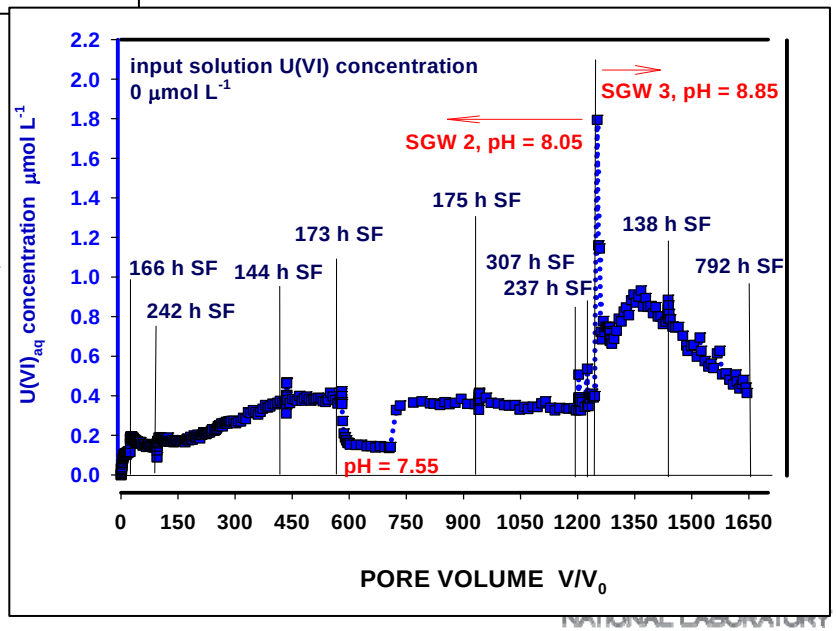


- Speciation model developed from EXAFS, S-XRD, and TEM/EPM
- Thermodynamic and kinetic model developed from studies of pure phase metatorbernite
- Column study integrates multiple pore-scale processes; provides data to evaluate whether metatorbernite controls solution concentrations from waste-impacted sediments

Column study to investigate mass-transfer controlled dissolution

(Catalano et al. 2006, Arai et al. 2007, Zachara et al. 2008)





Example SFA Research Topics FY09 - FY10

- Microbiology of 300 A unconfined aquifer.
- Biogeochemistry of 300 A microbial isolates toward Tc and U under microaerophilic conditions.
- Redox geochemistry of ^{99}Tc in 200 A and 300 A Ringold Formation sediments.
- Intragrain microscopic transport processes of U and Tc in different Hanford sediment facies.
- Reactive transport behavior and models of contaminant U in intact IFRC sediment cores.
- Pu molecular speciation and mobilization reactions in sediments beneath Z cribs.
- Pore scale and continuum reactive transport models.

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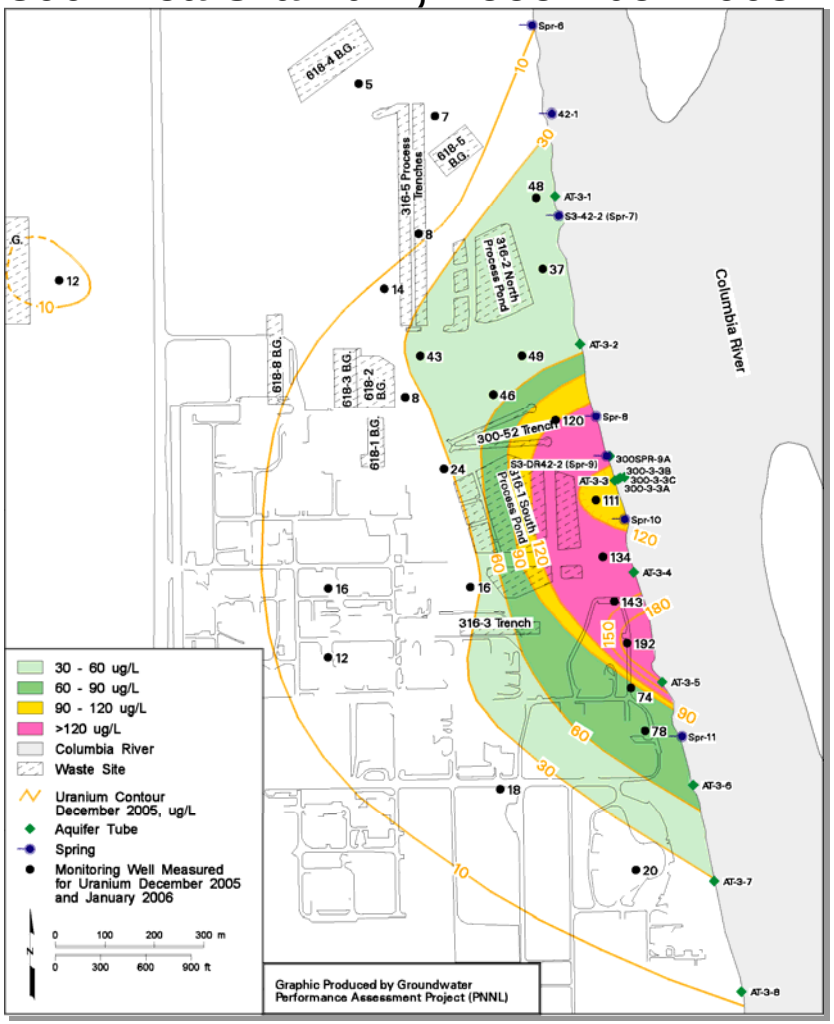
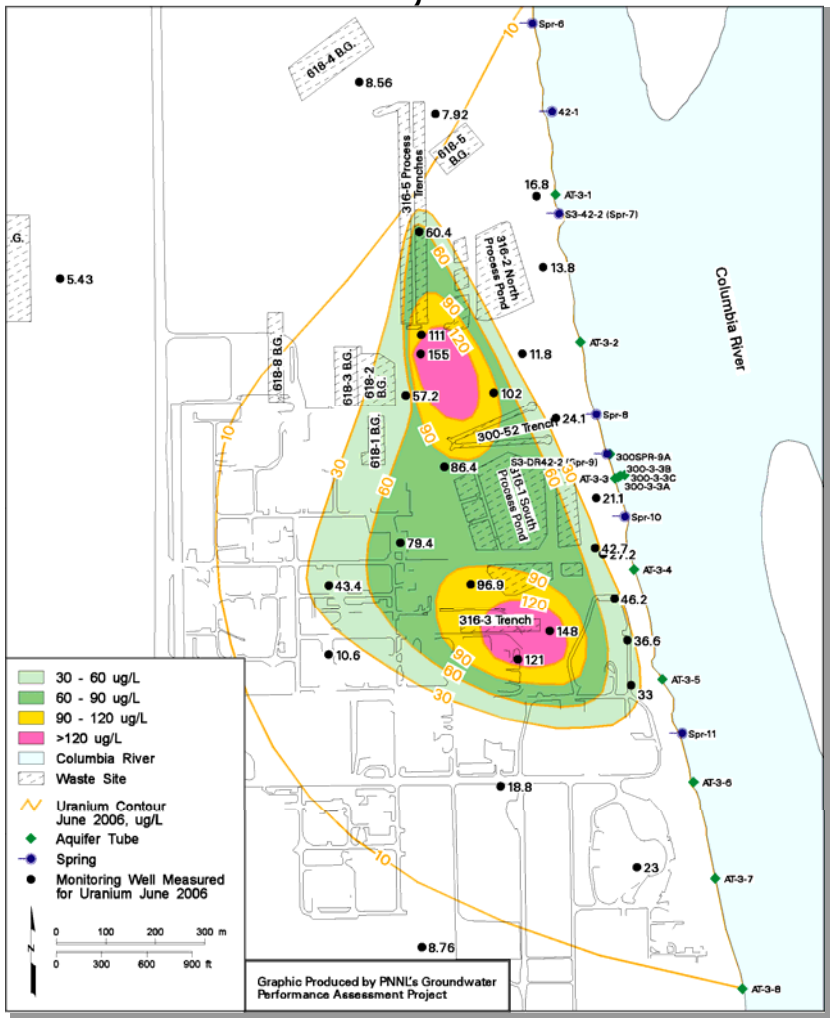
Seasonal Dynamics of 300 A Uranium Plume

300 Area Uranium, December 2005



300 Area Uranium, June 2006



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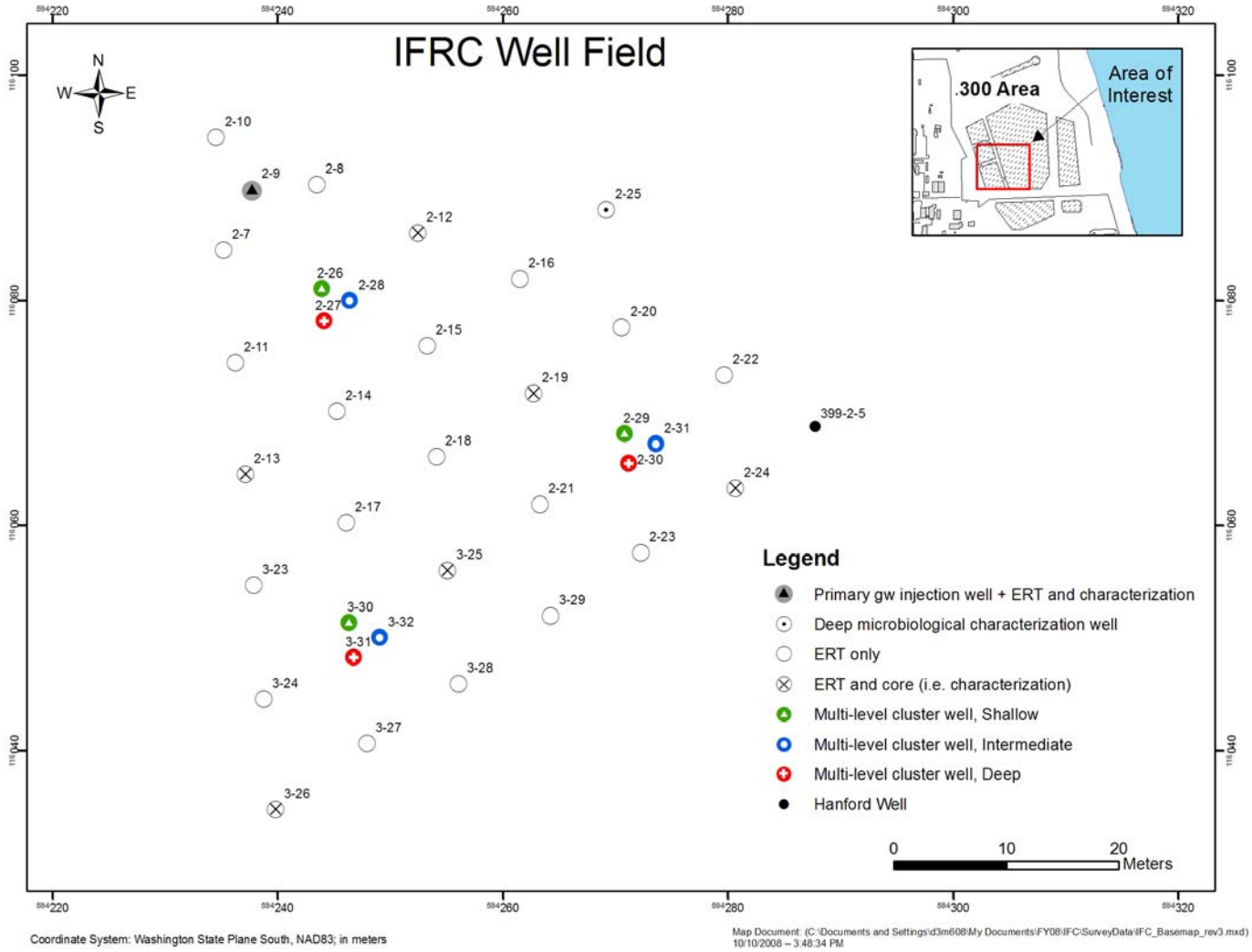
Hanford Integrated Field Research Challenge Site



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Hanford Integrated Field Research Challenge Science Theme

Multiscale mass transfer processes influencing sorbed contaminant migration

- Mass transfer is controlled by diffusion, and is influenced by the path length, tortuosity, thickness, and surface charge of immobile, water-filled pore space.
- It controls contaminant release at the particle scale from intragrain domains to porewater, and at the aquifer scale from fine-textured to coarse-textured aquifer facies.
- Kinetic behavior results, as well as long-term contaminant resupply after remedial activities.

<u>Associated Practical Issues</u>

1. Accurate projection of dissipation times for groundwater plumes
2. Optimal delivery of remediation reactants
3. Effectiveness of remediation

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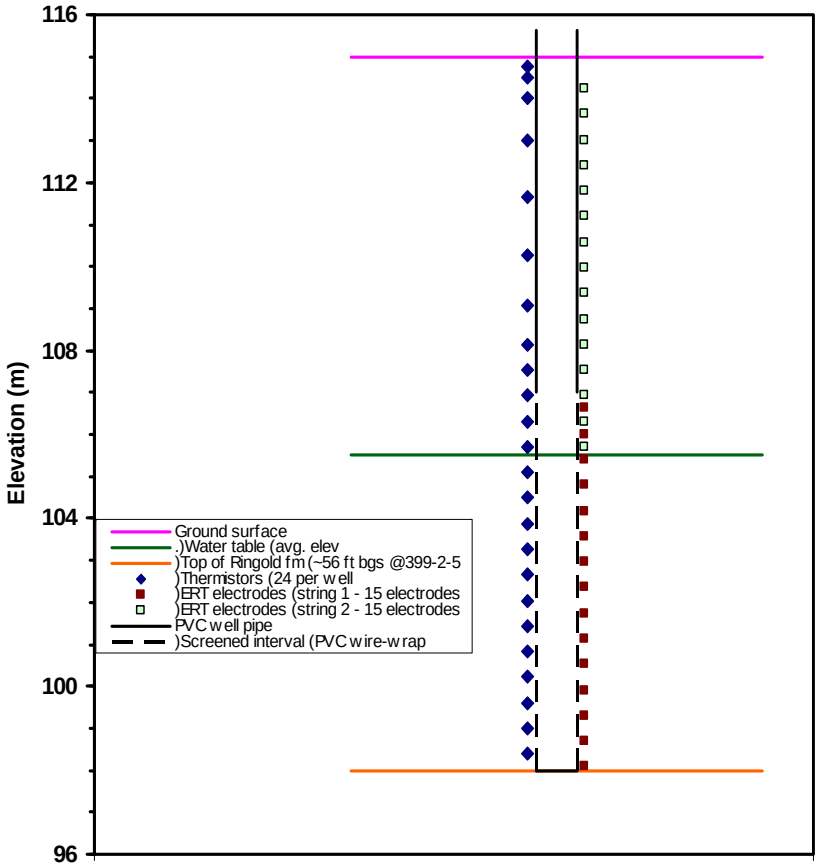
Schematic of ERT / Monitoring Wells



- Electrodes spaced at 60 cm (2 ft)
- Electrode length approx 10 cm (4 in)
- Electrode material 316 stainless steel
- Single wire connections to electrodes
- Wires run on outside of PVC well pipe
- Thermistors placed between electrodes
- Wire wrap PVC from 106-98 m elevation
- Tube capped at bottom
- Well head ~0.6 m (2 ft) above ground
- Central connector/DAQ box at top of wellhead
- Heat dissipation unit (HDU), time- domain reflectrometry (TDR) probe and porous cup solution sampler at multiple depths on 5 wells around infiltration site

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Field Electrode Measurements and Aqueous Sampling

Field Laboratory

Data Logging

Selected-Well Flow Cell Measurements

Continuous In-Well Electrode Readings *(Multi per well)*

Continuous Overpack Electrode Readings *(Multi per well)*

Flow Cell

Adaptive, Redundant, accessible measurements during experimentation

Consecutive Well-by-Well *EC, T, pH, Rhodamine, O2, ORP*

WASTE

Sampling Valve

Switching Valve

Overpack Electrode Signal

In-Well Electrode Signal

Well Array

Aqueous Samples

Cations, Anions, DIC, U, Specific Isotopes, etc..

Pumped Groundwater Samples

Electrode Array *EC, T, pH, Br⁻*

PUMP

Well Screen Overpack *EC, T, Samplers*

Well Instrumentation

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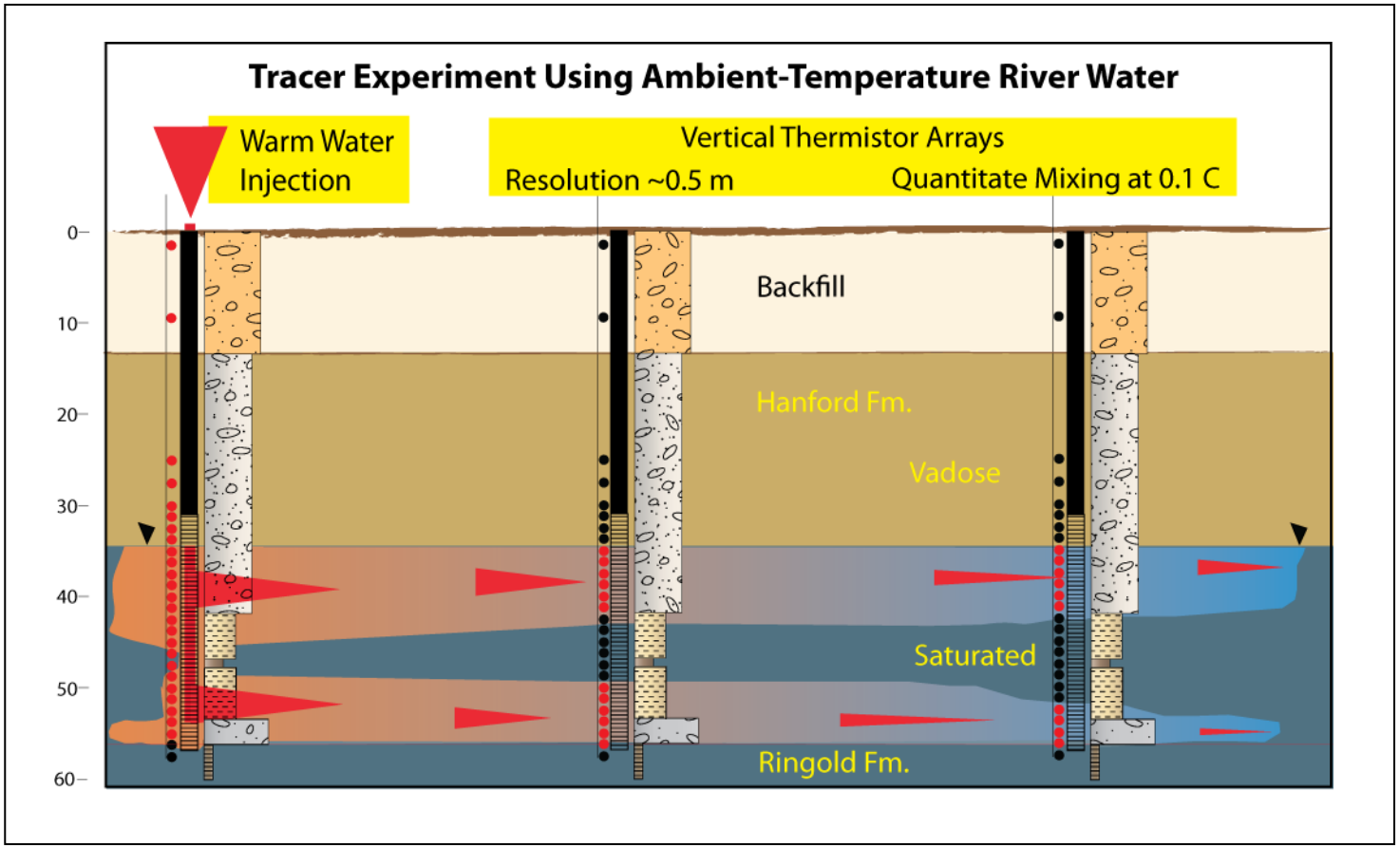
Defining Heterogeneities in Hydrologic Properties and Flow



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IFRC Experiments

- U(VI) concentration dynamics within the groundwater plume
  - Scale–dependent mass transfer involved in forward (adsorption), backward (desorption), and steady-state (isotopic exchange) reaction processes in flow paths with different trajectories and residence times
    - Injection experiments with varying HCO_3 and U(VI) concentrations, and U(VI) isotopic ratios
    - Passive experiments follow vadose zone pulses, or inland river water – groundwater gradients
- U(VI) fluxes from the vadose zone
  - Scale-dependent mass transfer, geochemical kinetics (adsorption/desorption) and water pathway effects on U(VI) fluxes to groundwater
    - Infiltration experiments with varying water application rates, volumes, and composition (pH, HCO_3, Na/Ca)
    - Passive experiments to explore rising and falling water table effects on U(VI) solubilization and release from lower vadose zone
- Optimized and sustained remediation strategies
  - Evaluate role of mass transfer and microbiological processes on different forms of phosphate used to precipitate and immobilize U
    - Injection experiments with polyphosphate, Ca-citrate/PO_4^{3-}, organic P with HCO_3
    - In collaboration with EM-20 and team

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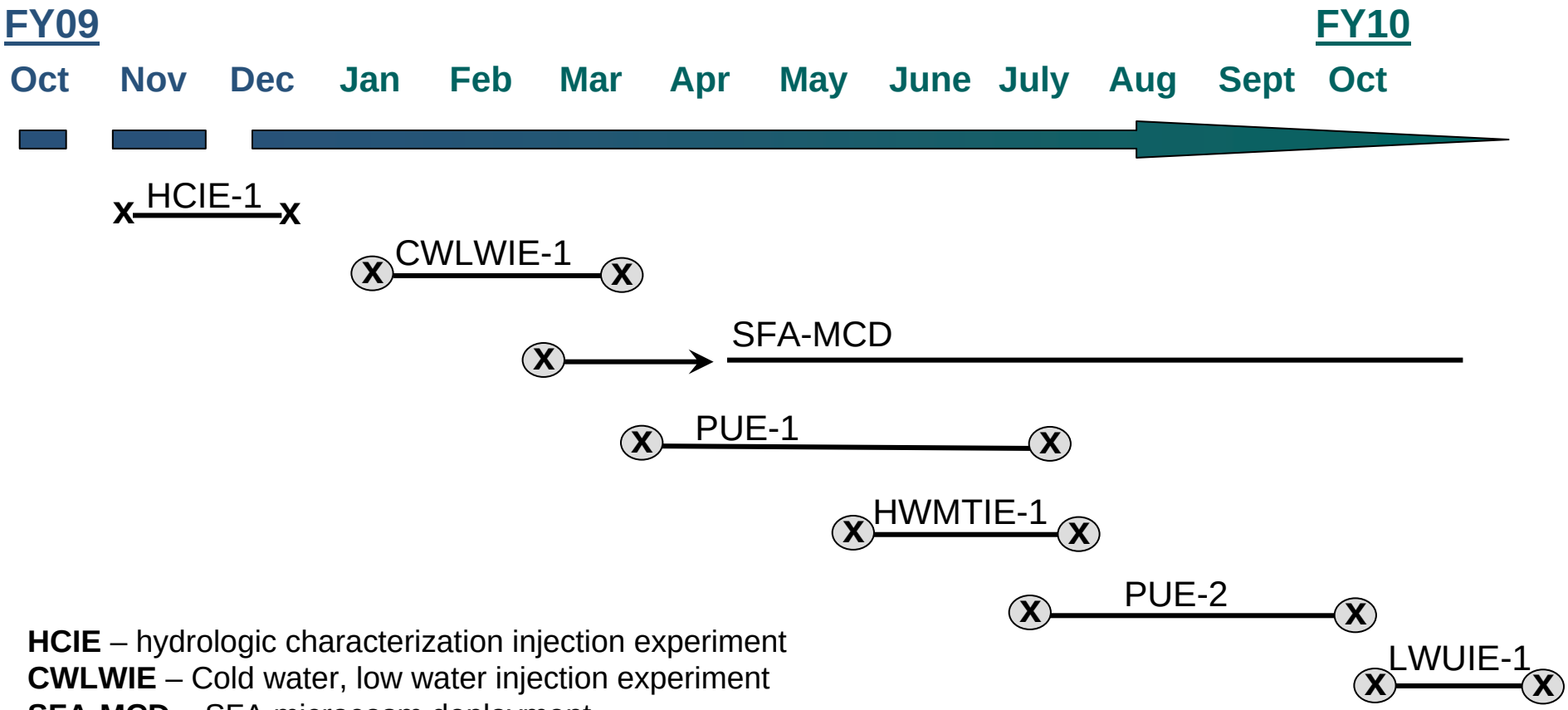
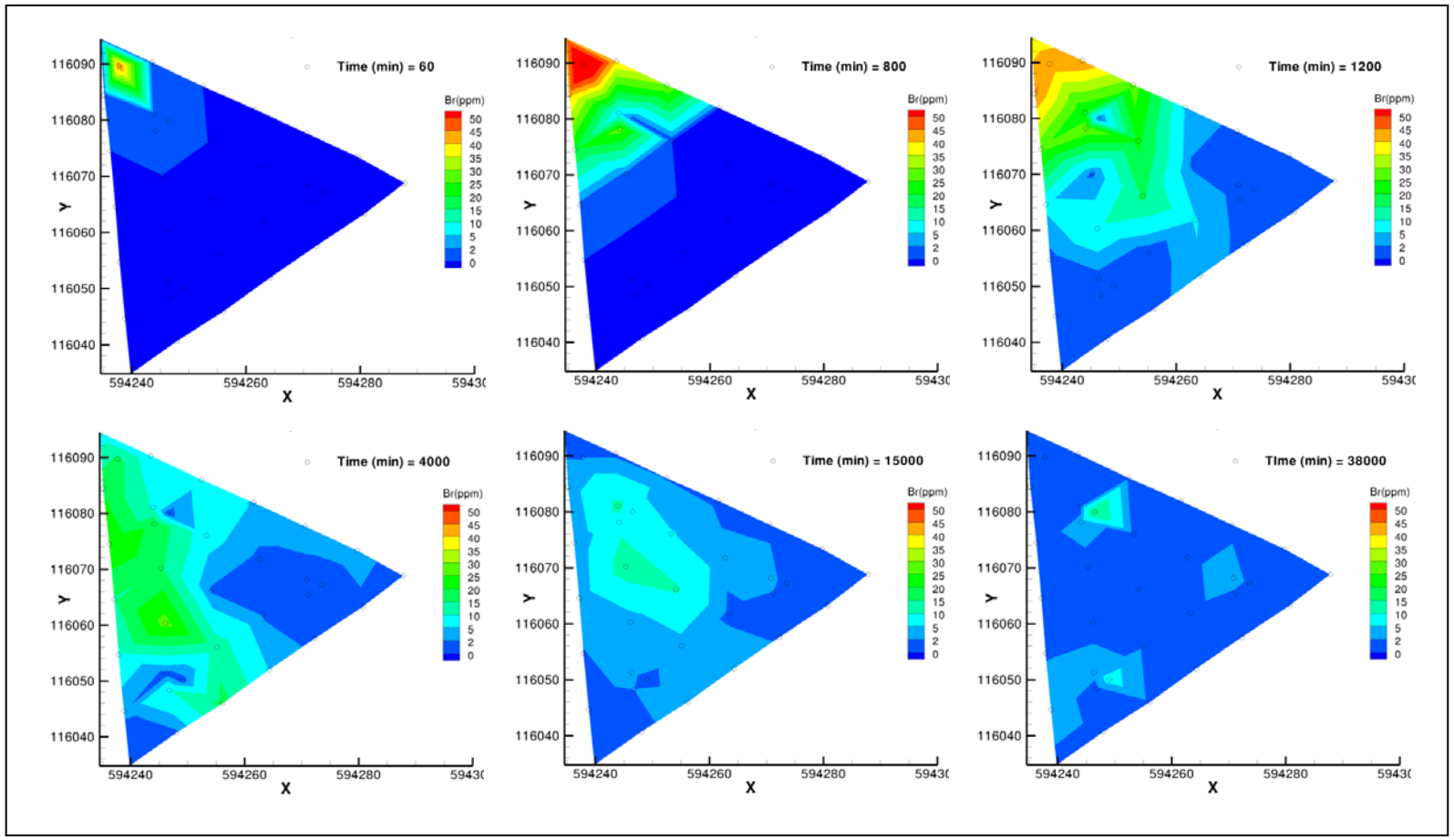
Hanford IFRC Preliminary Field Experimental Plan for FY09



HCIE – hydrologic characterization injection experiment
CWLWIE – Cold water, low water injection experiment
SFA-MCD – SFA microcosm deployment
PUE – Passive uranium experiment
HWMTIE – High water multi-tracer injection experiment
LWUIE – Low water uranium injection experiment

Results of November 2008 Tracer Test for Hydrologic Characterization



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Linkage of SFA/IFRC Research to Site Remediation, Closure, and Monitored Natural Attenuation

- Operational model for infusion of DOE science into site remediation and closure decisions
  - In-ground contaminant status and behavior
  - Understanding of processes and specific sites
  - Evaluation and testing of new models and measurements techniques
  - Knowledge to reduce uncertainty
  - Websites updated every 6 mo. to identify key findings and new publications
- 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
  - Critical characterization needs
  - MNA versus active approaches
  - Expectations for long-term remediation efficiency

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Summary

- ERSD has invested significant research funding at PNNL to investigate "Hanford inspired" fundamental environmental science issues associated with contaminant fate and mobility, environmental microbiology, and advanced subsurface characterization and modeling.
- SFA and IFRC research projects are independent, but are closely linked and synergistic. Both are bringing international scientific expertise to Hanford.
- Scientific targets have been selected for research that are consistent with ERSD's Strategic Plan and that will yield useful knowledge to forecast contaminant migration and transformation at the Hanford site.
- ERSD seeks impact from the research funding in ways consistent with the Office of Science mission. Meaningful collaborations with EM are sought.