Saturated Zone Injection Array

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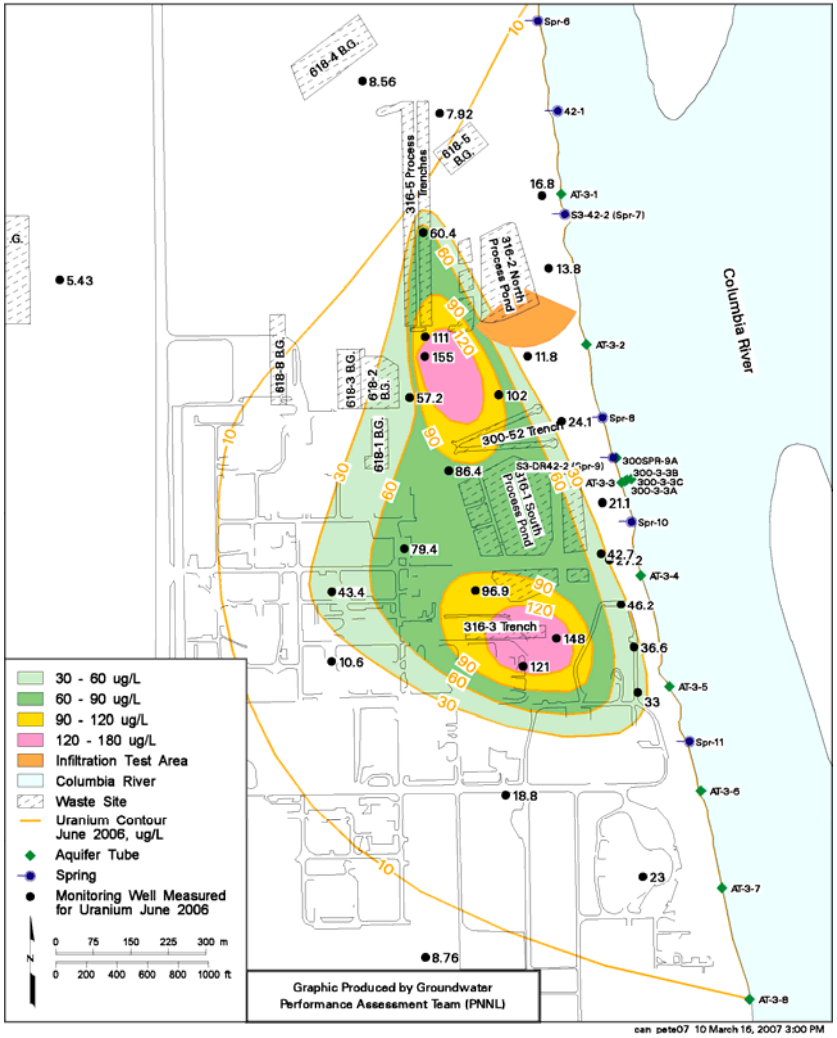
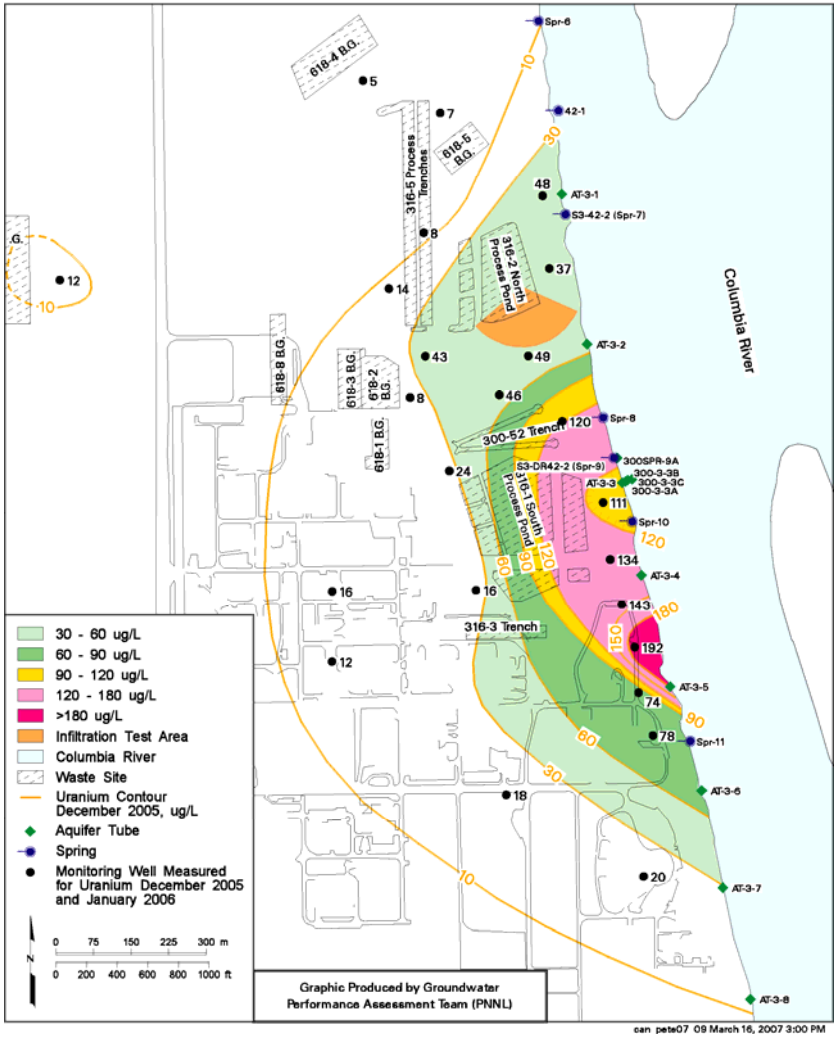
Uranium Plume Winter and Spring

300 Area Uranium, June 2006



300 Area Uranium, December 2005



The Injection Array and Experiments

Saturated zone injection site and well array

Radial well array that links with infiltration plot

Continuous monitoring of key variables

Interrogate multiple flowpaths/directions

Experiments

Vary HCO_3 to promote desorption

Vary $[U(VI)]_T$ to evaluate adsorption

$^{233}U(VI)$ to evaluate mass transfer w/o reaction

Necessary Supporting Information

Lithologic characterizations

Variability of U concentrations, spatially and v. lithology

In situ aqueous phase composition

A Saturated Zone Experiment

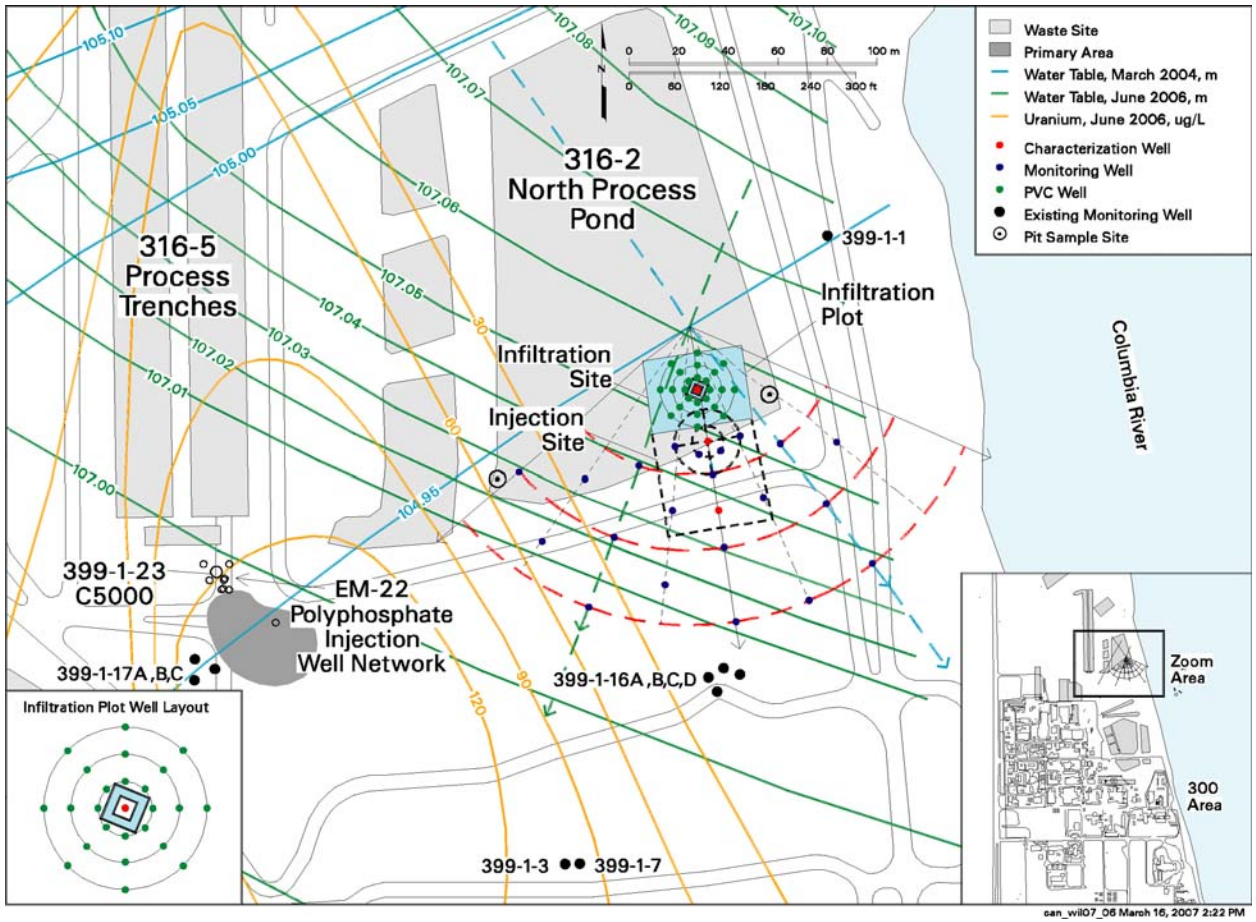
- **Natural Gradient Transport**
  - River or groundwater derived solutes injected
    - Stimulate desorption (carbonate solution)
    - Stimulate adsorption (high U with lower carbonate)
    - Isotope dilution using ^{233}U (not present in contaminant plume)
  - With non-reactive tracers (e.g., Br^-)
  - Injected over 1.5 m depth in the aquifer
  - Proceed until steady state concentration observed in 1st tier of observation wells
  - Cease injection; monitor elution
  - Monitor evolution of tracer and reactants downgradient 10 - 20 m (strive for mass balance of non-tracers)
  - 2- 40 day per field experiment
  - Along two+ flow paths determined by gradient variation
  - Parameterized by laboratory columns and characterization of field samples
- **Observation Wells**
  - Intensive U(VI) sample screening (250 aqueous samples)
  - In-plume analyses for cations, anions, DIC, DOC, pH

Characterization Details and Questions

"Rigorous site characterization essential;
physical, chemical, microbiological heterogeneity is extreme"

- Layout: Location, well density and spacing
- Aqueous sampling strategy/analytes
  - Solute, isotopes, etc., beyond U-cations-anions-carbon-pH
- Physical metering and metering density
  - Temperature, stage, gw level, velocity
- Geophysics: needs for linkage to characterization
- Solid-phase
  - Microscale, macroscale, chemical, physical for linkage to transport
- Microbiology
  - Sampling scale, scope of effort, link to EM polyphosphate
- Specific linkage to data from other projects
  - Geophysics, Groundwater, logging

The Injection Array



Seasonal variation in

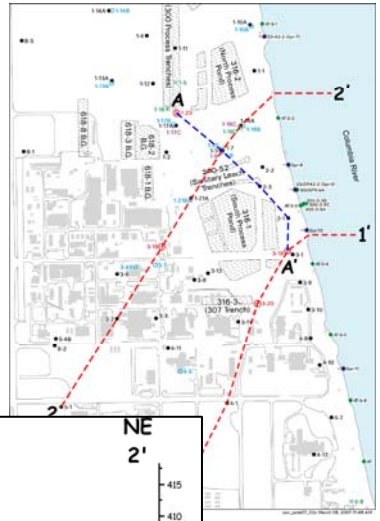
- flow direction (not well characterized; semiannual sampling)

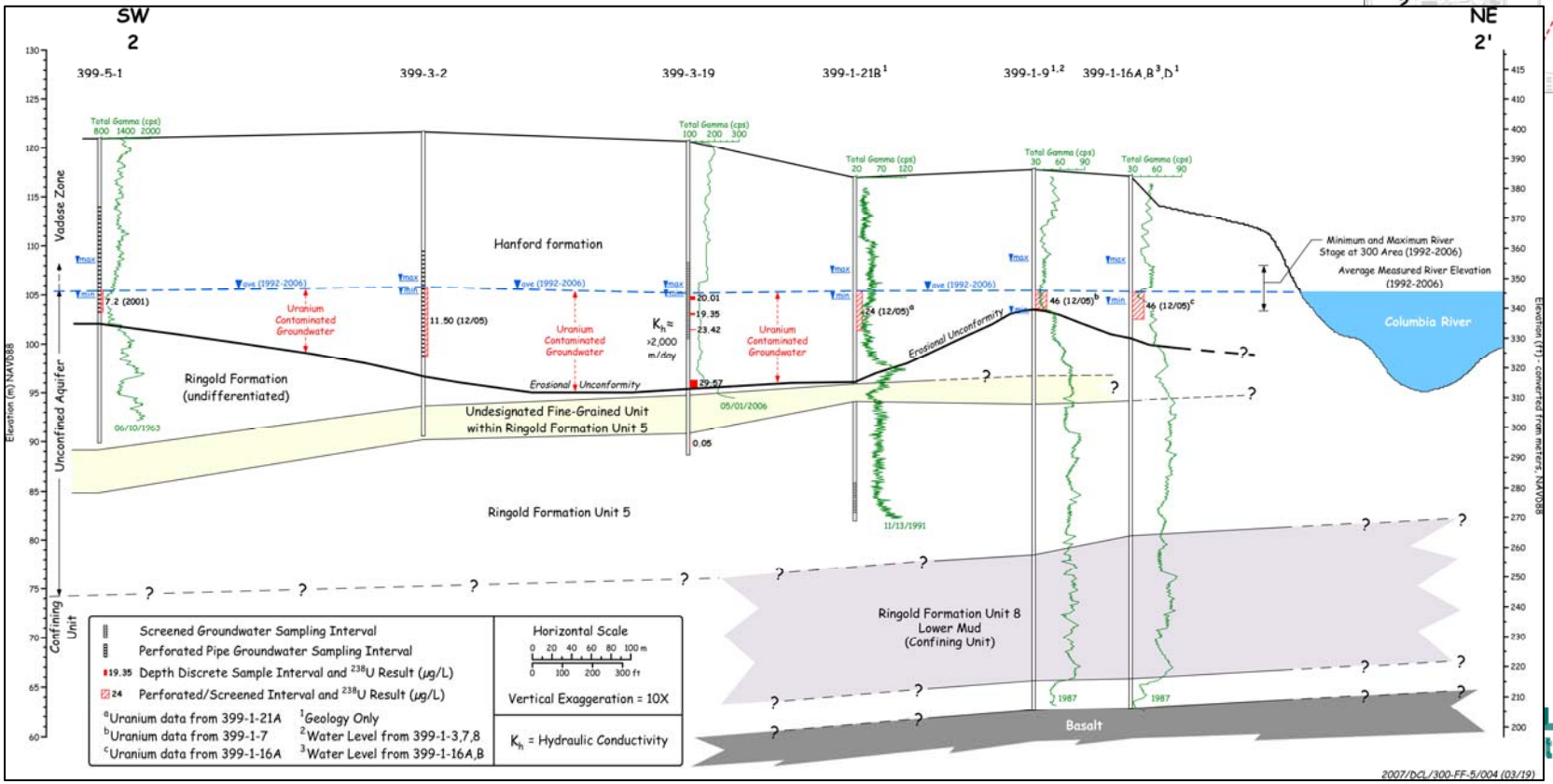
Array includes

- 3 Characterization Wells
- 21 observation wells

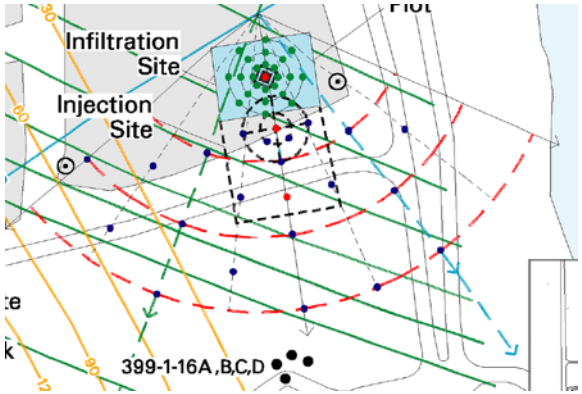
Characterization Wells

- 120’ deep, 6” diam, 35’ w.t., 15 - 20’ screen, pump installed at completion
- Address needs for transport experimentation
  - Stratigraphic Characterization
  - Geochemical characterization
  - Aquifer sampling





Characterization Wells



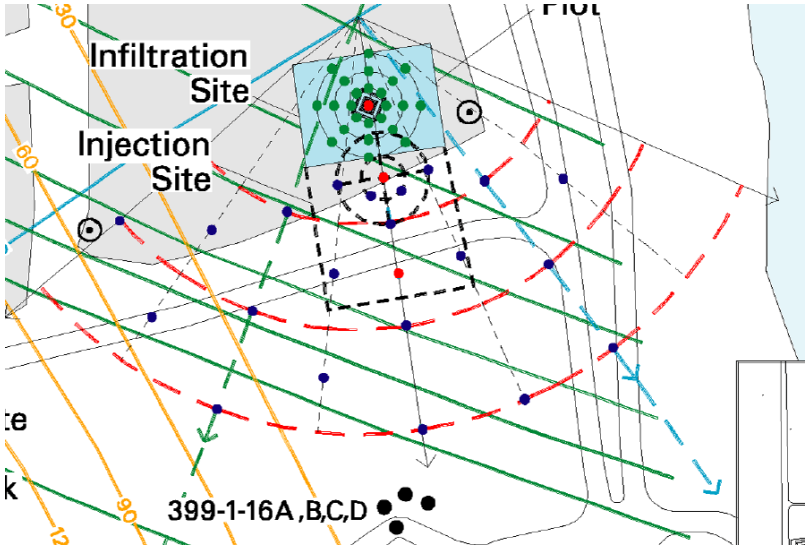
- Infiltration Site
  - Continuously cored to bottom
- Injection Array
  - Drilled to water table, continuously cored to depth

- Characterization: lithology, U concentration, fines mineralogy…
  - Permit correlation with geophysical measurements for 3D stratigraphy
  - Establish well-defined basis for hydrologic measurements and modelling
  - Saturated sediment concentration of U is unknown
  - Estimate of lateral variation in geochemical properties
  - Microbiological characterization; little understood

Microbiology

- **Limited Characterization to Date**
  - Near-shore samples from pit excavations
    - Glucose, N, P amendment: Fe(III) reduction rapid after 4 month incubation
      - Small indigenous population that responds slowly to biostimulation, then active
  - Three boreholes at 100N
    - PCR of *Bacteria* showed 10^5 - 10^7 cell equiv. g^{-1}
  - Direct injection of glycerol-polylactate compound at 100 H
    - $<10^5$ to 10^7 cells ml^{-1} after 2 weeks, decrease in Cr(VI)
  - Recent near-shore sampling showed widespread presence of *Shewanella*
- **Scientific Questions**
  - Effect of microbial activity on U mobility unknown
  - Effect on microbial community of injected phosphate unknown; stimulation (P limited) or no effect (e^- donor limited)?
  - Role of microbial community in stability of polyphosphate-induced autunite unknown.

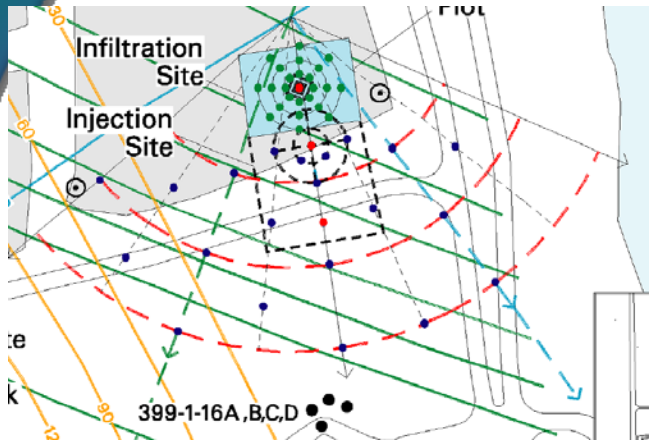
Observation Wells



- Radially downgradient from infiltration gallery
- 55’ deep, 2 - 4” diam., 35’ w.t., 5 - 20’ screen, pump installed at completion

•Address needs for transport experimentation
  •Monitor tracer and injection cloud migration

Observation Wells
Grab Samples



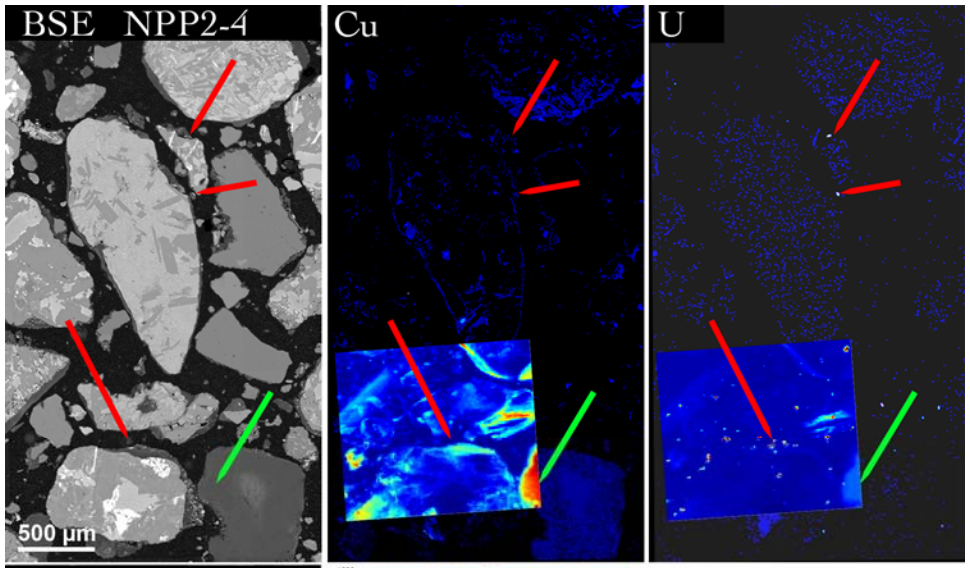
Characterization of samples collected during drilling to provide needed information regarding *in situ* geochemical properties

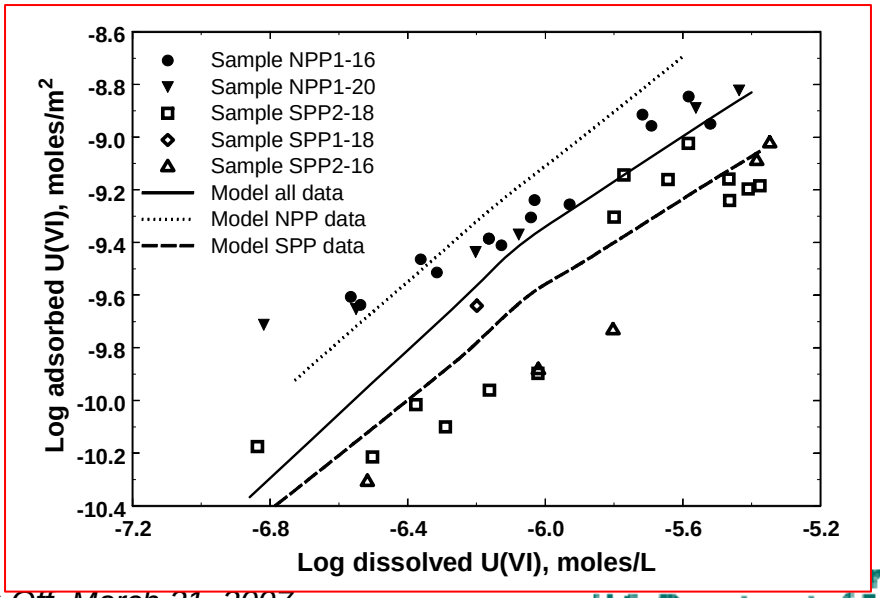
- Stratigraphic relationships across field site
- Vertical distribution of sediment U
- Lateral distribution of sediment U v. sediment texture
- *Direct estimate of K_D for in situ system derived from aquifer-level measurements*
- Tool for geophysical interpretations?

Unresolved

- Sample depths (vadose and saturated)
- Depth spacing (2', 5', etc.)
- Pore water expression or post-drilling pump/bail?

How is U Partitioned in the Saturated Zone?





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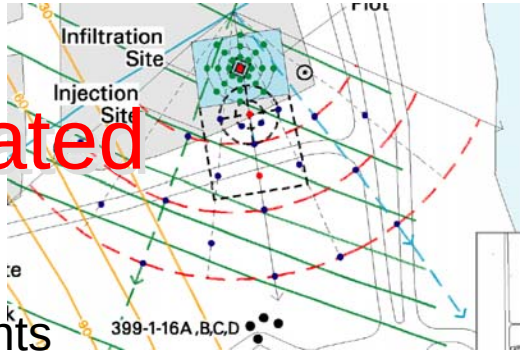
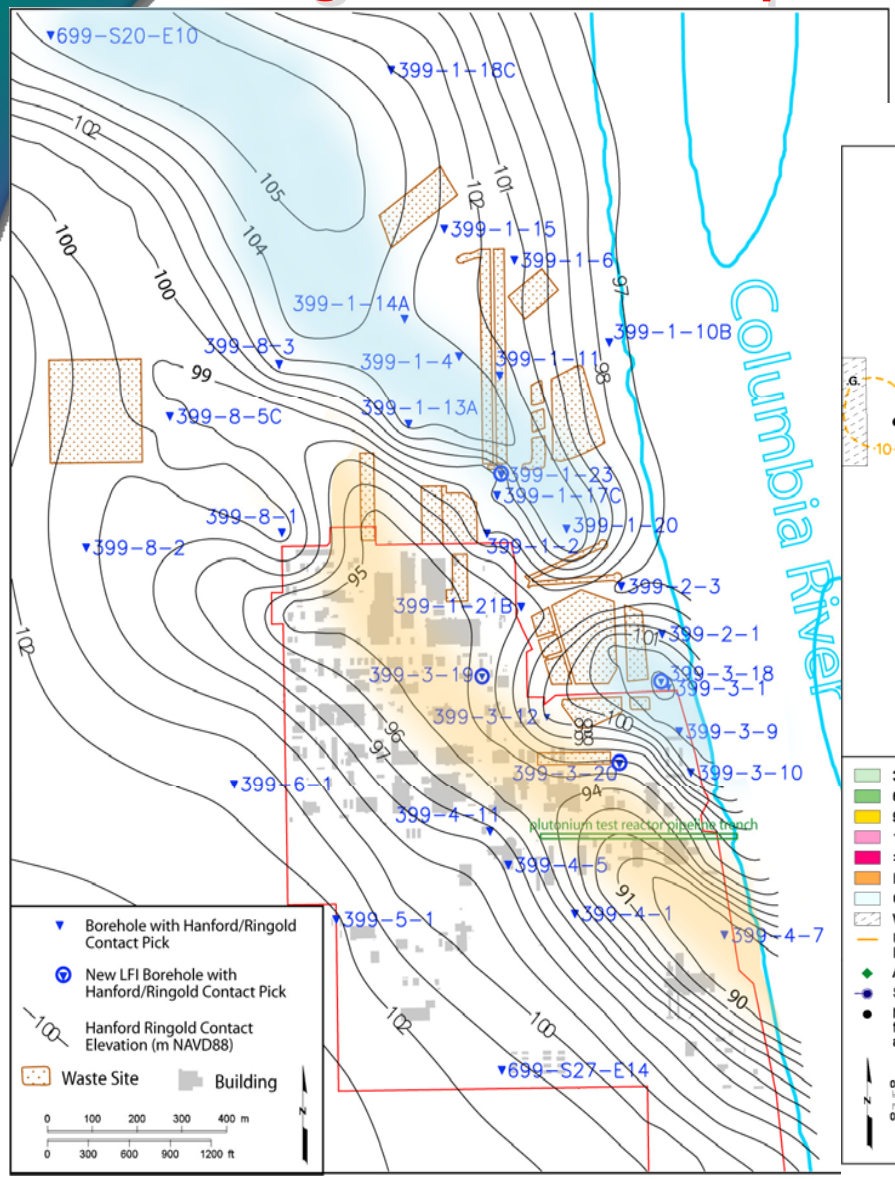


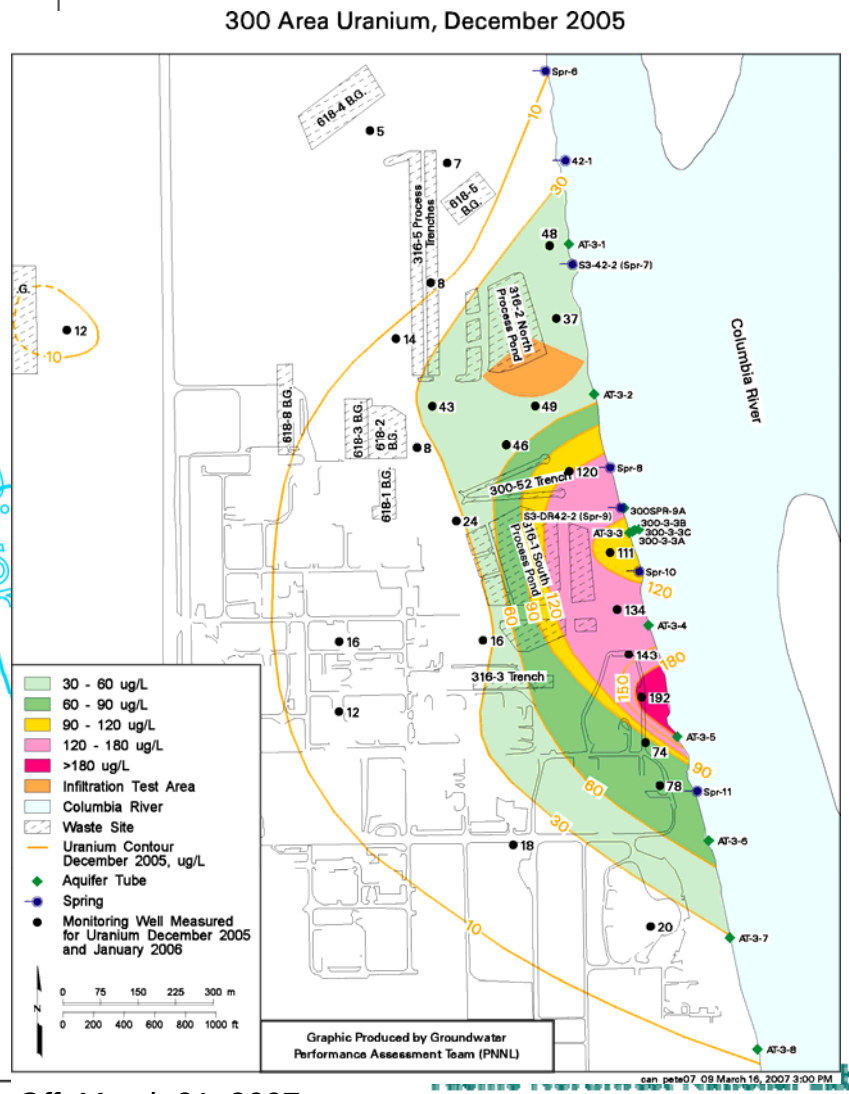
- Model based on desorption from contaminated sediments
- Experimentation with uncontaminated sediments underway
- Which is representative of the saturated subsurface?
  - Is U strongly retained by fines in the saturated zone; slow desorption affects mobility?
- What is the applicable K_D for the field site?
  - Does it vary laterally?
- Address by collecting field samples
  - Deepest samples at Observation Wells
  - Sediment and associated groundwater
  - Extraction of sediment U and groundwater U yields operational K_D
  - Use operational K_D for comparison to laboratory measurements
  - 2D variation of U and operational K_D to constrain results of transport experiments.

Data Summary

- Characterization Wells
  - Detailed, defined lithologic, geochemical, microbial characterization
    - Limited subaerial extent
- Observation Wells
  - Extensive characterization of subsurface
    - Limited analytes, limited resolution
  - Potential for defining solute-sediment interaction
- Combined
  - Geochemical definition of site variability
  - Baseline information for geophysical characterization
  - Accessible aquifer samples through distributed pump network
  - *Alternative sampling methods undetermined*

Ringold Subcrop and Low-Water U plume





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