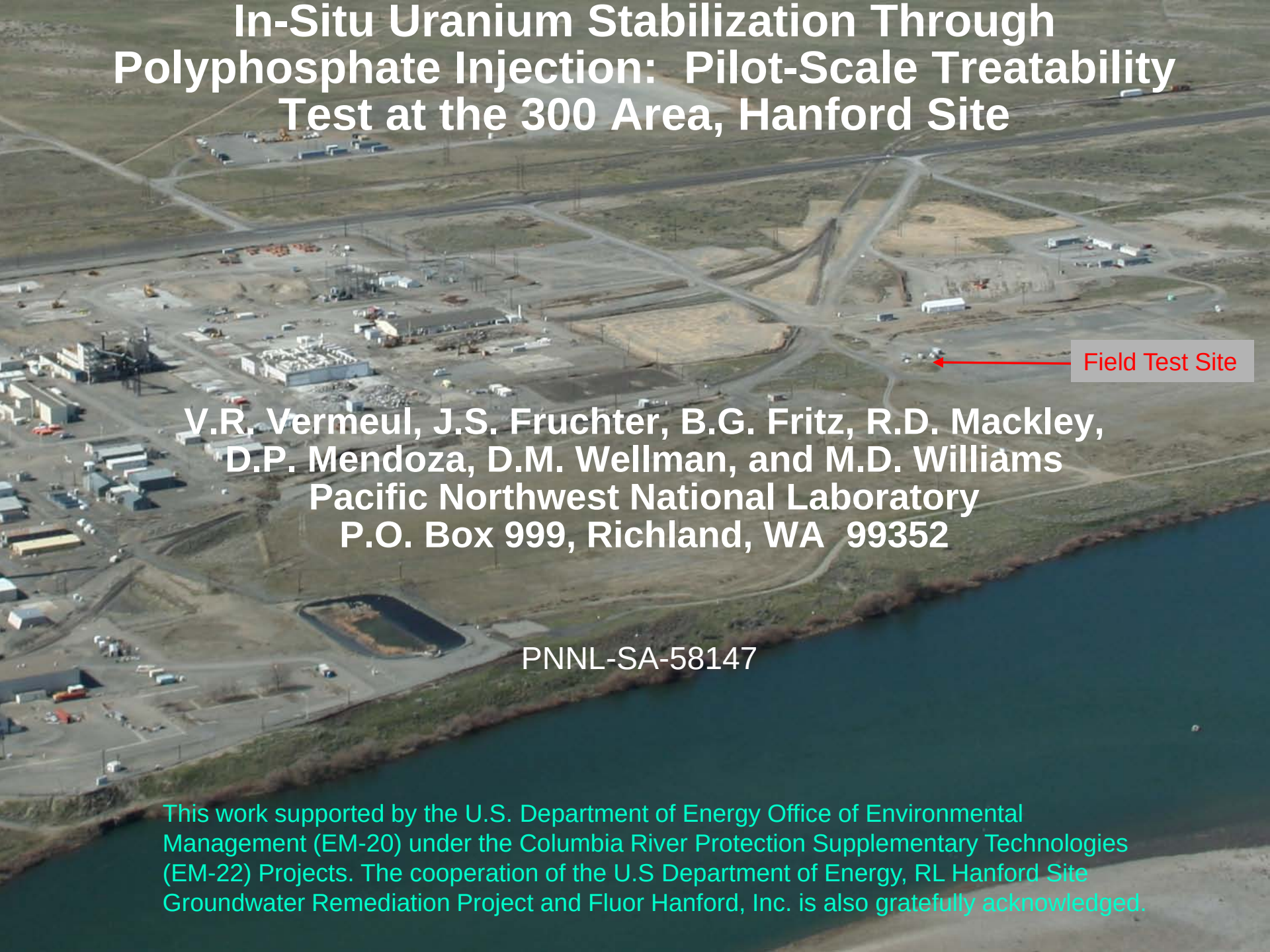
In-Situ Uranium Stabilization Through Polyphosphate Injection: Pilot-Scale Treatability Test at the 300 Area, Hanford Site



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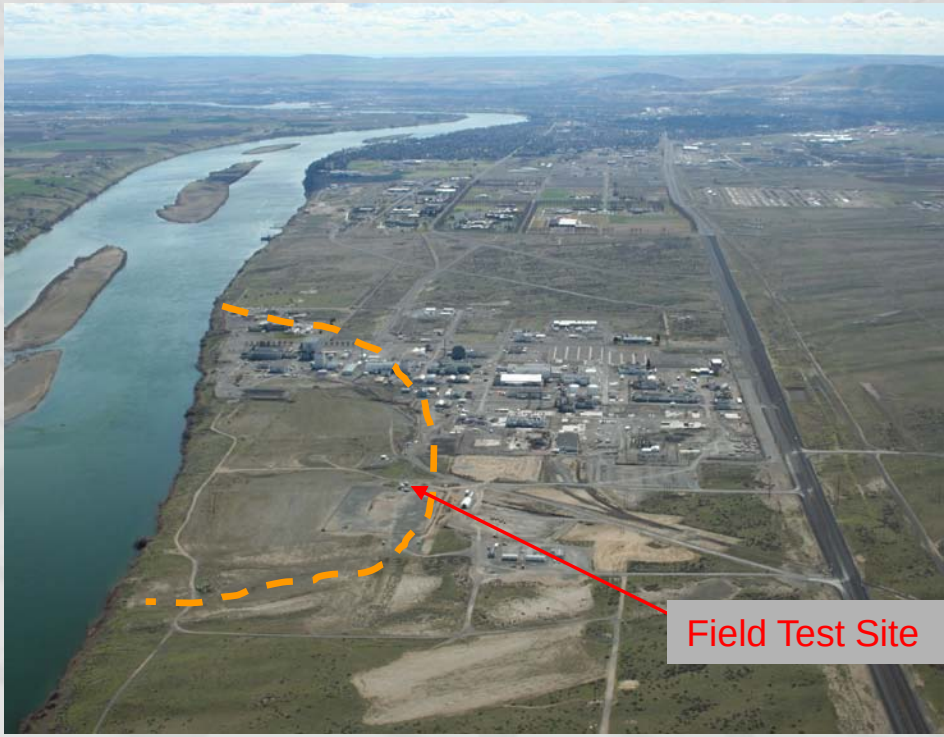
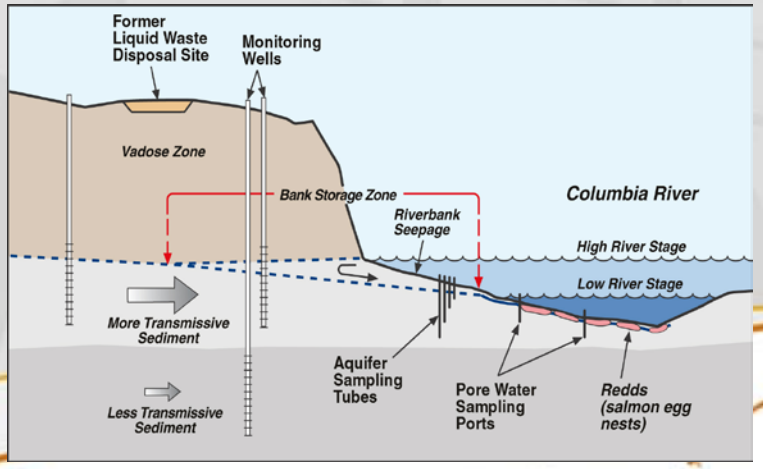
Site Description

- Uranium Plume
  - Large liquid waste disposal sites and burial grounds
  - Discharges from fabrication and research facilities
- Exposure routes
  - Hyporheic Zone - contaminated groundwater upwells into river
  - Riparian Zone - seeps containing a mixture of river water and groundwater
  - Groundwater





Conceptual Model for Uranium Transport to River Environment

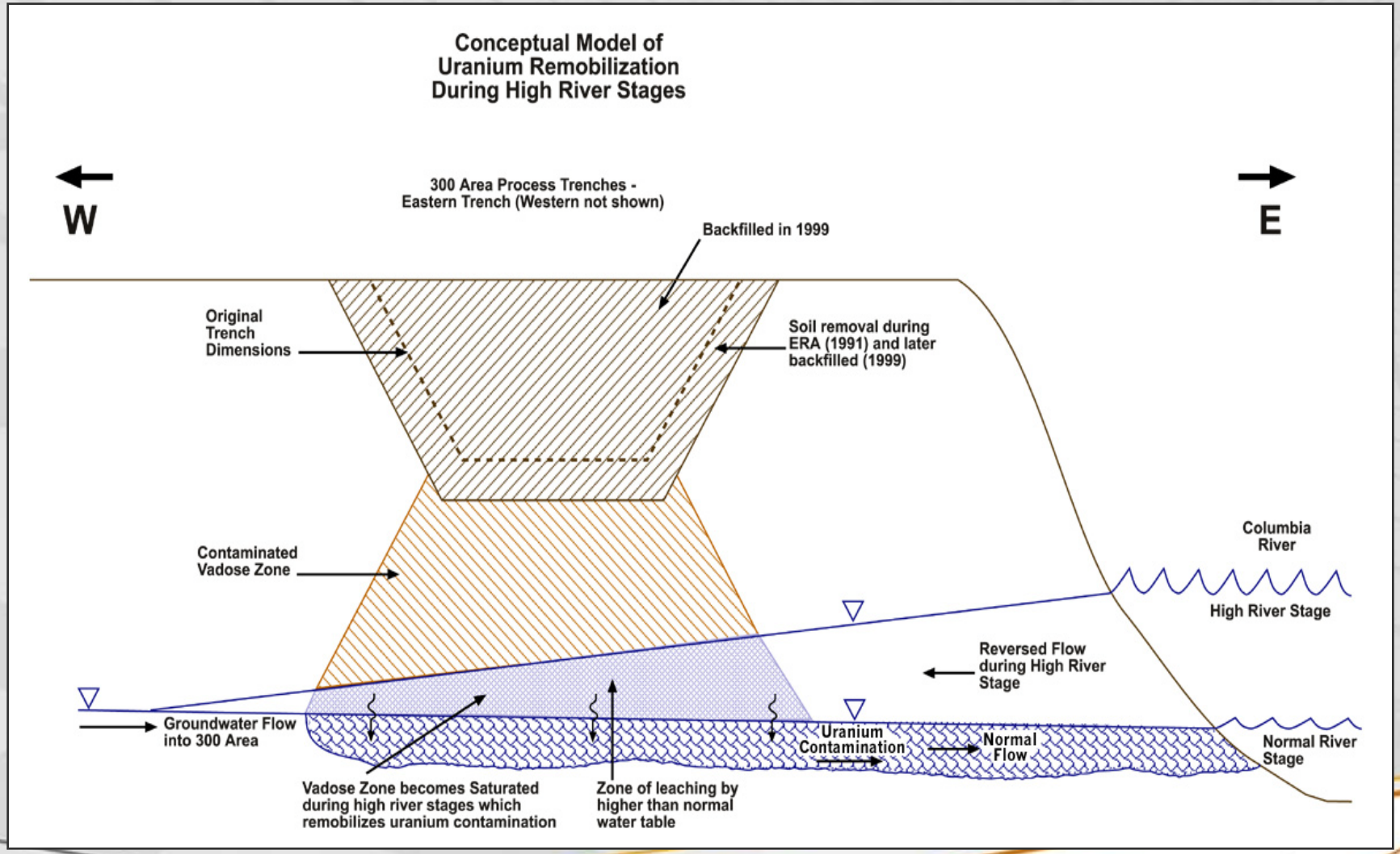


Figure Source: Lindberg 2002

Treatment Concept:

Deployment of Phosphate Amendment for In-Situ Immobilization of Uranium

- Injection of soluble polyphosphate amendment (and calcium supplement)
- Uranyl phosphate mineral (autunite) formation
  - Direct treatment
- Calcium phosphate mineral (apatite) formation
  - Sorbent for uranium
  - Long-term PO_4 source (apatite dissolution)
- Treatment focus
  - Saturated zone (focus of this talk)
  - Unsaturated/variably saturated zone (source treatment)

Polyphosphate Treatability Test

- Objectives
  - Evaluate the use of phosphate amendments for immobilization U
  - Identify implementation challenges
  - Evaluate feasibility of full-scale deployment
- Activities
  - Bench-scale studies
    - Amendment formulations finalized
    - Phased treatment approach selected
  - Site specific characterization
    - Installation of well network
    - Hydrogeologic characterization
    - Hydraulic/tracer injection testing
  - Polyphosphate injection design
    - Development of local-scale flow and transport model
    - Determine injection volumes, rates, and chemical mass requirements
  - Polyphosphate injection test performed in June 07

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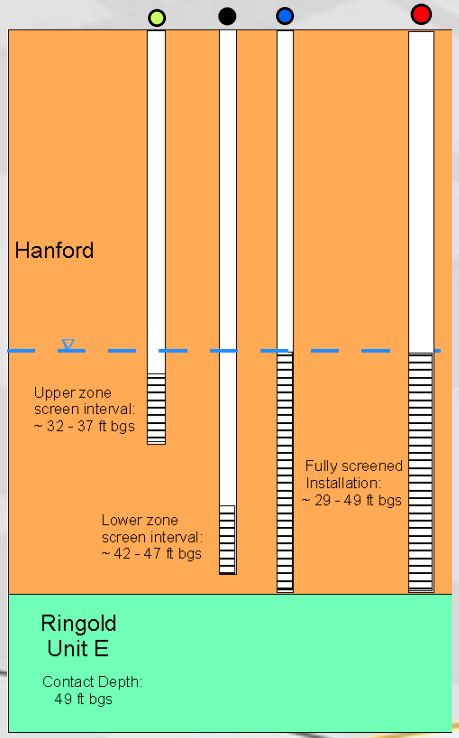
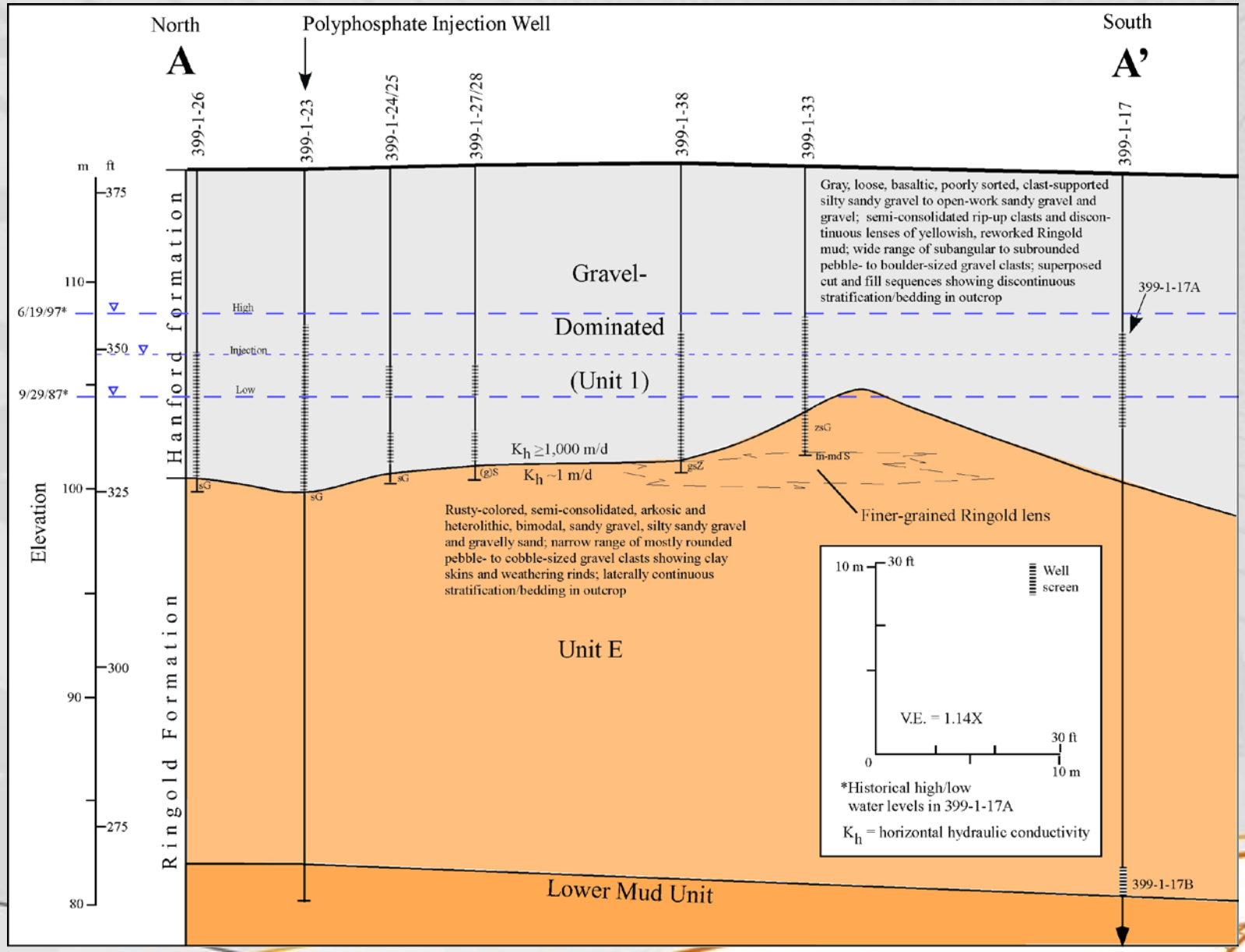
Polyphosphate Treatability Test site Well Layout



Geologic Cross Section



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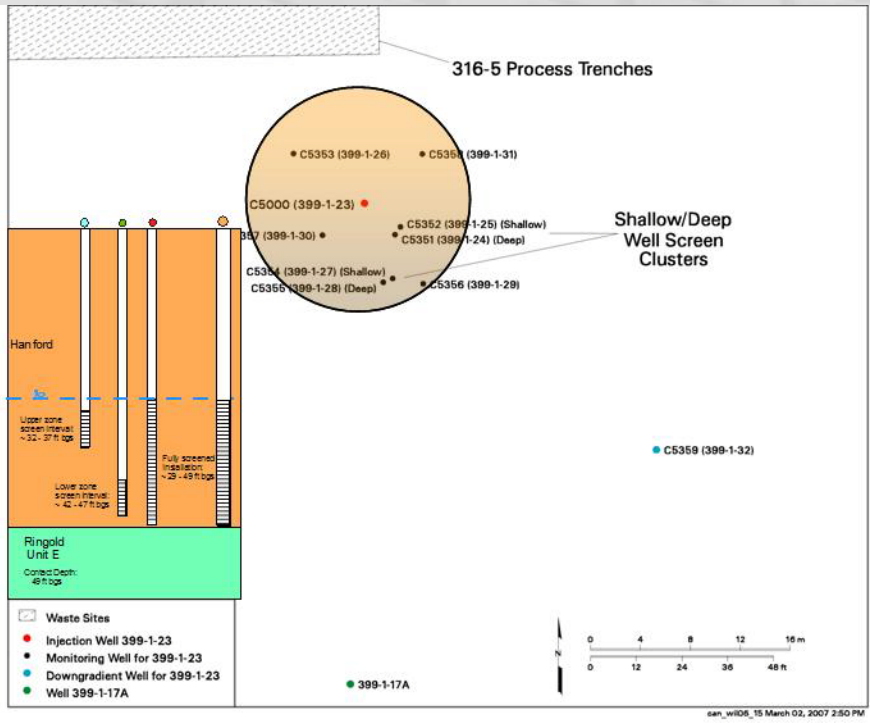
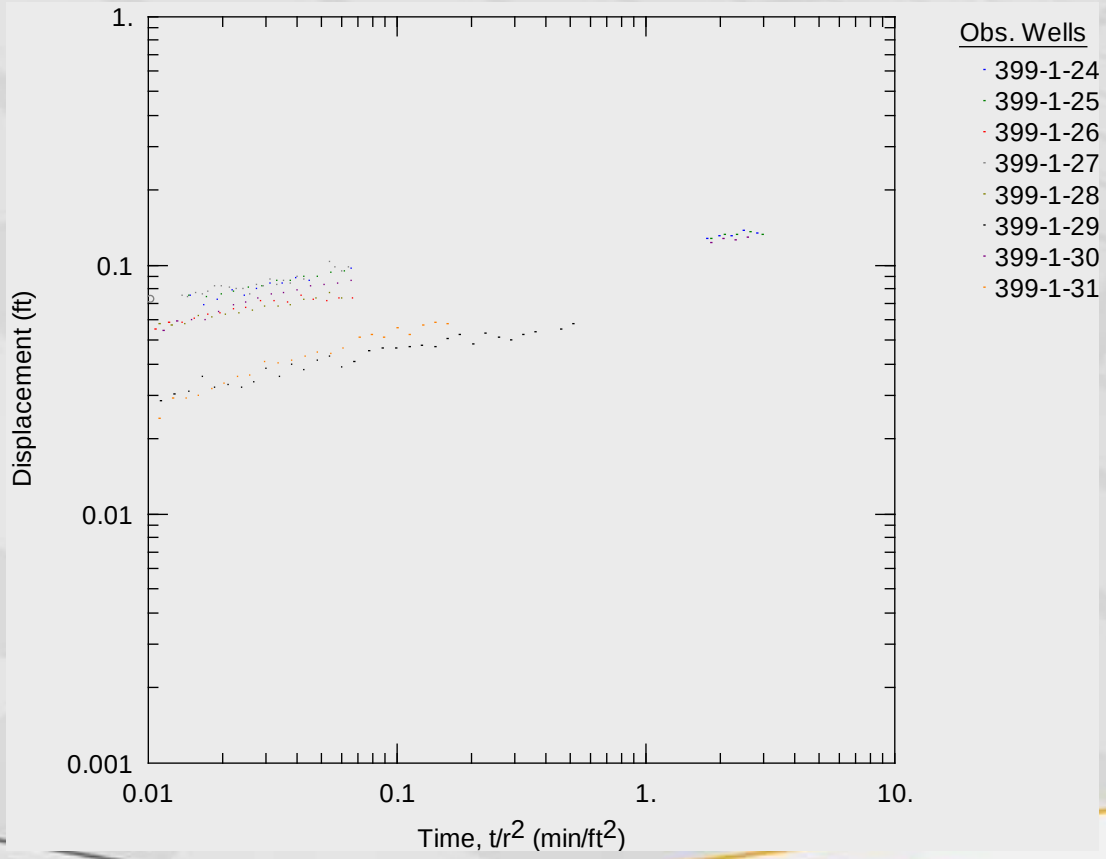
300 Area Polyphosphate Treatability Test Tracer Injection Test

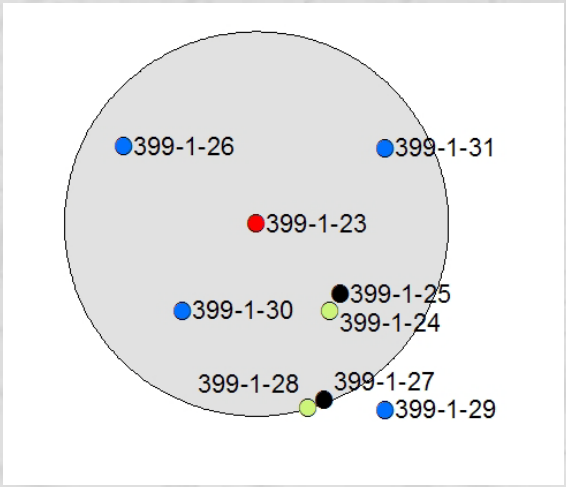
- NaBr tracer test on Dec. 13, 2006
  - Aquifer thickness ~ 15 ft
  - Injection Volume: 143,000 gallons
  - 200 gpm for 11.9 hrs
- Inline tracer mixing with water from Well 399-1-7 (620 ft DG)
- Br^- conc. measured in injection stream and surrounding monitoring wells
  - Samples analyzed on site with ISE
  - Archive samples→ verification by IC
  - Downhole ISE probes installed in all monitoring wells



Analysis of Pressure Buildup During Tracer Injection Test

- Composite plot showing radial distance normalized responses for direct comparison





Injection Well (399-1-23)

Fully-Screened Monitoring Wells

Lower-Zone Monitoring Wells

Upper-Zone Monitoring Wells

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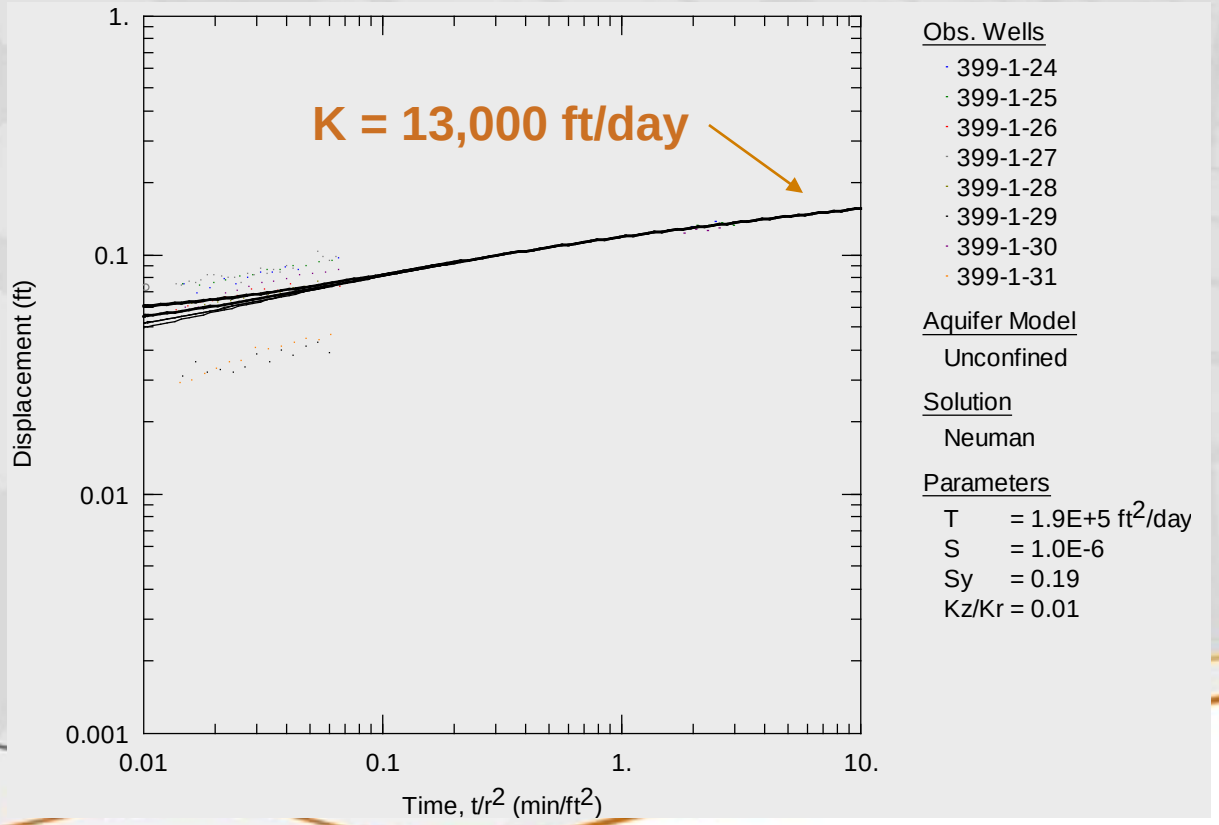
Analysis of Pressure Buildup During Tracer Injection Test (cont.)

- Neuman(1974) →analytical solution for unsteady flow to a fully or partially penetrating well in a homogeneous, anisotropic unconfined aquifer with delayed gravity response.
- Homogeneous criteria not met
- Semi-quantitative type curve analysis



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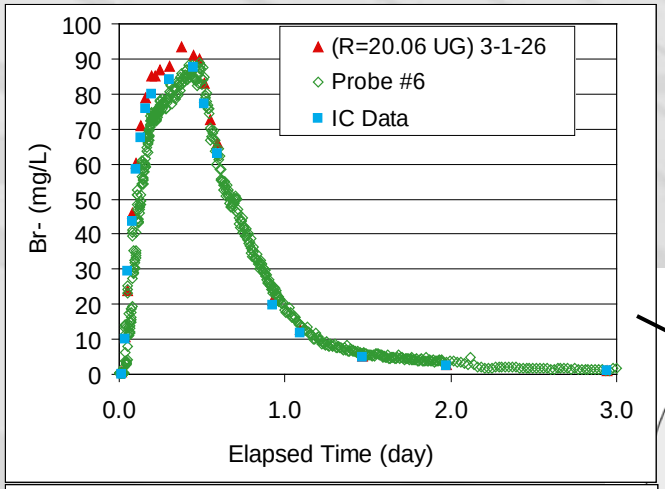
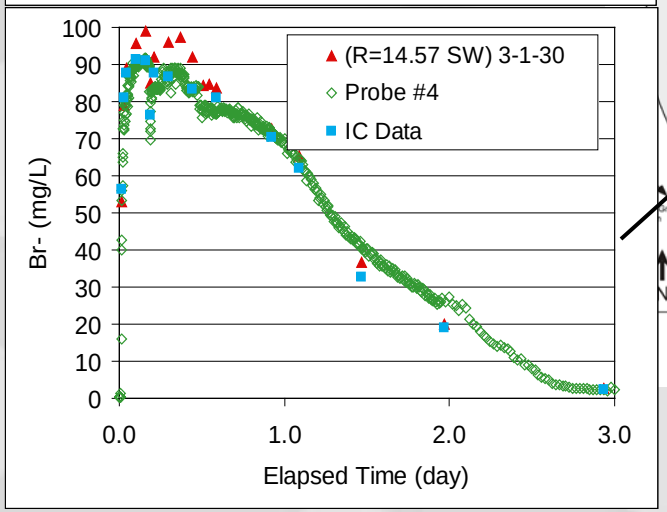
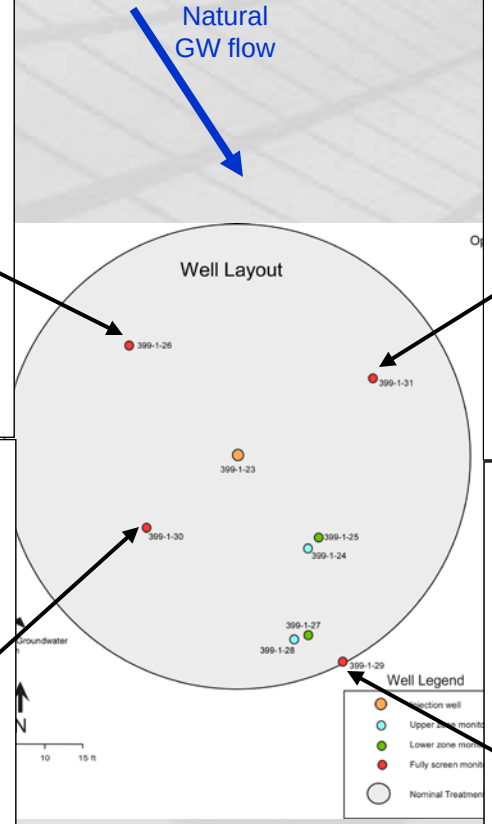
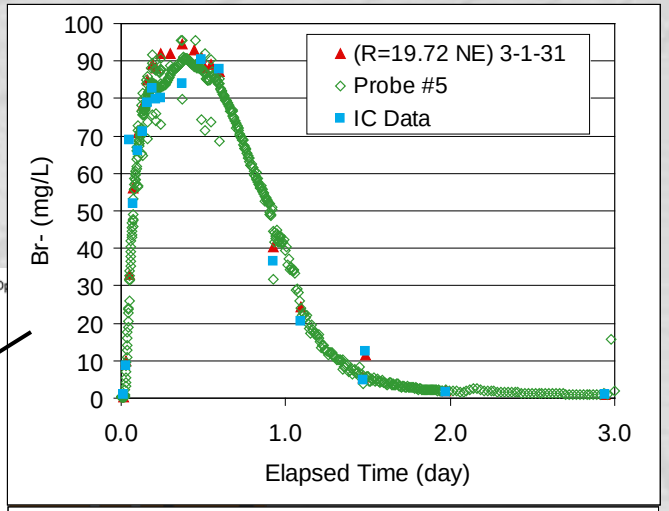
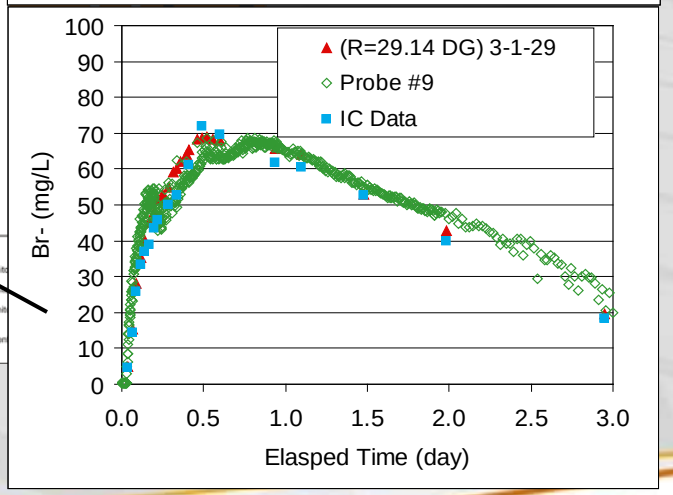
Tracer Arrival Response within Targeted Treatment Volume











- n_{eff} (based on tracer arrival)= 0.19
- Consistent with porosity estimates based on physical property analysis

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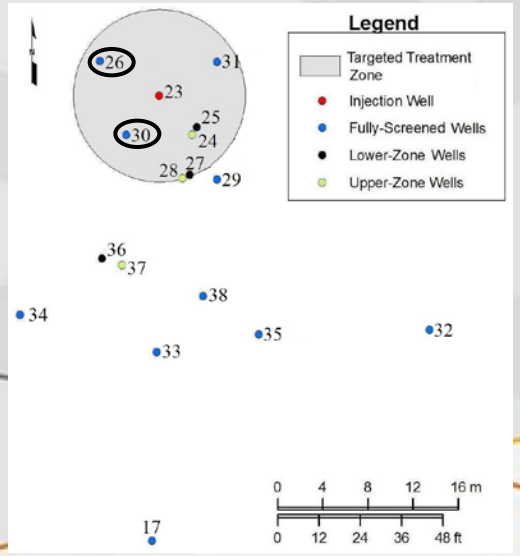
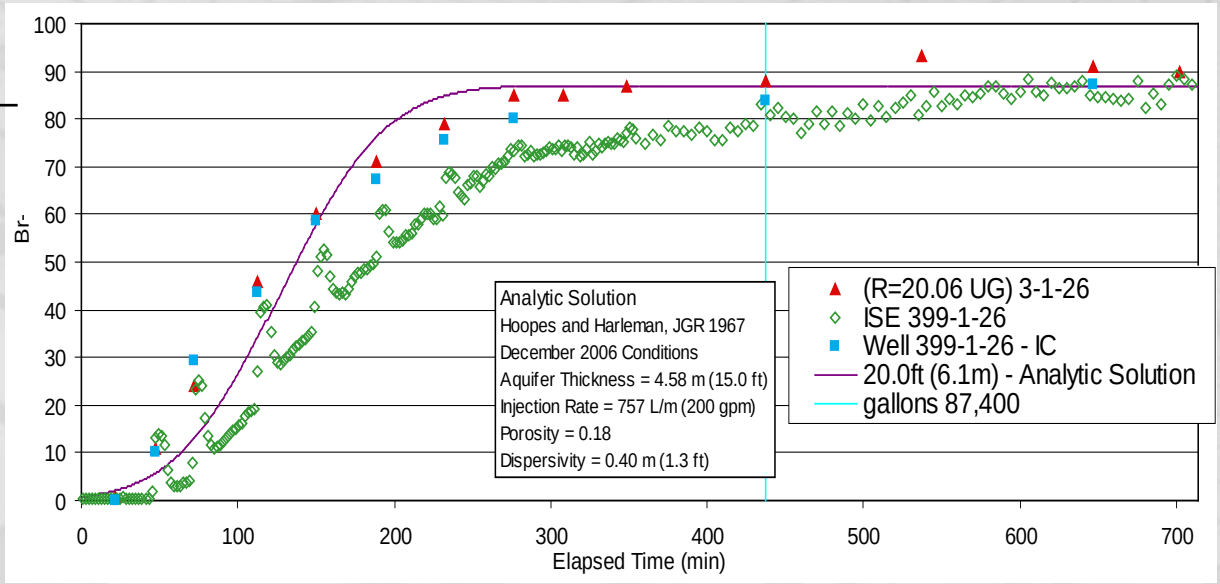
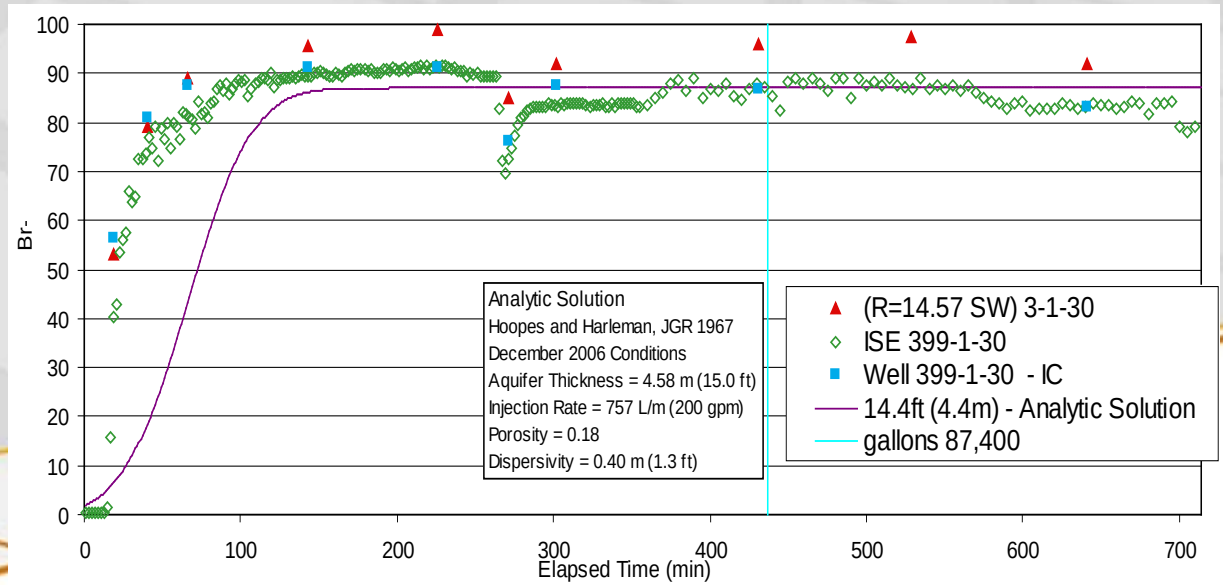
Tracer Test Results within Targeted Treatment Volume

Well ID	Radial Distance (ft)	50% tracer Arrival (min)	Estimated Porosity
399-1-23	0.0	--	--
399-1-24	14.9	123.9	0.32
399-1-25	14.4	39.1	0.11
399-1-26	19.9	111.1	0.16
399-1-27	24.5	na	--
399-1-28	24.9	216.5	0.20
399-1-29	29.6	310.0	0.20
399-1-30	14.8	16.1	--
399-1-31	19.6	89.9	0.13





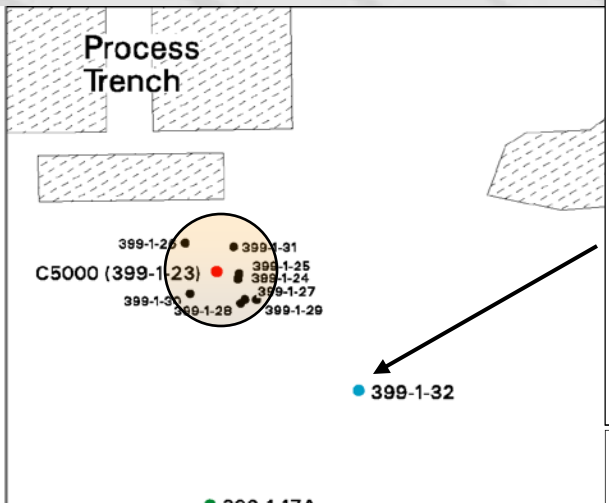


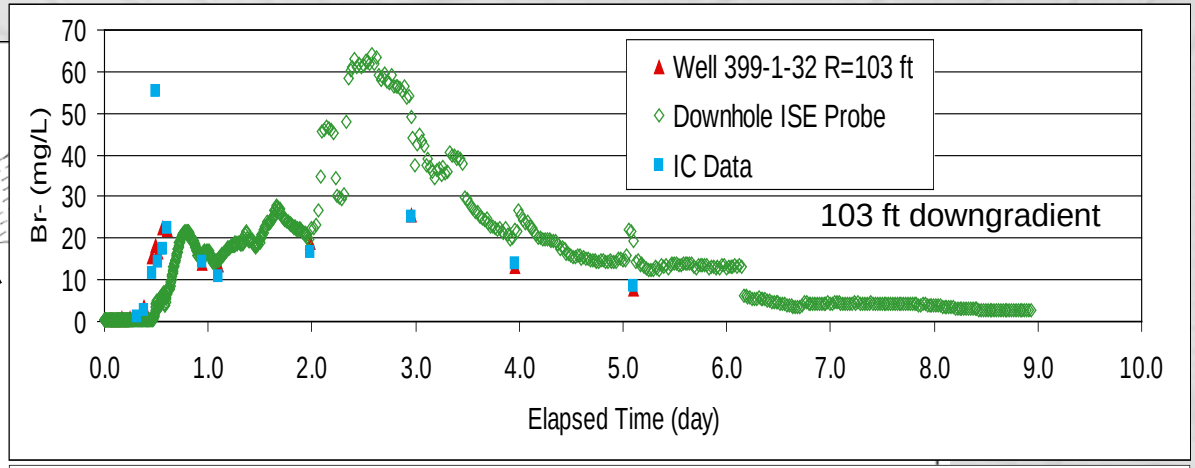
Treatment Volume Estimation

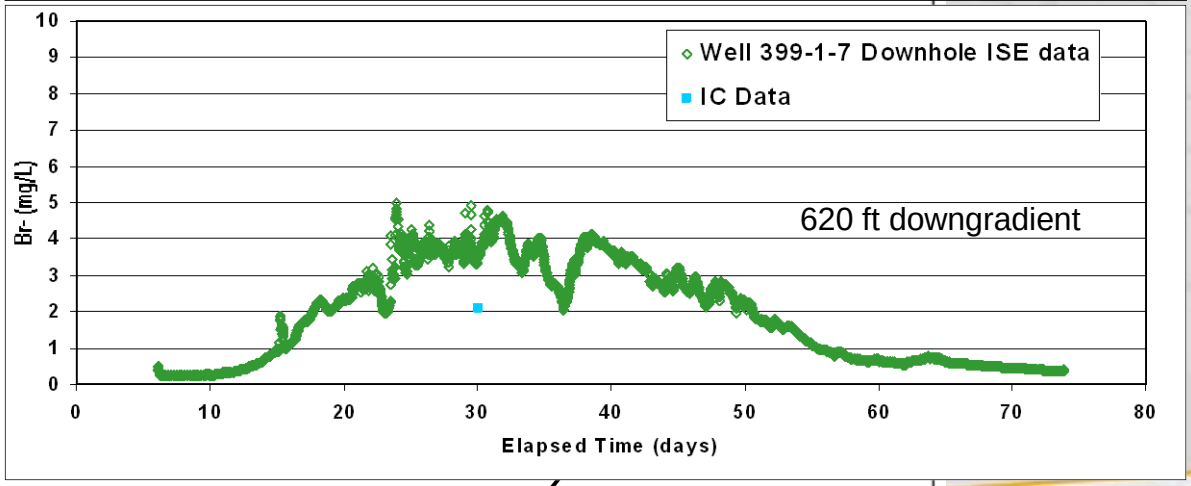
- Idealized $PV_{25\ ft}$ ~ 42,000 gal
- Tracer arrival data normalized to 25 ft radius based on volumetric ratio
- Injection volume requirements:

Well Name	Distance to 399-1-23 (ft)	50% tracer Arrival (gal)	80% tracer Arrival (gal)	90% tracer Arrival (gal)	100% tracer Arrival (gal)
399-1-23	0.0				
399-1-24	14.5	77,425	125,072	148,895	339,481
399-1-25	14.1	25,093	50,185	62,731	138,009
399-1-26	20.1	34,175	62,136	86,990	201,940
399-1-27	24.1	----	----	----	----
399-1-28	24.3	46,659	95,438	125,130	151,216
399-1-29	29.1	45,640	104,973	----	----
399-1-30	14.6	11,785	17,677	23,569	58,923
399-1-31	19.7	28,941	61,099	77,177	112,550
Average		**38,531**	**73,797**	**87,415**	**167,020**
Avg. @ high WT		**48,292**	**92,492**	**109,561**	**209,332**

Tracer Arrival Response at Downgradient Wells 399 1-32 and 399-1-7





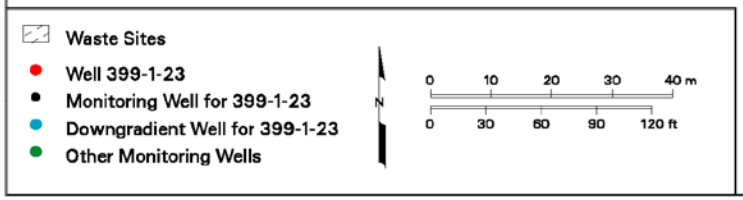


399-1-32 tracer drift data

- Arrival in ~ 2 days
- v = 50 ft/d (15 m/d)
- K = 14,000 ft/d (4,300 m/d)
- K_{fast} = 20,000 ft/d (6,100 m/d)

399-1-7 tracer drift data

- First arrival after ~ 12 days
- Tracer plume well dispersed



399-1-3 399-1-7

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Polyphosphate Injection Test

- Polyphosphate injection on June 11-15, 2007
  - Design target → 90% arrival at 25 ft
  - PV definition → 109,000 gal
  - Inj. Vol. definition → PV * R_f (R_f [PO_4] ~ 2.4, R_f [Ca] ~ 4.8)
- 3 phase approach: PolyPO_4 / CaCl / PolyPO_4
  - Amendment injection volumes (Kgal): 250 / 500 / 250
  - 200 gpm injection Rate
- Polyphosphate Amendment Formulation:
  - 50% Tripolyphosphate ($Na_5P_3O_{10}$)
  - 25% Pyrophosphate ($Na_4P_2O_7$)
  - 25 % Orthophosphate (NaH_2PO_4)

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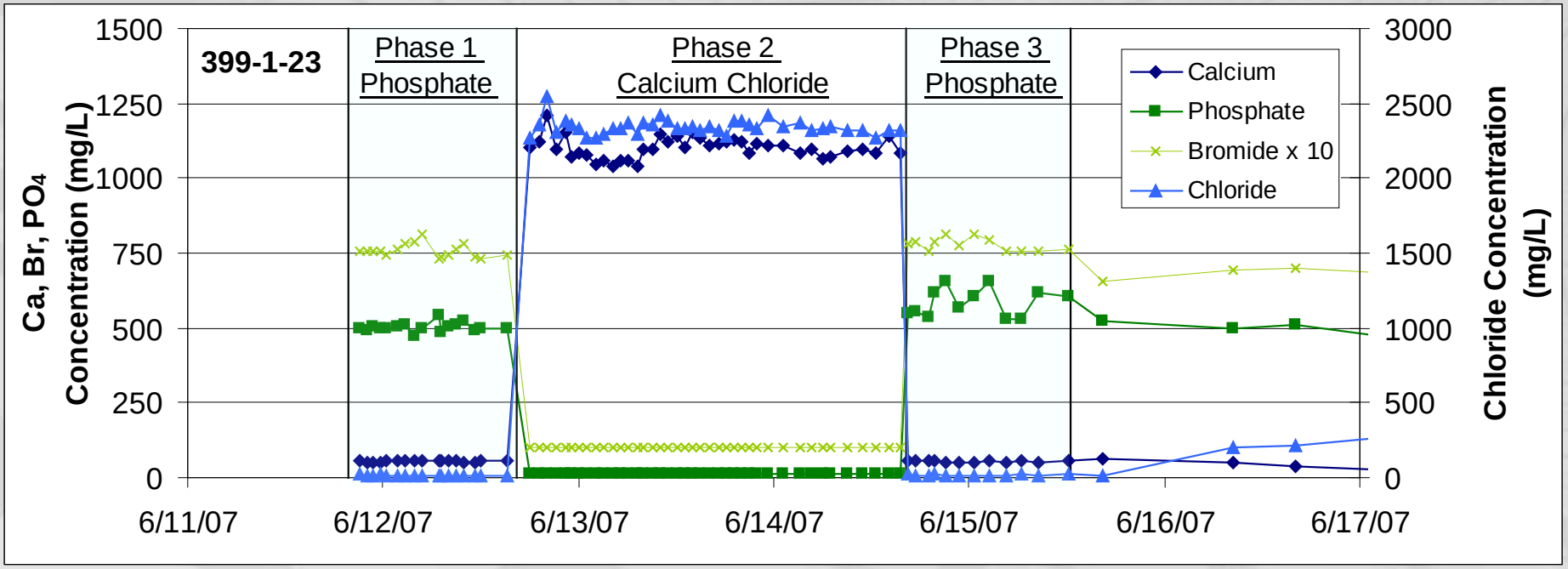
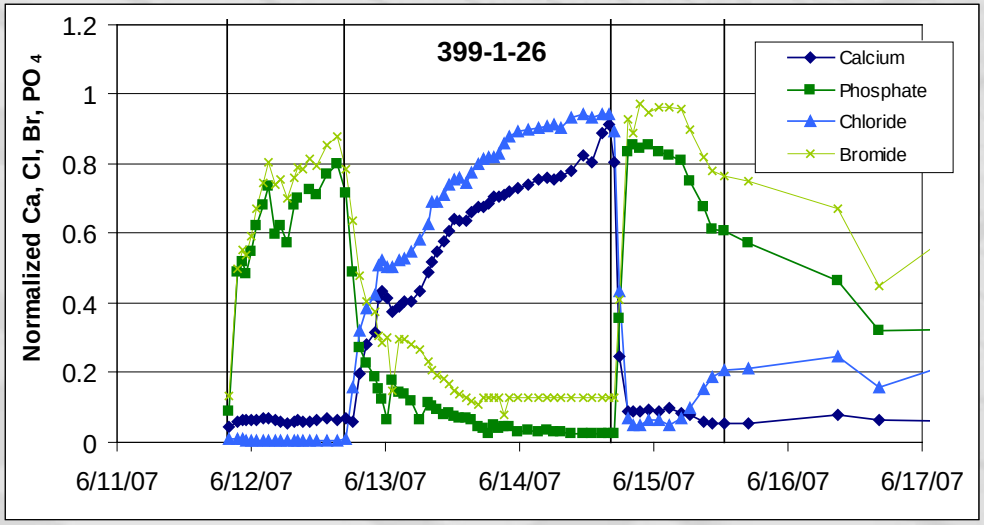
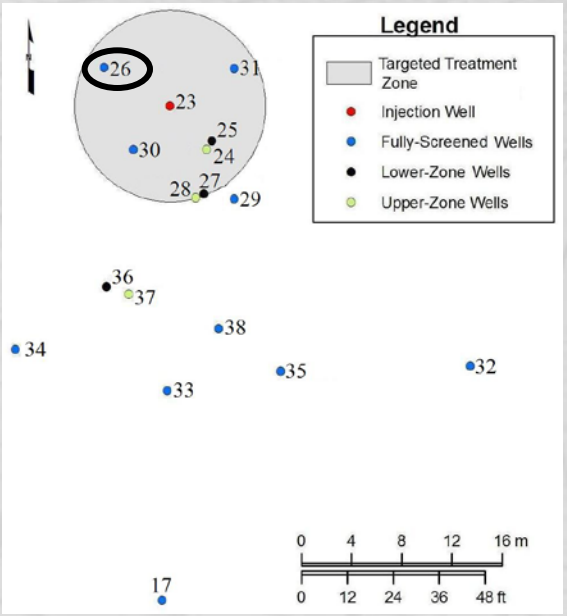
Injection Summary



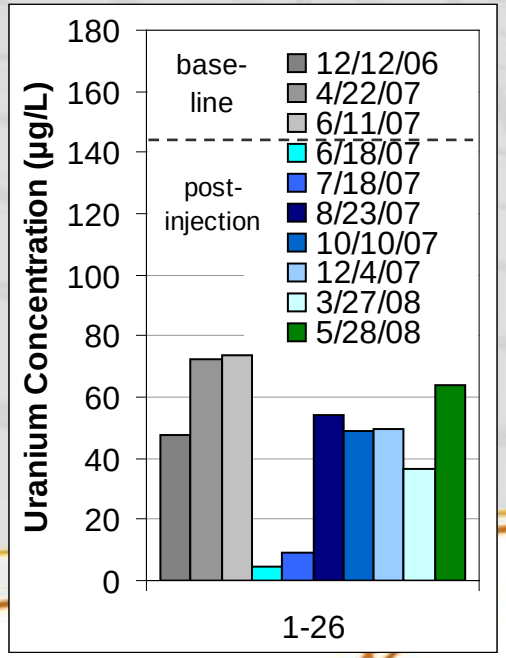
- Phase 1- 255,000 gallons polyphosphate solution injected (4950 gallons concentrated solution)
- Phase 2- 580,000 gallons CaCl solution injected (4100 gallons concentrated solution)
- Phase 3- 245,000 gallons polyphosphate solution injected (4900 gallons concentrated solution)

Injection Performance





- Limited Ca/PO_4 sorption/mixing during injection (classic mixing problem)
- Initial U performance data indicates good direct treatment/displacement
- Significant rebound in U concentration observed, consistent with limited/no apatite formation
- 399-1-26 is on up-gradient side of treatment zone so would be expected to rebound first



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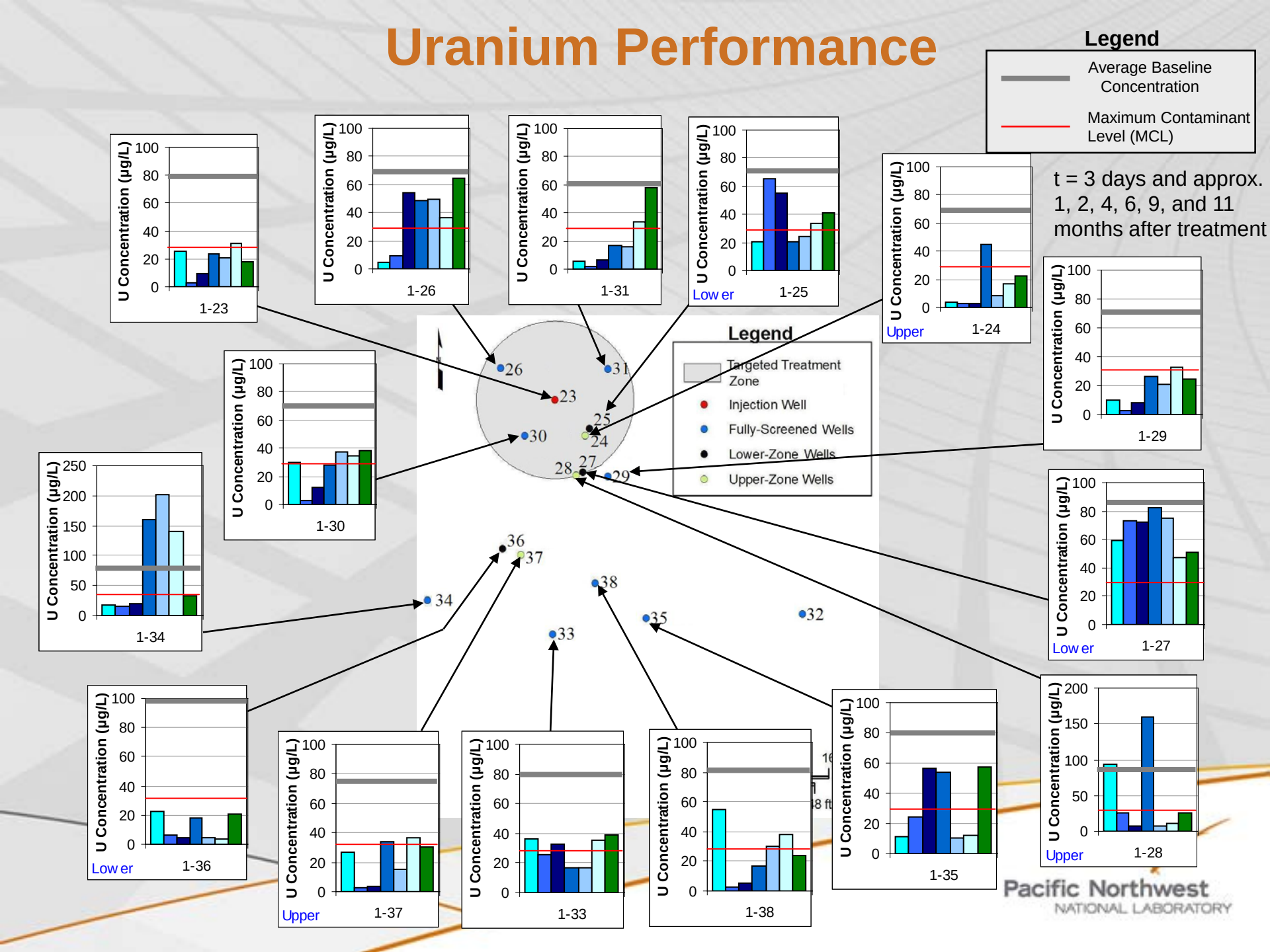
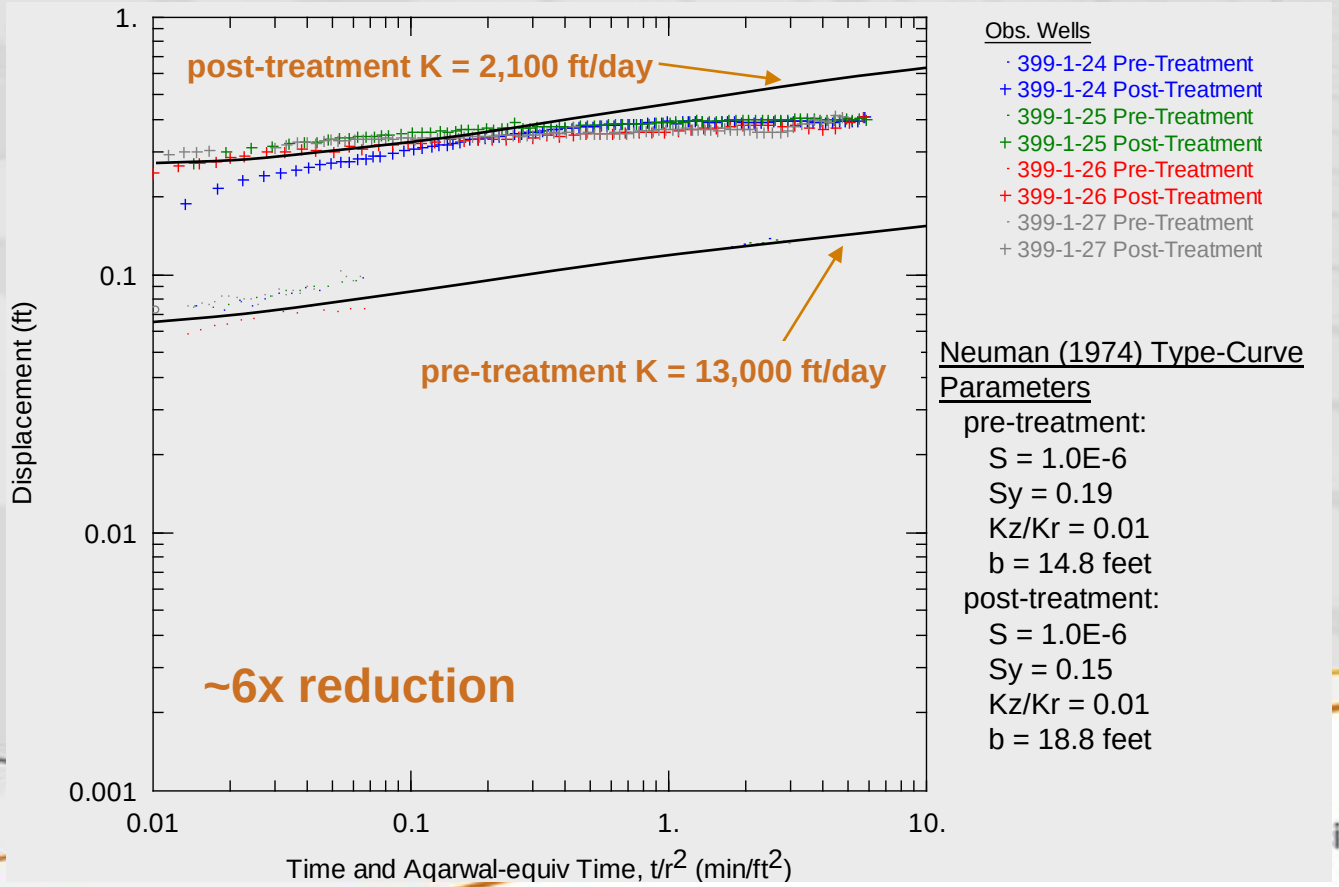
Uranium Performance



Evidence of Permeability Reduction

- Comparison of pre- and post-treatment hydraulic response
- Neuman(1974) type curve match – composite plots
- Post-treatment data deviates from predicted late-time response
  - Indicative of high K boundary (fits conceptual model)
- Permeability reduction evident in hydraulic response data



Evidence for Change in Permeability Distribution

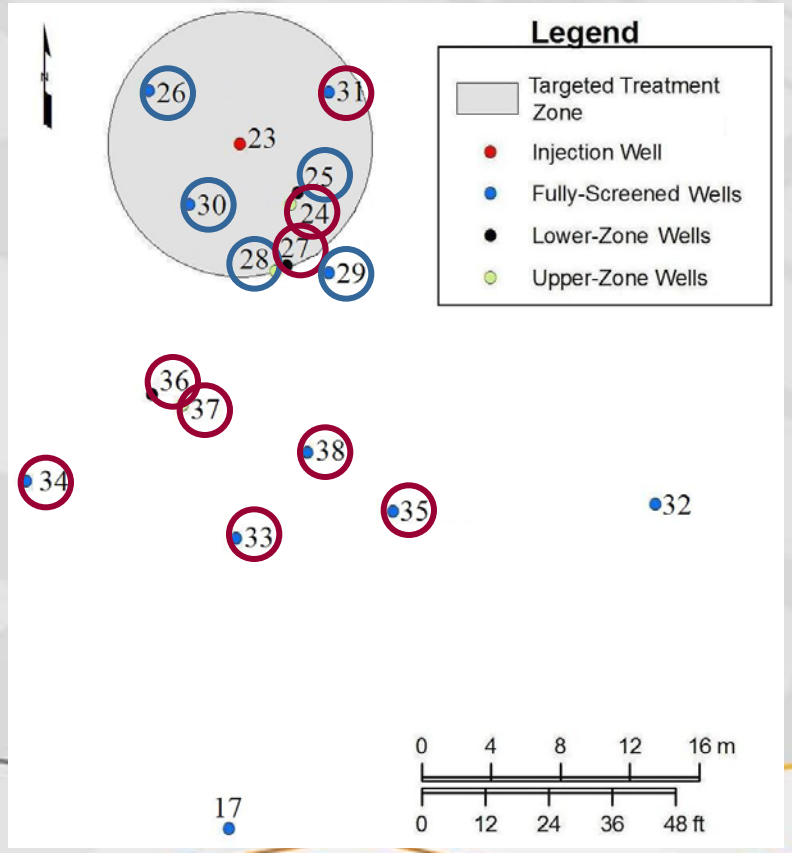
Wells showing some indication of Ca/PO_4 overlap

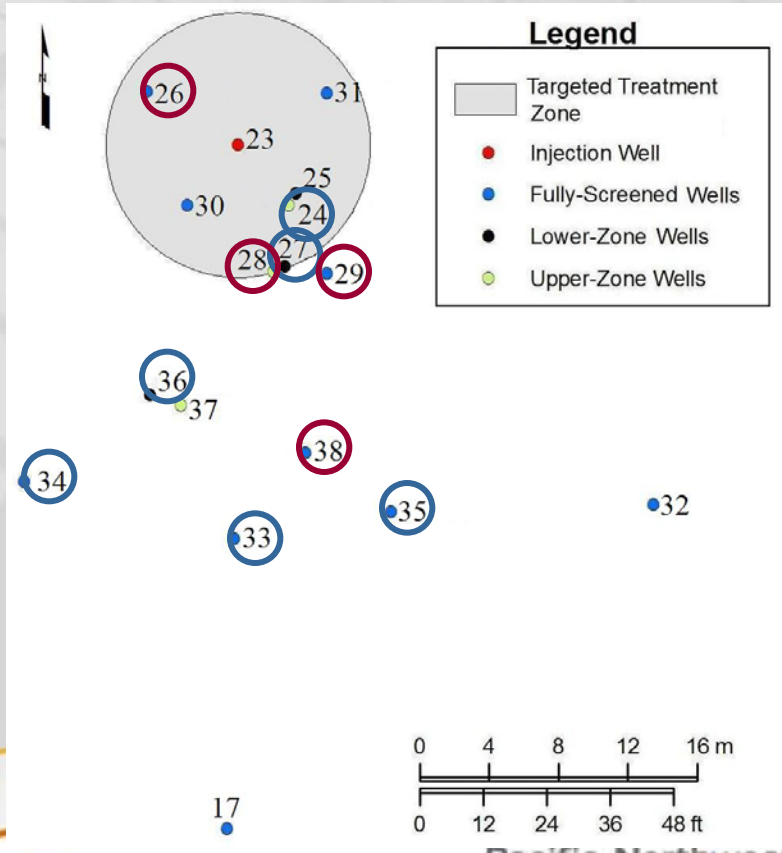
Limited Ca/PO4 overlap indicated

Wells showing increased flow*

Wells showing decreased flow*

*Based on conservative tracer arrival response during all 3 phases of the test





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Summary

- Objectives
  - Evaluate the use of phosphate amendments for immobilization U
  - Identify implementation challenges
  - Evaluate feasibility of full-scale deployment
- Initial groundwater performance monitoring data show mixed results
  - Initial reduction in U concentrations to below MCL in most wells within a radial distance of 75 ft
  - Limited Ca/PO_4 sorption/mixing and U concentration rebound indicates calcium-phosphate mineral formation may be small relative to design target
  - Performance monitoring is ongoing (one more sampling event planned)
  - Preliminary data indicate complex hydrogeologic conditions may not be well suited to saturated zone application of the technology

Earned Value Report

Polyphosphate	FYTD (K)
BCWS	$1,657
BCWP	$1,600
ACWP	$1,760
SV	-$57
CV	-$160

- No significant schedule variance
- The project has a 10% cost variance associated with additional bench-scale testing