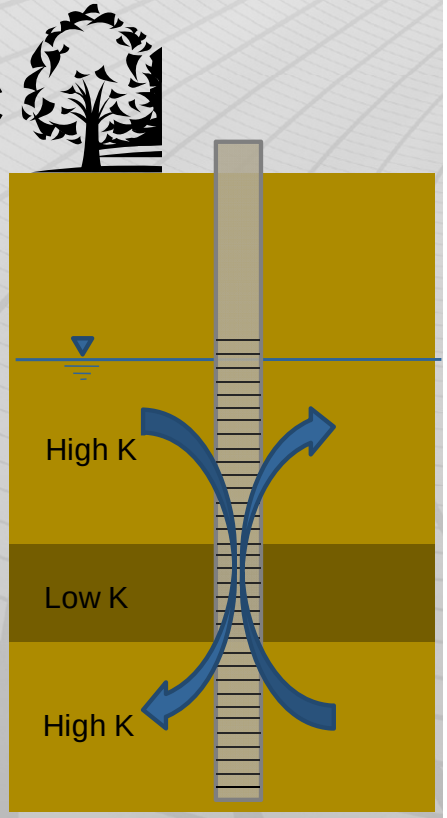
River Induced Wellbore Flow Dynamics in IFRC Long-Screen Wells: Assessment of Mitigation Strategies

IFRC Project Meeting

January 19-20, 2011

Conceptual Model of Wellbore Flow

- Wellbore flow in long-screen wells at the IFRC site is related to:
  - Geohydrologic conditions – upper and lower high K zones separated by lower K zone
  - River hydrodynamics
  - Well construction – long-screen wells allow intercommunication between high K zones
  - Differing degrees of connectivity between the upper and lower high K zones and the river, resulting in head differences that drive flows upward or downward
- Temporally variable – fluctuating river boundary
- Spatially variable – can be used to infer river connectivity and geologic structure between wellfield and river



Subsurface Biogeochemical Research

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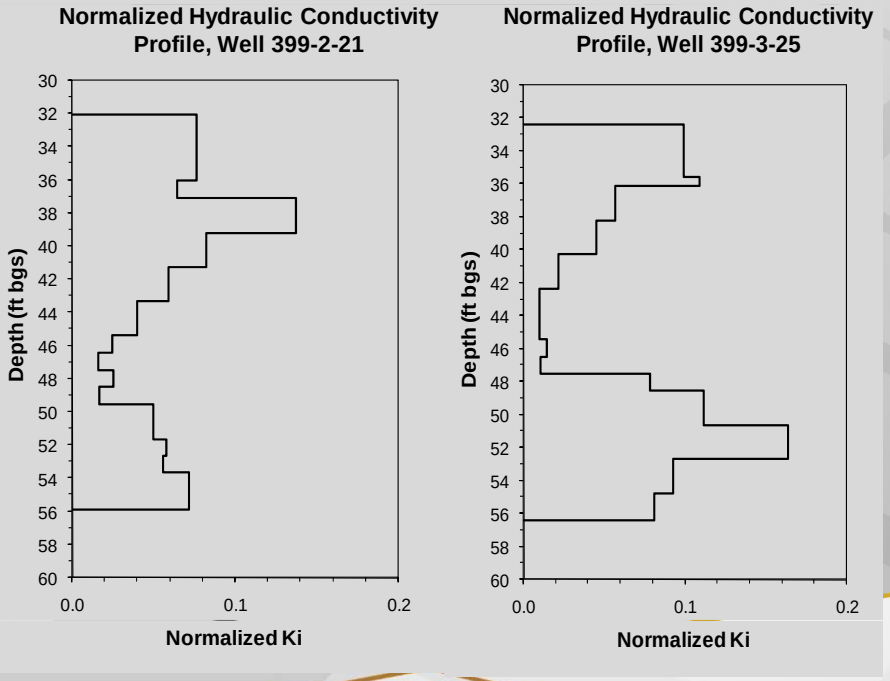
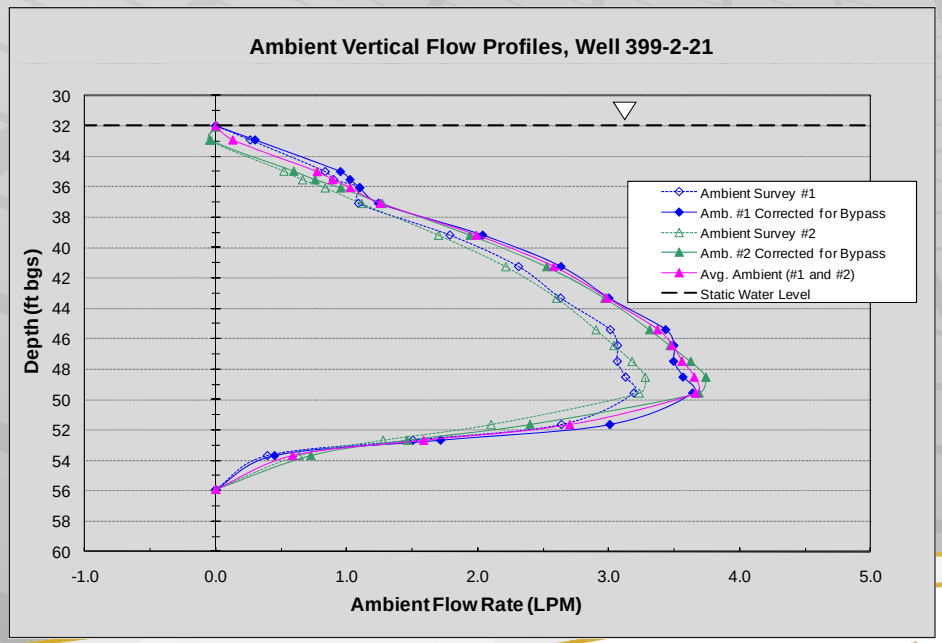
Ambient Wellbore Flow Characterization

- First identified during initial site characterization that included ambient and dynamic EBF profiling
- Potential for impacts to aqueous sampling results was recognized, tracer and passive experiments required to quantify impacts





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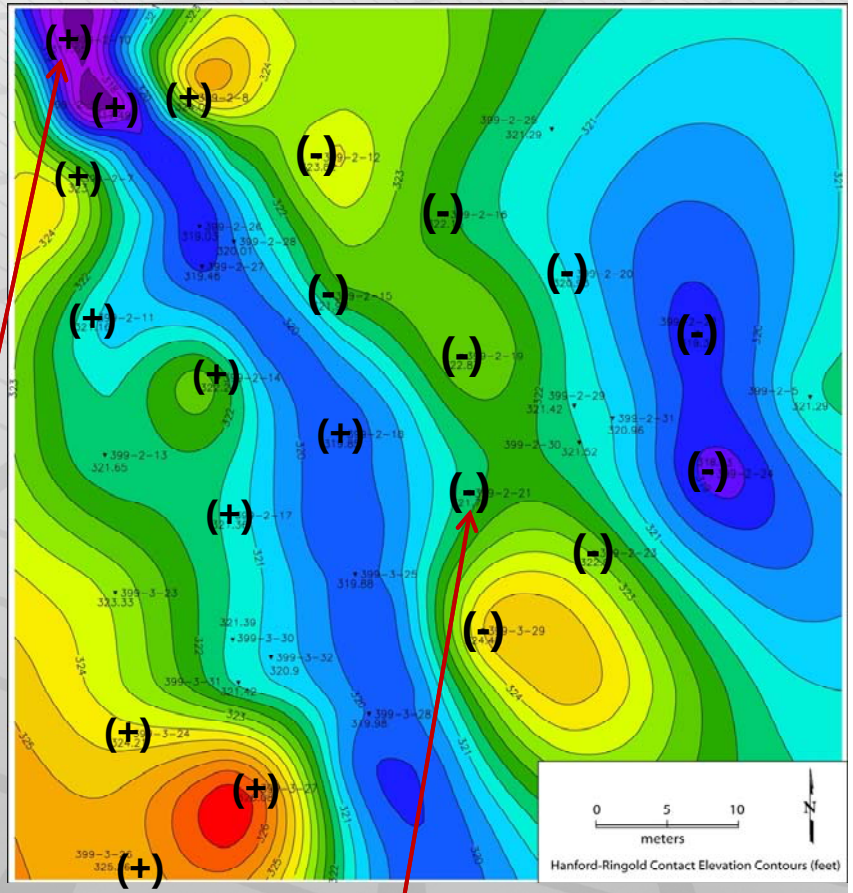
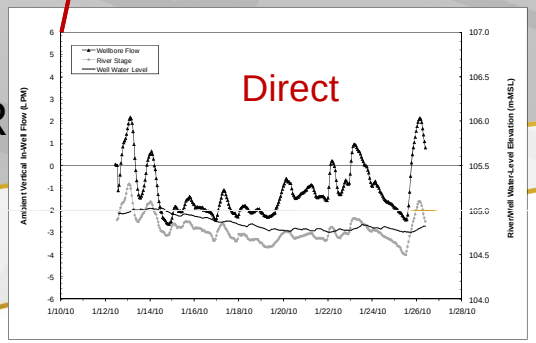
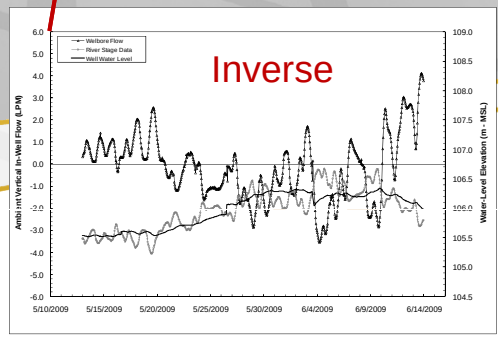
Spatial Distribution of Ambient Wellbore Flow

- Ambient wellbore flows measured at multiple locations across the IFRC site (time discrete)
  - Both direct and inverse correlations observed
    - (-) Inverse correlation indicated
    - (+) Direct correlation indicated
- Generally consistent with spatial distribution of observed concentration variability during U desorption experiment
- One plausible CM for observed spatial variability is associated with geologic controls and their impact on hydraulic connection to the river
  - Western wells – lower zone predominantly connected to river through paleochannel
  - Eastern wells – lower zone less connected due to a high in the H/R contact (not shown)



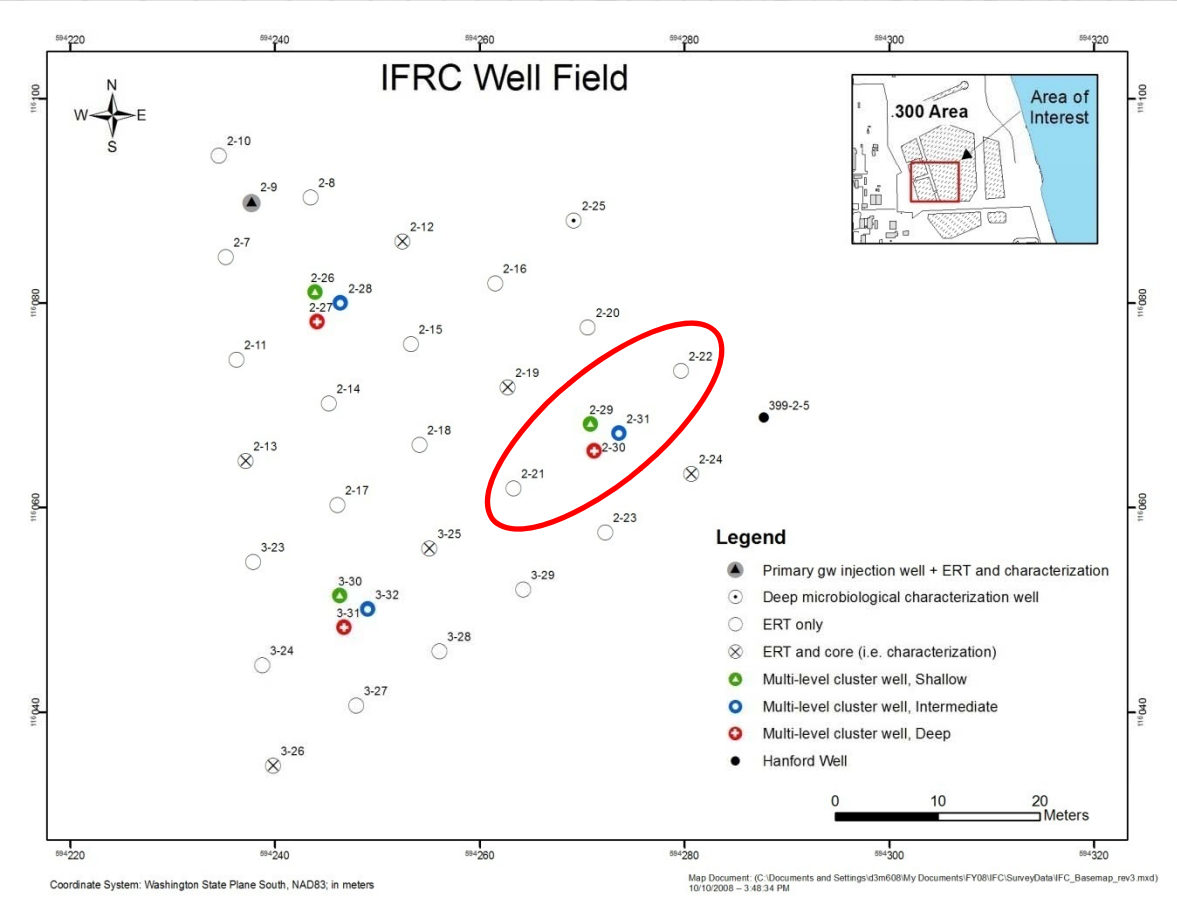




Temporal data at select locations

Temporal Evaluation of Wellbore Flow at Wells 399-2-21 and 399-2-22

- Comparison of U concentrations at fully screened well 399-2-21 and adjacent well cluster
- EBF monitoring in fully screened well 399-2-21 and 2-22
- Pressure monitoring in multi-well cluster



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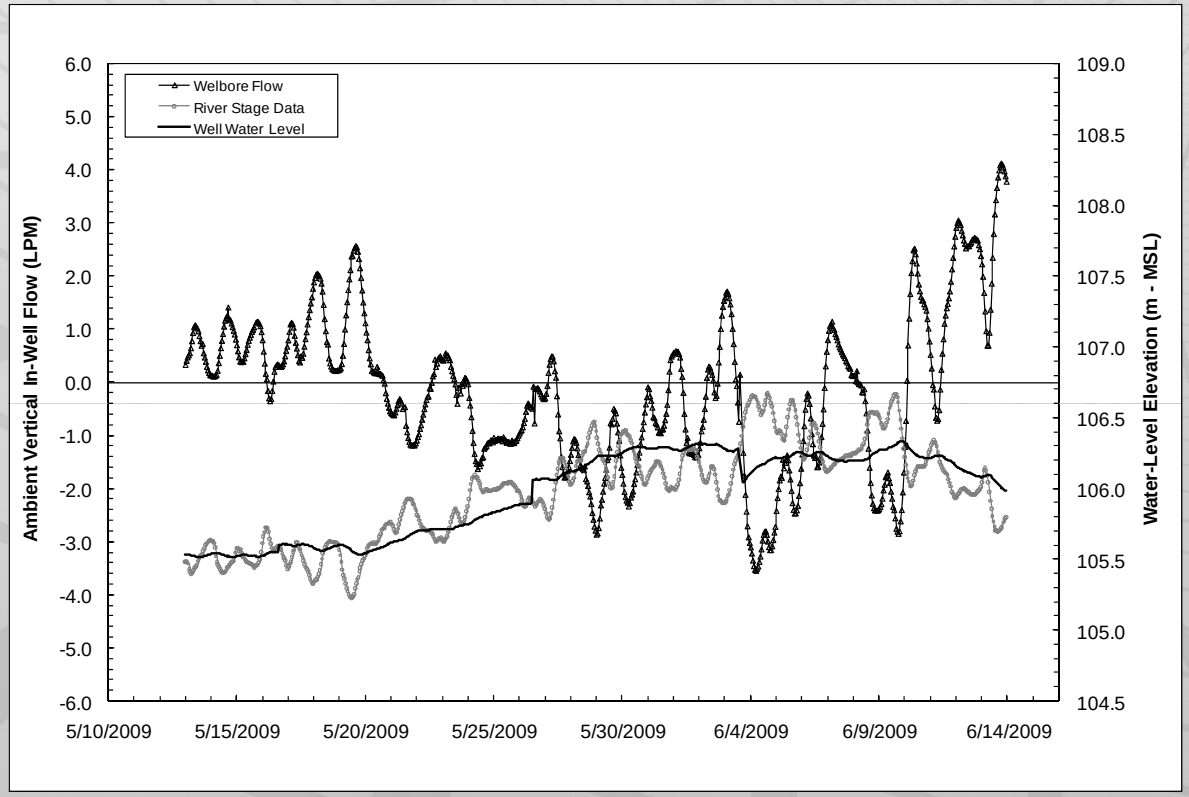
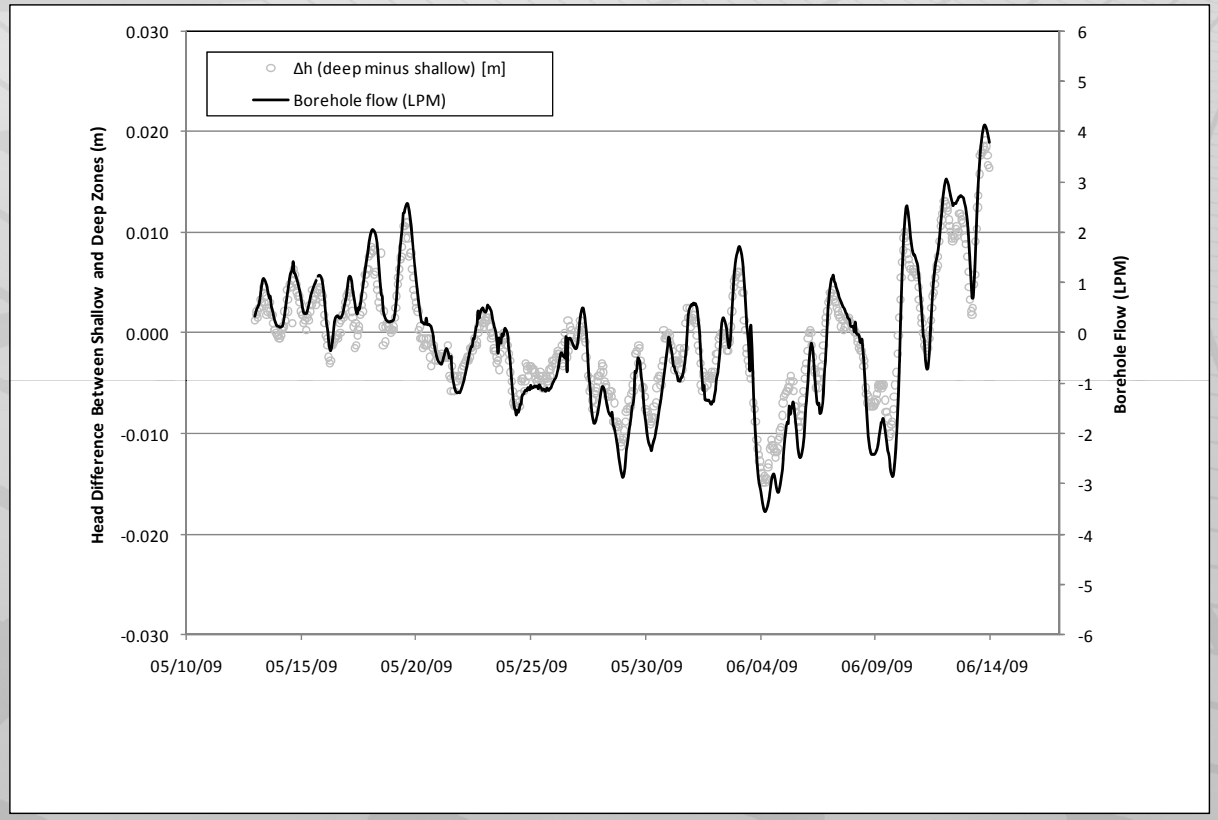
Ambient Wellbore Flow at Well 399-2-21

- Relationship between wellbore flow, well water-level, and Columbia River stage elevations
  - Positive flow values indicate upward flow
  - Changes in wellbore flows are inversely correlated with river stage at this location



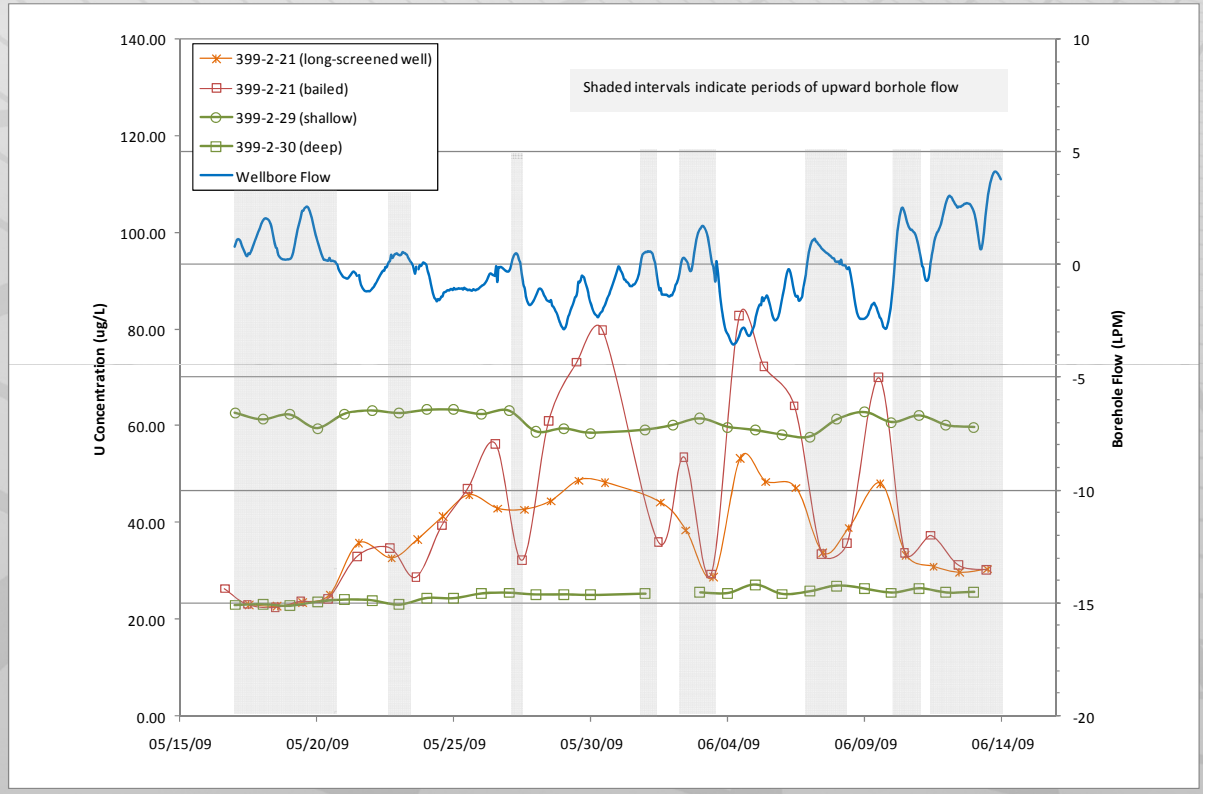
Ambient Wellbore Flow at Well 399-2-21 (cont.)

- Water-level elevations in the adjacent multi-level well cluster were used to calculate head differences between the upper and lower high K zones
  - As expected, Δ h and flow are highly correlated
  - Δh of ~2 cm resulted in wellbore flow of ~ 4 LPM



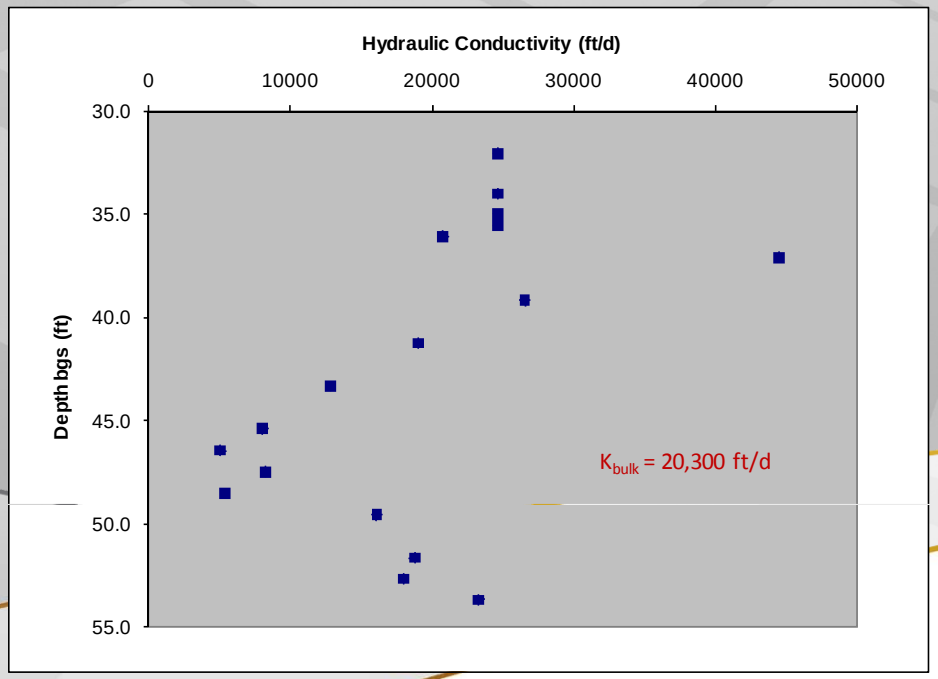
Implications for Aqueous Monitoring

- Direct measurement of wellbore flows and their impact on aqueous U concentrations during passive U desorption experiment
  - Decreases in U concentration associated with periods of upward wellbore flow
  - Magnitude of variability observed in long-screen well consistent with depth discrete concentrations



Mitigation Approach

- **Objective:** Minimize intercommunication between upper and lower high K zones
  - Install inflatable packer(s) to increase hydraulic resistance within wellbore
  - Seal entire lower section of the well screen using coated bentonite pellets
  - More aggressive approach required?



Filter pack K ~ 1,400 ft/d
(Schroth et al. 1996)

Inflatable Packers

Test Ball Packer

Solinst® Low Pressure Packer

Dual Solinst® Packer String

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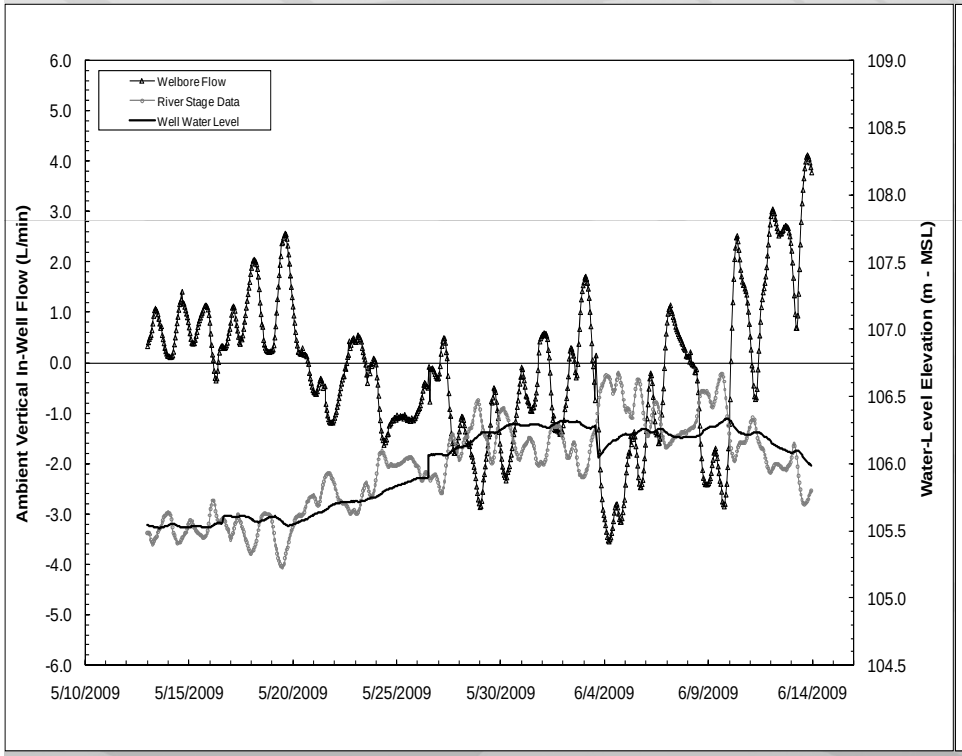
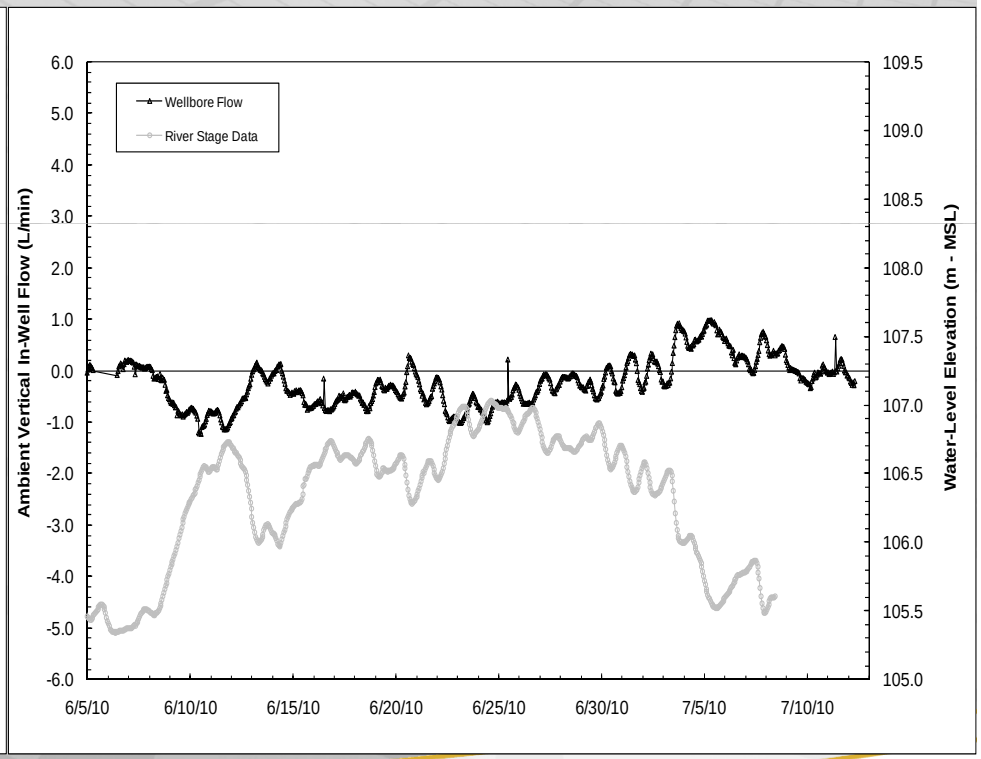
Performance of Single 30-in Packer (399-2-21)

No Packer Installed



Single Solinst® Packer Installed



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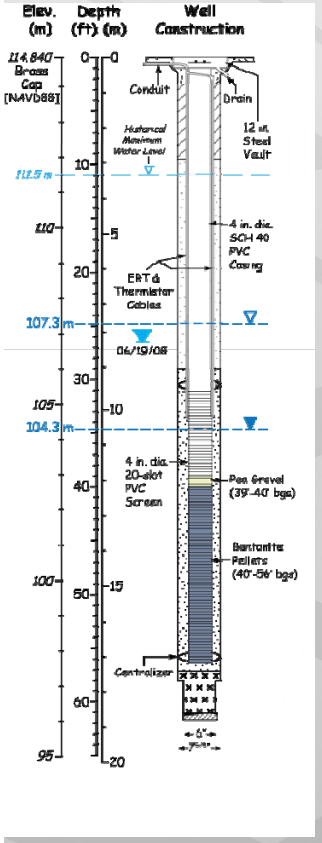
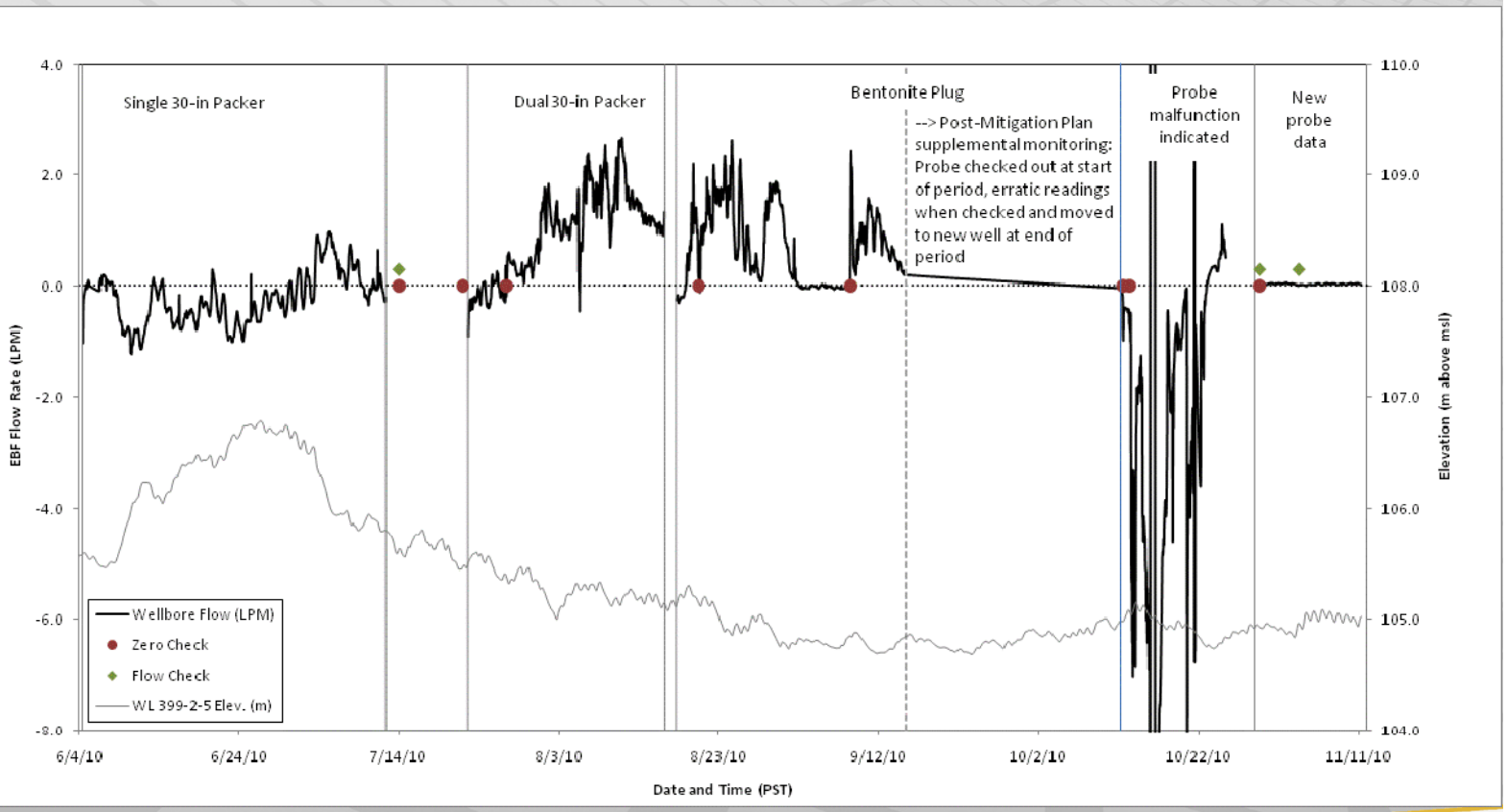
Mitigation Trials in Well 399-2-21: EBF and Water-level





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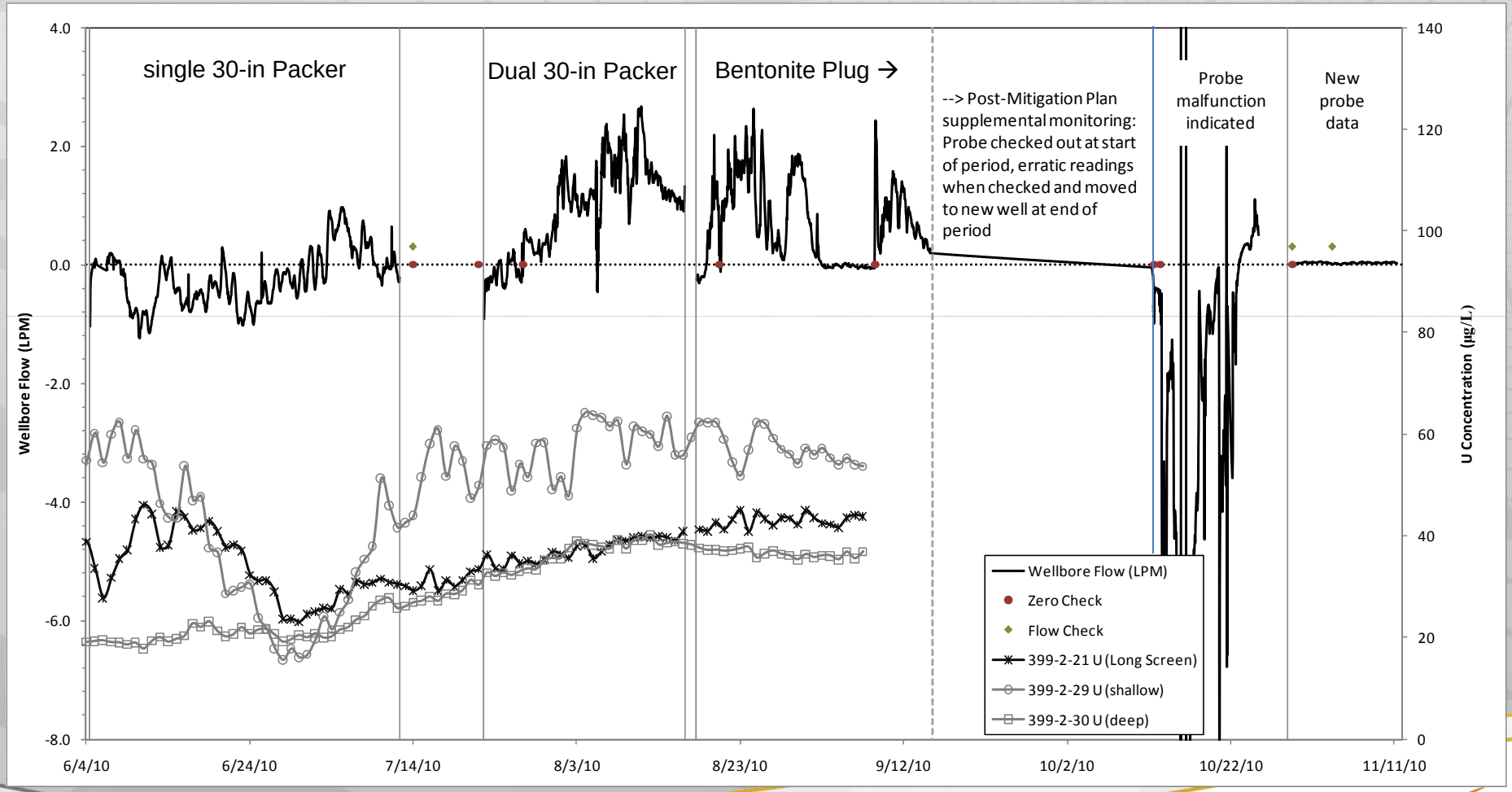
Mitigation Trials in Well 399-2-21: EBF and U Concentration



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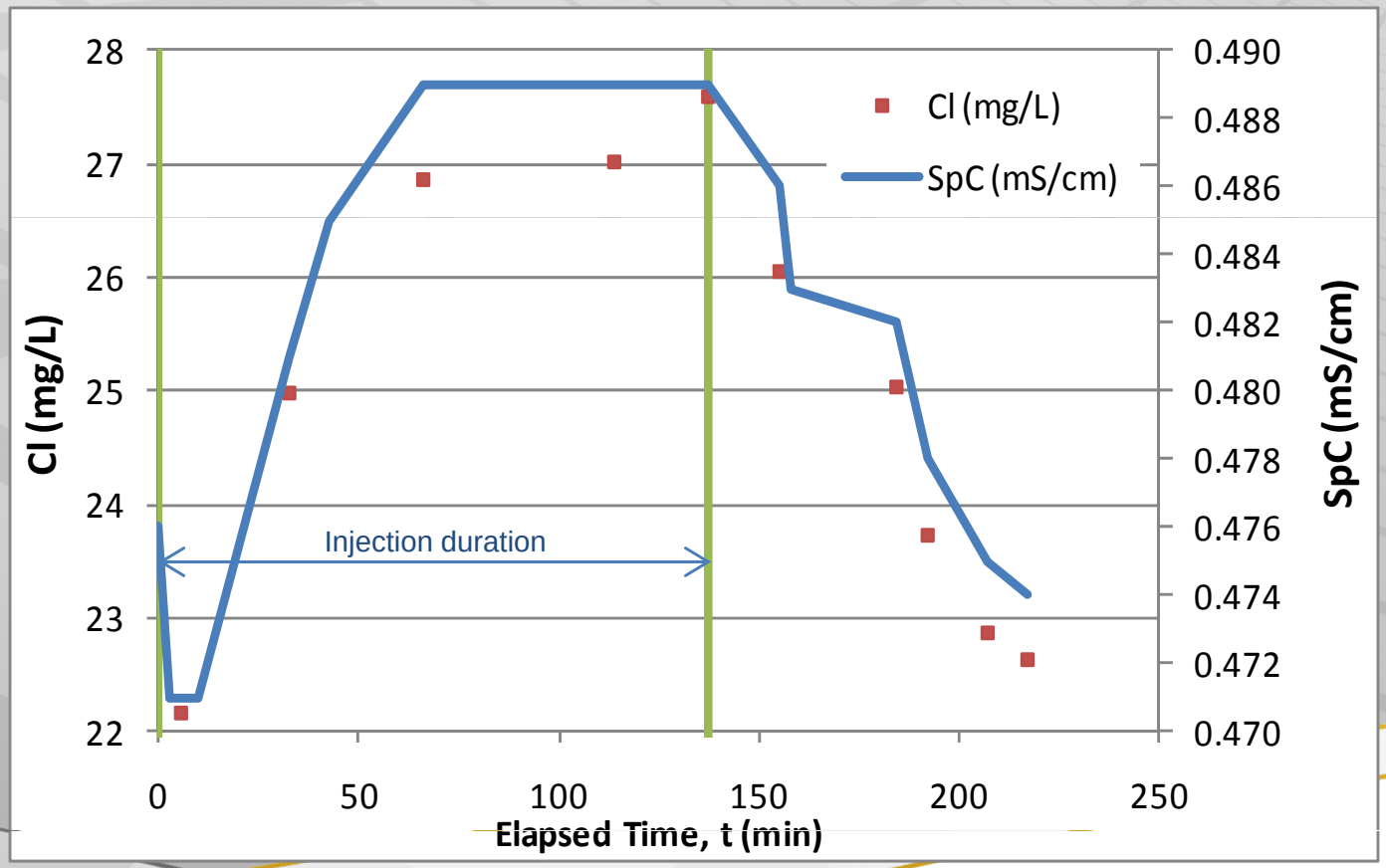
Tracer Intercommunication Test Results

- Dual 30-in packer string set in well 399-2-21
- Upper zone continuously pumped (purge rate of ~ 1gpm)
- 1000 mg/L Cl^- solution injected into lower zone at 67 mL/min for 137 min.



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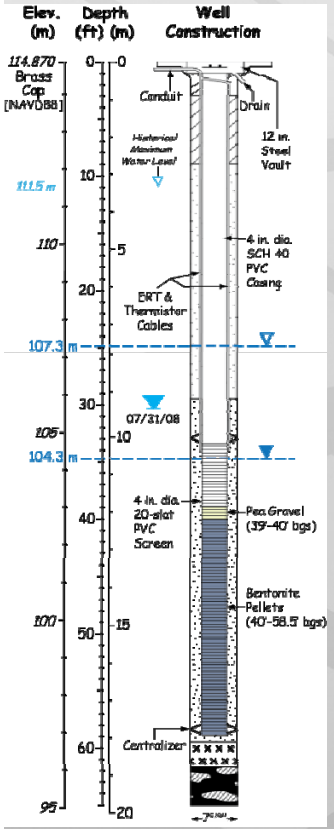
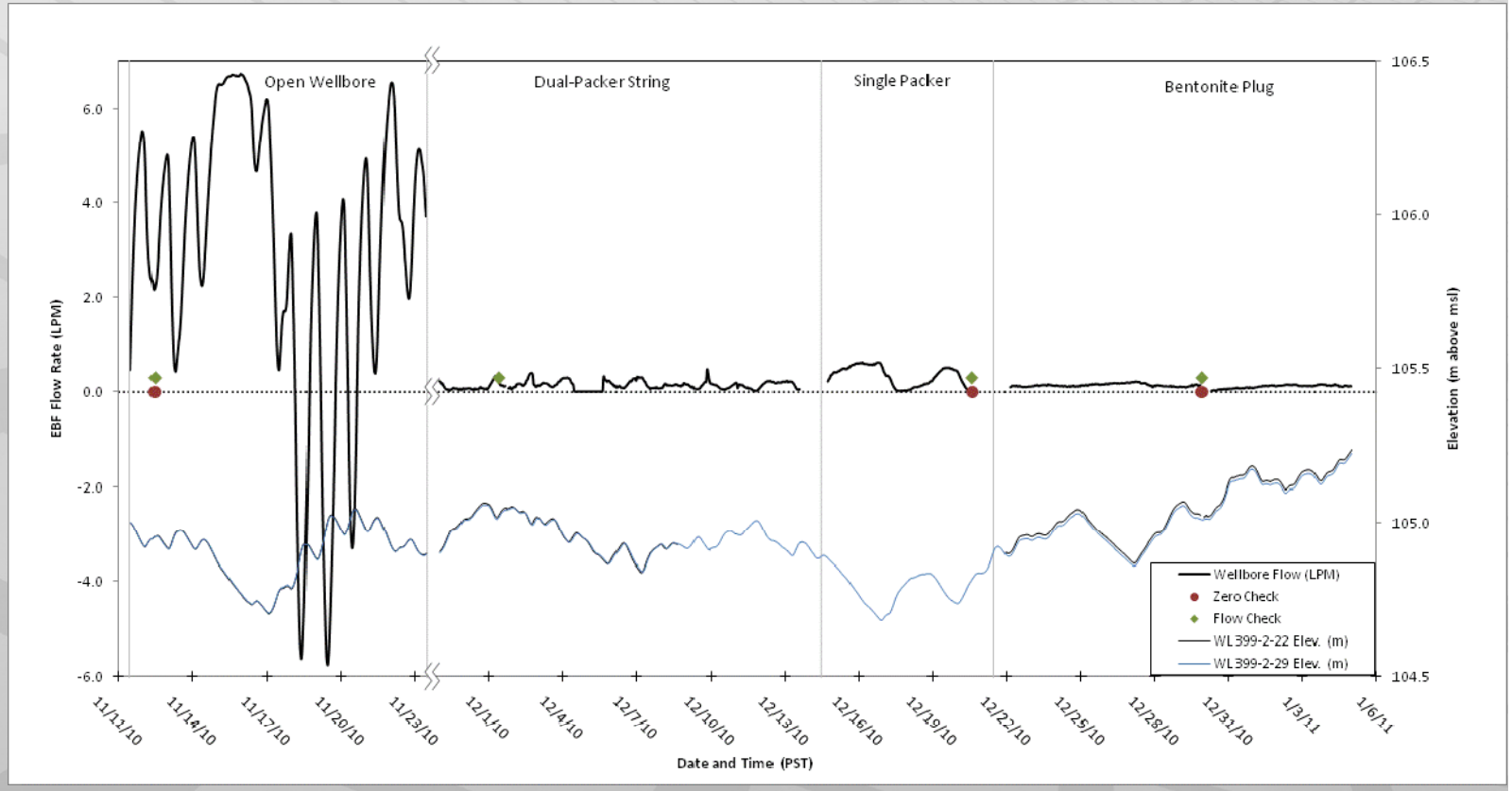
Mitigation Trials in well 399-2-22: EBF and Water-level





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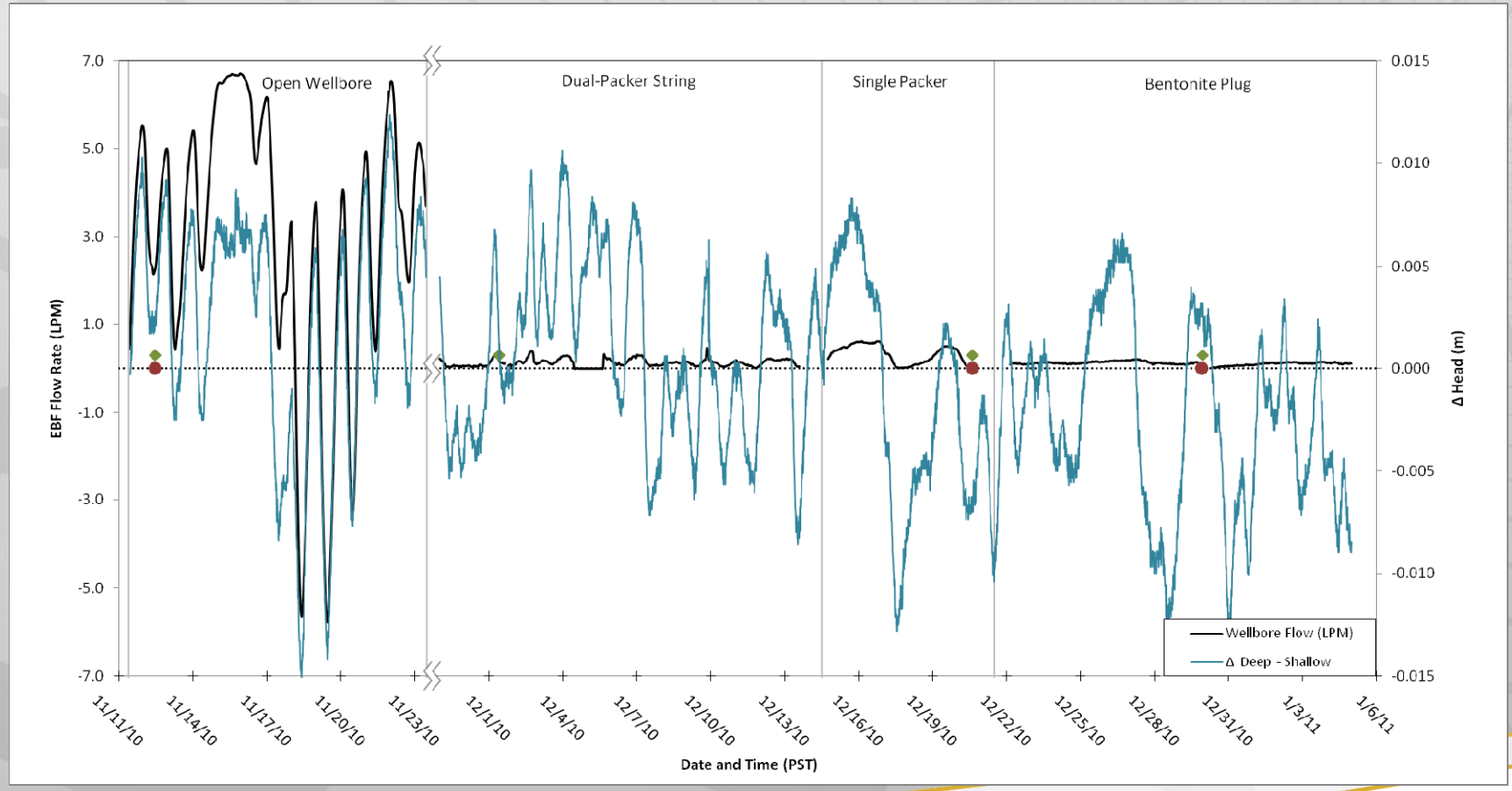
Mitigation Trials in well 399-2-22: EBF and Δ Head



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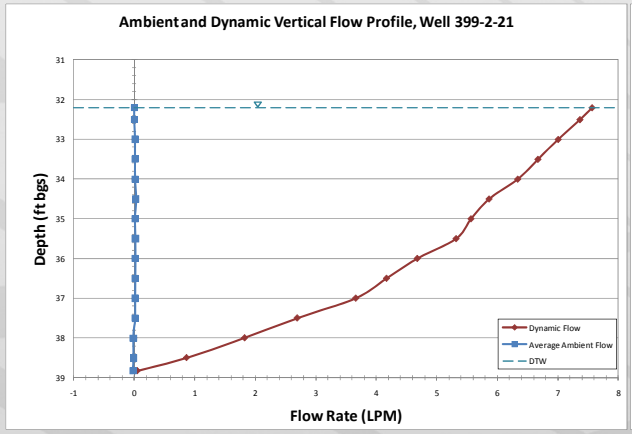
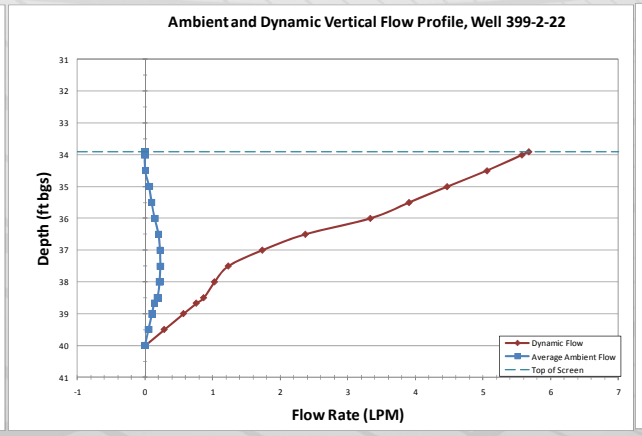
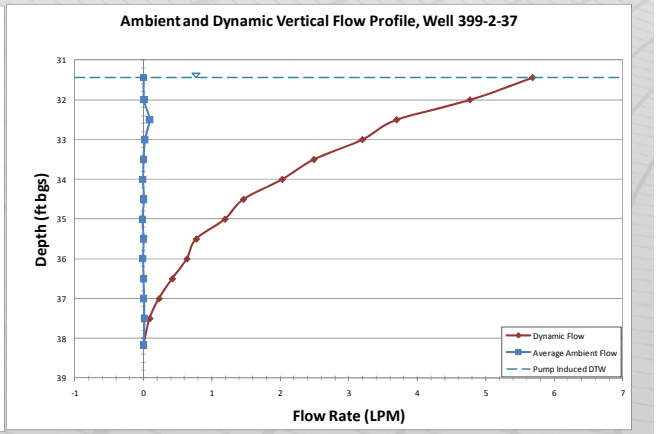
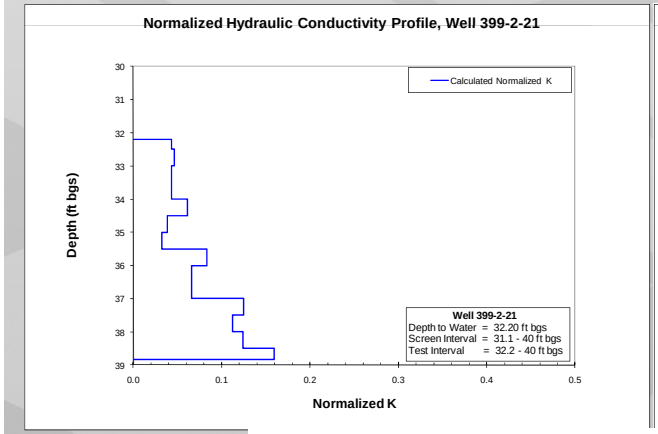
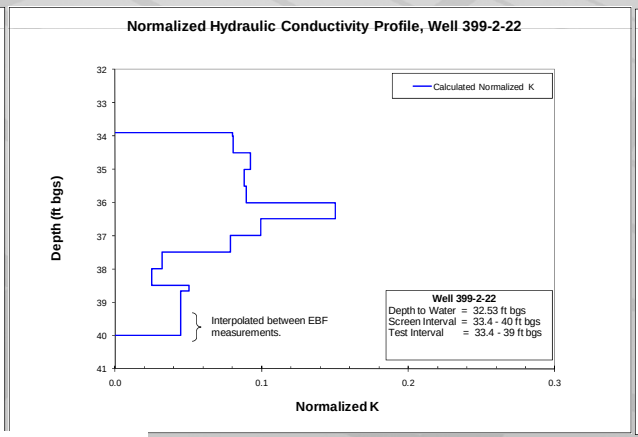
Upper Zone Ambient/Dynamic EBF Profiles

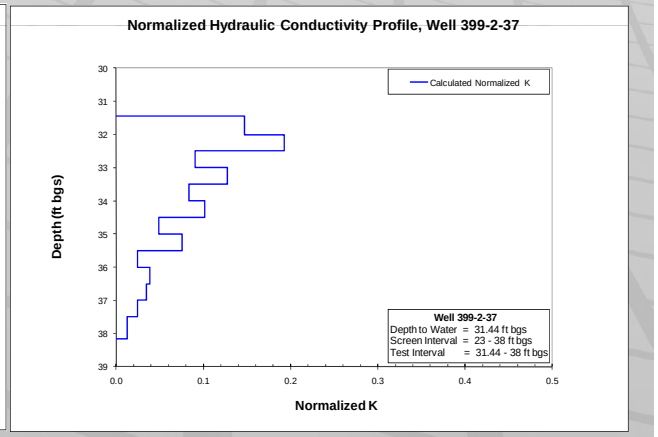


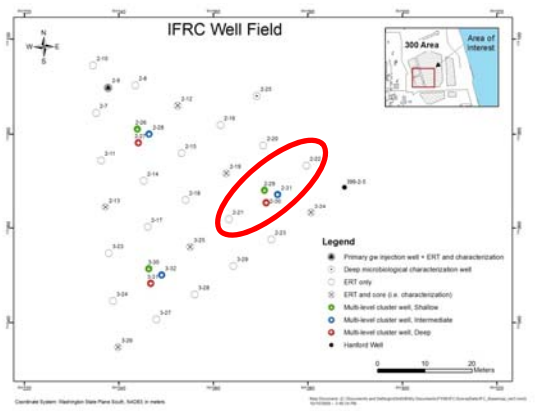












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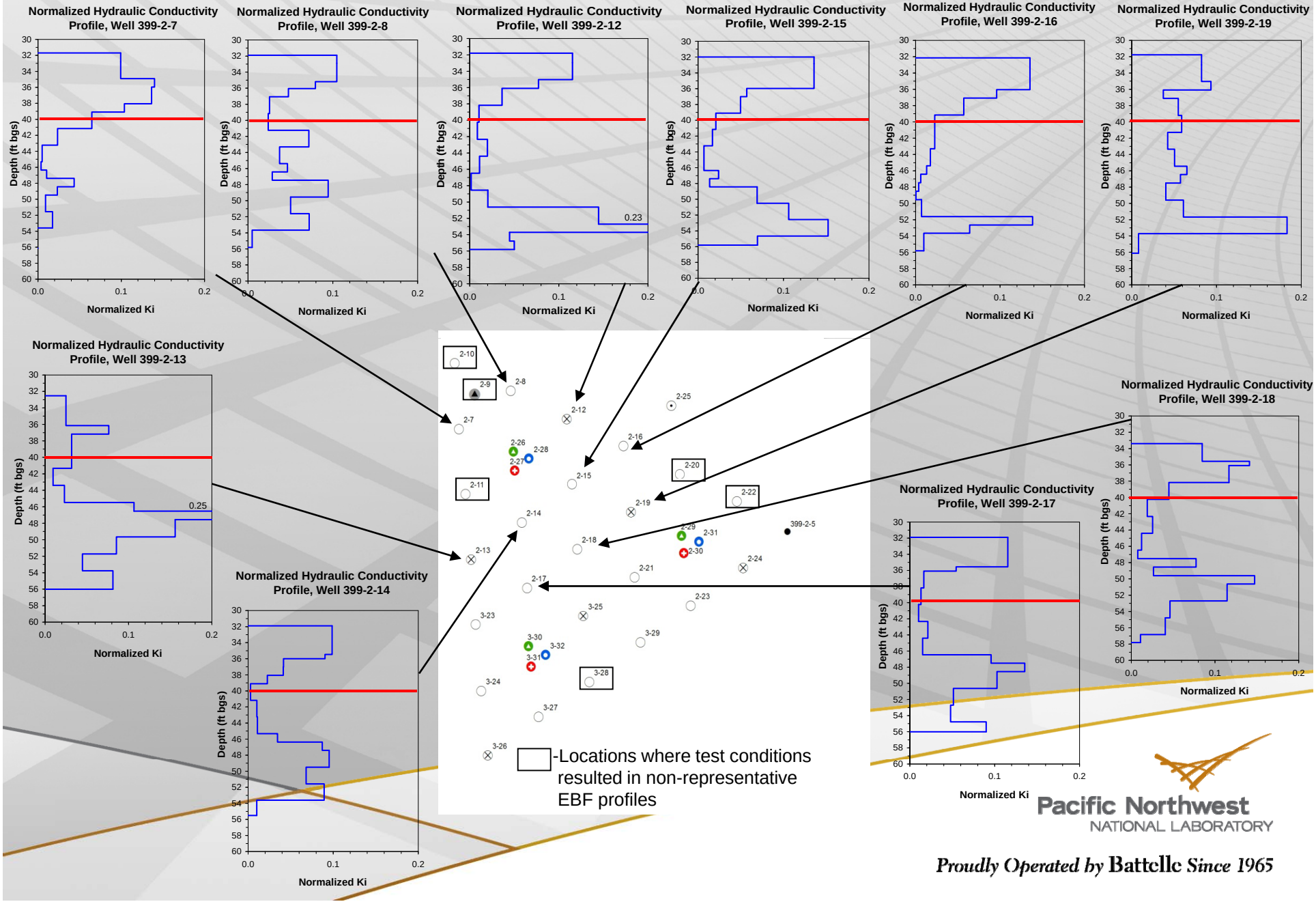
Bentonite Plug Specification (uniform plug top at 40 ft bgs?)



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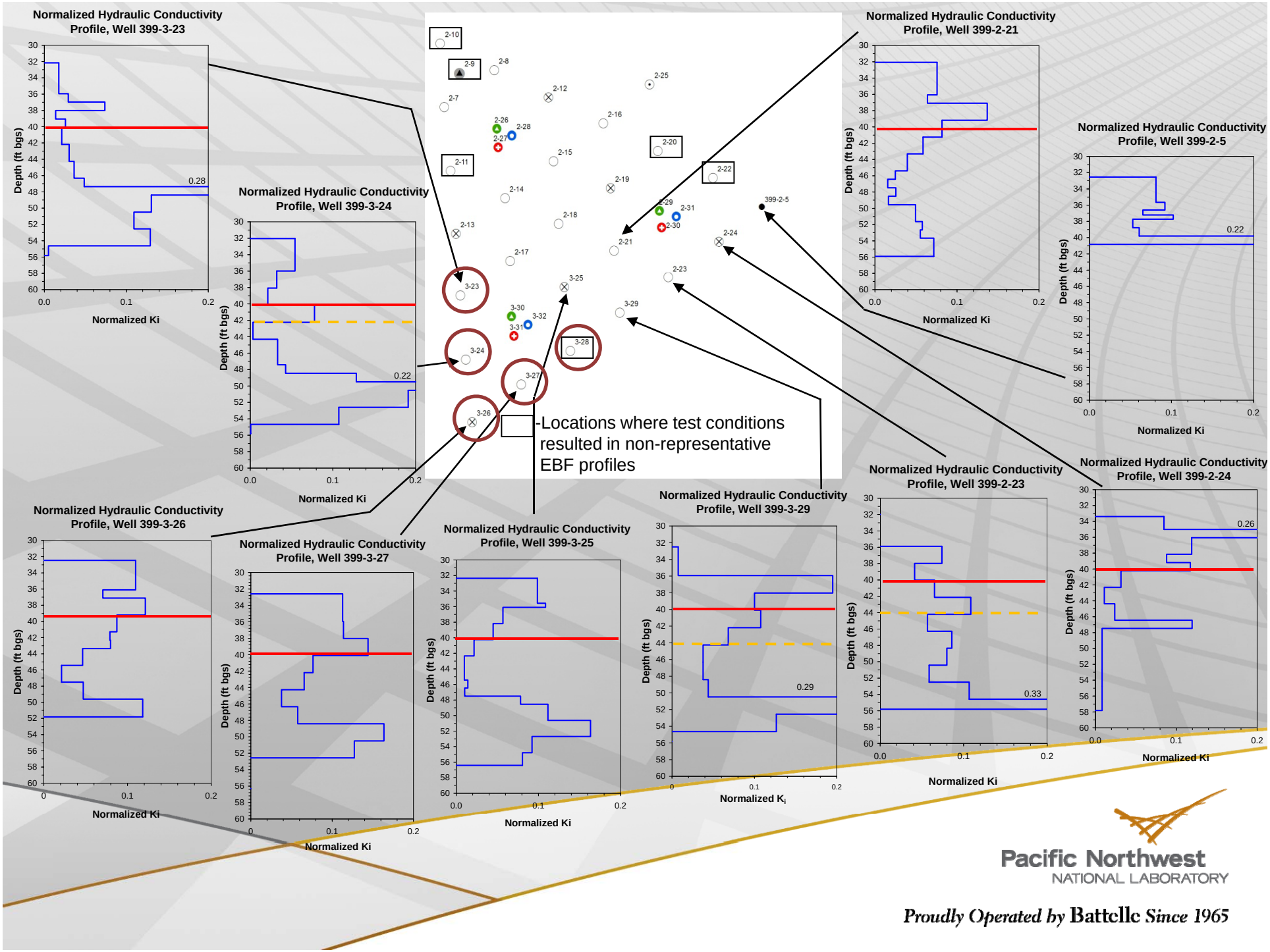
Normalized Hydraulic Conductivity Profile, Well 399-3-23
Depth (ft bgs)
Normalized Ki
0.28
Normalized Hydraulic Conductivity Profile, Well 399-3-24
0.22
Normalized Hydraulic Conductivity Profile, Well 399-2-21
Normalized Hydraulic Conductivity Profile, Well 399-2-5
0.22
Normalized Hydraulic Conductivity Profile, Well 399-3-26
Normalized Hydraulic Conductivity Profile, Well 399-3-27
Normalized Hydraulic Conductivity Profile, Well 399-3-25
Normalized Hydraulic Conductivity Profile, Well 399-3-29
Normalized K_i
0.29
Normalized Hydraulic Conductivity Profile, Well 399-2-23
0.33
Normalized Hydraulic Conductivity Profile, Well 399-2-24
0.26
2-10
2-9
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399-2-5
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3-26
-Locations where test conditions resulted in non-representative EBF profiles
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Plans for Upper Zone Characterization

- Conduct ambient and dynamic EBF profiling throughout the wellfield
  - Perform at multiple water table elevations to provide different scales of interrogation
  - Three new upper zone wells have screens that extend high enough to support 3 scales of interrogation (low, mid, and high water table conditions)
  - Most existing wells will only support low and mid WT conditions
- Conduct constant-rate injection tests in a subset of wells distributed throughout the wellfield
  - Same distribution as previous hydraulic testing campaign?
    - 14 wells distributed throughout wellfield
  - Test all wells?

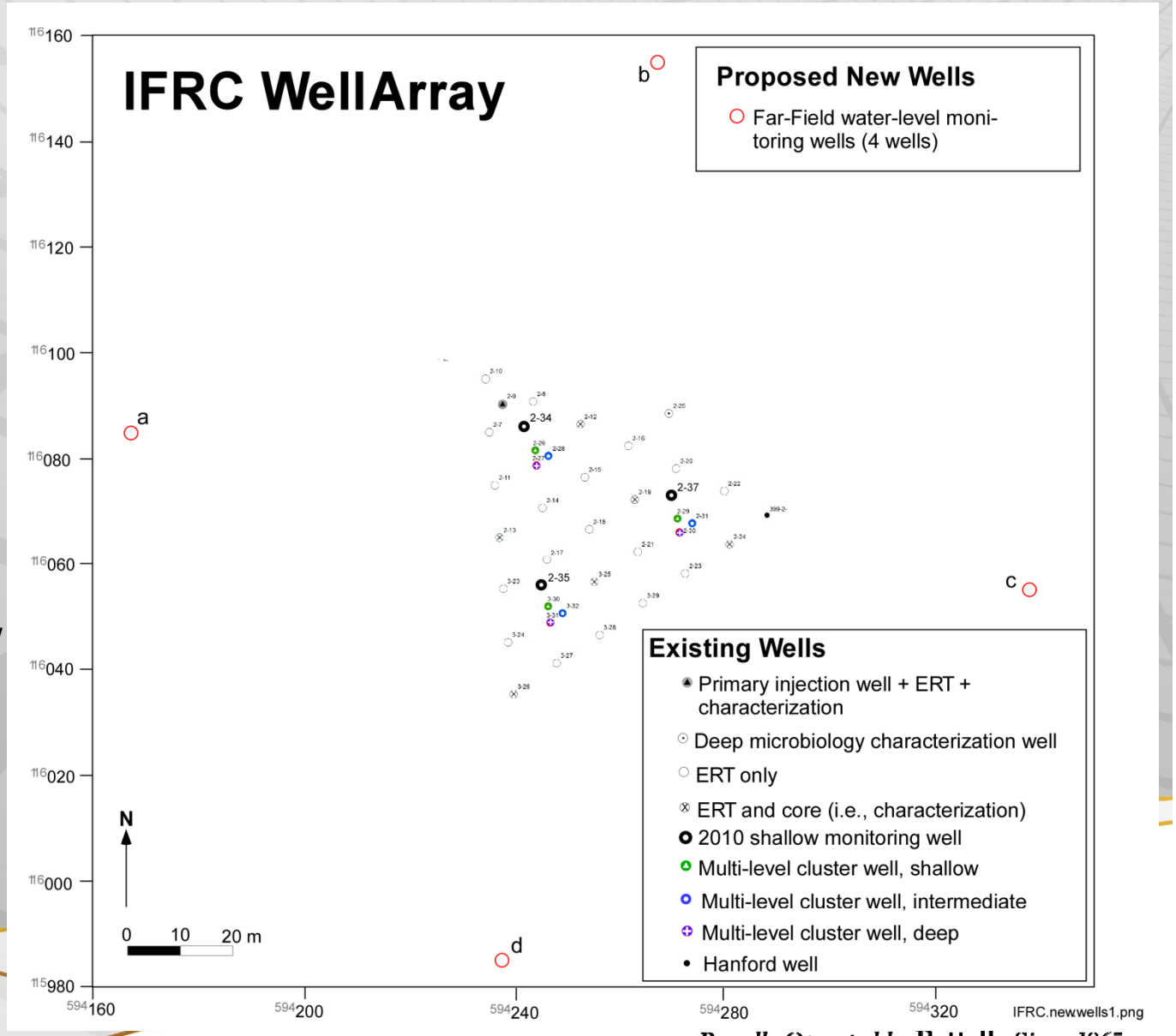
Recent and Planned Drilling

FY 2010

- 3 new shallow monitoring wells

Early spring 2011

- 4 new far-field gw monitoring wells



Sampling and Well Construction