Hydraulic Pulse Testing of Permeable Reactive Barriers

By

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Presentation Outline

RTDF Permeable Reactive Barrier Meeting
Niagara Falls, NY – Oct 15-16, 2003

Permeable Reactive Barrier Construction Methods

- Continuous Trencher
- Excavated Slurry Wall
- Caisson, Soil Mixing, Vibrating Beam
- Hydraulic Fracturing Technology

Hydraulic Conditions Across PRB

- Potentiometric Levels for Various PRB Configurations
- Partially Clogged PRB
- Slug Tests within PRB

Hydraulic Pulse Interference Tests

- Test Method
- Type Curve Analysis for Hydrogeological Characterization
- PRB Thickness by Inclined Profiling
- Hydraulic Pulse Tests to quantify PRB Hydraulic Impact

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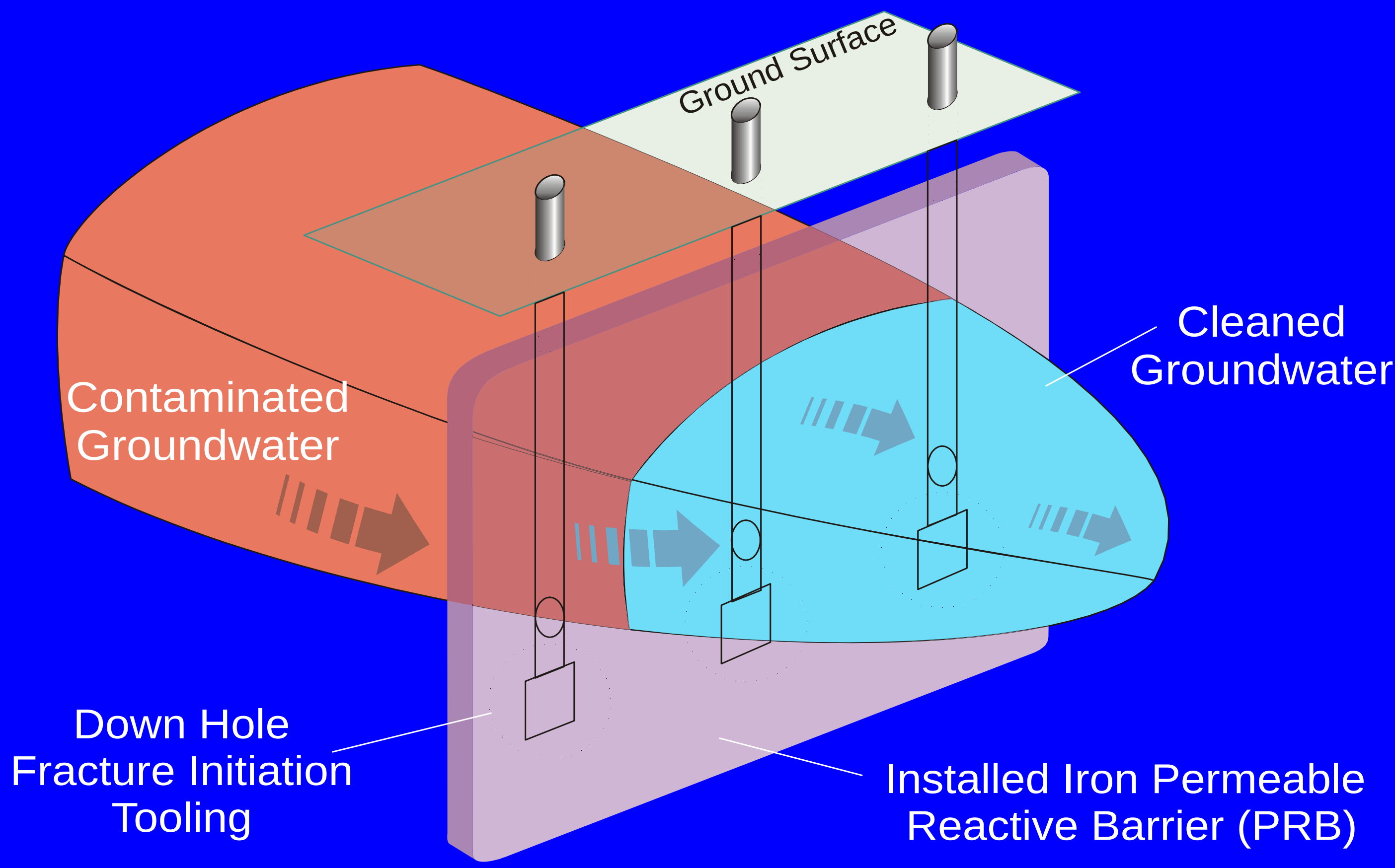
Various Iron PRB Construction Techniques

Azimuth Controlled Vertical Hydrofracturing Installed Iron Permeable Reactive Barrier



Injection Build Sequence

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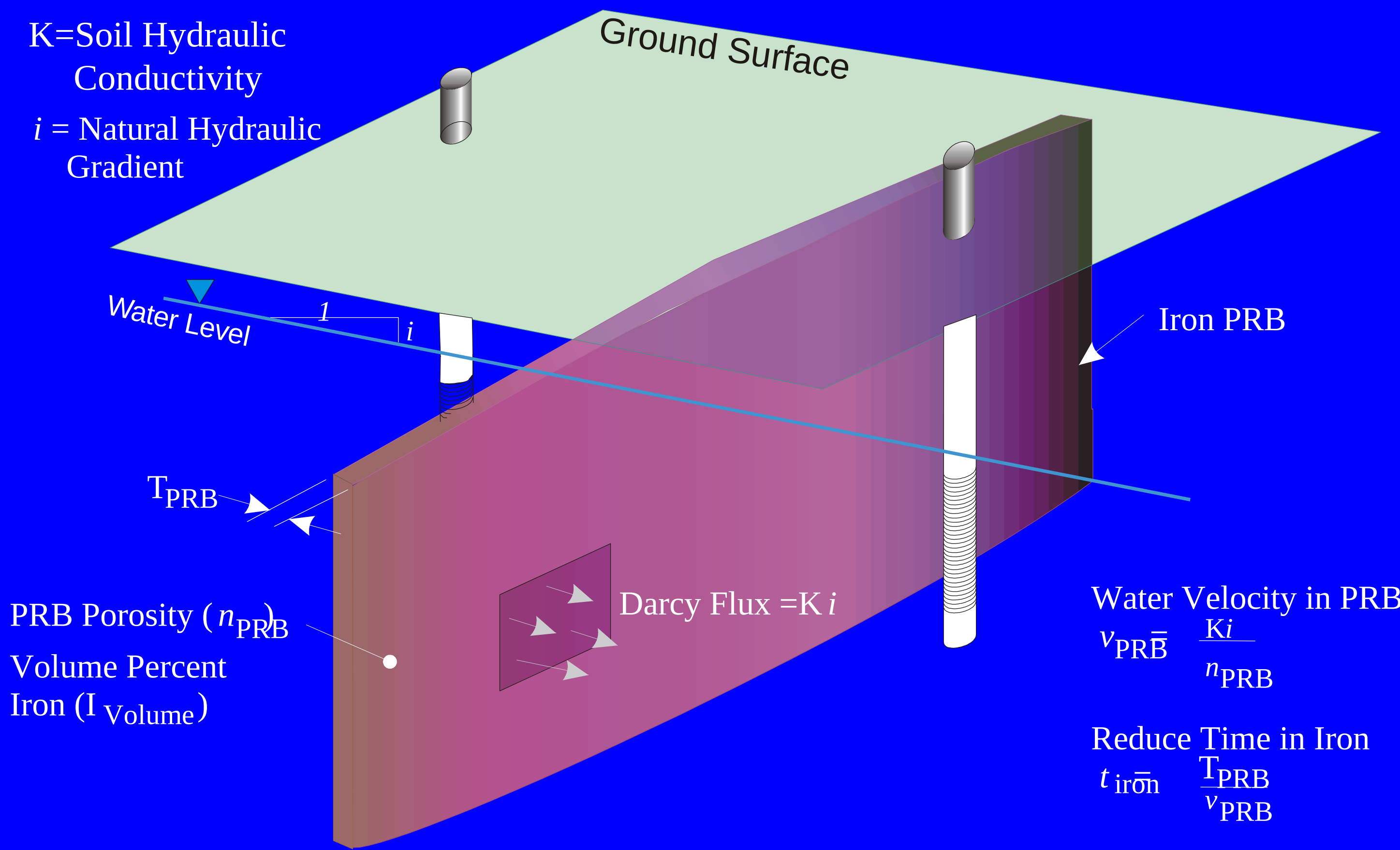
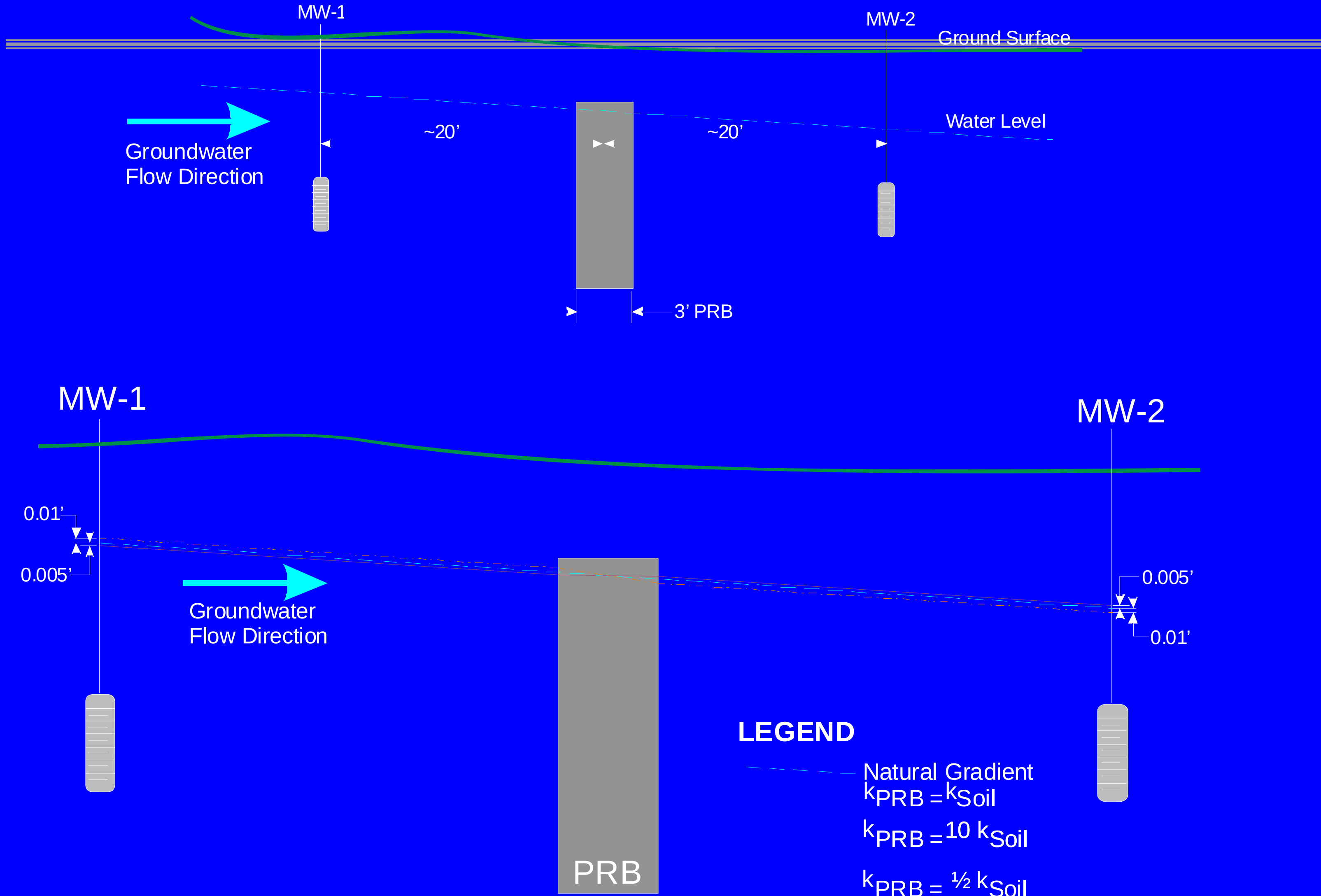
Contaminant Resident Time in Iron PRB



Hydraulic Gradient Across Iron PRB



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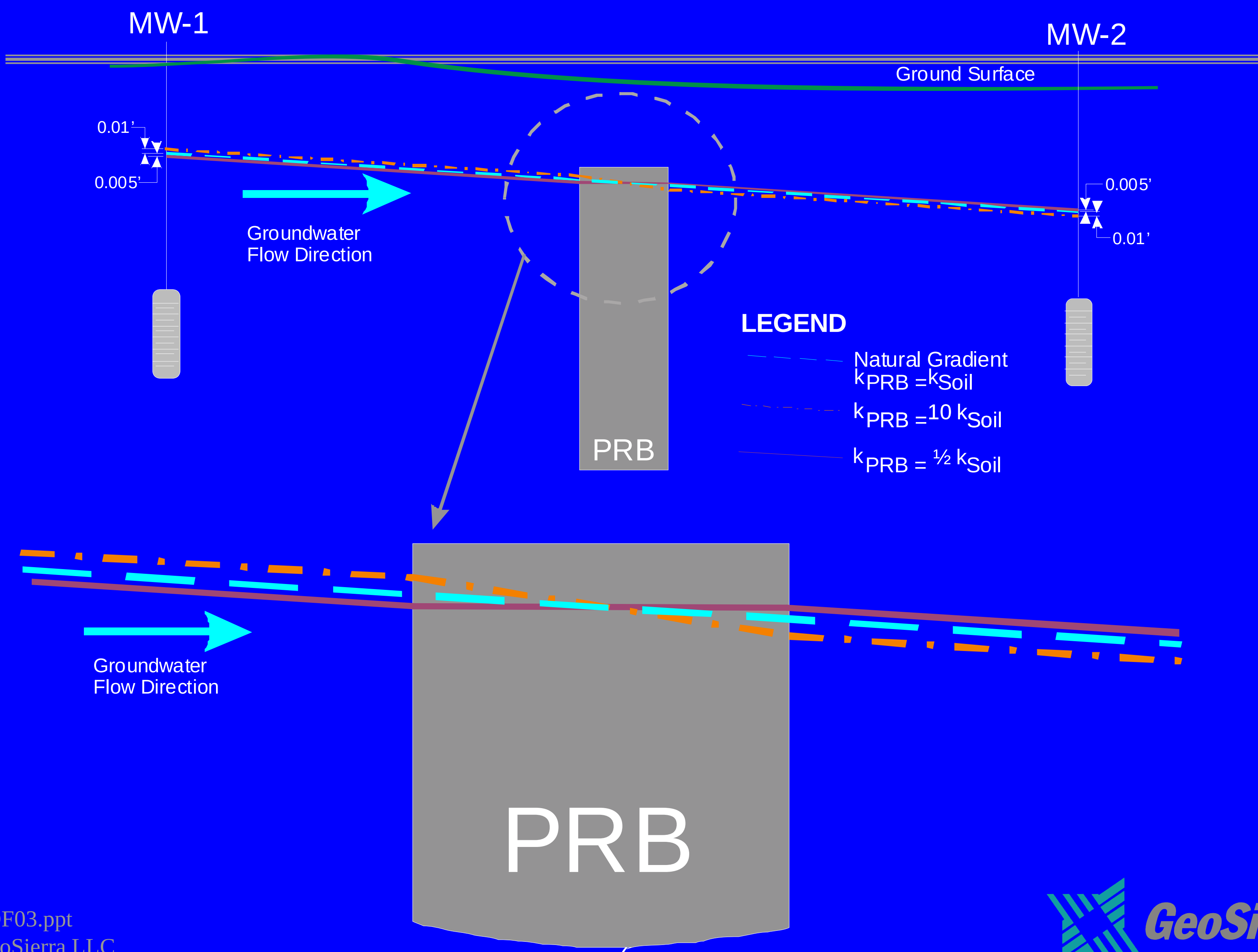
Hydraulic Gradient Across Iron PRB



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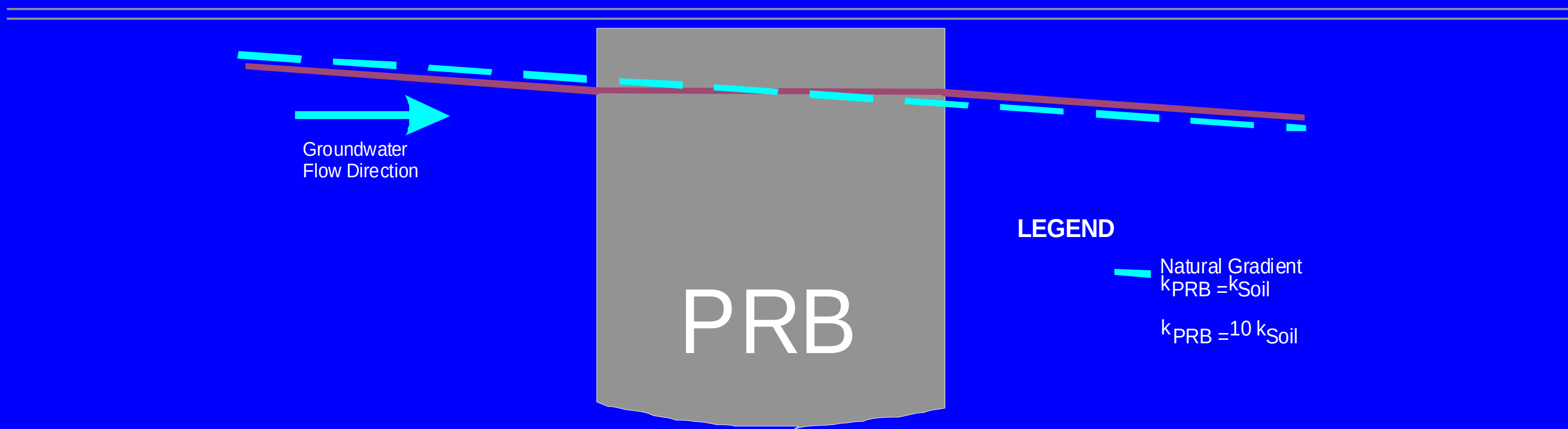
Hydraulic Gradient Across Iron PRB



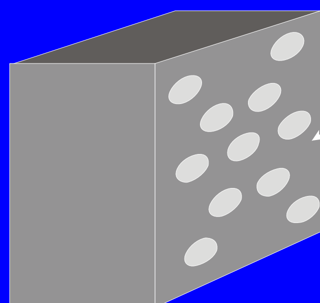
LEGEND

Natural Gradient
$k_{PRB} = k_{Soil}$

$k_{PRB} = 10\ k_{Soil}$

$k_{PRB} = k_{Soil}$

(90% Clogged for
$k_{PRB} = 10\ k_{Soil}$)



90% of Face Clogged

- No Gradient Change
-Flow Through PRB ~10x Faster

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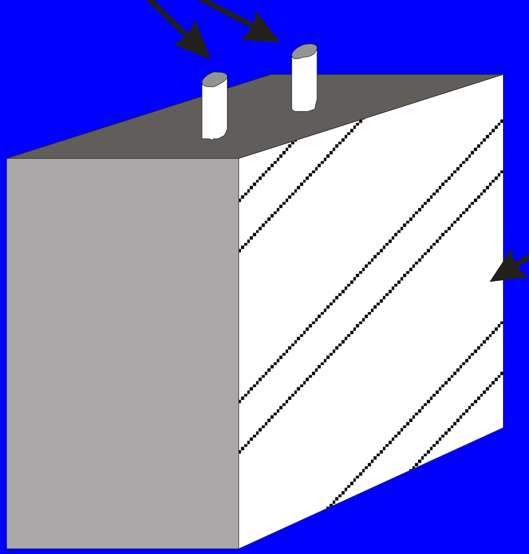
Slug Test in Slurry Wall Constructed PRB

Slug Test on Wells



Skin Effects
(Smear & Filter Cake)
Potential Clogging of
Side Walls

Slug Test in Iron PRB and Zone of Influence

HVORSLEV SLUG TEST ANALYSIS
RISING HEAD TEST B21-72-PZ

$$K = \frac{r_c^2}{2L_e} \ln \frac{L_e}{R_e} \left[\frac{\ln\left(\frac{y_1}{y_2}\right)}{(t2 - t1)} \right]$$

where:
- r_c = casing radius (feet)
- R_e = equivalent radius (feet)
- L_e = length of screened interval (feet)
- t = time (minutes)
- y_t = head at time t (feet)

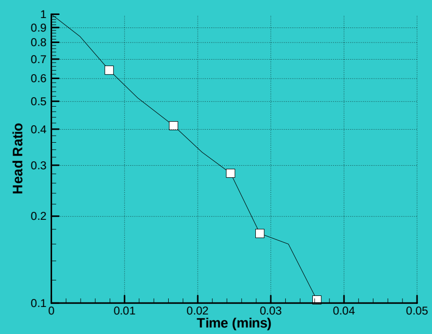
INPUT PARAMETERS

r_c =	0.08
R_e =	0.33
L_e =	15
t_1 =	0.0022
t_2 =	0.0125
y_1 =	0.47
y_2 =	0.26

RESULTS

K=	2.36E-02	cm/sec
K=	6.68E+01	ft/day

Rising Head Slug Test B21-72-PZ



Project Name: MACTEC/SIERRA ARMY DEPOT, CA
Project No.: 6014
Analysis By: RIO
Checked By: GH

$L^2 = K.t/S$

$L \sim 10$feet

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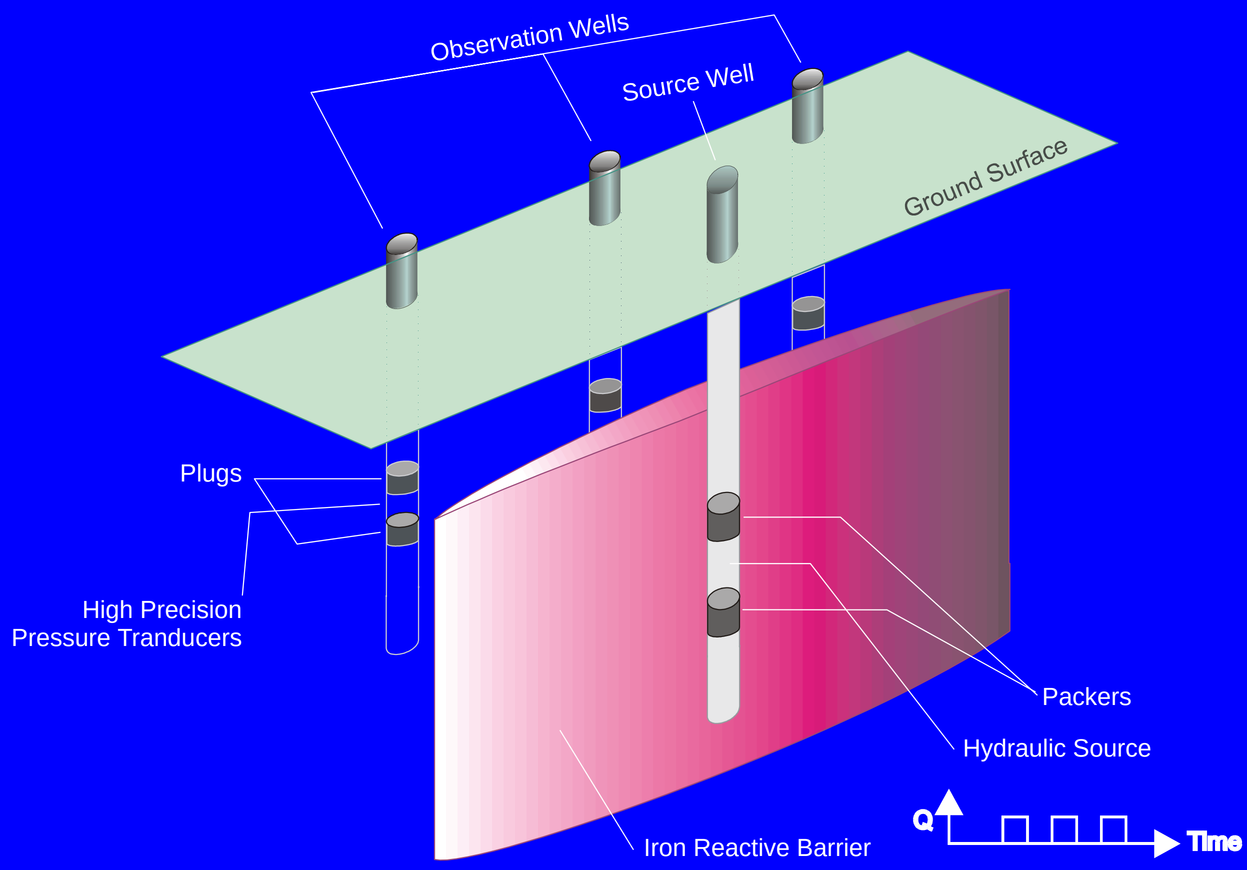
Hydraulic Pulse Interference Test



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Pulse Test Solution and Dimensionless Pressure & Time

The pressure response in a receiver well, denoted as $\Delta p(t)$ for a continuous flow rate injection of q in the injection/source well, is given by equation (1).

$$\Delta p(t) = \frac{q}{4\pi K r_w r_D} erfc(r_D / \sqrt{4t_D}) \qquad (1)$$

where K is the formation hydraulic conductivity, S_s is the formation specific storage, r_w is the wellbore radius of the source well, r_D is the dimensionless distance being equal to r/r_w, in which r is the distance from the receiver well to the source well, and t_D is denoted as dimensionless time as defined in equation (2).

$$t_D = \frac{Kt}{r_w^2 S_s} \qquad (2)$$

where t is the elapsed time since start of injection and p_D is denoted as the dimensionless pressure as defined in equation (3).

$$p_D = \frac{4\pi K r_w \Delta p(t)}{q} \qquad (3)$$

For the solution of the pulse interference test, equation (1) needs to account for the periodic nature of the injection flow rate in the source well. The time intervals of injection and shut in do not need to be the same, but account for their periodic nature needs to be included. The dimensionless time interval for injection and shut in have been assumed to be the same in this paper with the dimensionless time interval for injection tp_D as defined in equation (4).

$$tp_D = \frac{Ktp}{r_w^2 S_s} \qquad (4)$$

where tp is the pulsed injection time interval.

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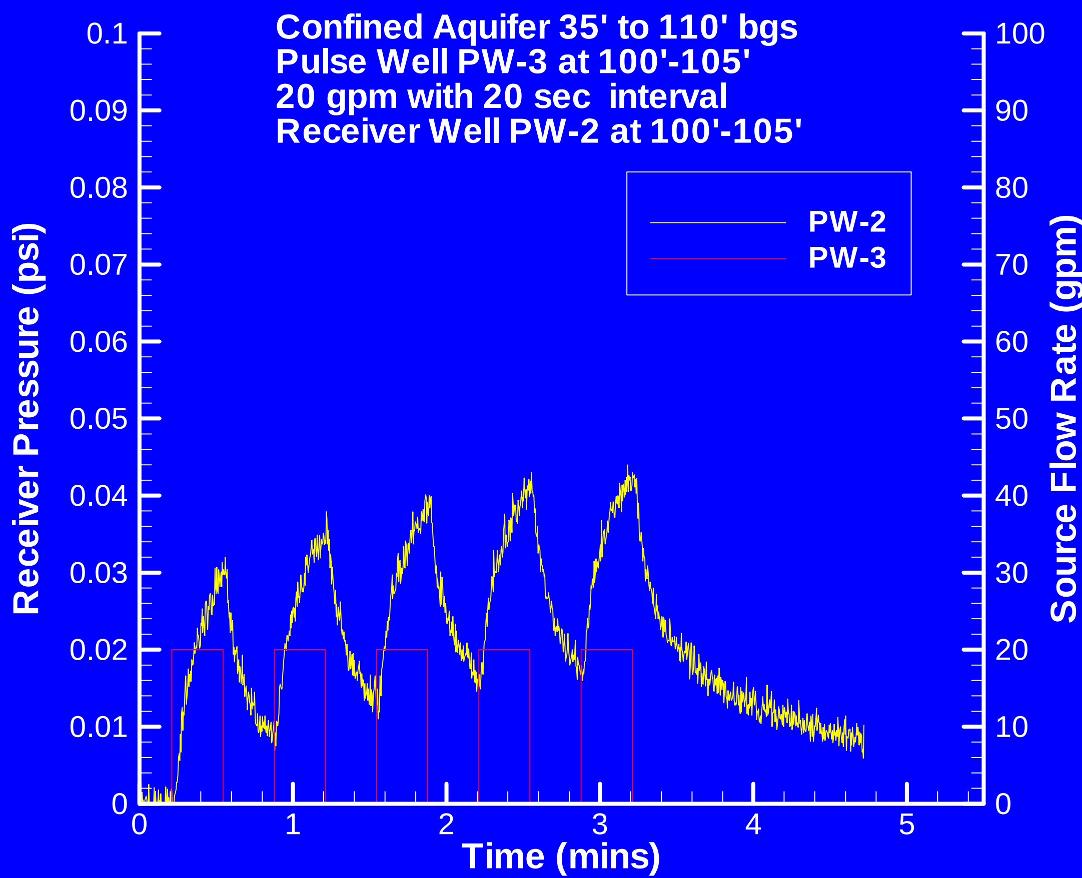
Typical Hydraulic Pulse Interference Test Setup

Typical Hydraulic Pulse Interference Response Data



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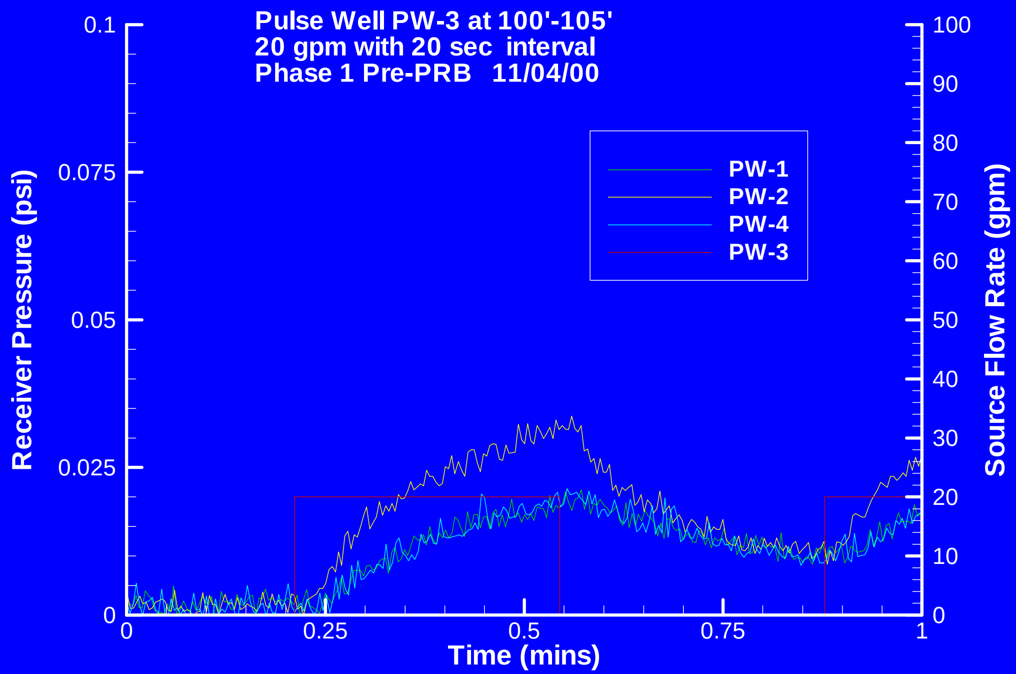
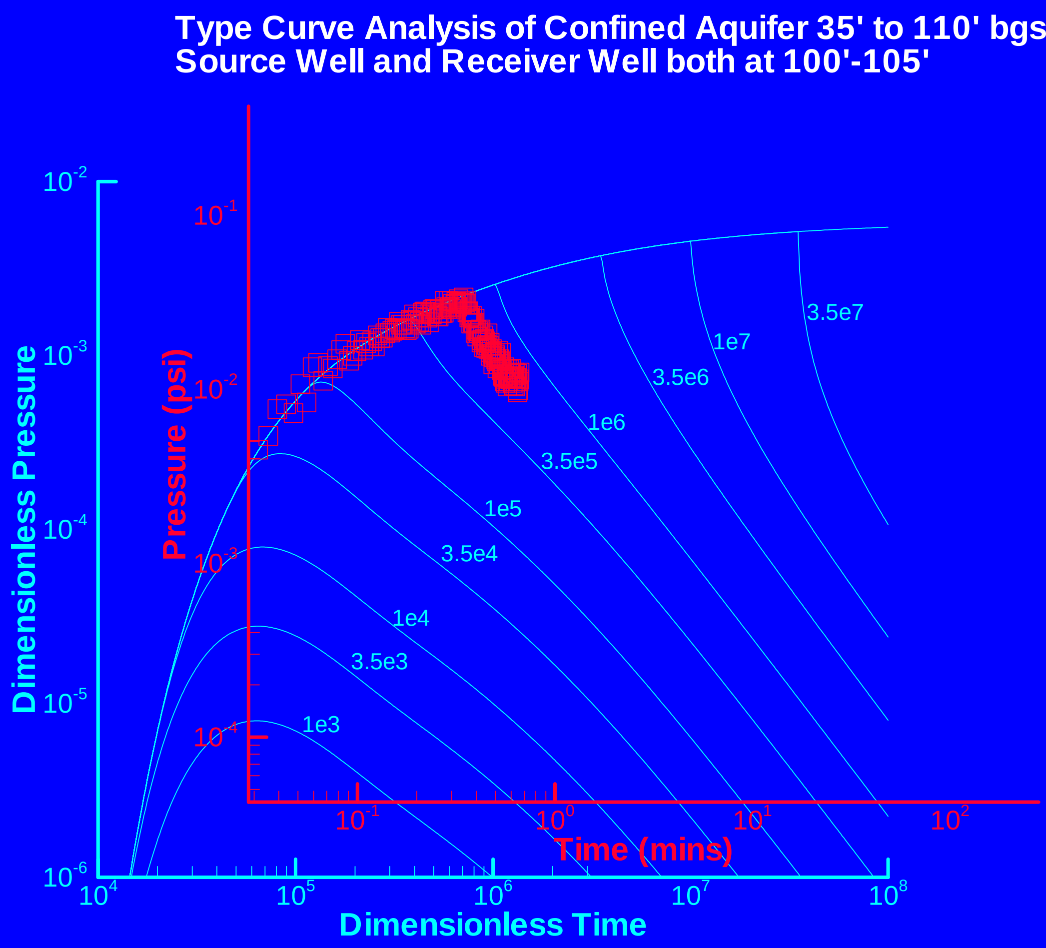
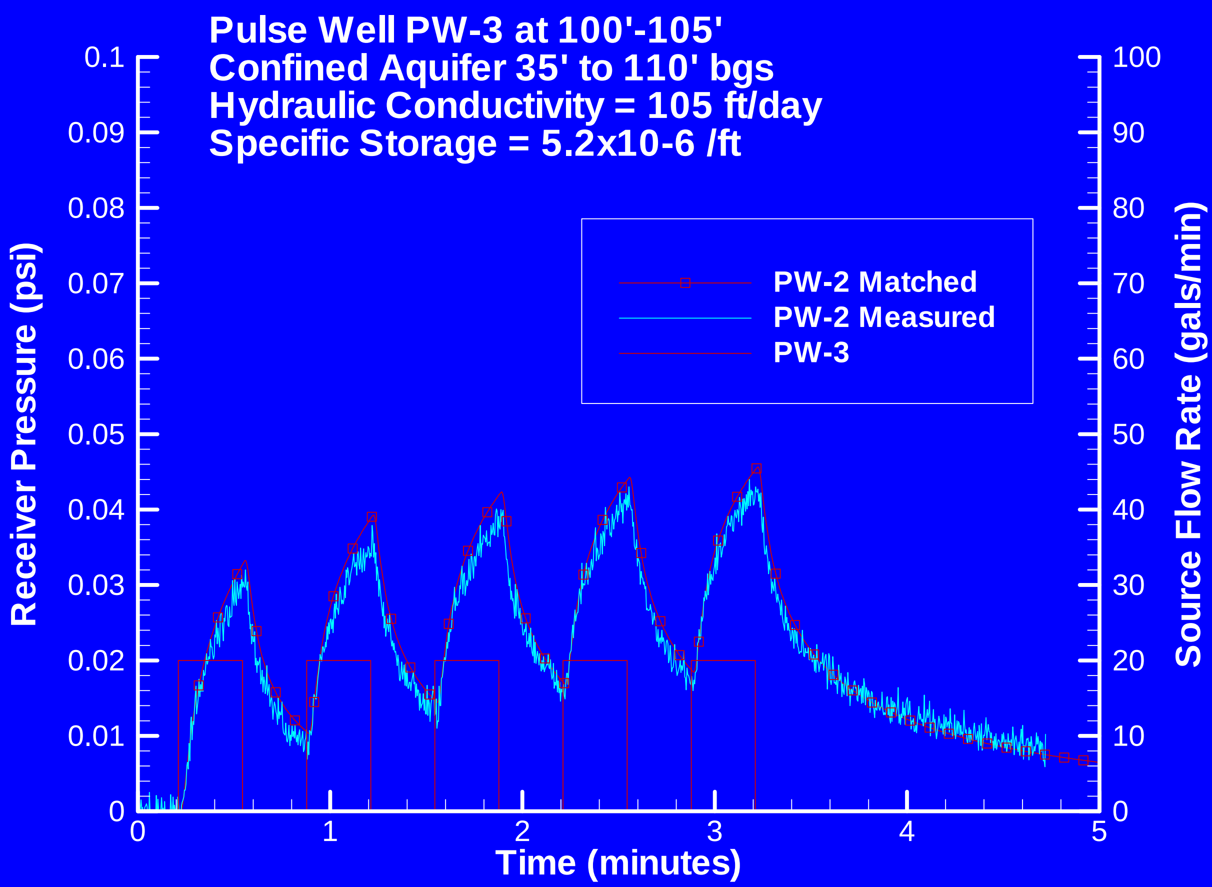
Hydraulic Pulse Interference
Pre-Construction Results



Type Curve Analysis of Hydraulic Pulse Interference Data



Match of Hydraulic Pulse Interference Data



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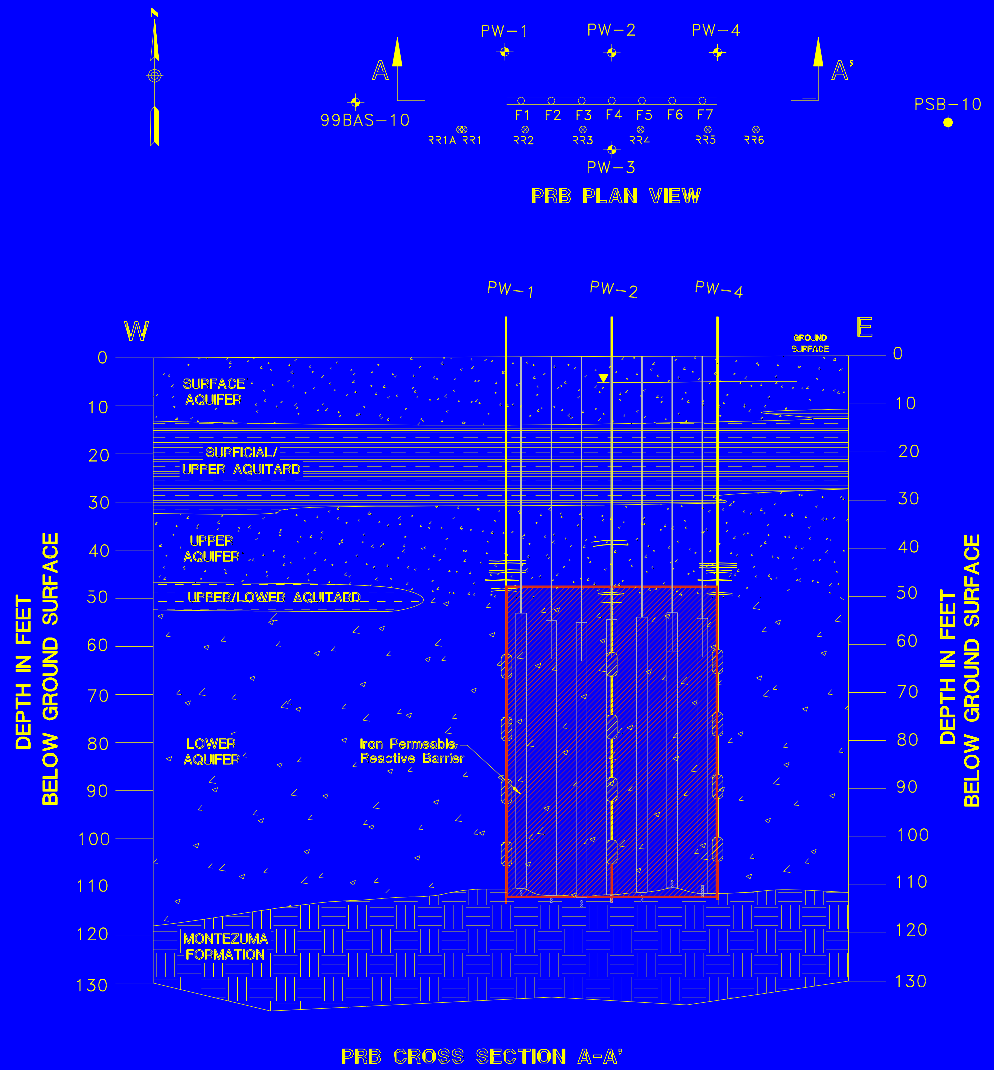
View of Frac Equipment and Final PRB Alignment

Plan & Cross Section of Iron PRB



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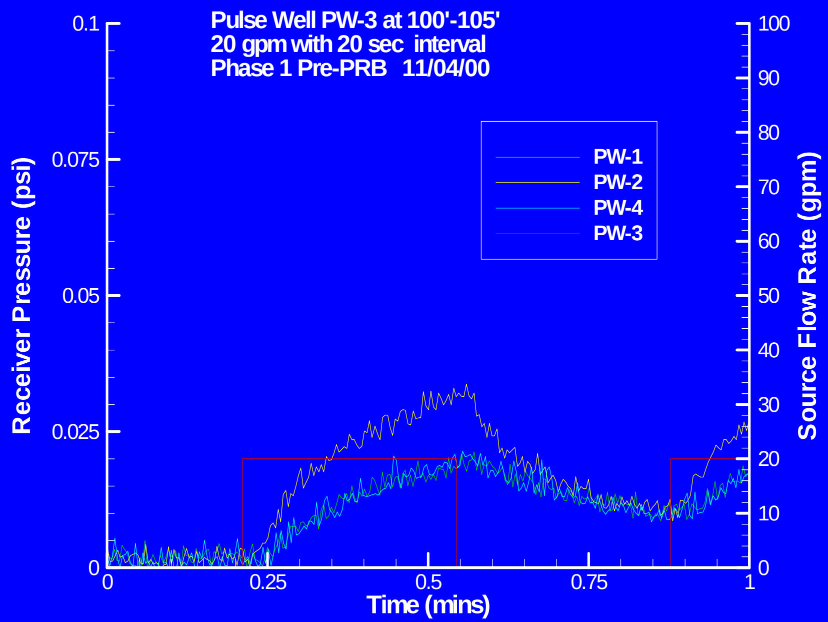
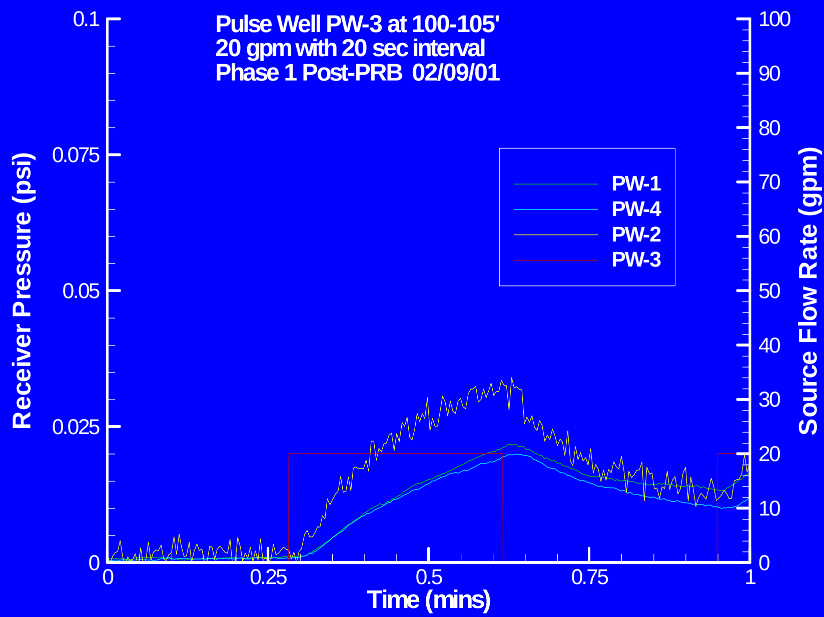
Pre and Post PRB Construction Pulse Interference Tests





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Conclusions

Groundwater monitoring well water level data insufficient to quantify PRB permeability or clogging issues

PRB Slurry Wall Construction Method

- Reduced residence time within the PRB could be due to partial clogging of PRB faces (skin effect) during construction
- Jetting and surging to remove PRB skin virtually impossible to achieve

Hydraulic Pulse Interference Test

- Ideal to quantify hydraulic impact of PRB and partial clogging issues
- Test very sensitive to hydrogeological conditions between source and receiver wells
- Test can quantify PRB skin effects
- Simple and straightforward test

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