

Field Characterization of Mass Transfer in a --- NAPL Source Zone

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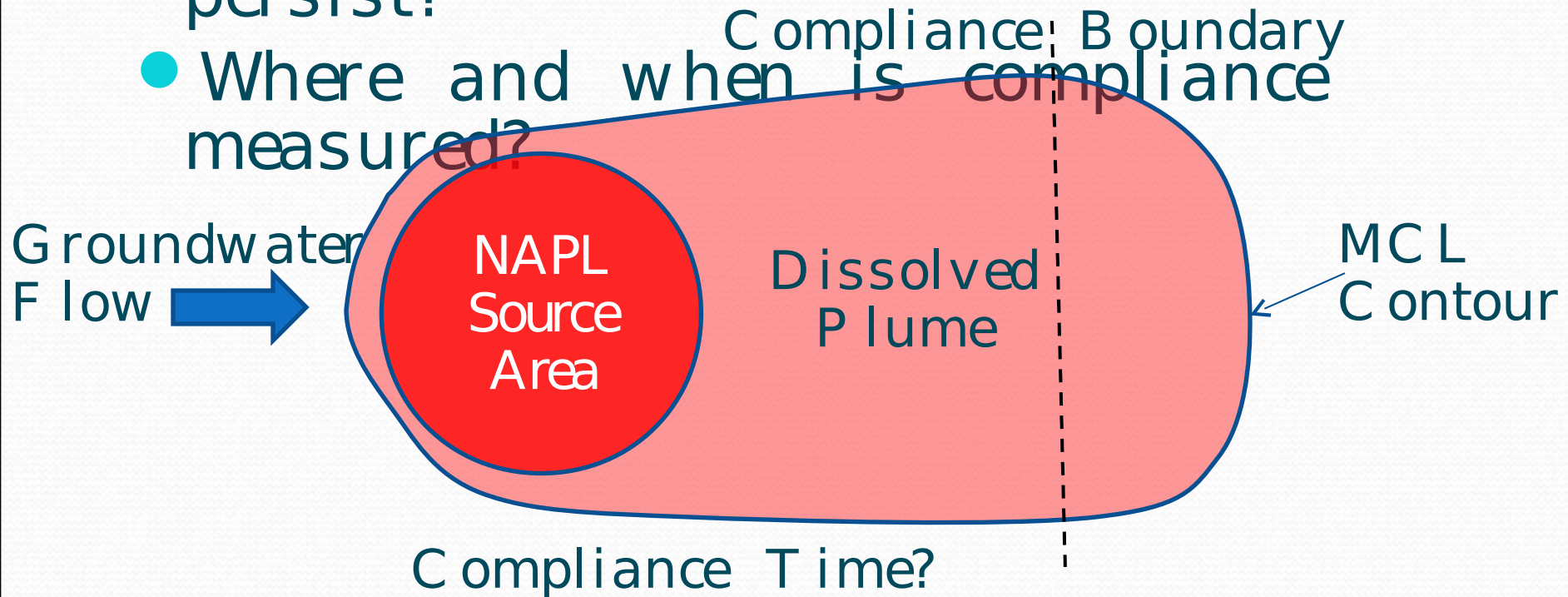
PRAXIS

Overview

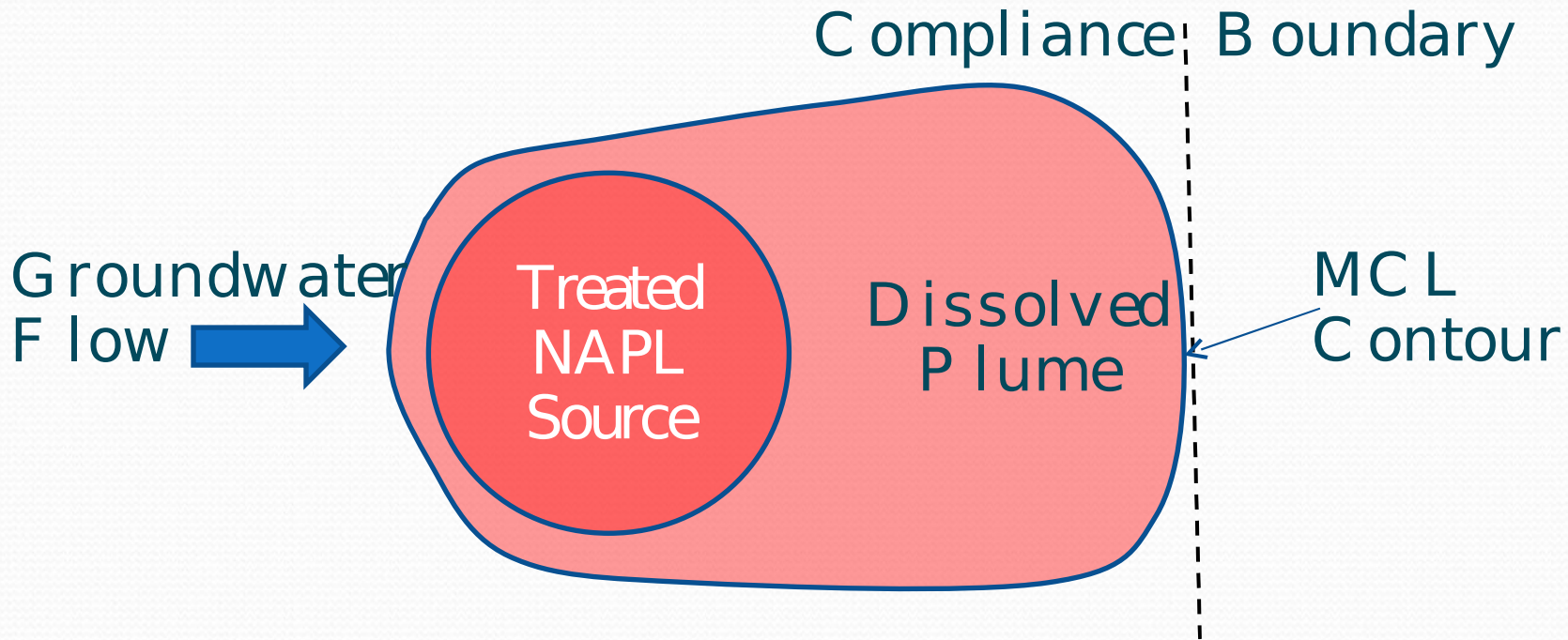
- The Problem
 - How much NAPL mass?
Components?
 - How long will the NAPL persist?
 - Where and when is compliance measured?
- The “Mass Transfer Test”
- Example Results
- Implications for Modeling

The Problem

- How much NAPL mass?
Components?
- How long will the NAPL persist?
- Where and when is compliance measured?



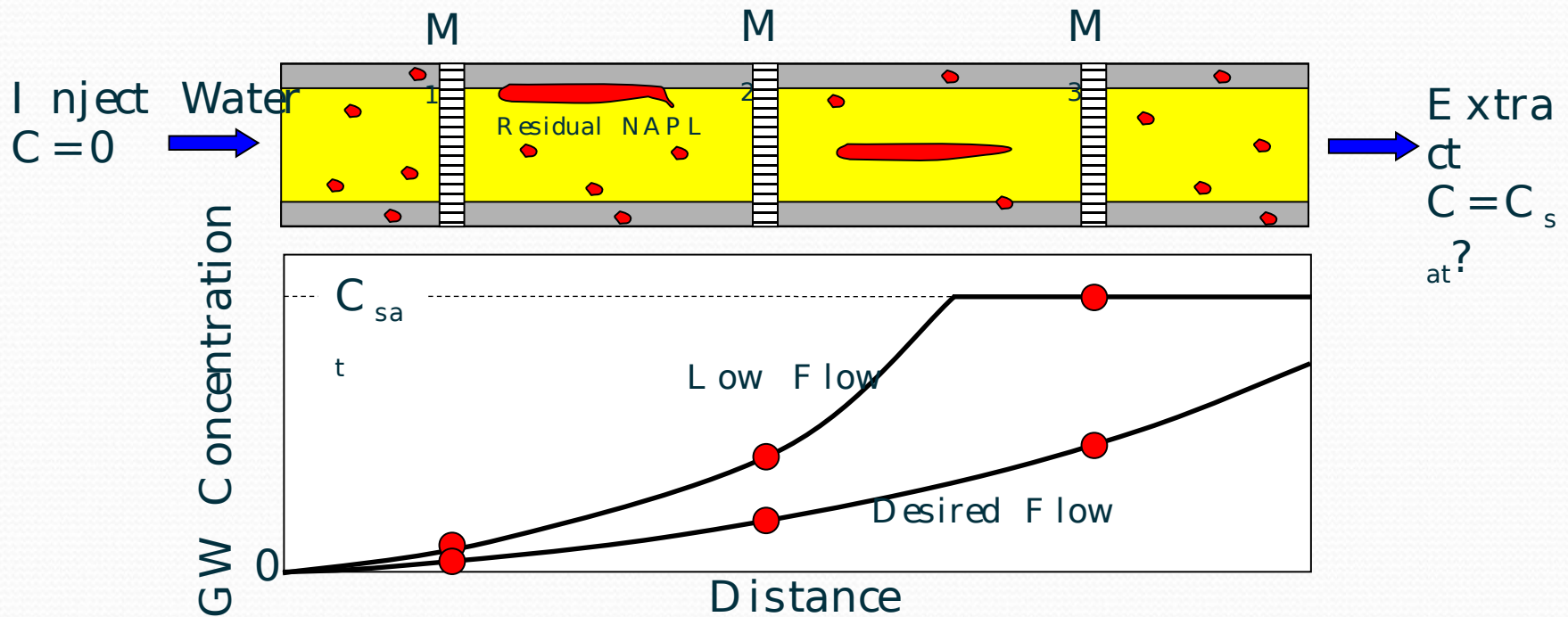
The Problem



Is this the remedial action goal?
When will we know if this goal was achieved?

Mass Transfer Assessment

source mass transfer of COC quantifiable



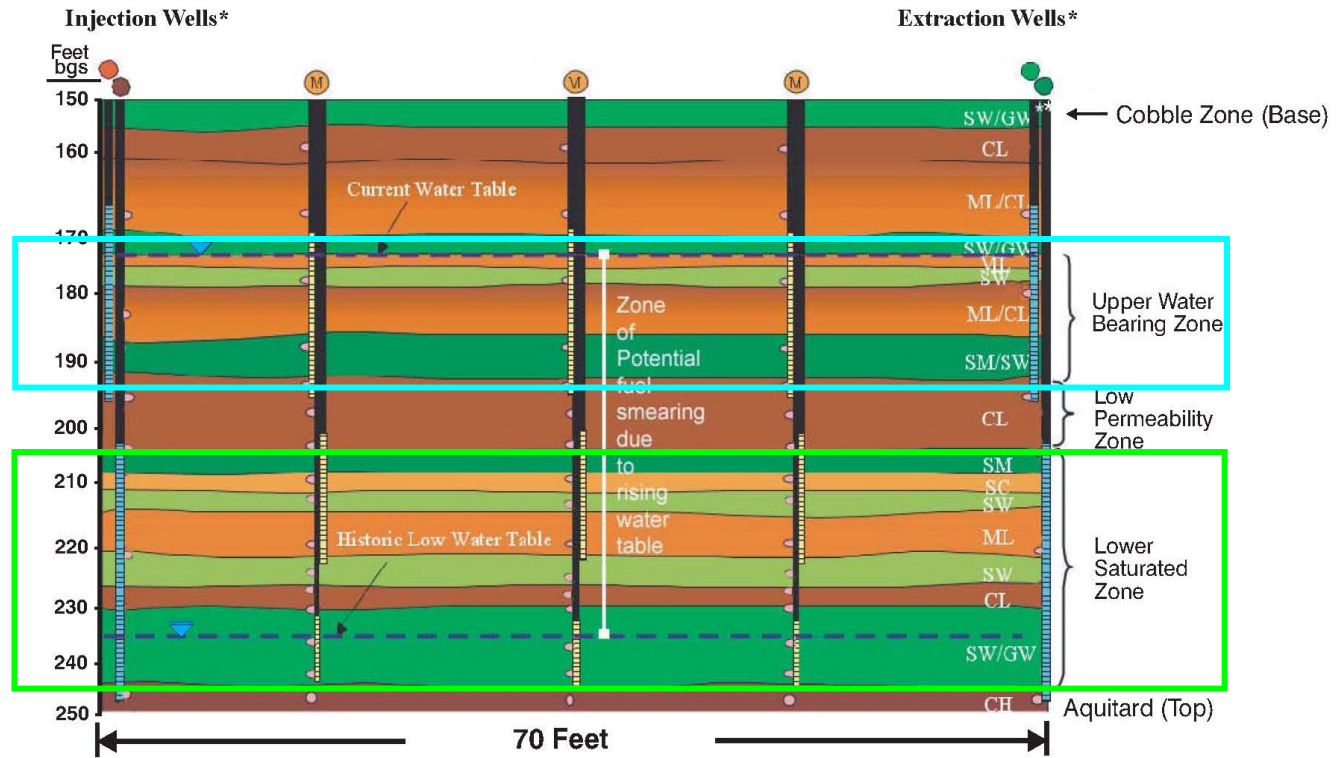
Project Objective

Demonstrate an innovative field technique for estimating the mass of NAPL in subsurface source zones, NAPL persistence into the future, and the potential impact of NAPL source reduction on contaminant mass discharge

Site Description

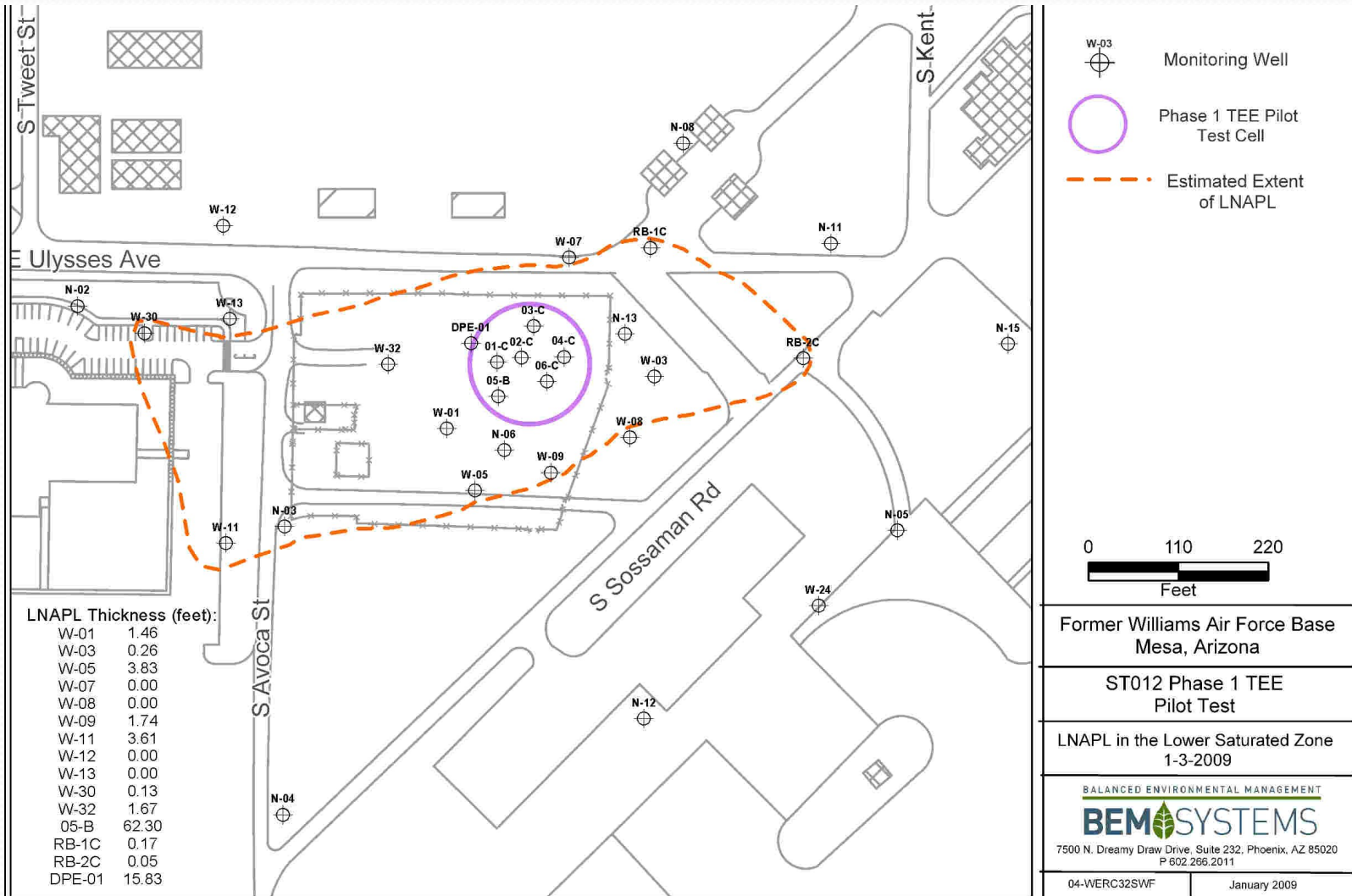
- Multi- component N A P L source zone
 - J P - 4 fuel, B T E X , naphthalene
- Variety of N A P L architecture
 - E xtensive smear zone from rising water table; dispersed ganglia
 - P ooled N A P L below low permeability, semi-confining unit
- P ilot test of thermal enhanced extraction (T E E)
 - Duration: October 2008 - May 2009
 - Mass transfer tests before and after T E E - thru Nov 2009

Conceptual Cross Section in Test Cell

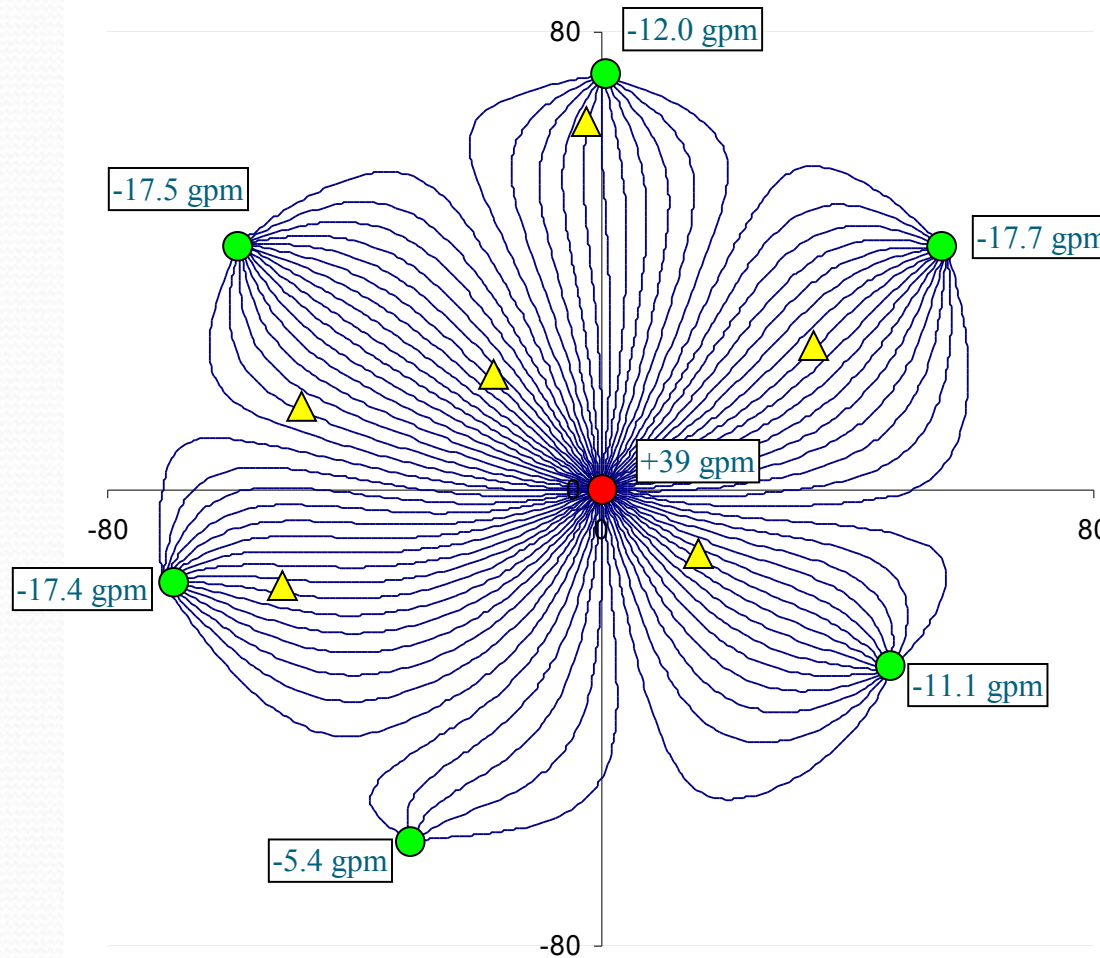


Pilot Test Cross-Section

Pre-Test NAPL Source Zone (Jan-09): LSZ



Mass Transfer Test



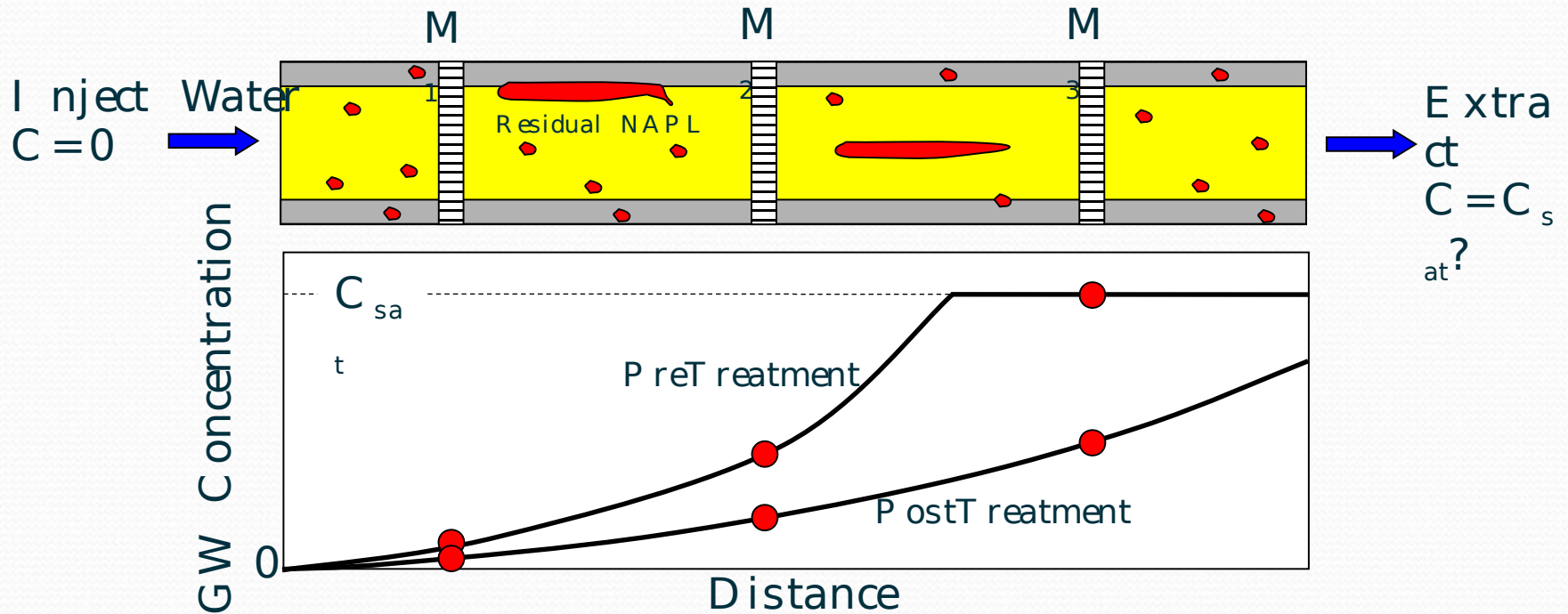
$$Q_{in} = 39 \text{ gpm}$$
$$Q_{out} = 81.1 \text{ gpm}$$

LEGEND

- Extraction well
- Injection well
- ▲ Monitoring well nest

*Streamlines of Idealized Groundwater Flow During Post TEE LSZ Mass Transfer Test
(PFMs deployed at nested monitoring wells)*

Mass Transfer Test



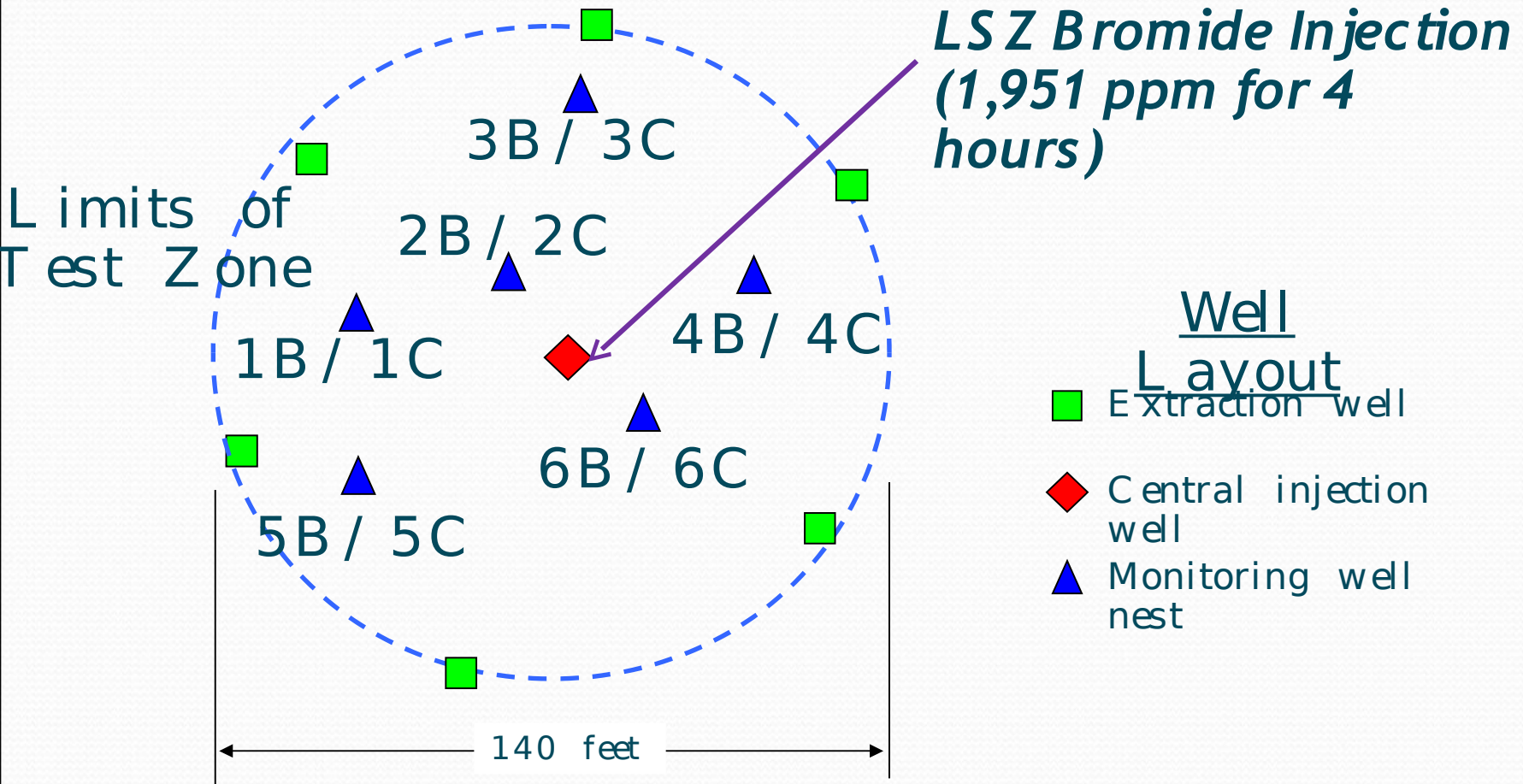
Technologies Utilized

- Conventional Monitoring Well Data
 - Dissolved concentrations of target chemicals
 - Water levels
 - NAPL thickness and recharge rate
- Integrated Pumping Test (IPT)
 - Modified to include water injection
 - Modified to include tracer test (bromide)
- Passive Flux Meters (PFMs)
 - Vertically segmented within multiple monitoring wells

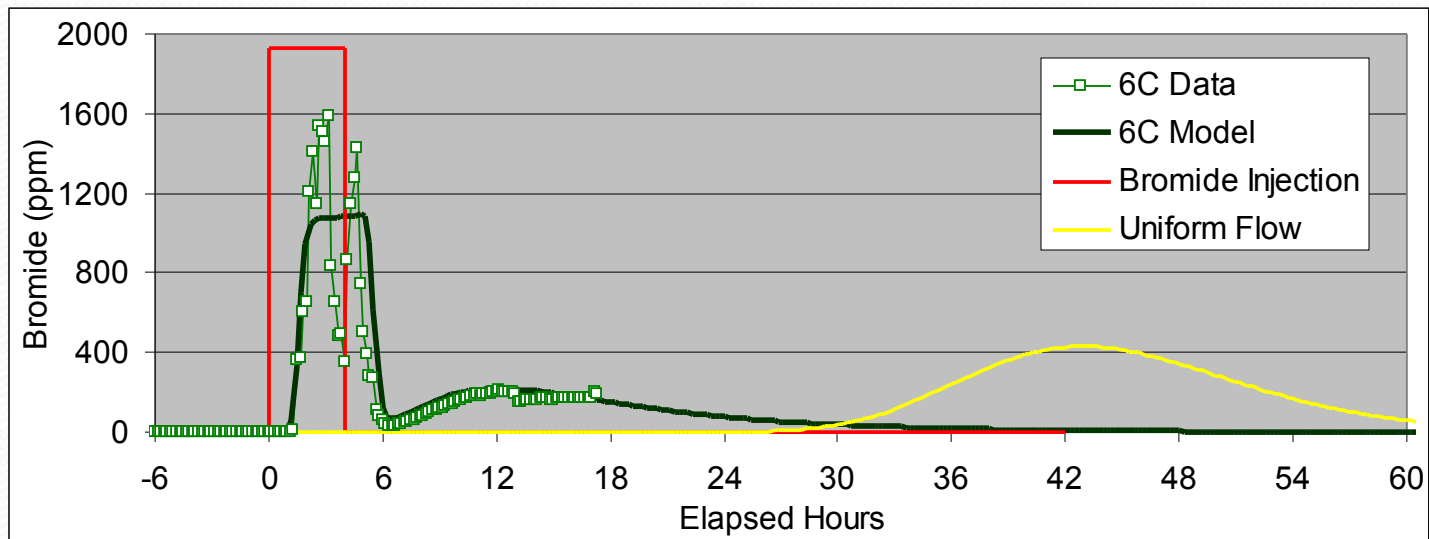
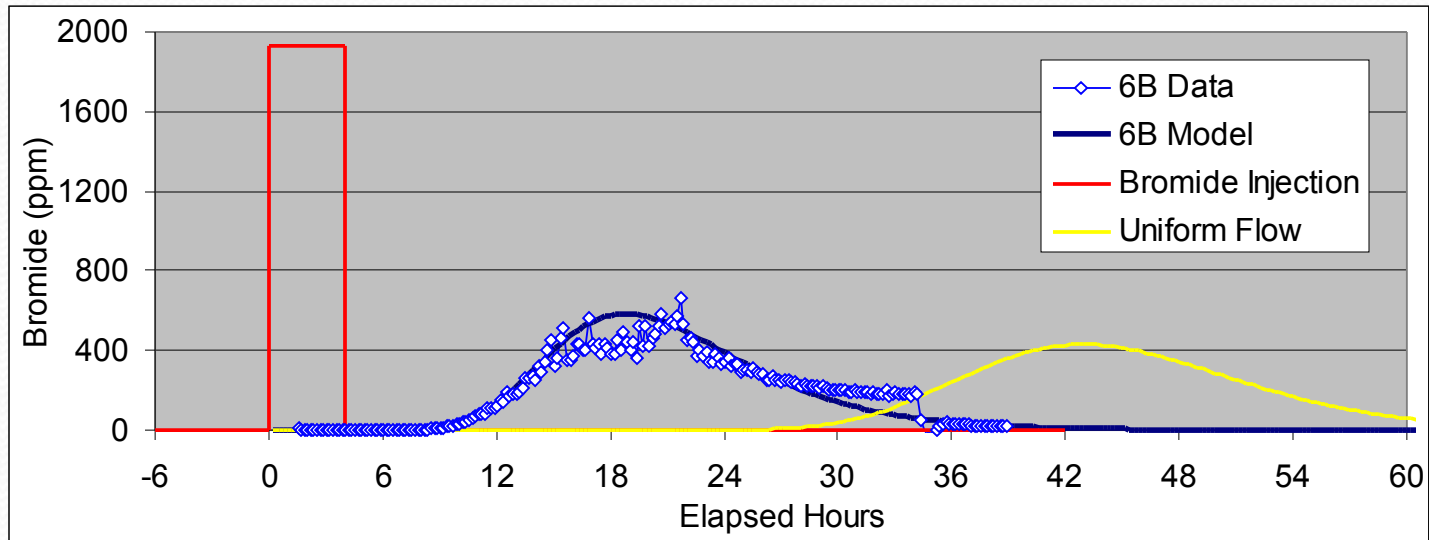
Data Collection

- Conventional Data
- Bromide injections
 - 1,951 ppm for 4 hours in the L S Z in Aug 08
 - 1,851 ppm for 4.3 hours in the UWB Z in Aug 08
 - 2,113 ppm for 23.5 minutes in the L S Z in Oct 09
- P F M Deployment
 - 3 5- ft P F Ms deployed in each B - series well (L S Z) in Oct 08
 - 3 5- ft P F Ms deployed in each A - series well (UWB Z) in Aug 08

Tracer Tests

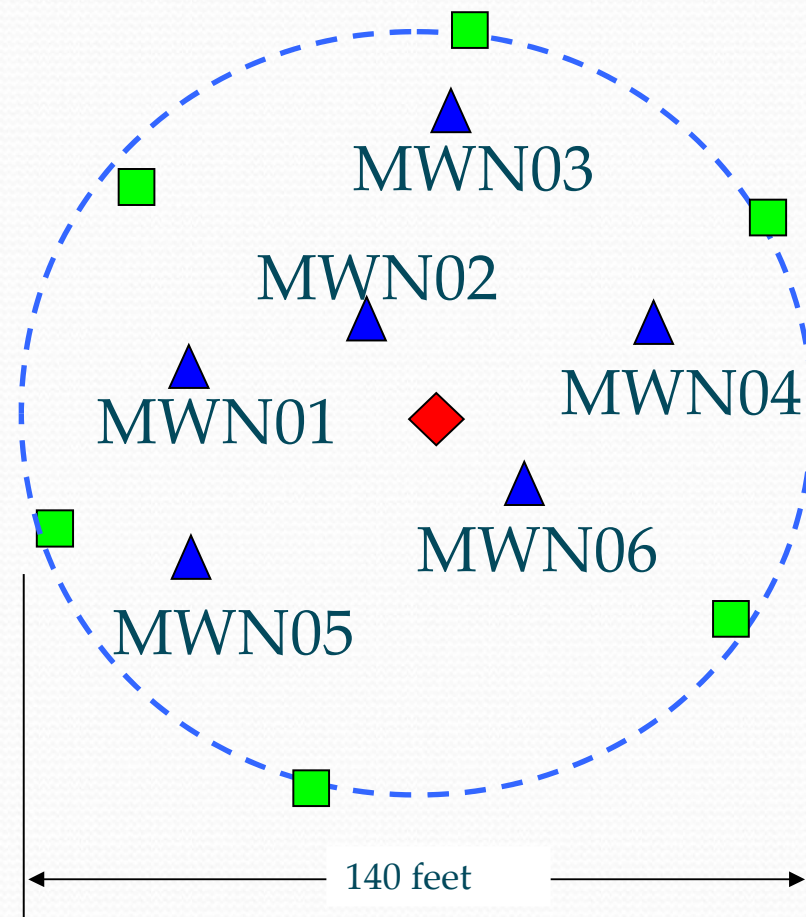


Bromide Responses



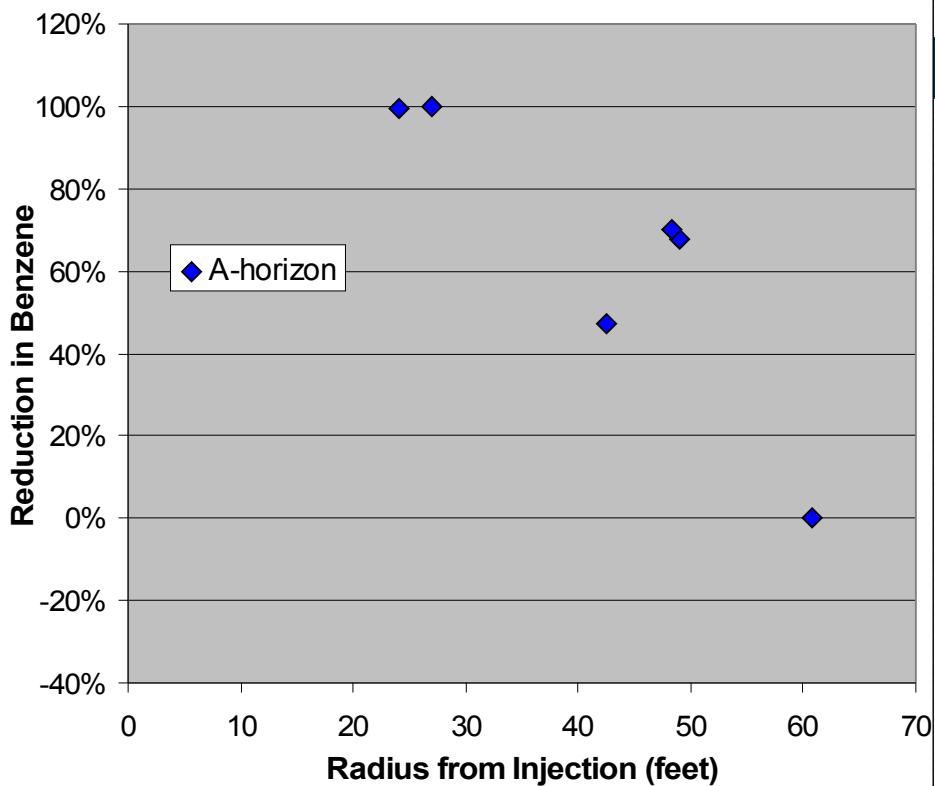
Monitoring Concentrations

Monitoring Well	Radius from Injection (feet)	Benzene Concentration (mg/L)		
		2006 Sampling Result	Mass Transfer preTEE	Mass Transfer postTEE
MWN01A	42	0.76	5.5	2.9
MWN02A	27	2.1	4.8	0.0067
MWN03A	61	0.26	1.6	1.6
MWN04A	49	2.9	3.7	1.2
MWN05A	48	7.8	11	3.3
MWN06A	24	1.2	2.9	0.019
MWN01B	48	18	18	23
MWN02B	28	24	19	0.012
MWN03B	60	17	15	0.81
MWN04B	43	26	15	0.92
MWN05B	54	20	18	2
MWN06B	18	24	3.6	0.0028
MWN01C	49	2.8	1.7	0.011
MWN02C	25	5.5	3.6	0.017
MWN03C	57	5	1.5	0.58
MWN04C	40	8.3	0.76	0.0092
MWN05C	54	3.9	2.6	0.01
MWN06C	18	10	5.7	0.0014

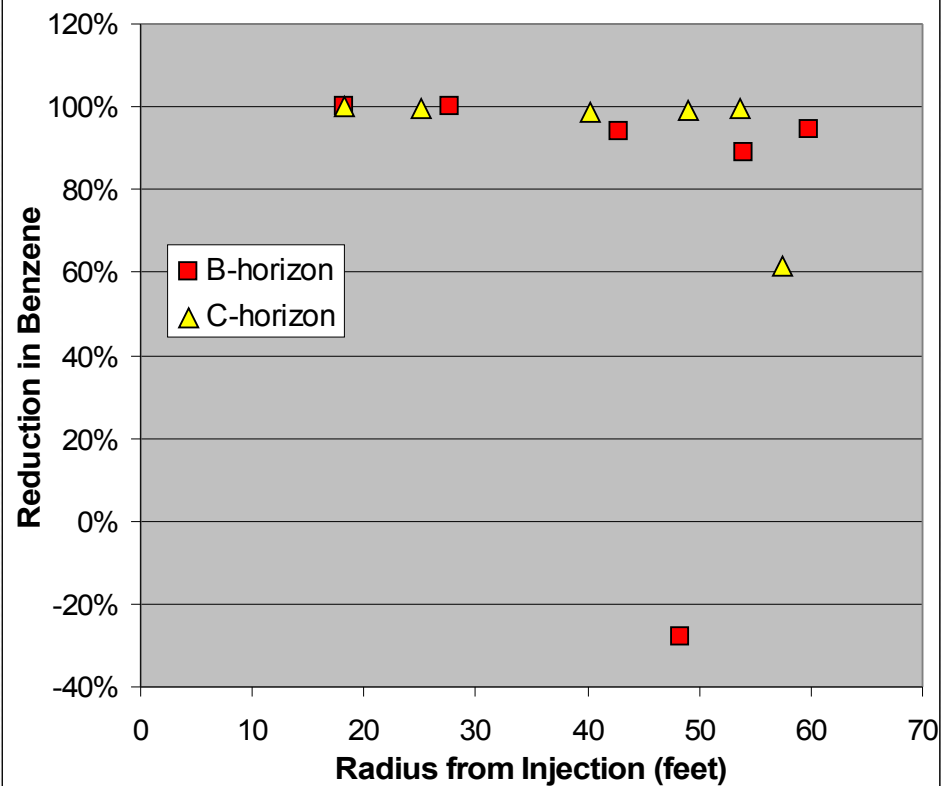


Concentration Changes:

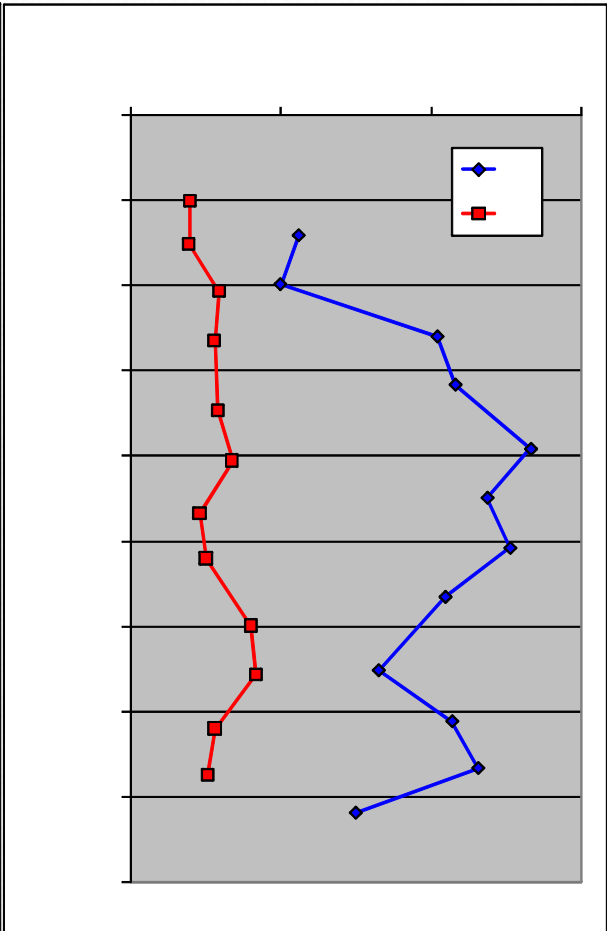
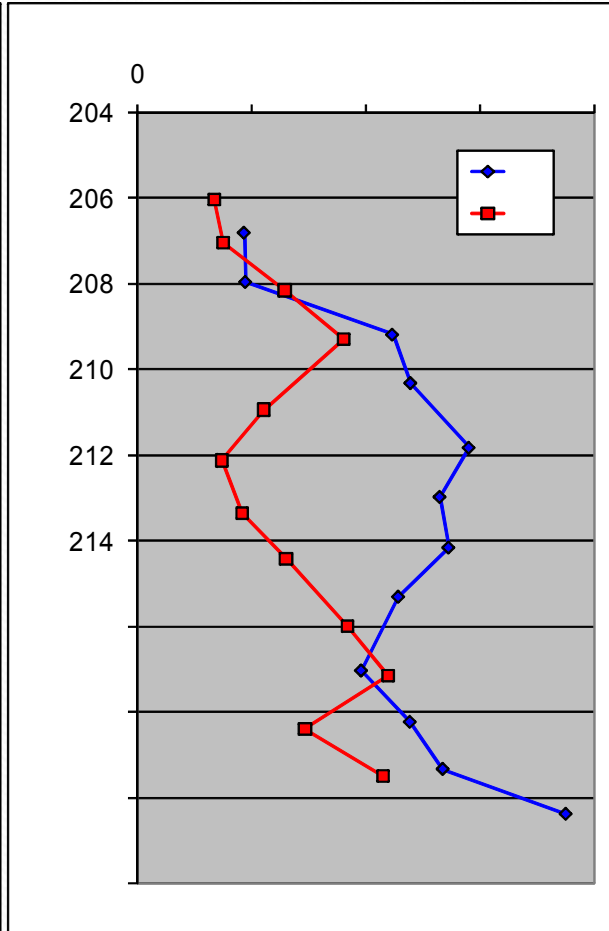
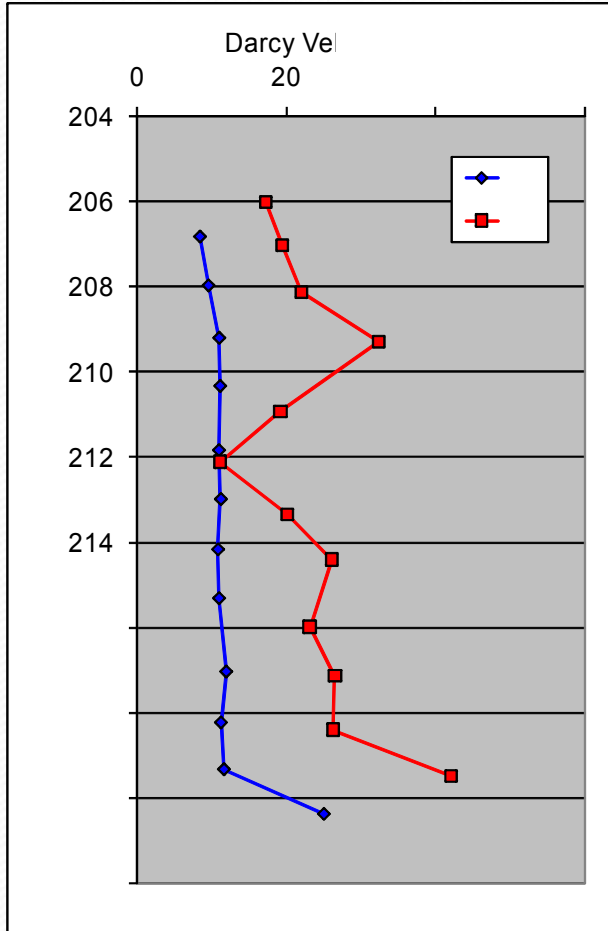
UWBZ



LSZ

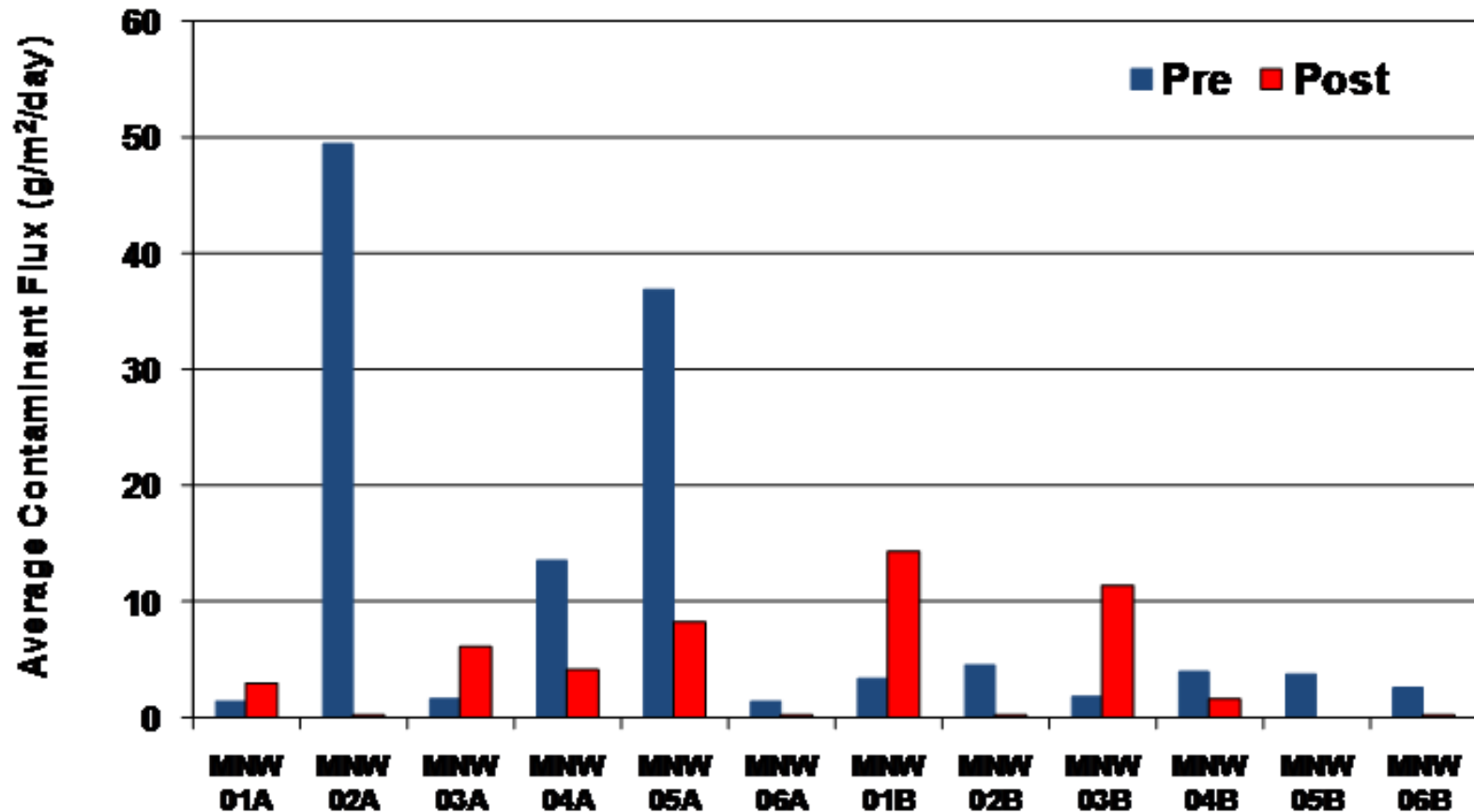


Passive Flux Meters



Passive Flux Meters

Benzene



Bulk K

Large-scale bulk mass transfer coefficient determined from the IPT (yields a maximum value):

$$M_{source,i}^{NAPL} = K_{i,IPT} C_i^{eq} V_{IPT} = QC_{i,ext}$$

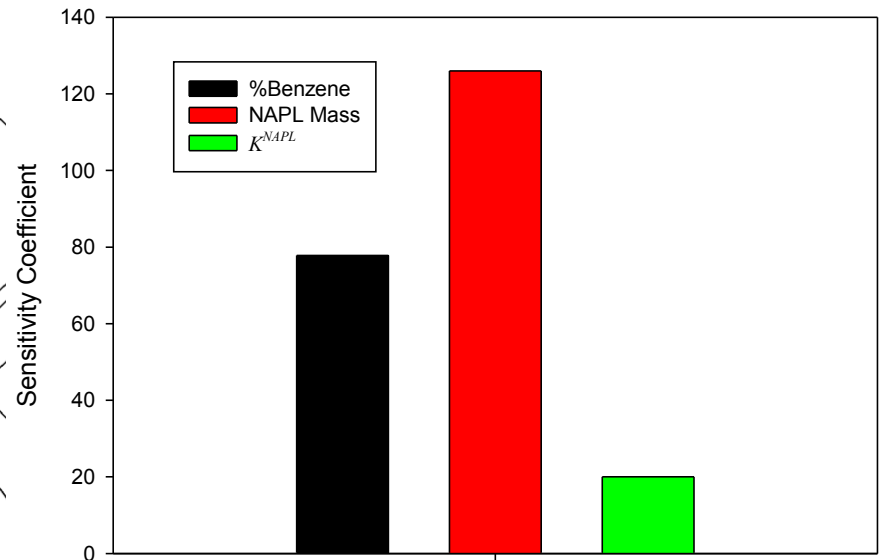
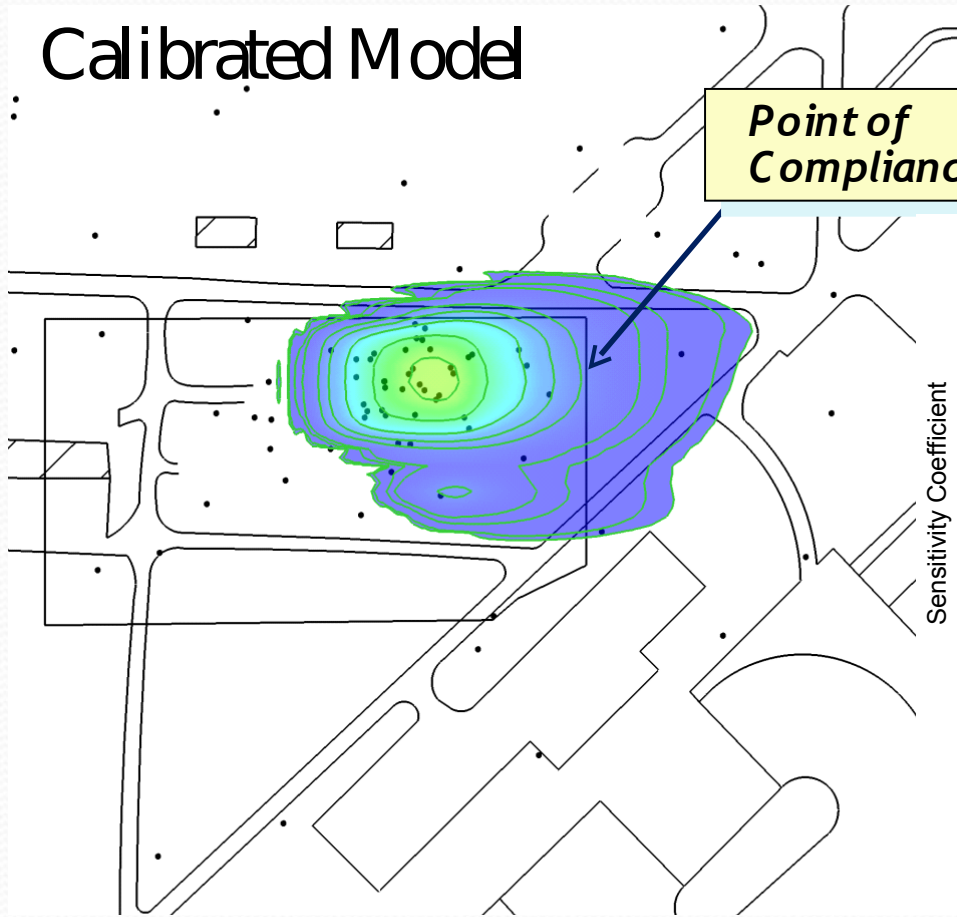
$$K_{i,IPT} = \frac{QC_{i,ext}}{C_i^{eq} V_{IPT}}$$

- ◆ M^{NAPL} = total mass extraction/ dissolution rate of component i
- ◆ Q = total extraction rate
- ◆ C_i^{eq} = equilibrium aqueous concentration
- ◆ $C_{i,ext}$ = concentration of i in extracted groundwater
- ◆ $K_{i,IPT}$ = bulk mass transfer coefficient
- ◆ V_{IPT} = sweep volume

Model Interpretation

Calibrated Model

Point of Compliance

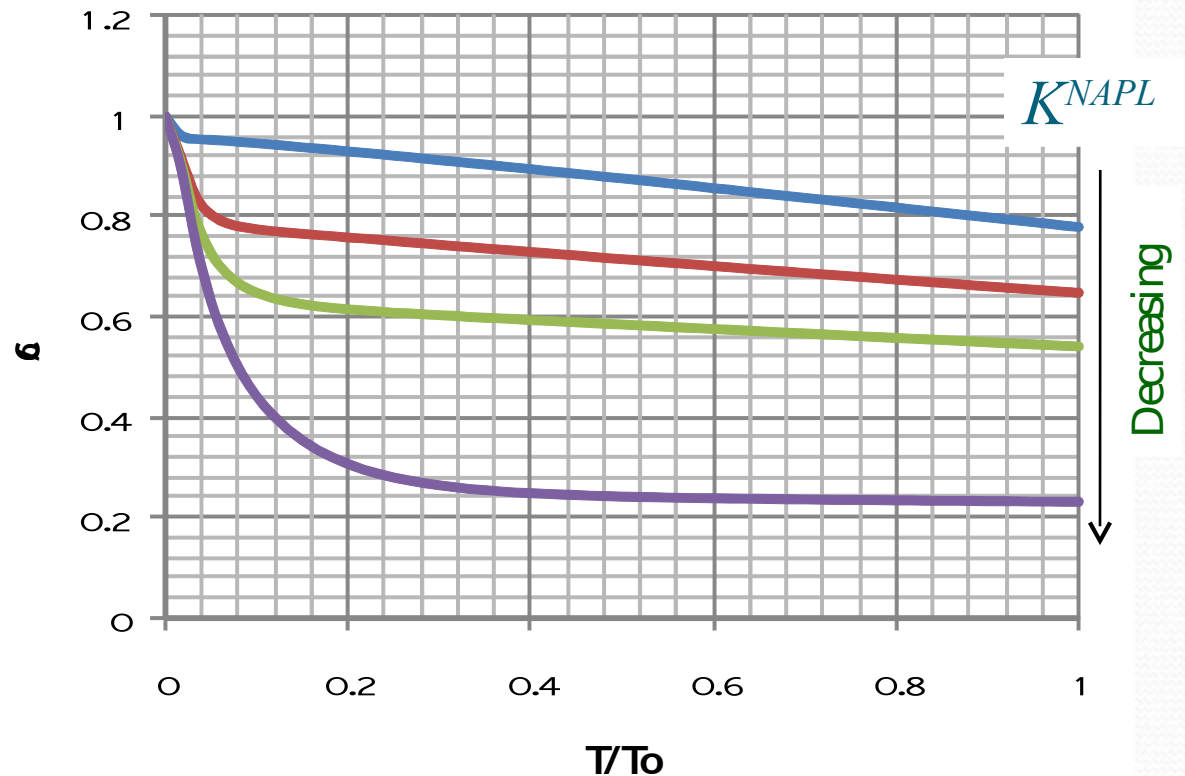


Sensitivity Analysis

Model Interpretation

Parameter sensitivity results suggest that concentrations are controlled by NAPL properties

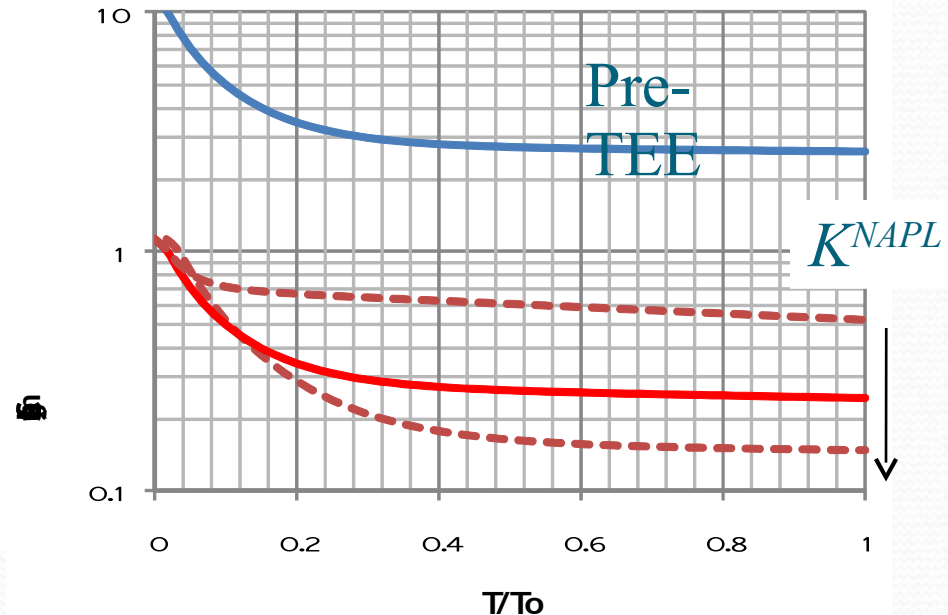
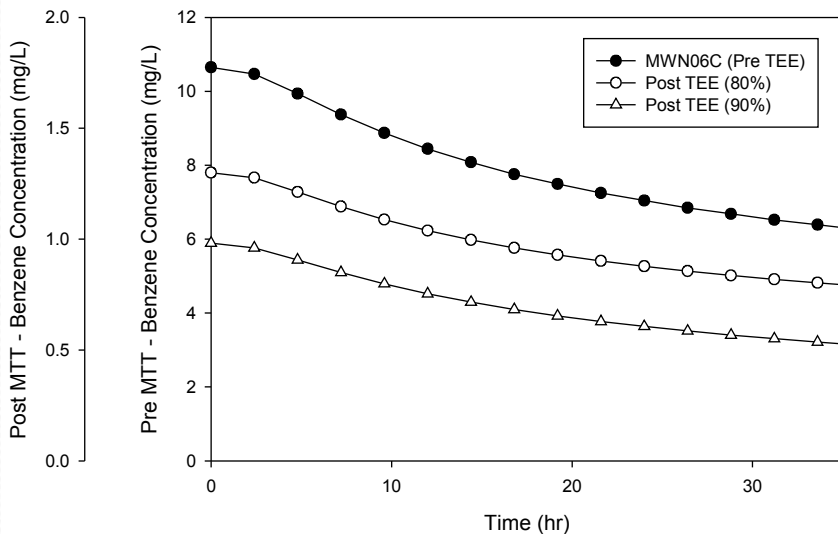
Decrease in concentration during the test influenced by K^{NAPL}



**Breakthrough Curves -
Pre-TEE Mass Transfer
Test**

Model Interpretation

Changes in source zone properties will be evaluated using the model as a tool to interpret data and constrain NAPL parameters for post-TEE TOR estimates



**Breakthrough Curves -
Post-TEE Mass Transfer
Test**

Final Thoughts

- Source terms are usually poorly defined
- Dissolved plume data provide little insight to source mass when NAPL exists and therefore little information on persistence
- Measures in the source zone (ie, Mass Transfer Test) are needed
- Should we be considering a “Compliance Time” for the Source Zone?

Project Team

- Malcolm Pirnie, Inc.
 - Michael Kavanaugh, Ph.D., P.E.
- Praxis Environmental Technologies, Inc.
 - Lloyd "Bo" Stewart, Ph.D., P.E. (co-PI)
- Virginia Polytechnic Institute and State University
 - Mark Widdowson, Ph.D. (co-PI)
- BEM Systems, Inc.
- GeoTrans, Inc.
 - Jim Mercer, Ph.D.

PostTreatment Mass Transfer

Water Pumping, Air Injection

