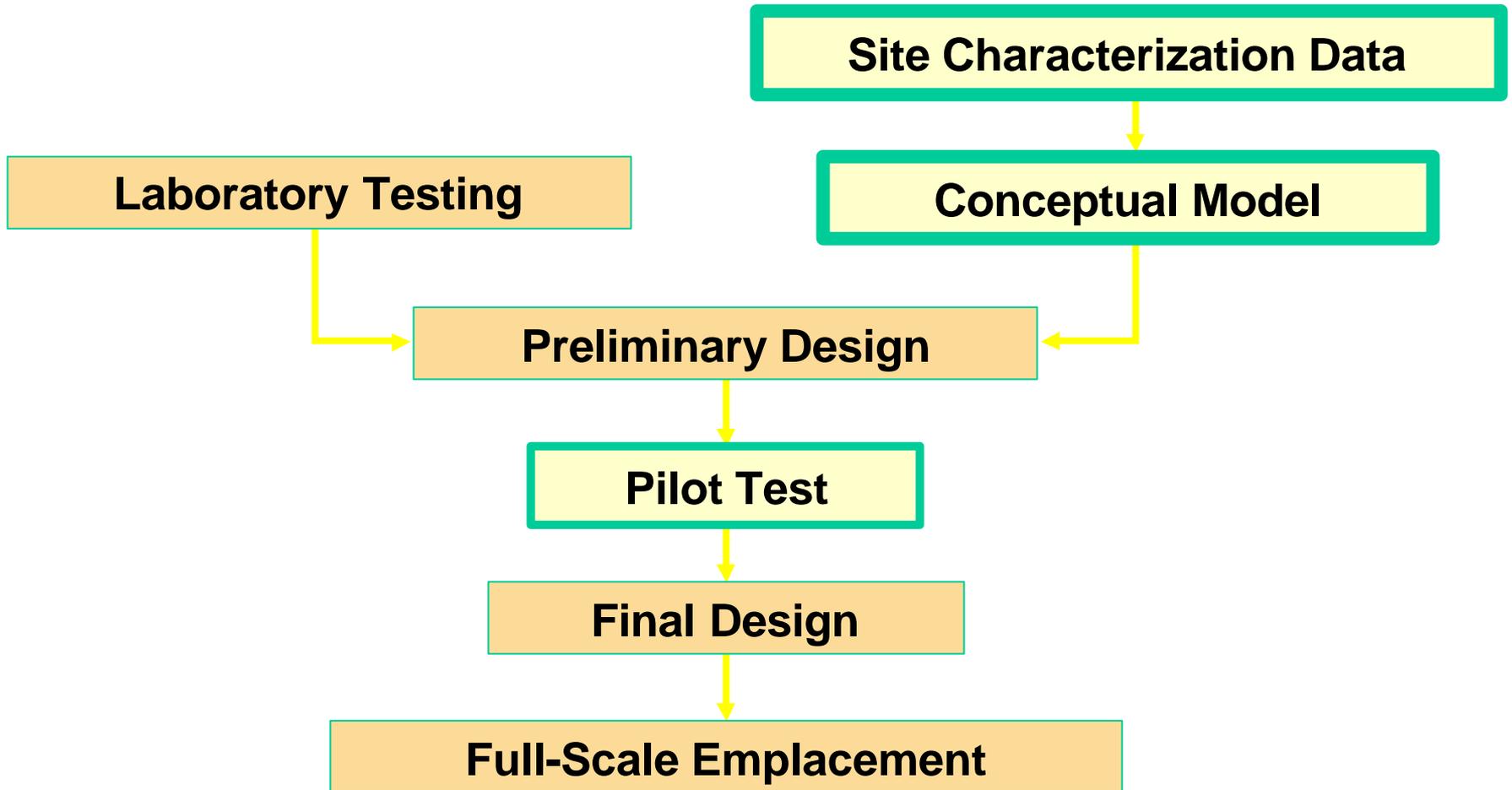


2003 AFCEE Technology Transfer Workshop

Collection of Design Data: Site Characterization for
Permeable Reactive Barriers

Robert W. Puls, Ph.D., National Risk Management
Research Laboratory, USEPA, Ada, OK

Path to PRB Design and Emplacement



Purpose

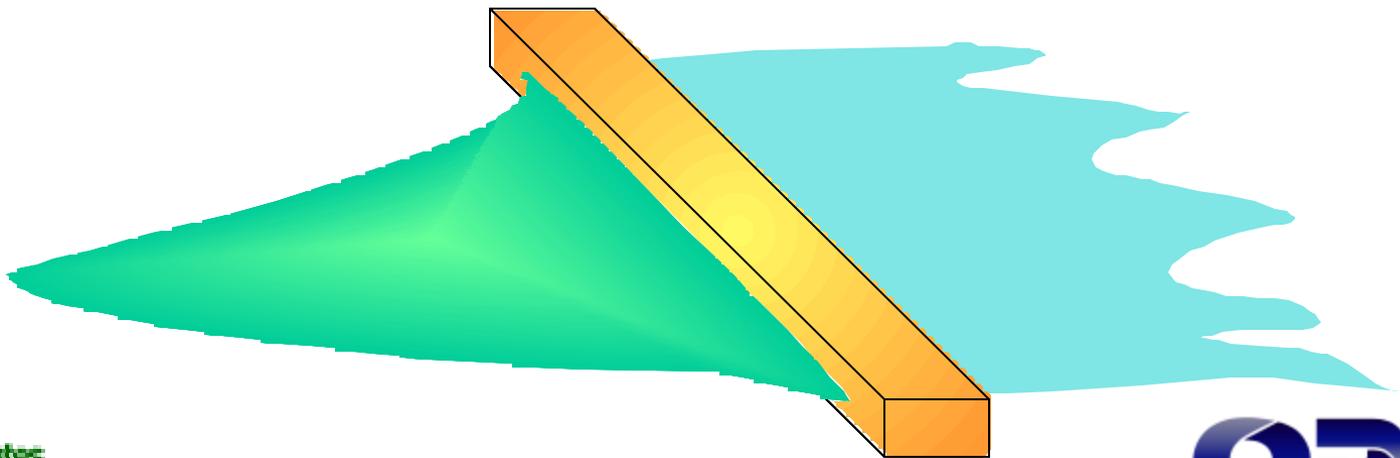
- To address the importance of characterizing a site before reactive barrier installation
- To identify the critical aspects and data needs of site characterization
- To discuss ways to get this information

Topics

- Goals, potential problems with PRBs
- Site characterization issues
- Conceptual model development
- Site characterization methods and tools

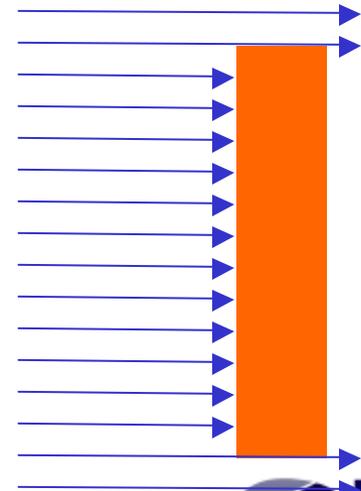
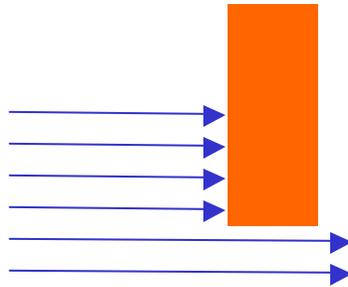
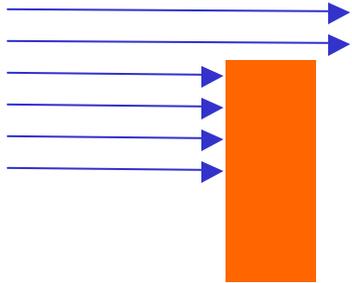
Goal = Passive Remediation System

- The plume enters under the natural gradient
- The entire plume is captured by the system
- Remedial goals are achieved at point of compliance



Potential Problems

- The plume could pass over, under, or around the barrier
- The groundwater flow direction or velocity might change
- Incomplete remediation as higher concentrations reach the barrier
- Loss of surface reactivity—precipitate coatings, etc.
- Barrier plugging, decreased permeability



Site Characterization Issues to Address to Achieve Goal

- Hydrology
- Geology
- Contaminant distribution within the aquifer
- Geochemistry
- Microbiology

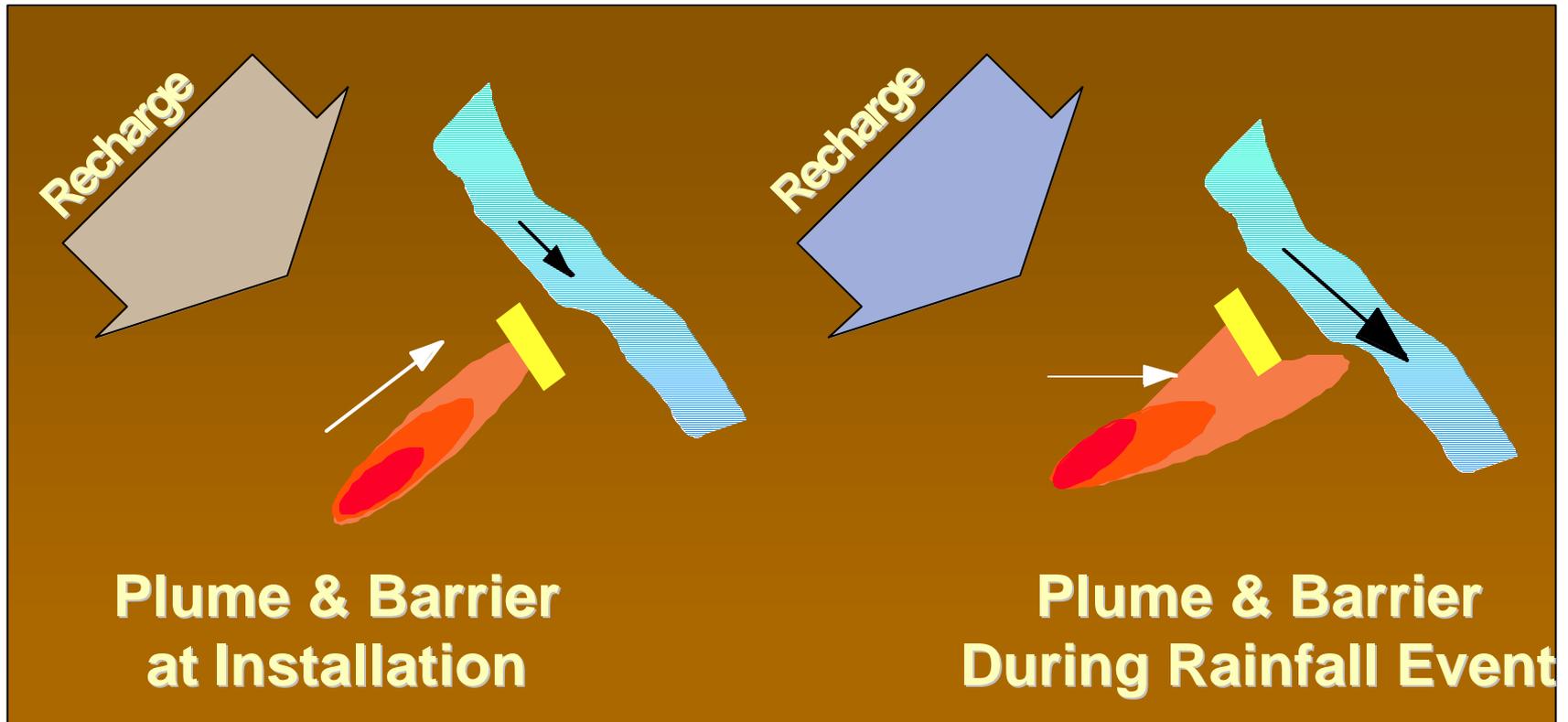
These parameters are not discrete, but highly interactive.

Hydrology

- Groundwater flow
 - direction
 - velocity
 - flux
- Seasonal changes in groundwater flow velocity, direction (e.g. due to recharge events)
- Effects of nearby intermittent pumping
- Provide data for construction of groundwater flow model

Plume /Hydrologic Characterization

Time

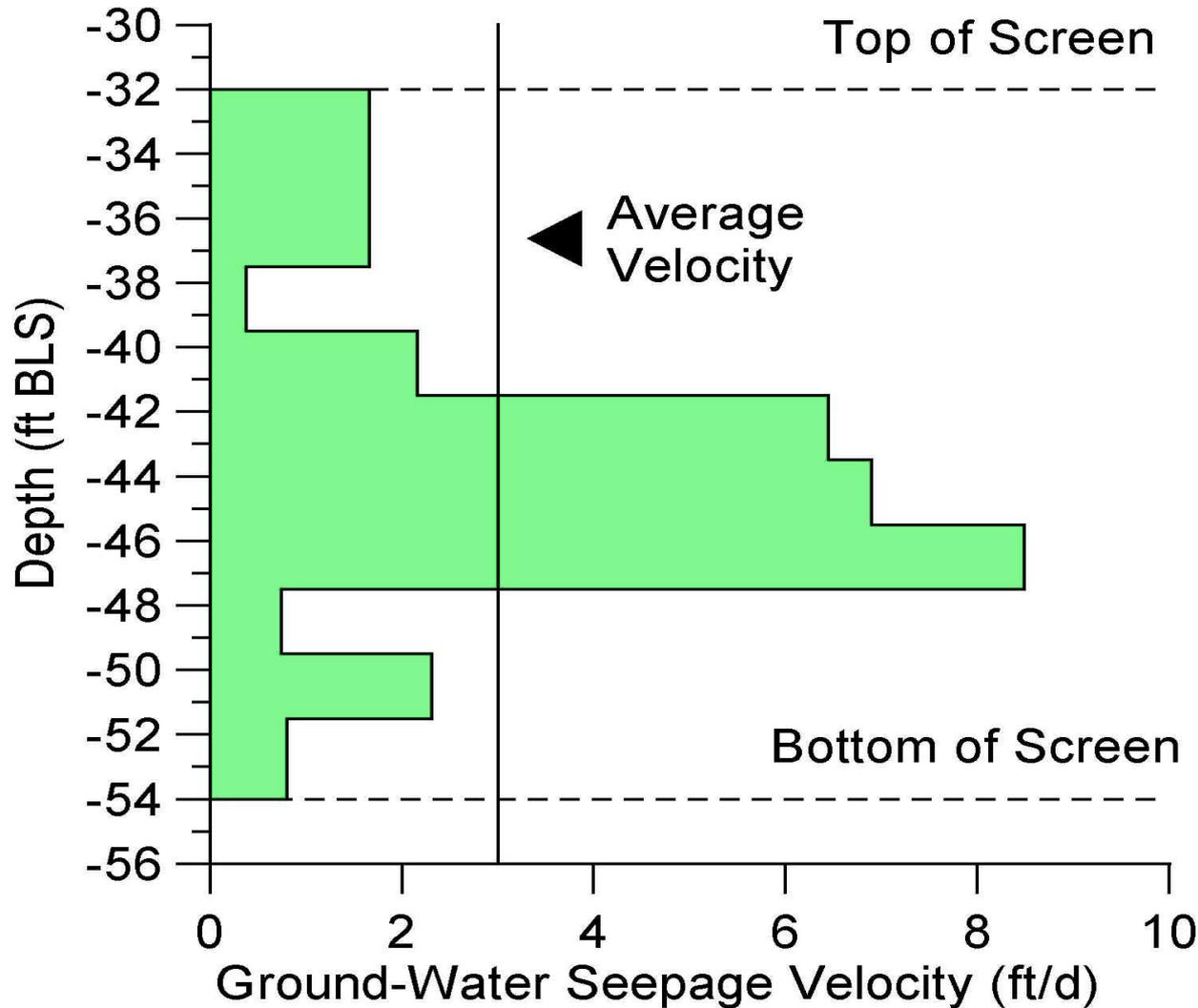


Hydraulic Conductivity Distribution

- Controls flux
- May vary by several orders of magnitude
- Knowledge of variations in flow velocity field important for optimized PRB design

Well PBTW2

Seepage Velocity



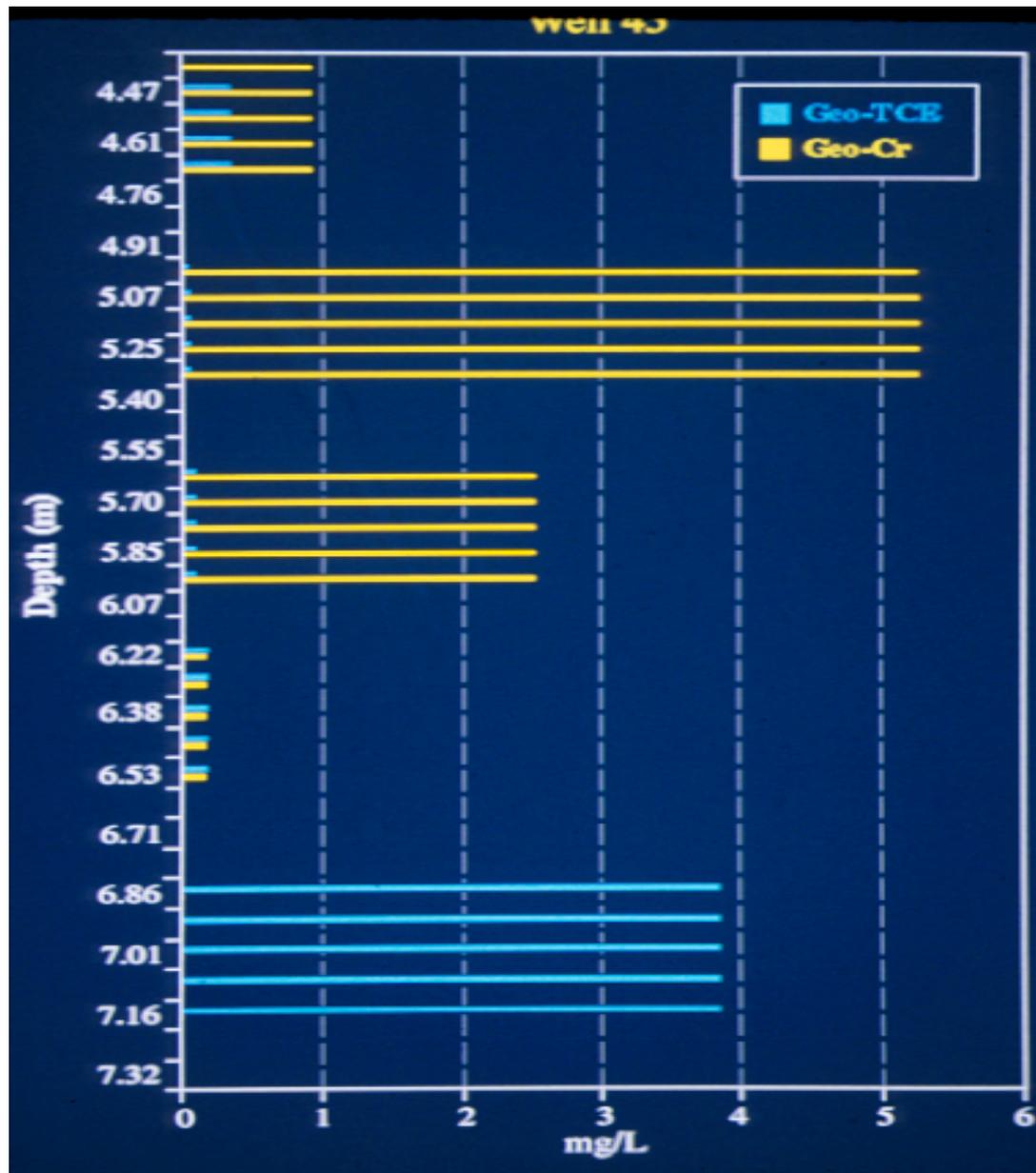
Geologic Setting

- Depositional environment & hydrochemistry
 - Red flags: fine textured strata, high TOC, high NO₃, high SO₄, high CO₃
- Stratigraphy
 - depths and continuity of sand layers, clay layers, bedrock
 - keyed barrier or hanging wall
 - zones of water/contaminant movement
 - degree of fracturing

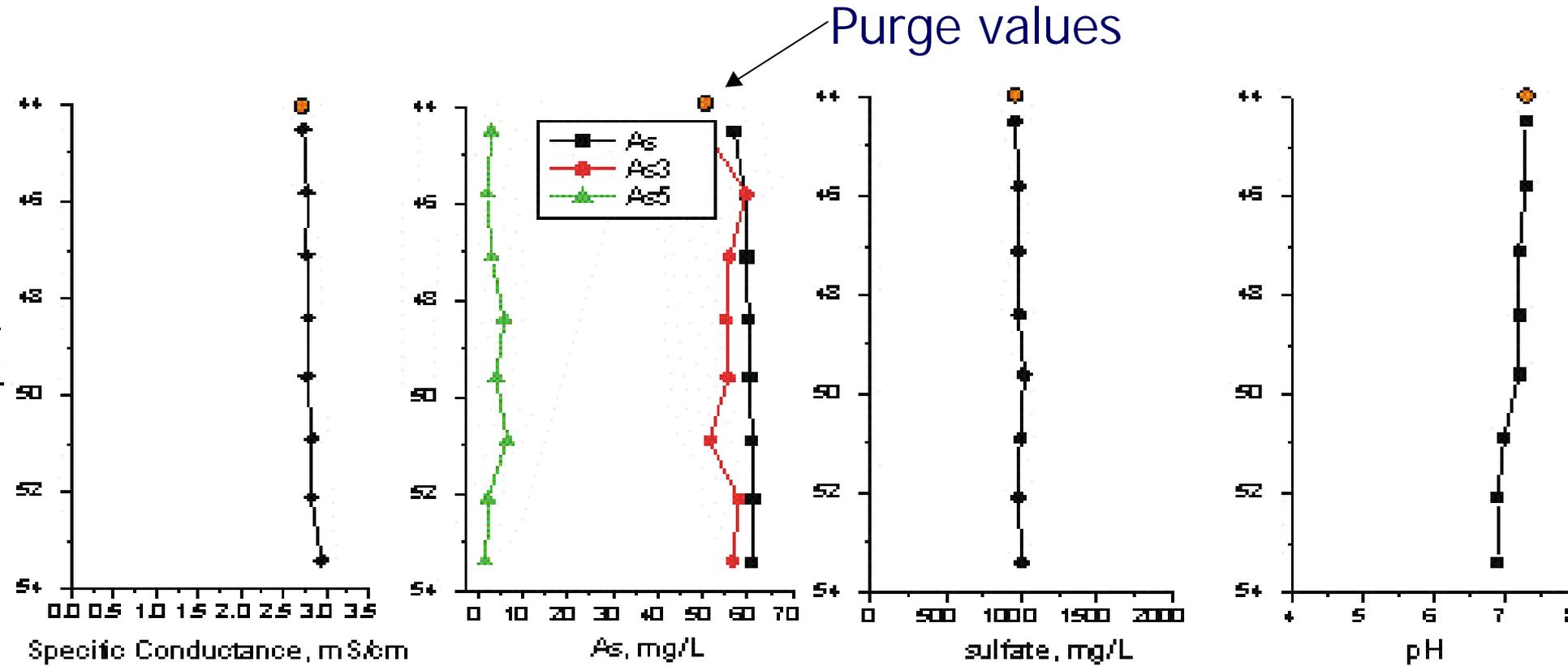
Contaminant Distribution

- Identify contaminants and degradation products
- Plume location in all dimensions
 - x, y, z , concentrations and time
 - Is natural attenuation occurring?
 - Has steady state been reached?
 - Are the high concentration zones moving?
 - What concentrations will reach the wall?
- Identification of ALL sources?

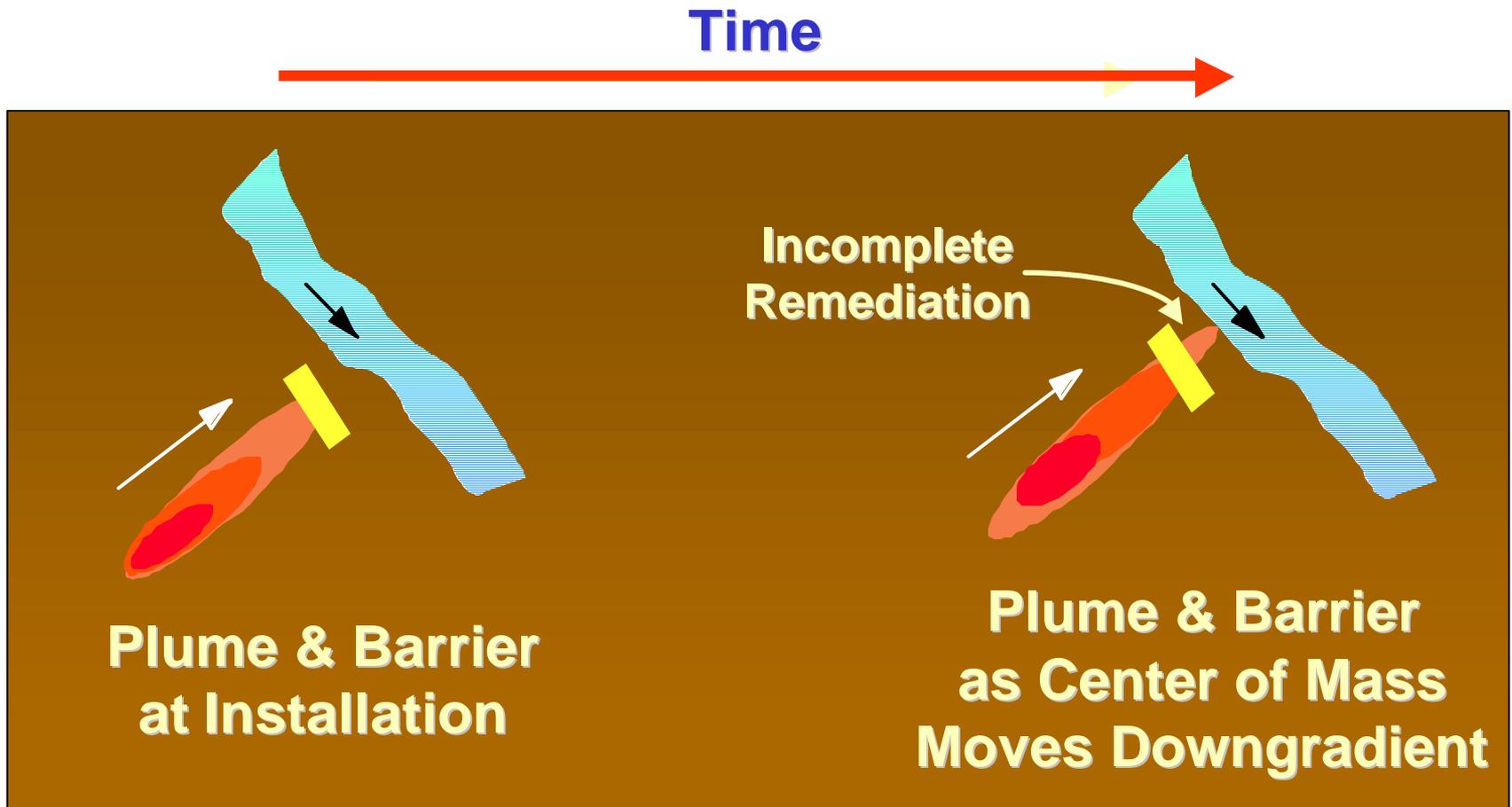
Geoprobe Cr and TCE Data



Discrete multi-level sampling well PBTW2



Plume Stability, Steady State



Geochemistry Considerations

- Oxygen concentration
 - O_2 is preferred electron acceptor
 - high O_2 , increased $Fe(OH)_3$ precipitation
- Carbonate alkalinity
 - precipitation of $Ca(CO)_3$ (calcite) and other carbonate minerals
- Sulfate concentration
 - possible sulfide formation
 - possible microbial fouling
- Nitrate concentration
 - decreased reactivity for chlorinated compounds, chromate, others

Water Quality Parameters

- Major ions (Na, Ca, Mg, K, SO₄, Cl, HCO₃)
- Dissolved oxygen distribution
- Redox potential (Eh)
- pH
- Specific conductance
- Needed input parameters for geochemical modeling

Microbiology

- **Beneficial effects, i.e., enhanced remediation**
 - upgradient natural attenuation of plume
 - degradation products?
 - increased degradation in vicinity of wall
- **Detrimental effects**
 - biofouling and loss of permeability

Conceptual Model

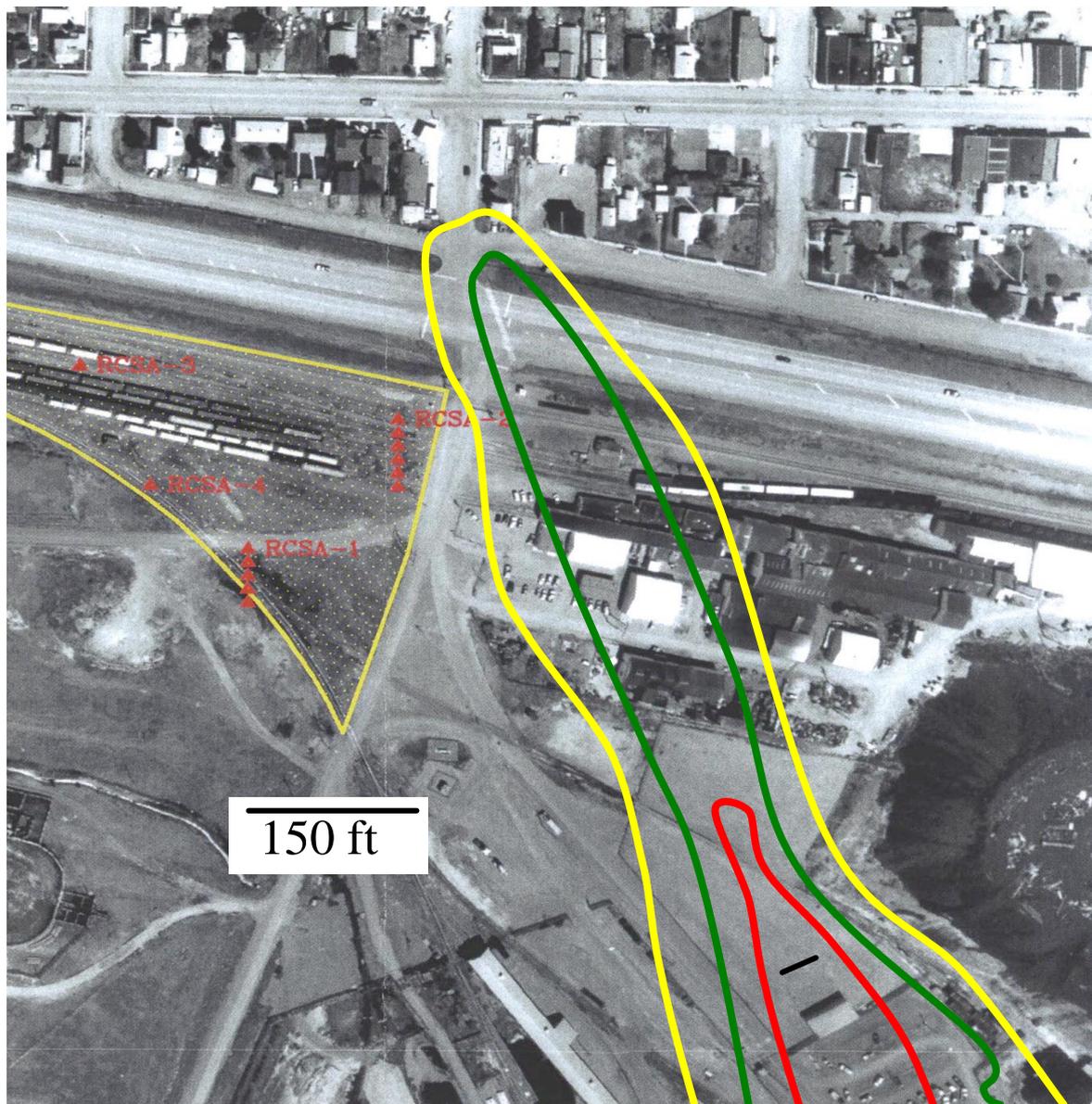
- Develop conceptual model based on site characterization
- Iterative process as more data is collected
- Does the conceptual model coincide with increased observations

Arsenic in shallow aquifer

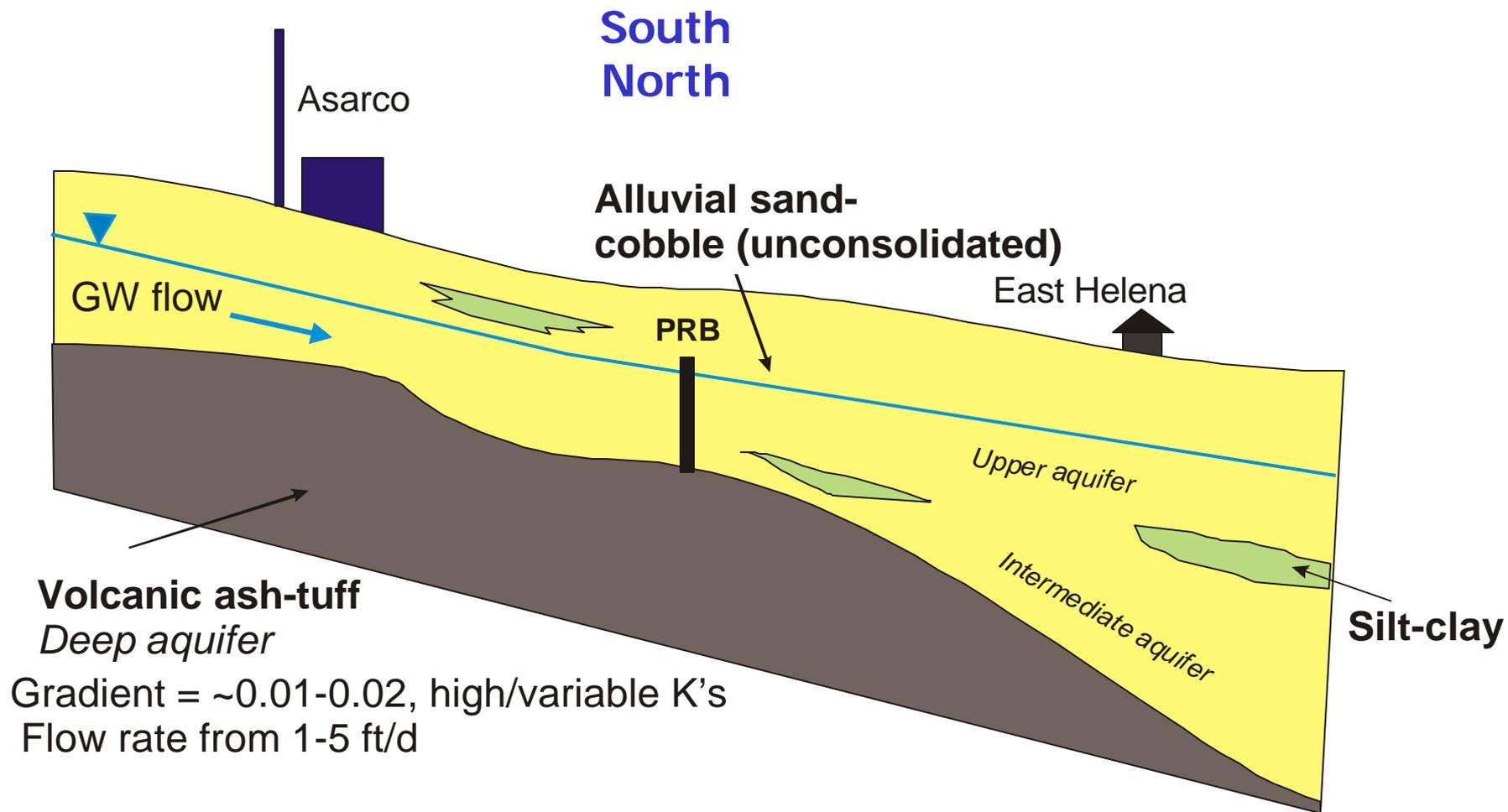
5 ppm

10 ppm

50 ppm



Site Conceptual Model



Volcanic ash-tuff
Deep aquifer
Gradient = ~0.01-0.02, high/variable K's
Flow rate from 1-5 ft/d

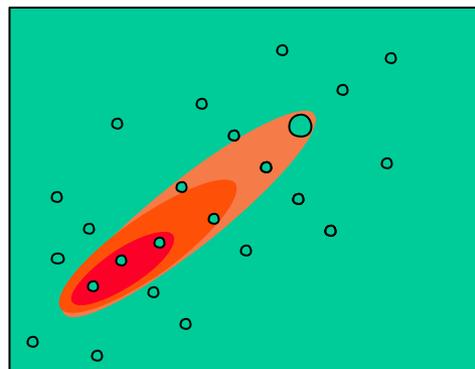
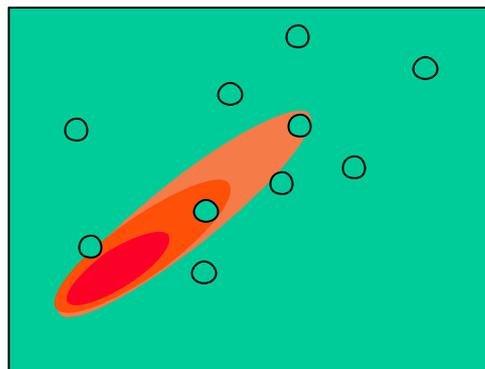
At PRB location:
40-55 ft to ash
15-25 ft saturated thickness

Characterization Methods

- Use push tool technologies
 - Geoprobe[®] and Hydropunch[®]
 - cone penetrometers
- Examine K variability
 - Flowmeters
 - Mini slug tests
- Map and model the results
 - hydrologic
 - geochemical

Push Tool Technologies

- Driven rapidly and inexpensively
 - more samples can be collected, allowing:
 - denser coverage of the area
 - evaluation of a larger area
- Can collect water, soil, and soil-gas samples



Geoprobe® Model 5400



Geoprobe® Model 4220

Geoprobe® Model 540B



Push Tool Technologies

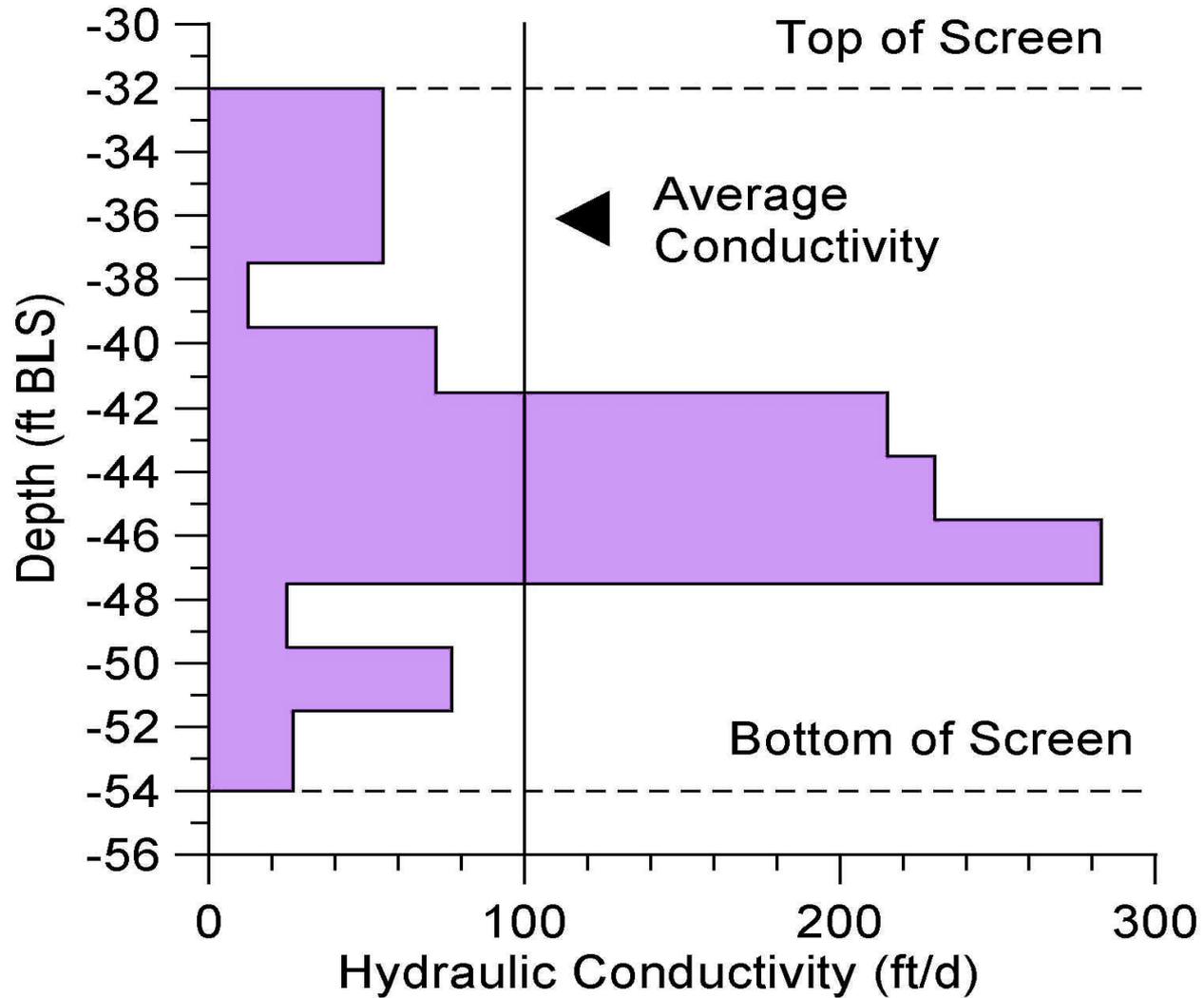
- Discrete vertical delineation of aquifer
 - better data on stratigraphic continuity
 - depending on the tools, you can get:
 - soil resistance to penetration
 - soil saturation
 - hydraulic conductivity
 - electrical conductivity
 - NAPLs using laser-induced fluorescence, etc.

Hydrologic Characterization Tools

- Pumping tests
- Mini-Slug tests
- Borehole flowmeters
- Borehole dilution tests
- Tracer tests
- Potentiometric information

Well PBTW2

EM
Borehole
Flowmeter



Groundwater Flow Modeling Studies

- Determine design velocity through treatment zone
- Determine length of system required to capture plume
- Assess potential for bypass/underflow

Groundwater Flow Modeling Studies

- Combine aquifer characteristics and reactive material properties
- Effects of reactive material variability
- Effects of changing material properties over time
- Permeable barrier configuration
- Identification of monitoring well locations

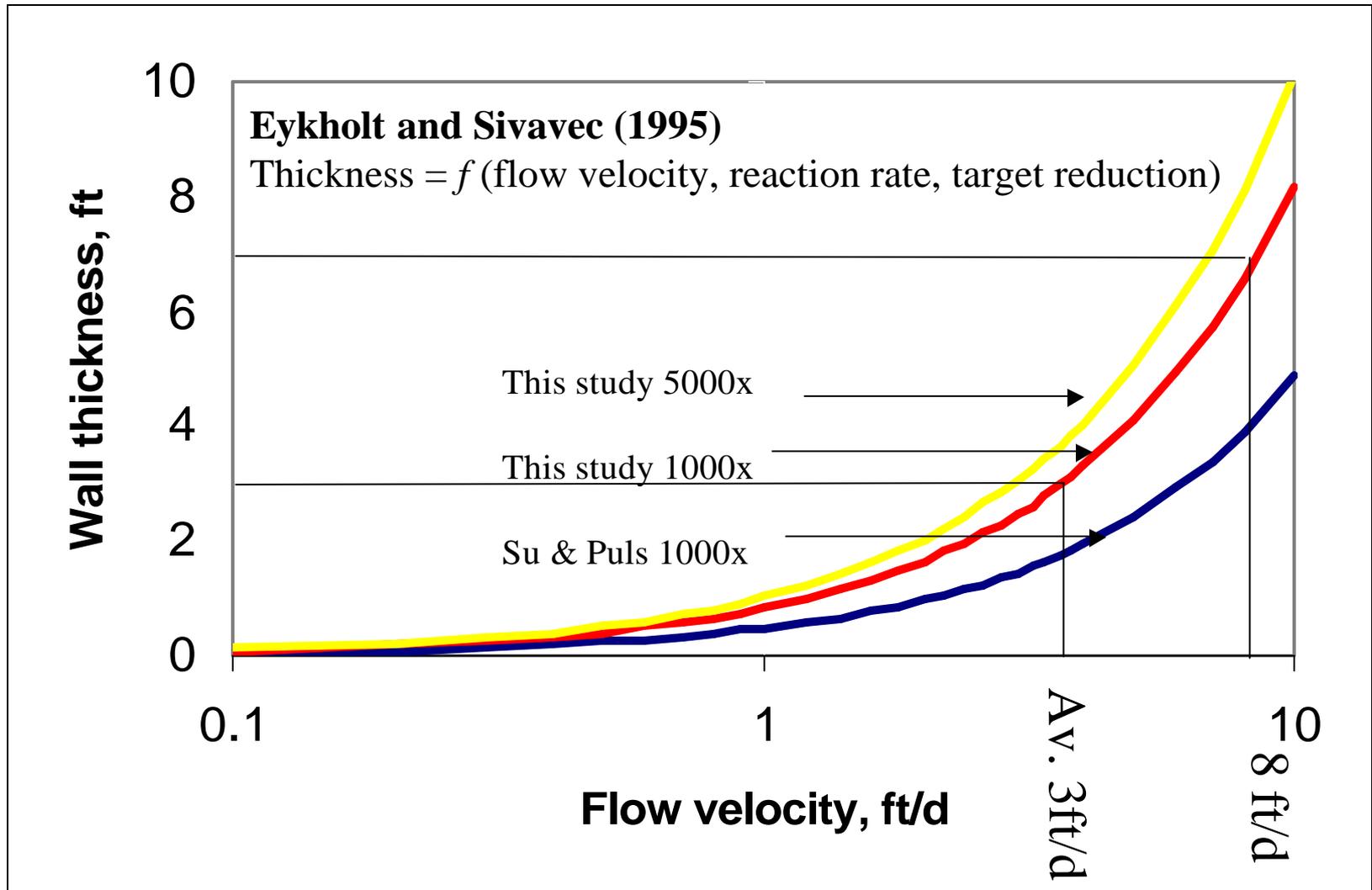
Groundwater Velocity through a PRB

- For a continuous wall, ground water flow velocity can be approximated using:
 - $V = Ki / n$, where
 - V = ground water velocity
 - K = hydraulic conductivity
 - i – gradient
 - n = porosity

Dimensions of PRB

- Residence time requirement (bench scale studies/database)
- Treatment zone flow velocity (model results)
- Thickness = residence time x groundwater velocity
- Determine length and depth of system required to capture plume, prevent underflow etc.

PRB Thickness



Why do a Pilot?

- Proof of concept
 - Contaminant(s)
 - Reactive media
- Challenging site characteristics
- New design
 - Construction
- NO substitute for field testing

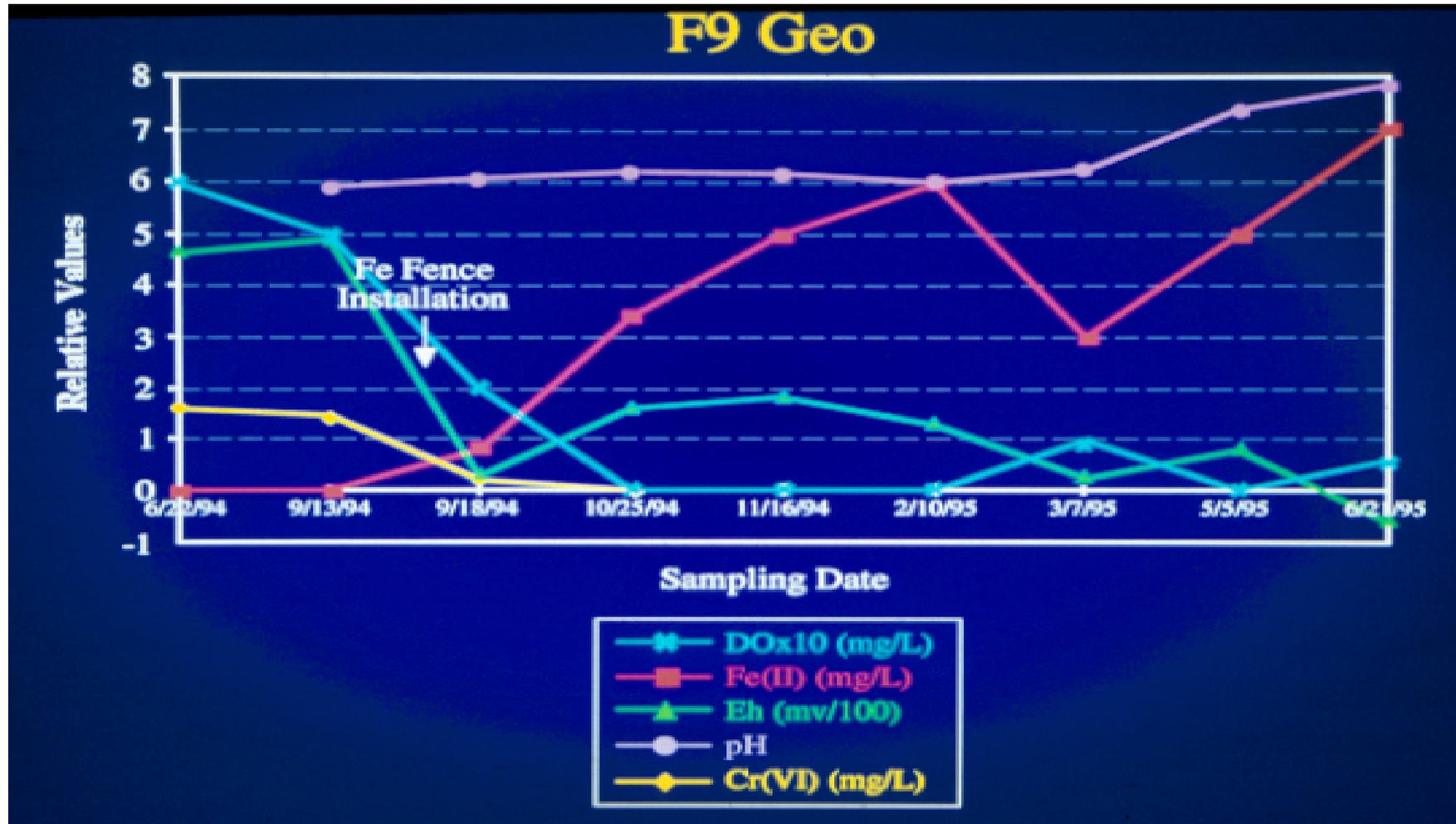
Pilot Installation—Moffett Field



Elizabeth City Pilot Test Site Sep 1994



Geochemistry Data PRB Pilot Test, 1994



Conclusions

- A thorough site characterization is needed for the immediate and continued success of a reactive barrier installation
- The “passive” nature of the technology makes this critical
- Good hydrologic characterization essential to remedial effectiveness

Conclusions (continued)

- Current conditions must be known and future conditions predicted
- Push technologies offer rapid, economical ways to get the needed data

Summary List of Field Design Data

- Groundwater flow, direction, velocity, temporal and spatial variability
- Aqueous geochemistry (pH, Eh, DO, alkalinity, sulfate, nitrate, other cations-anions, TOC)
- Microbiology (natural attenuation?, biofouling)
- Stratigraphy (esp. confining layers)
- Contaminant distribution, flux (3D and time)

Acknowledgments

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