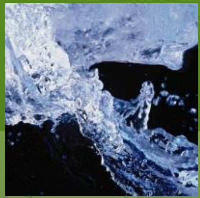





Potentially Applicable Tools

EPA
United States
Environmental Protection
Agency

Thanks to:
Steve Dyment, U.S. EPA ORD
Seth Pitkin, Stone Environmental

Overview

- **Tools for unconsolidated environments**
  - » Shallow
  - » Deep
- **Tools for fractured or porous media environments**
- **Tools for non-depth-specific applications**

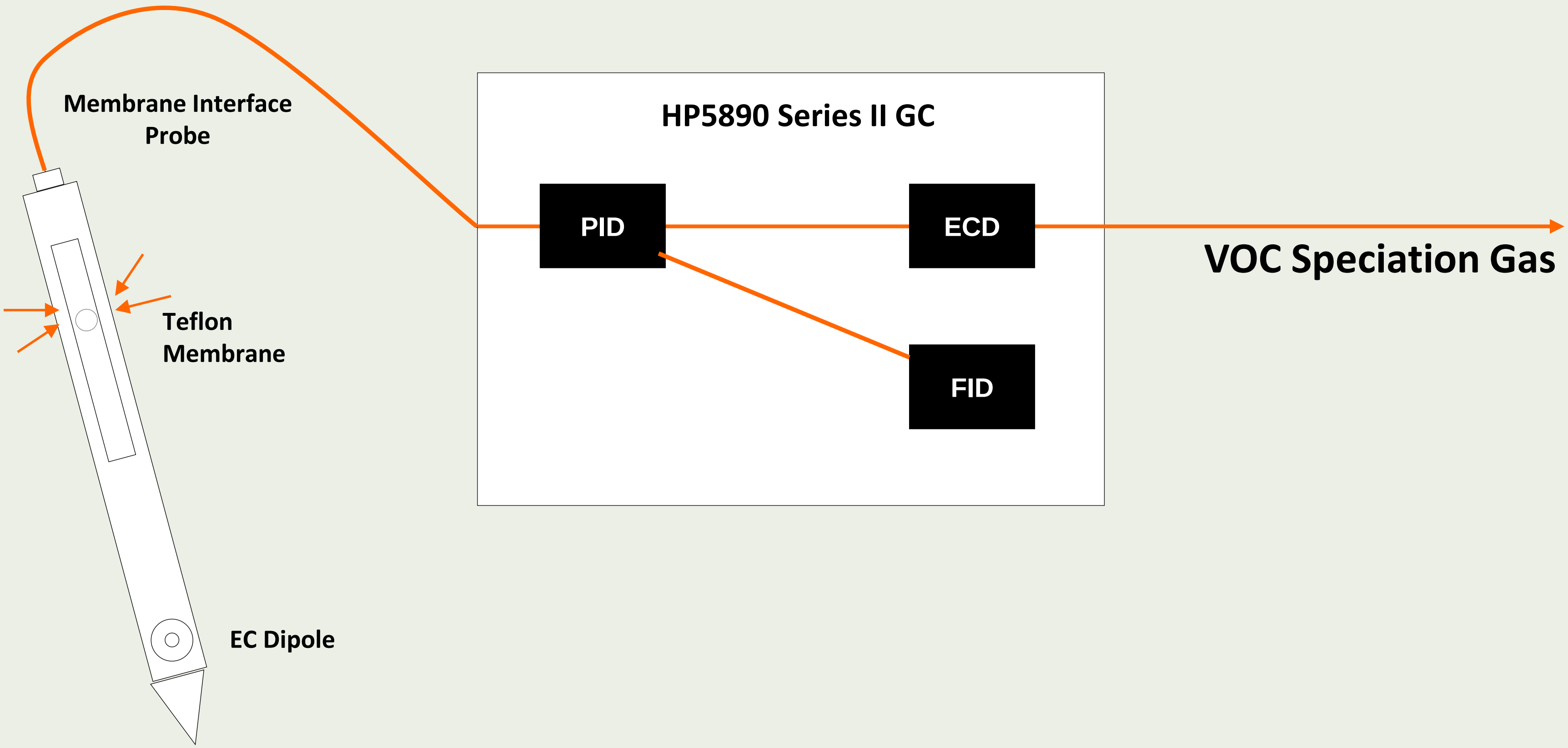
Tools for Shallow Unconsolidated Environments

Preview

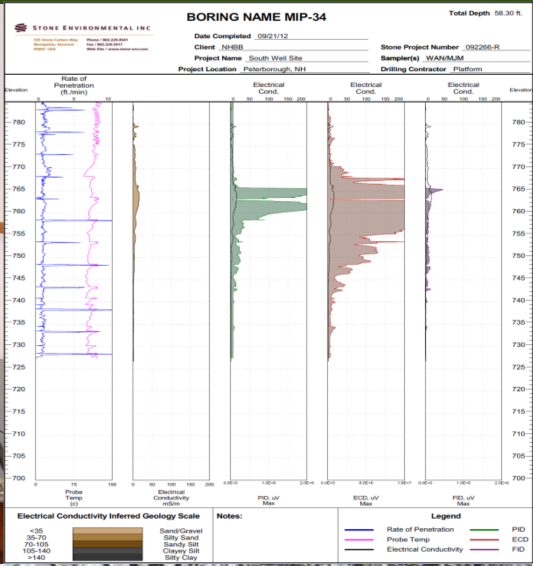
- Soil coring
- Hydrostratigraphic tools
- Qualitative tools for contaminants
- Sampling and quantitative tools for contaminants

Qualitative Tools for Contaminants

Membrane Interface Probe (MIP) Schematic



MIP in Action



MIP Strengths and Limitations

- **Strengths**
  - Vertically continuous, real-time data on VOC distributions and soil electrical conductivity
  - Can typically complete 150 to 250 linear feet of exploration per day
  - Ideal for locating source areas and plume cores
- **Limitations**
  - "Delicate" instrumentation and limited depth penetration
  - Units (volts) not the same as with soil or water concentration
  - Correlations with soil and water concentrations problematic
  - Generally does not distinguish between groups of analytes
  - Apparent "dragdown" of contamination

Recent Study Confirms MIP is Only a Qualitative Screening Tool

MIP works well for rapid location of relative high concentration zones such as plume cores or source areas.

MIP does not work well for estimating contaminant concentrations or mass.

Groundwater

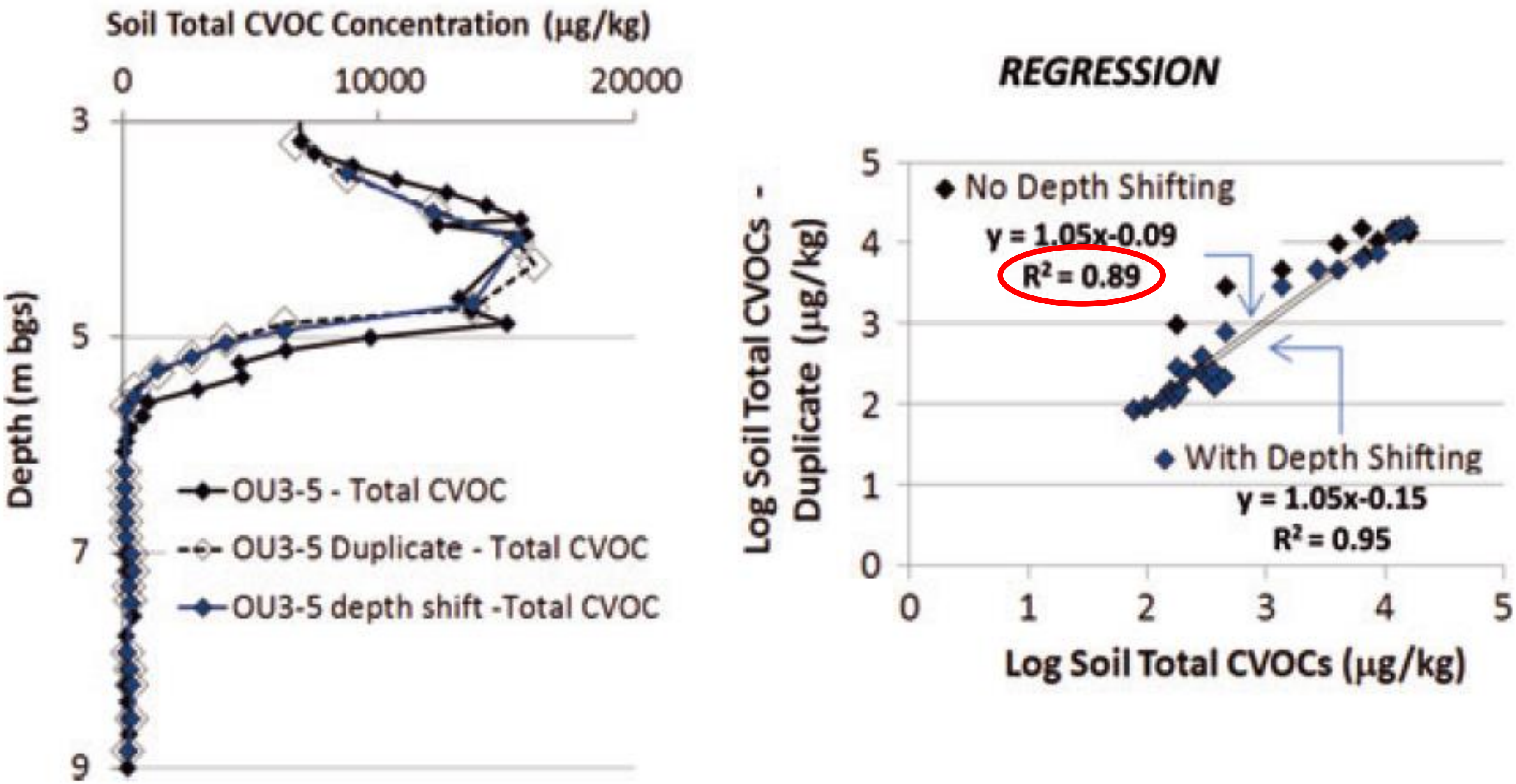
Membrane Interface Probe Protocol for Contaminants in Low-Permeability Zones

by David T. Adamson[1], Steven Chapman[2], Nicholas Mahler[3], Charles Newell[3], Beth Parker[2], Seth Pitkin[4], Michael Rossi[4], and Mike Singletary[5]

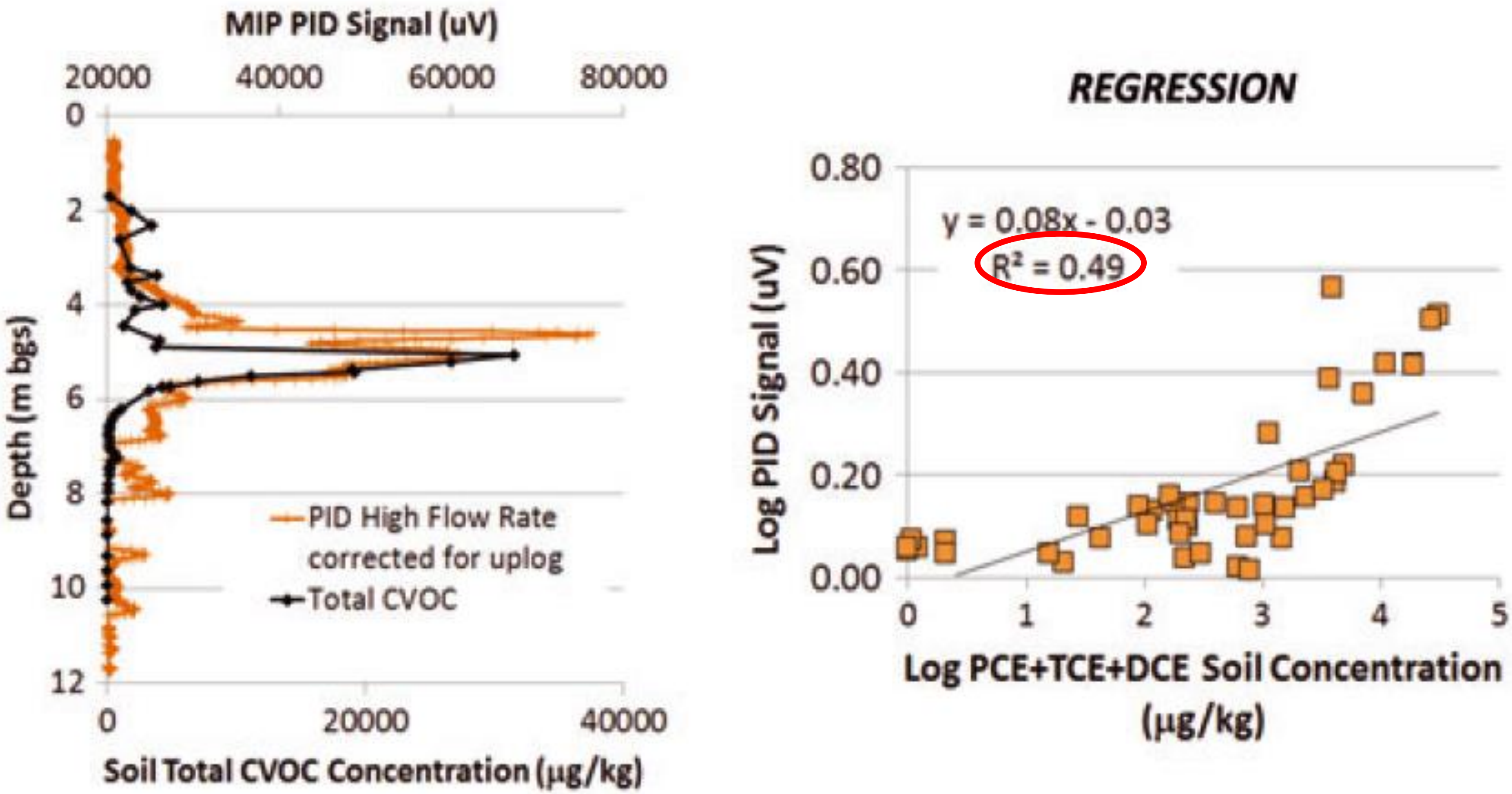
Abstract

Accurate characterization of contaminant mass in zones of low hydraulic conductivity (low k) is essential for site management because this difficult-to-treat mass can be a long-term secondary source. This study developed a protocol for the membrane interface probe (MIP) as a low-cost, rapid data-acquisition tool for qualitatively evaluating the location and relative distribution of mass in low-k zones. MIP operating parameters were varied systematically at high and low concentration locations at a contaminated site to evaluate the impact of the parameters on data quality relative to a detailed adjacent profile of soil concentrations. Evaluation of the relative location of maximum concentrations and the shape of the MIP vs. soil profiles led to a standard operating procedure (SOP) for the MIP to delineate contamination in low-k zones. This includes recommendations for: (1) preferred detector (ECD for low concentration zones, PID or ECD for higher concentration zones); (2) combining downlogged and uplogged data to reduce carryover; and (3) higher carrier gas flow rate in high concentration zones. Linear regression indicated scatter in all MIP-to-soil comparisons, including R^2 values using the SOP of 0.32 in the low concentration boring and 0.49 in the high concentration boring. In contrast, a control dataset with soil-to-soil correlations from borings 1-m apart exhibited an R^2 of $\geq$0.88, highlighting the uncertainty in predicting soil concentrations using MIP data. This study demonstrates that the MIP provides lower-precision contaminant distribution and heterogeneity data compared to more intensive high-resolution characterization methods. This is consistent with its use as a complementary screening tool.

Analytical Results from 2 Adjacent Soil Cores: Good Correlation

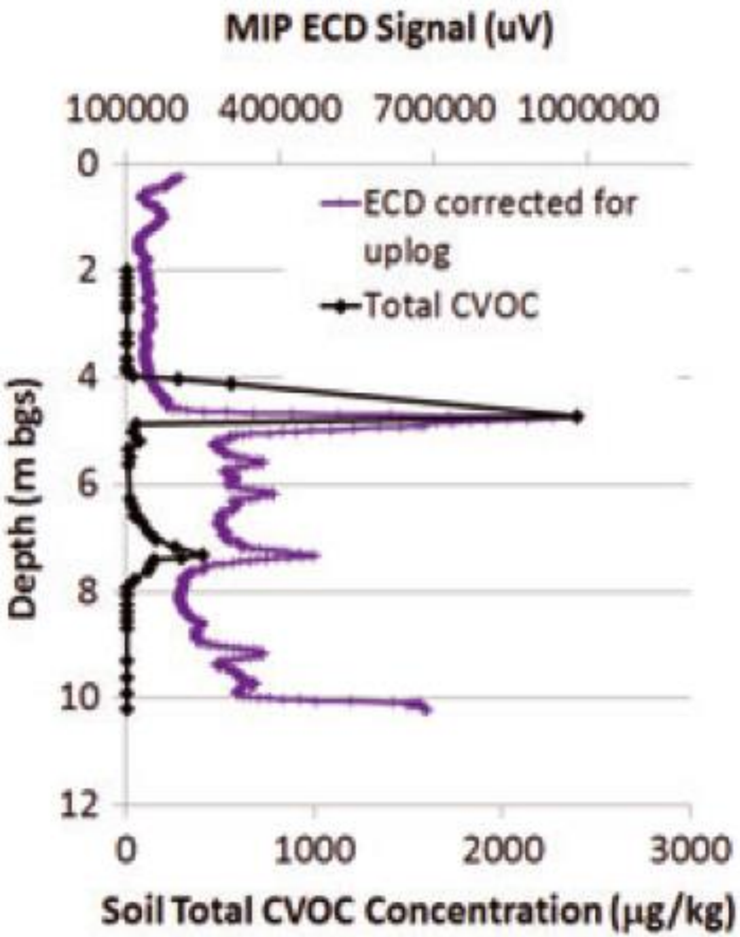


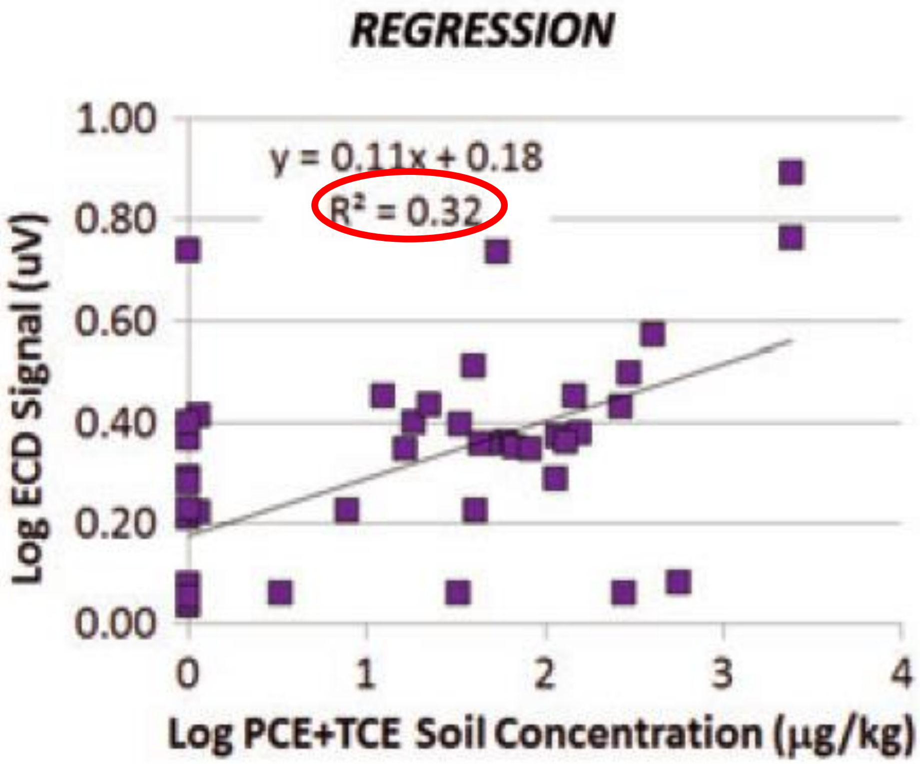
MIP and Soil Core High Conc. Location: Reasonably Good ID of Plume Location – Poor Concentration Correlation



Adamson et al., 2013

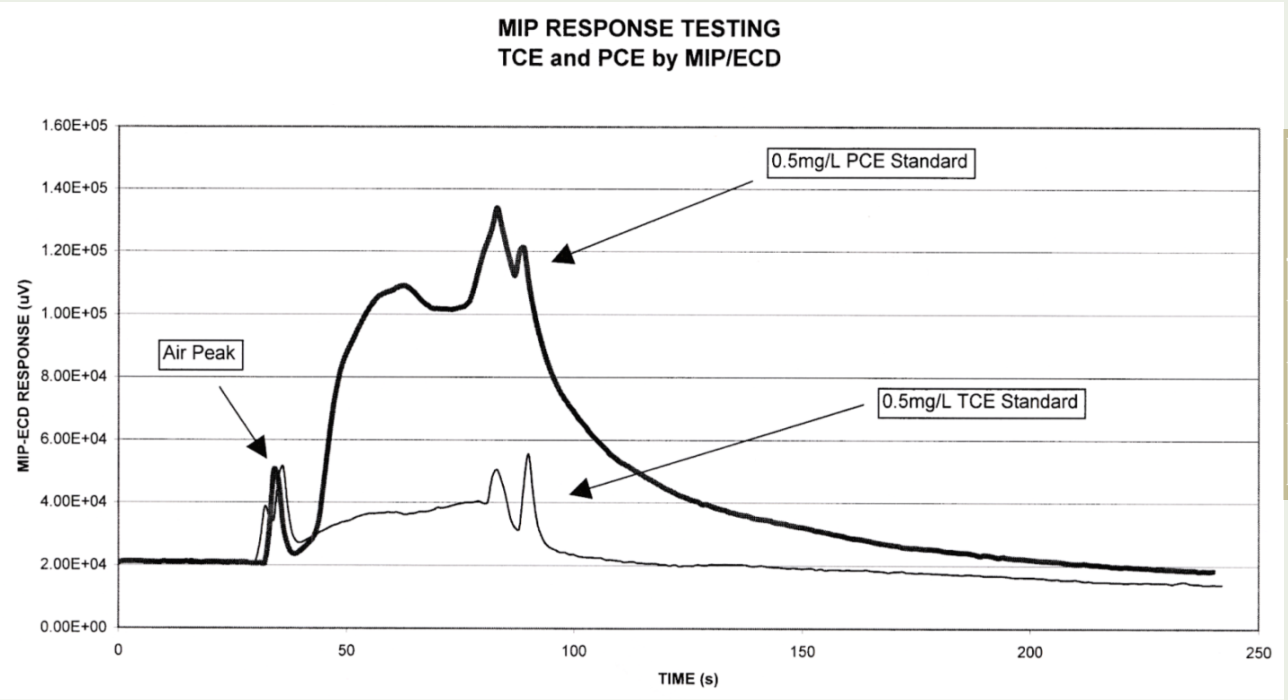
MIP and Soil Core Low Conc. Location: Reasonably Good ID of Plume Location – Poor Connection Correlation





Adamson et al., 2013

Variability in ECD Detector Response



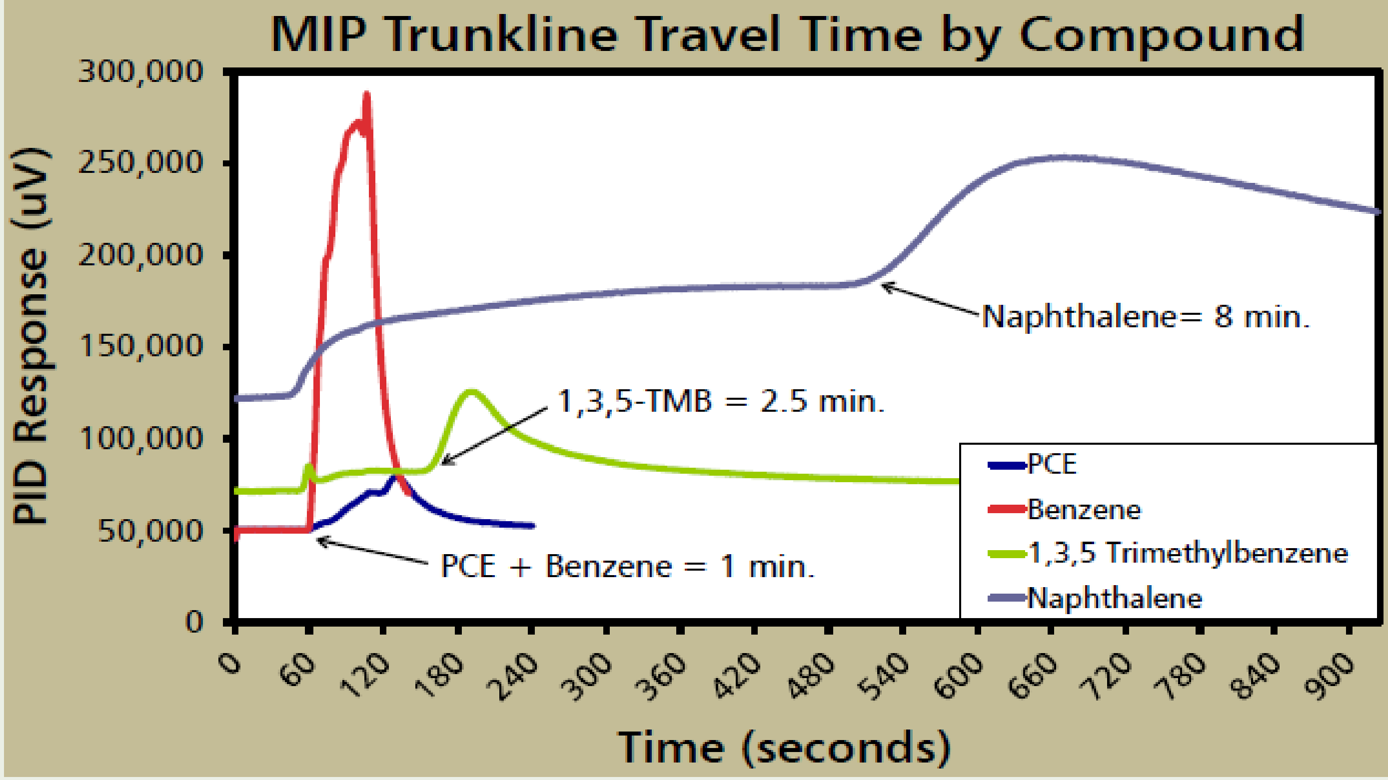
Response Test Results: ECD & PID with PCE, TCE and c-DCE

Compound	ECD Response, mV	PID Response, mV
PCE	1800	16
TCE	690	23
C-DCE	22	19
	Dramatic Decrease	No Significant Change

XSD, PID and FID RFs much more uniform

Factors Impacting MIP Performance

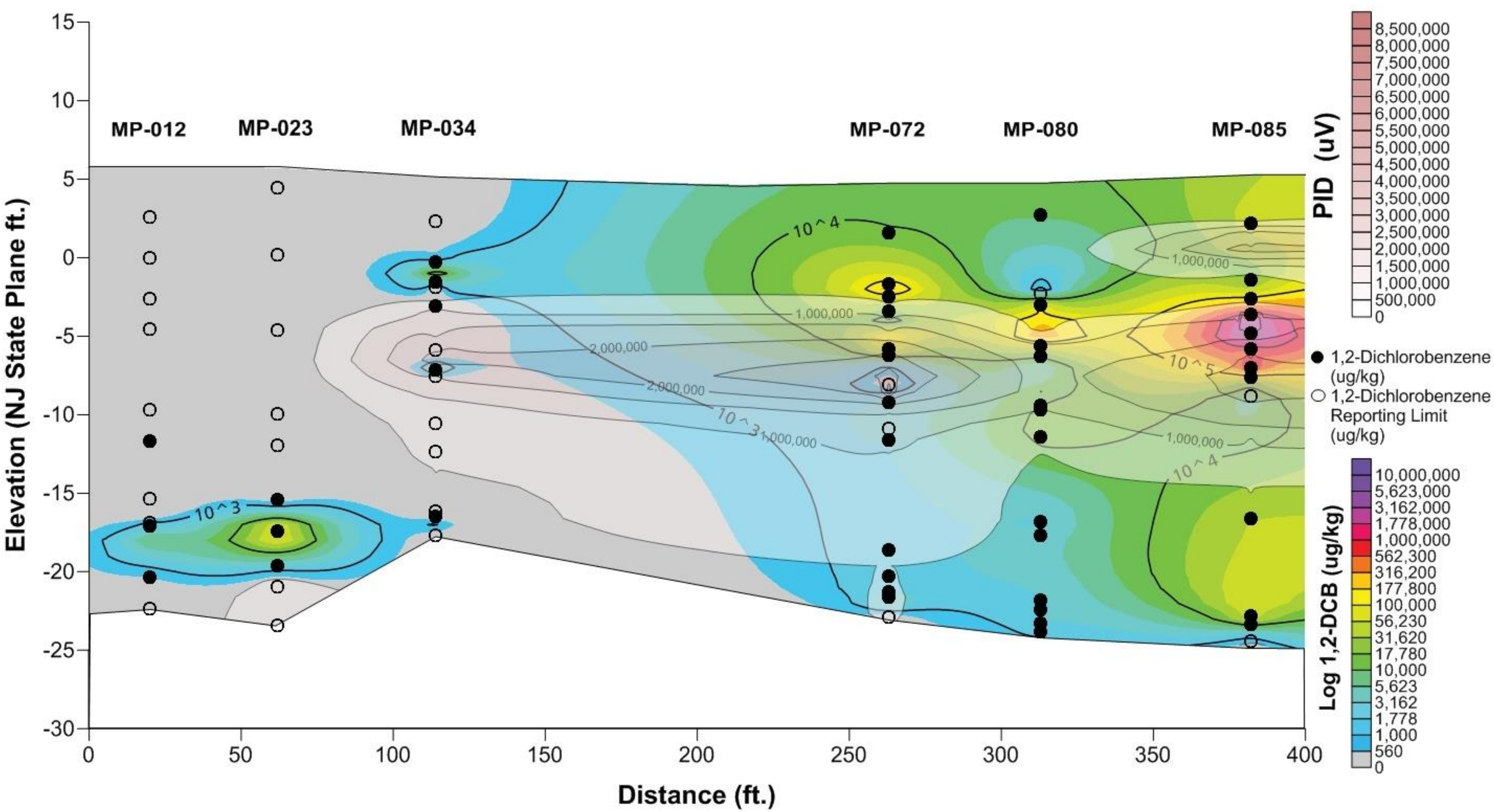
Trip Time Disparity



- Different compounds travel at different rates causing potential inaccuracies in contaminant distribution

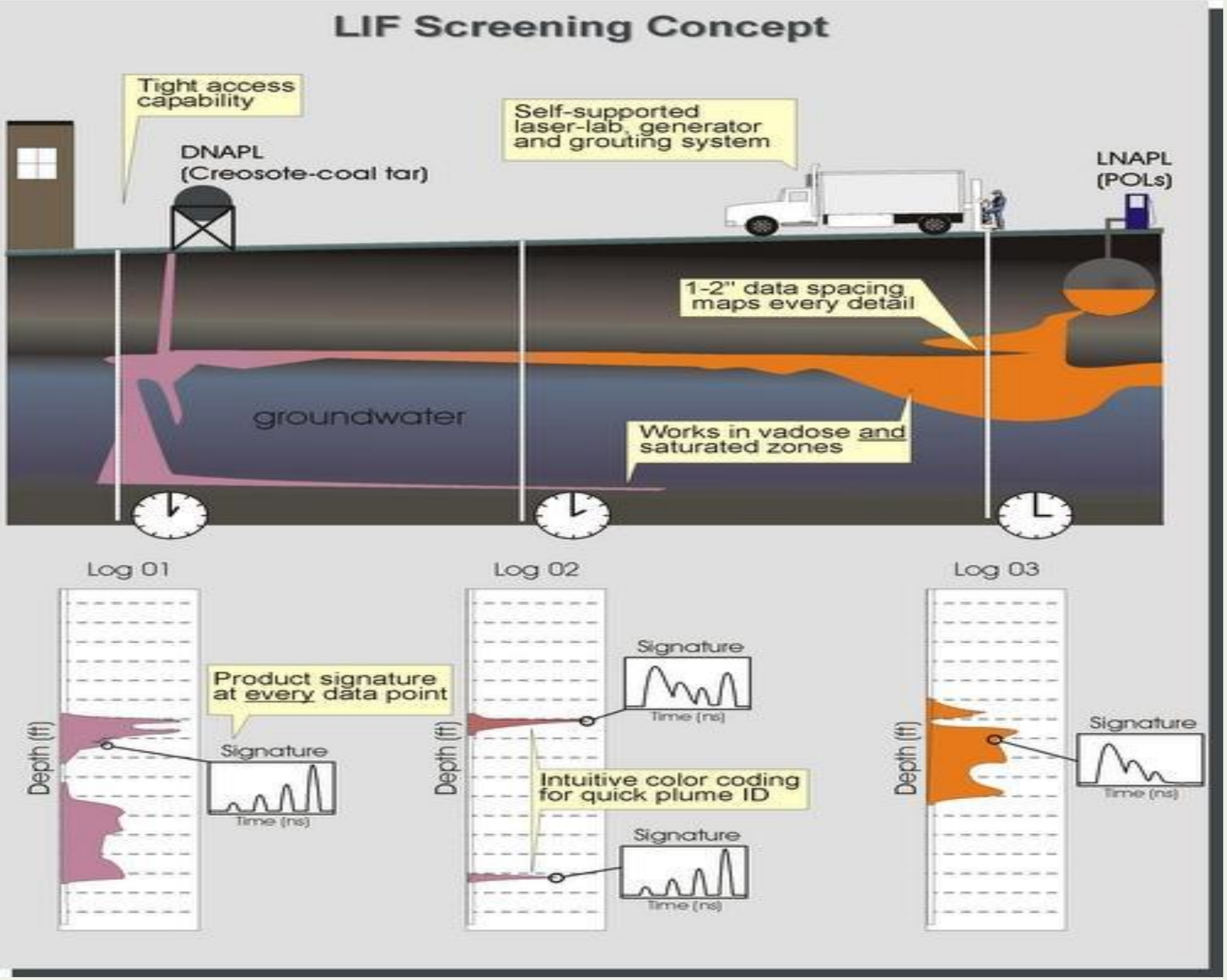
Correlations and Complex Mixtures

Trip Time Disparity



Laser Induced Fluorescence (LIF) – Basics of Optical Screening Tools

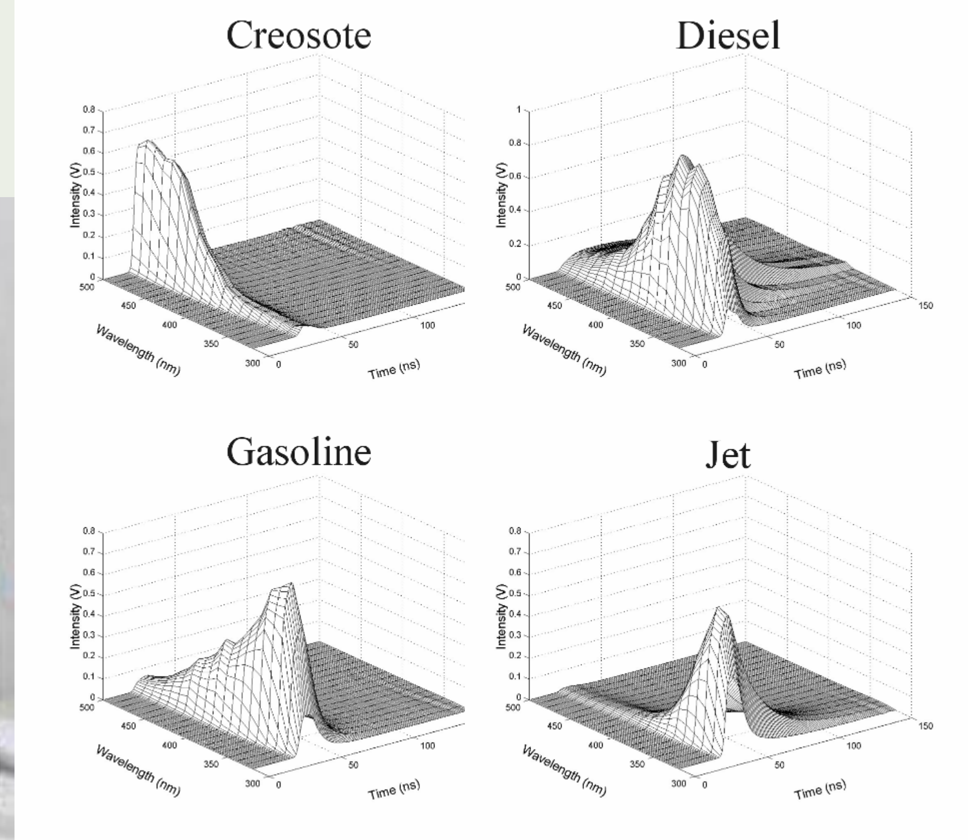
- ♦ **Work for Aromatic Compounds (PAH)**
- ♦ **Detect NAPL**
- ♦ **Employ sapphire-windows**
- ♦ **Direct push**
- ♦ **Log of depth vs. fluorescence**



Dakota Technologies, Inc.

Ultraviolet Optical Screening Tool (UVOST)

Wavelength/time matrix (WTM)



LIF – UVOST and TarGOST

- **Ultra Violet Optical Screening Tools (UVOST)**
  - Gasoline, diesel, jet (kerosene), motor oil, cutting fluids and hydraulic fluid
  - Does not see PCBs and straight chain halogenated compounds
  - Can give product class information though use of waveform evaluations
  - 10-500 ppm DLs - From "sheen to neat" – might not see dissolved phase PAHs
  - Best for use where presence of NAPL is driver for investigation
  - Matrix effects from soil particle size and color and other things that might be found in soils (sea shells, peat, calcite and calcareous sands)
- **Tar Specific Green Optical TarGOST**
  - Coal tar (MGP waste) and creosote (wood treatment)

LIF – What's Next

- **Dye-LIF for Halogenated NAPLs**
  - Fluorescent hydrophobic dye is injected ahead of sapphire window
  - Dye dissolves into NAPL but not in water
  - LIF detects the dye in the NAPL
- **This device has been commercialized and is currently being tested at a number of field sites**

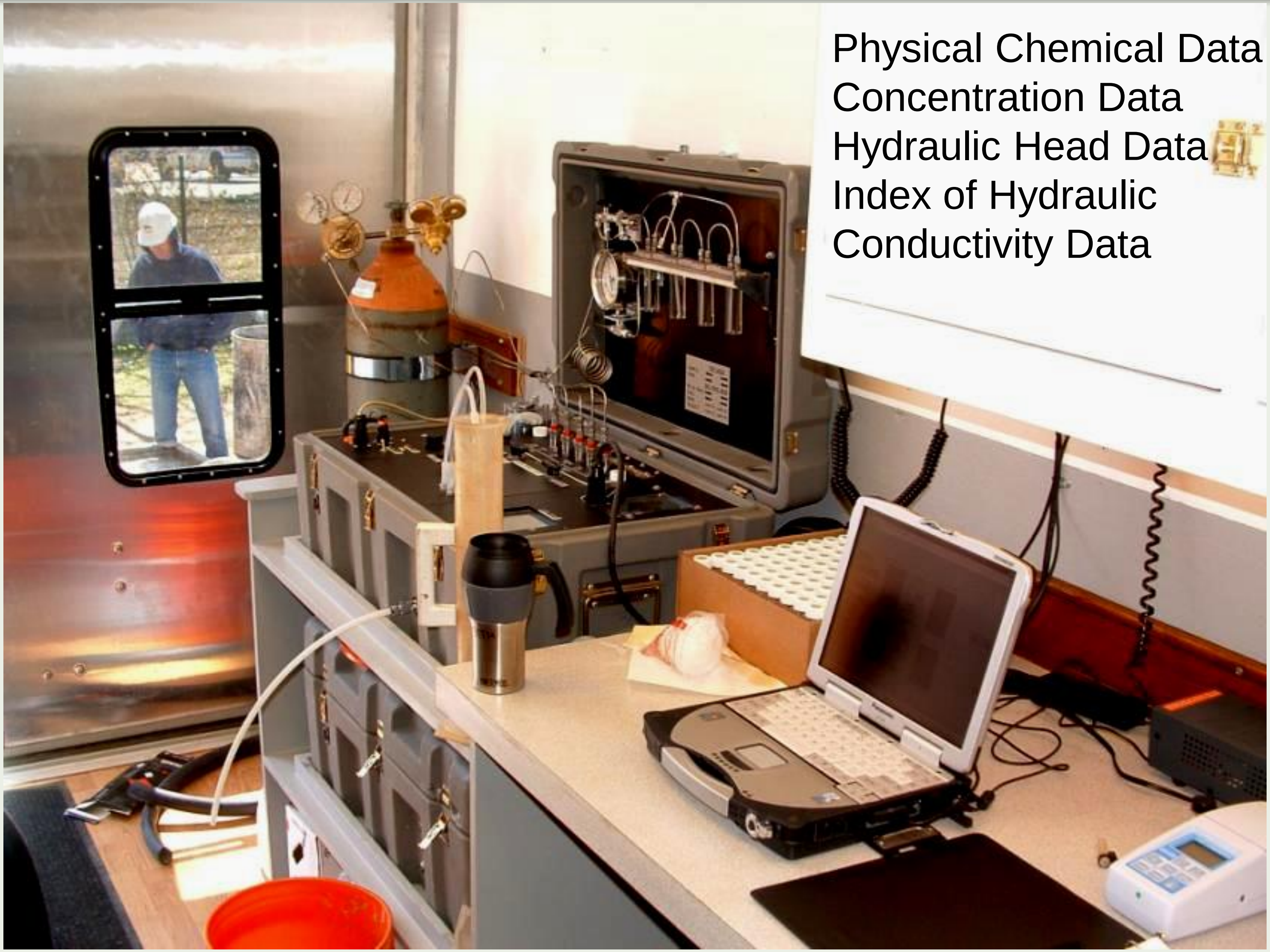
Sampling and Quantitative Tools for Contaminants

Direct Push Groundwater Sampling Tools

- ♦ **Geoprobe SP16/SP21**
  - » Small diameter
  - » Variable screen length
- ♦ **Removed (tripped) following collection of each sample**

Integrated Data Acquisition

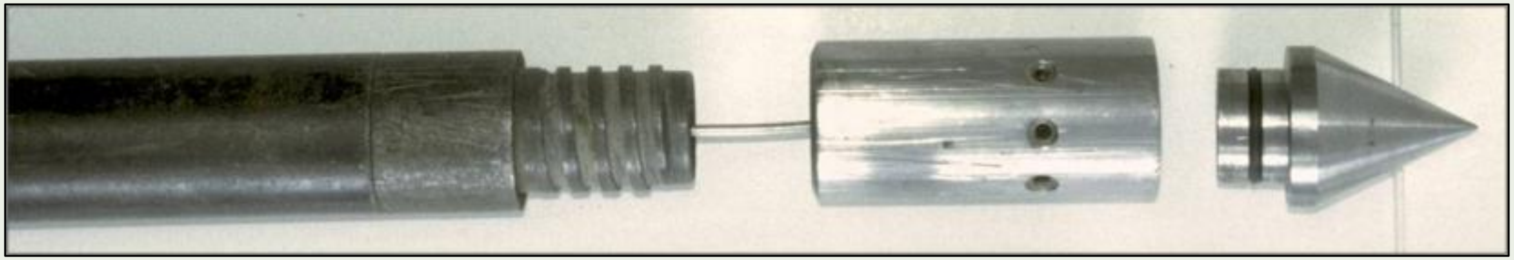
Waterloo APS™
ADVANCED PROFILING SYSTEM



Physical Chemical Data
Concentration Data
Hydraulic Head Data
Index of Hydraulic Conductivity Data

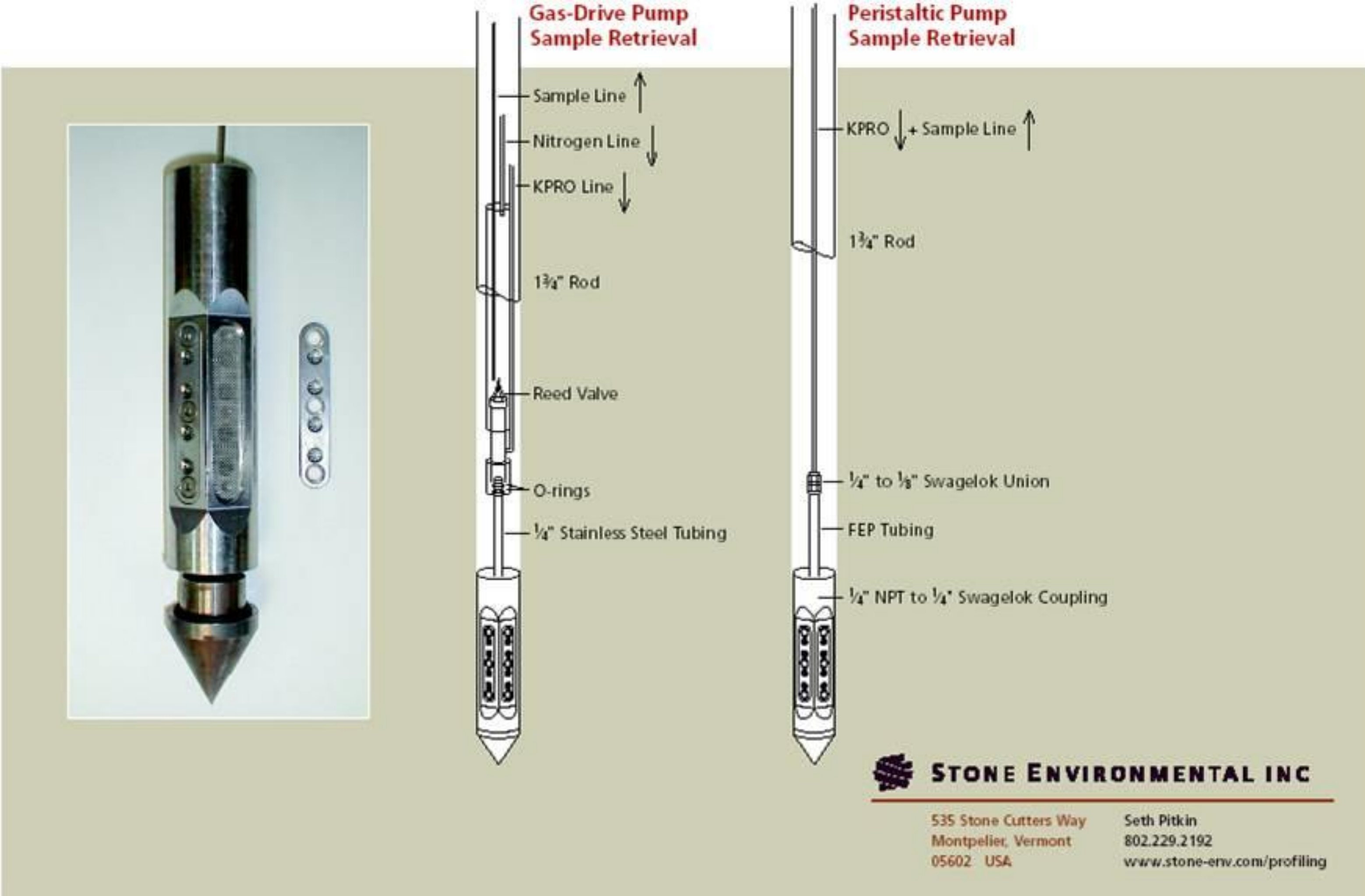
Profiler Hardware and Tip Modifications

1994 Waterloo Profiler

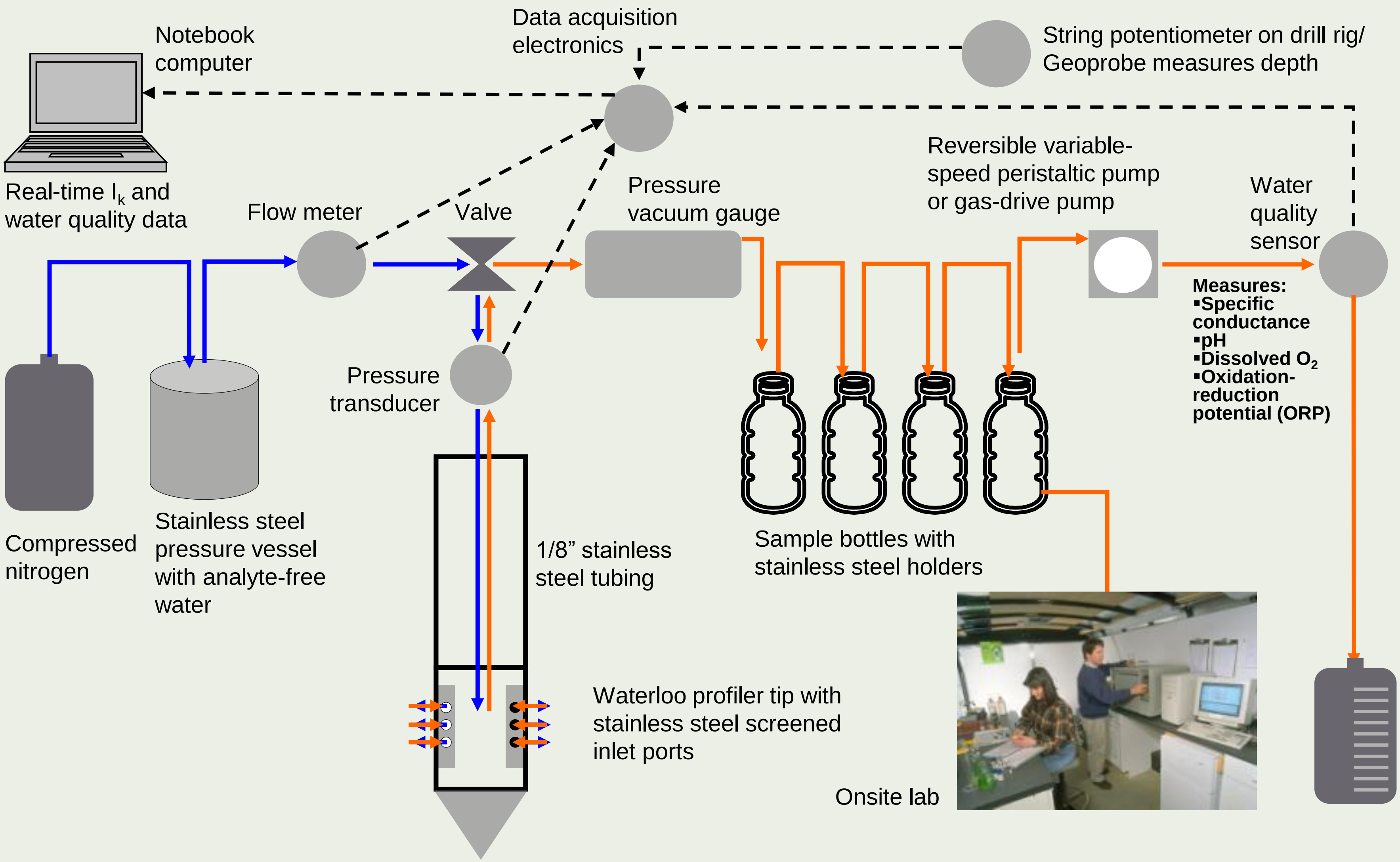


Waterloo Advanced Profiling System (Waterloo$^{APS™}$)

Waterloo^APS Sampling Configurations

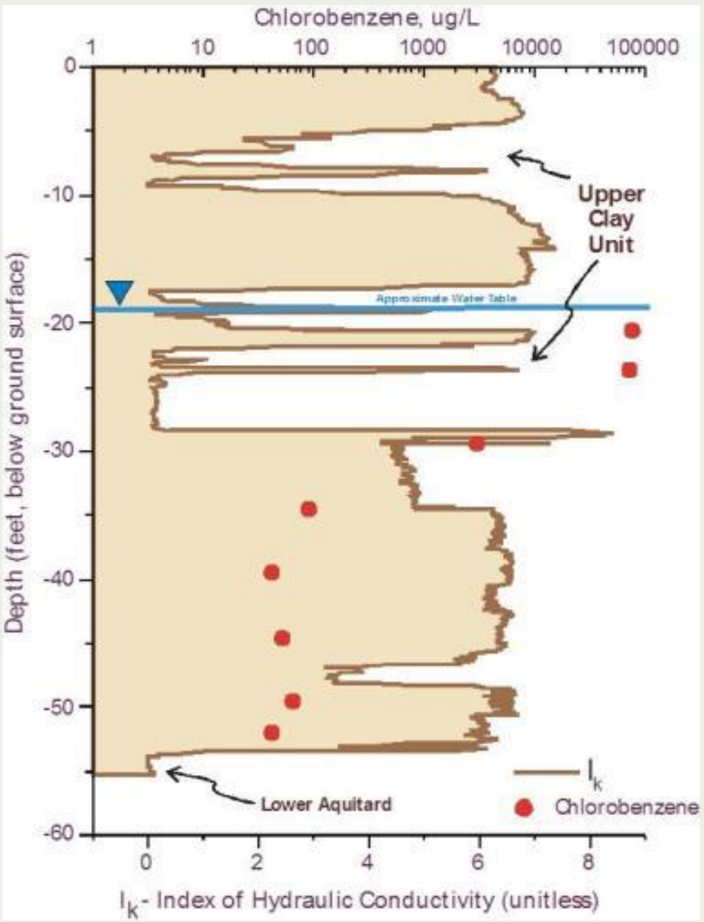


Waterloo^{APS} Data Acquisition Configuration and Process

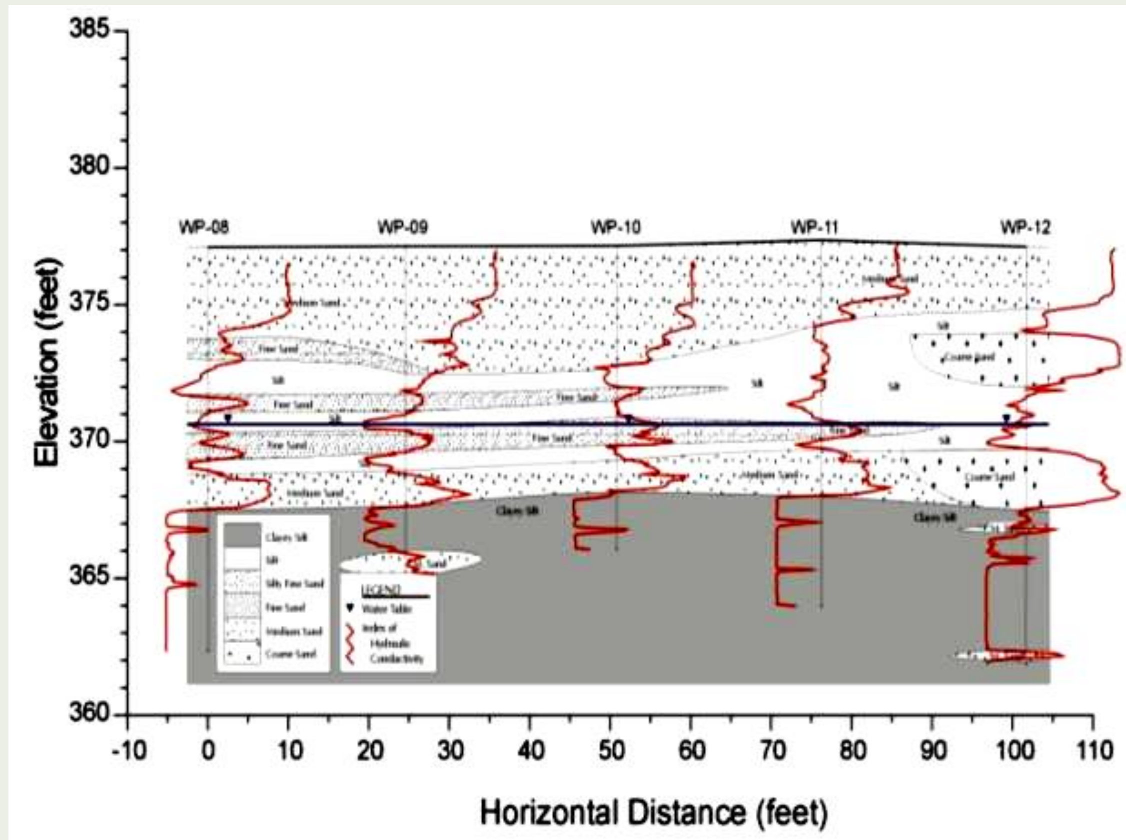


Two Uses of I_K Data

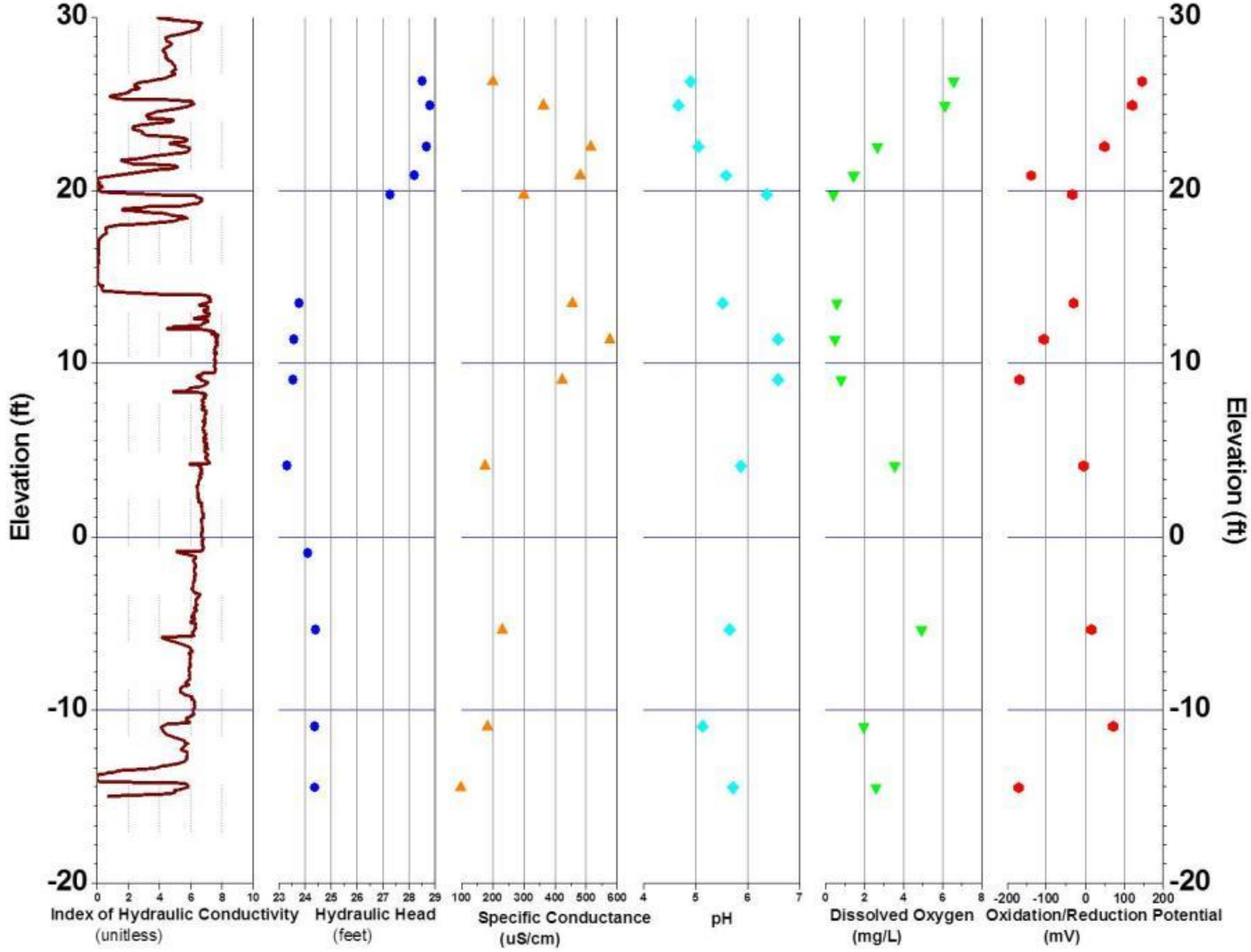
Sample depth selection



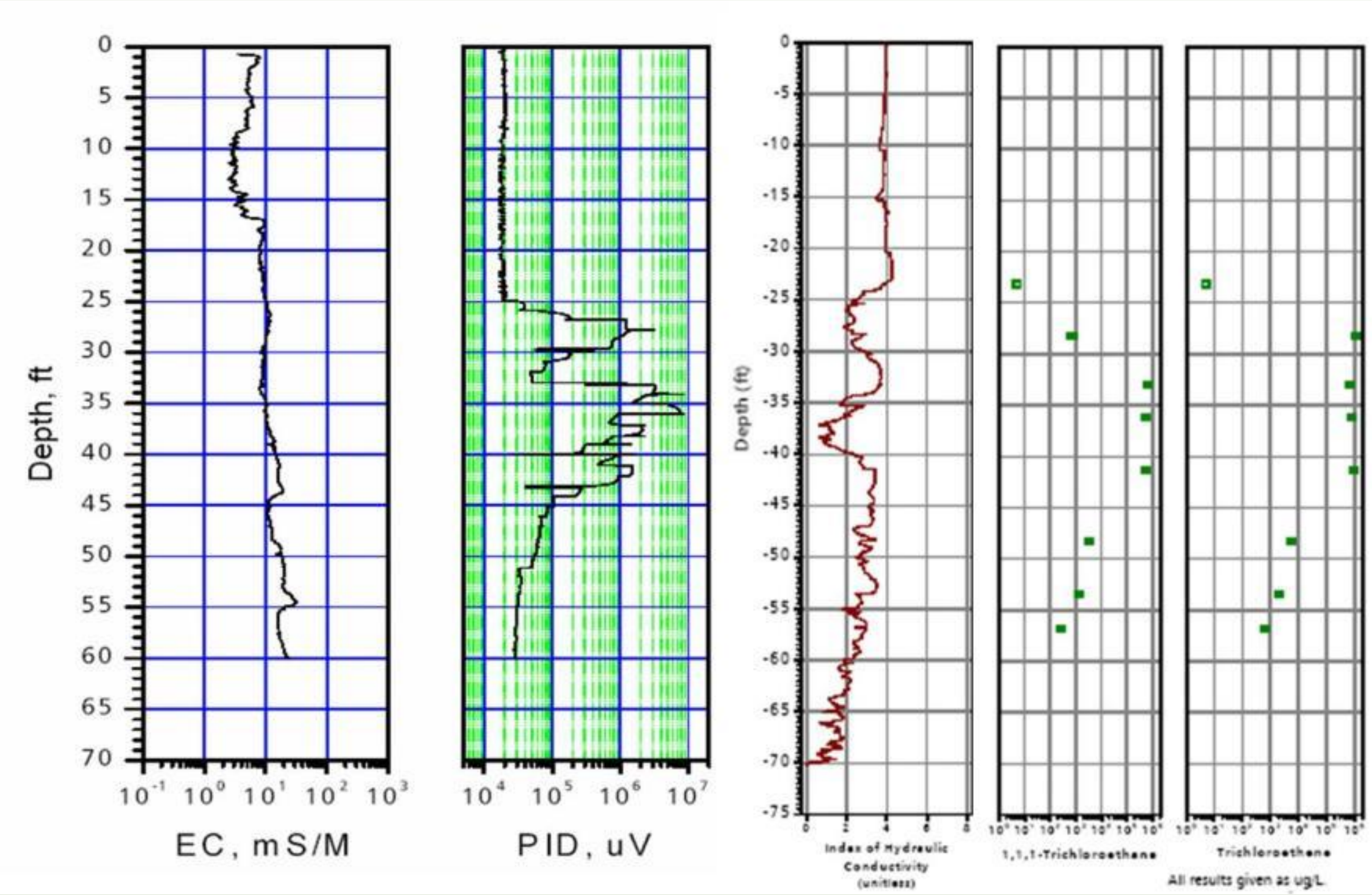
Stratigraphic Interpretation



Waterloo^{APS} Multiple Data Set



MIP and Waterloo^{APS}



Tools for Deep Unconsolidated Environments

Preview

- Hybrid drive platforms
- Sampling systems

Hybrid Drive Platforms

Profiling to depths > 550 ft

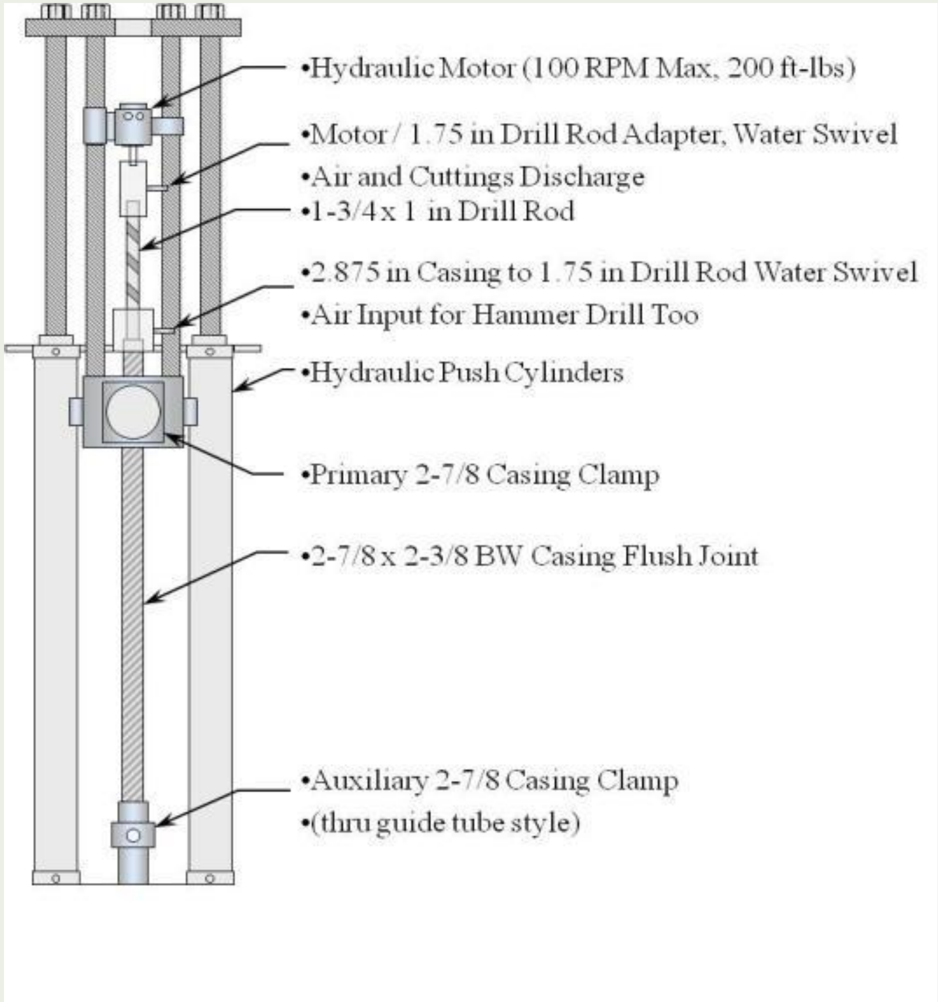
Enhanced Access Penetration System (EAPS) Approach for Drilling in Deep Unconsolidated Geology

- **Implement overburden drilling to penetrate through refusal layers**
  - Air rotary drilling combined with an under-reaming feature
  - Used to install casing through refusal layers
  - Casing eliminates sidewall friction, allowing for extremely deep penetration of Wireline
- **Wireline sampling tools**
  - Continuous gas sampling in vadose zone
  - Soil sampling at selected depths
  - Groundwater sampling at selected depths

EAPS – Selected Bits and Tools Used With Drill System

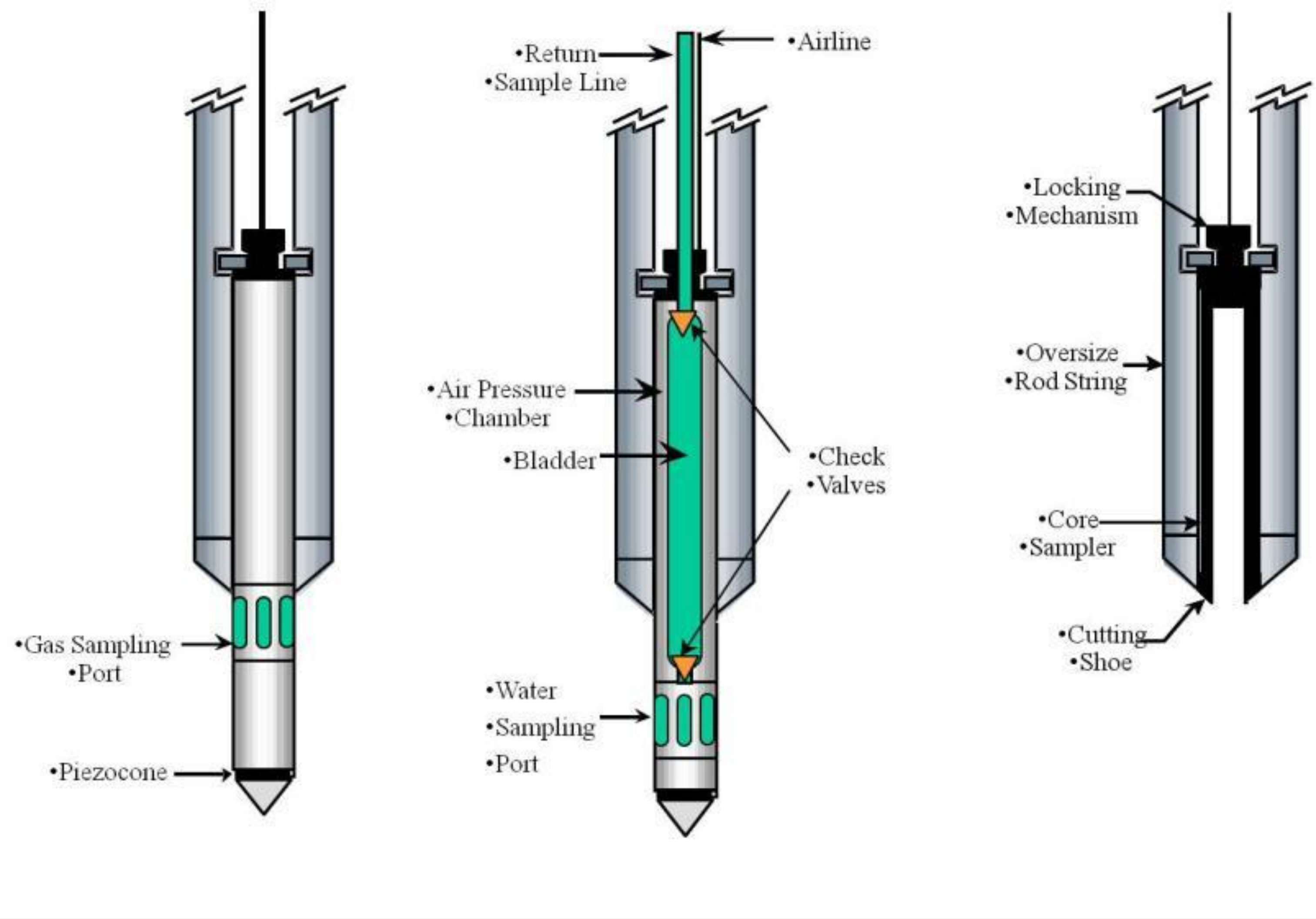
EAPS Configured for CPT Overburden and Combination CPT – Rotary

Overburden Drilling System



Combination CPT - Rotary Drill System

EAPS – CPT Wireline Sampling Systems



Tools for Fractured or Porous Media Environments

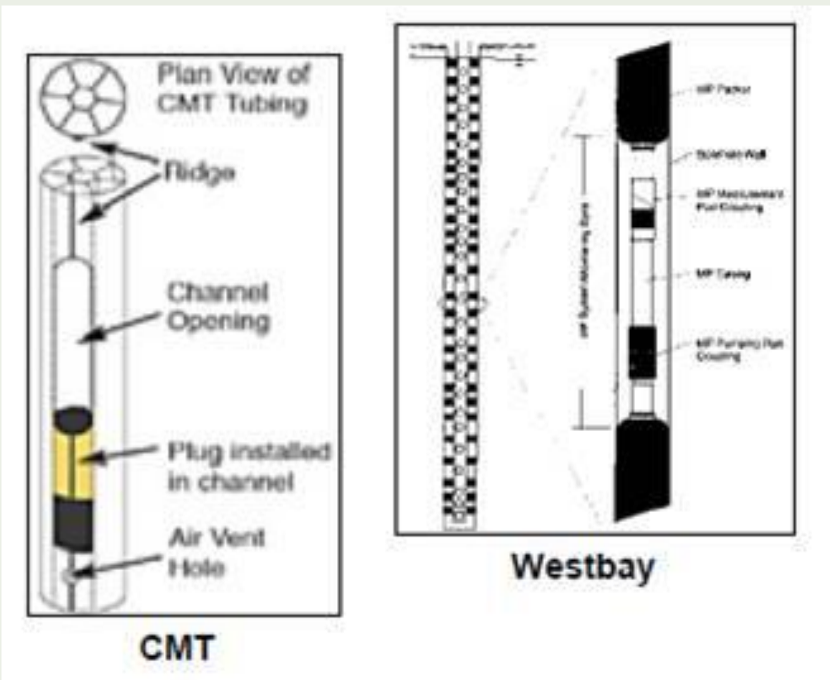
Preview

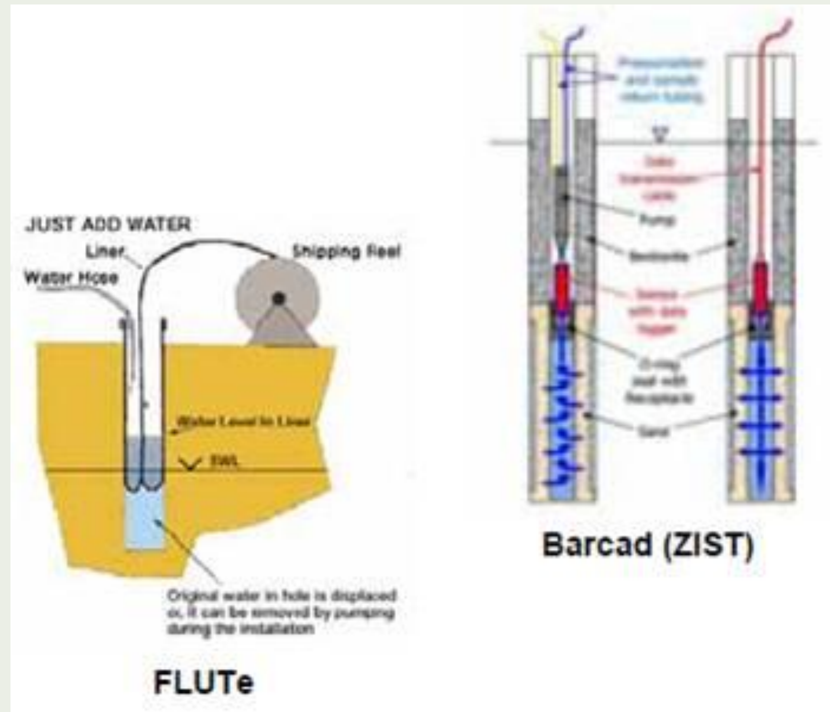
- Borehole geophysics
- Multi-level sampling tools
- Packer testing
- FLUTe liners
- Discrete Fracture Network Approach

Borehole Tool Matrix

	Readily Available		Specialty	
Target	**Primary Tools**	**Secondary Tools**	**Common**	**Limited**
Lithology and Mineralogy	• Gamma • Conductivity / Resistivity • Spectral gamma	• Acoustic televiewer • Video • Optical televiewer • Magnetic susceptibility • Full waveform seismic	• Density • Neutron • Vertical seismic profiling	• Temperature ALS • FMI • NMR
Weathering	• Full waveform seismic • Video	• Cross hole seismic • Acoustic televiewer • Conductivity / Resistivity +Gamma	• Magnetic susceptibility • Density • Neutron	• Vertical seismic profiling
Elastic Properties	• Full waveform seismic	• Vertical seismic profiling	• Cross hole seismic	
Porosity		• Caliper • Conductivity / Resistivity	• Neutron	• NMR • Induced polarization
Bulk Fracturing	• Temperature • Acoustic televiewer • Video • Optical televiewer	• Caliper • Conductivity / Resistivity • Full waveform seismic	• Micro resistivity • Neutron • Density • GPR	• Tube wave seismic
Individual Fractures	• Acoustic televiewer • Video • Optical televiewer	• Caliper • Temperature passive	• Temperature ALS • GPR	• Tube wave seismic • Micro-resistivity
Orientation of Fracturing	• Acoustic televiewer • Optical televiewer		• GPR	• 4 arm dip-meter • FMI
Water Flow Cross-connected	• Heat pulse flow meter • Impeller flow meter	• Temperature open-hole • Video	• Temperature ALS	• FEC with BH dilution • Electromagnetic flow-meter
Water Flow Ambient	• Temperature passive lined-hole		• Temperature ALS lined-hole	
Water Quality	• Conductivity / Resistivity • Water Conductivity	• Direct sampler	• Ph, DO, Redox, Salinity	
Borehole Properties	• Acoustic televiewer • Caliper	• Full waveform seismic	• Magnetic (+tilt-meter) deviation • Borehole (gyro) deviation	• FMI

Multi-level Characterization/Monitoring in Fractured Rock

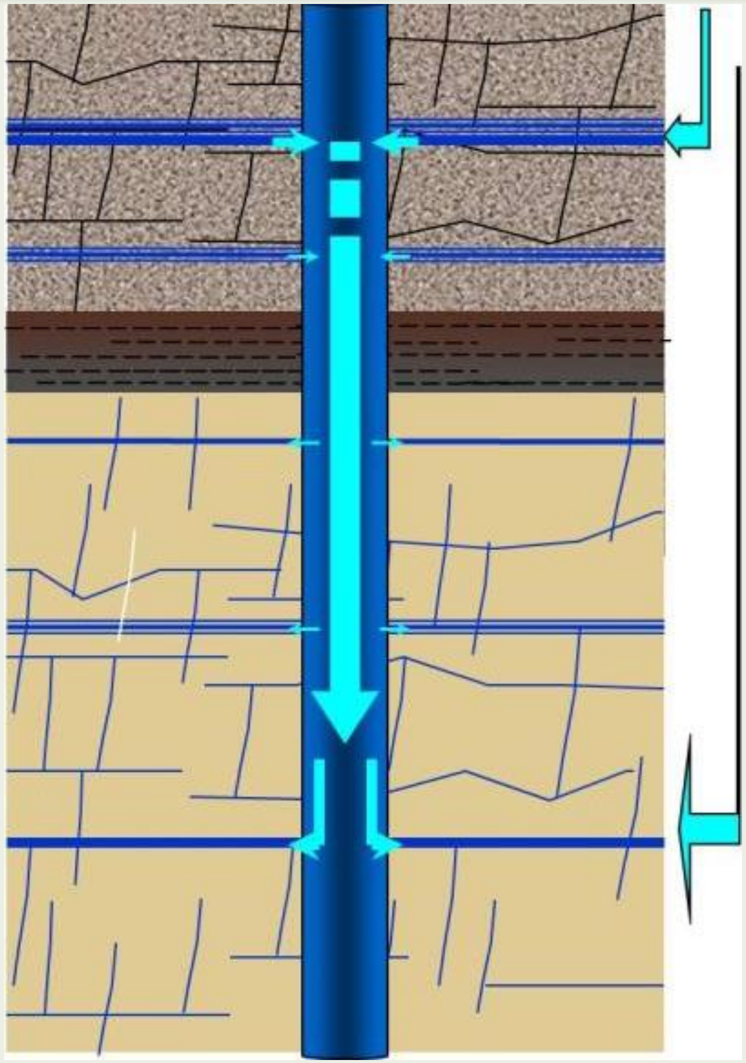




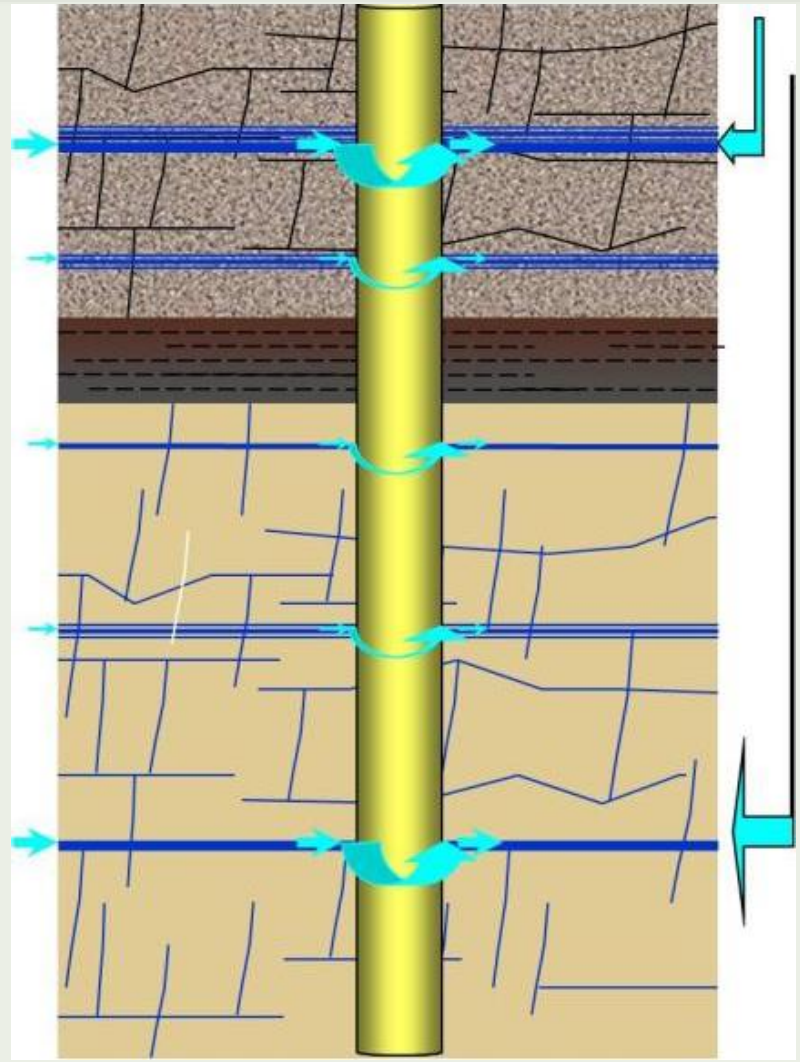
Packer Testing

- ♦ **Measure hydraulic head**
- ♦ **Measure hydraulic conductivity**
  - » Calculate effective fracture aperture
- ♦ **Collect water samples from isolated section of borehole**

Cross-Connected

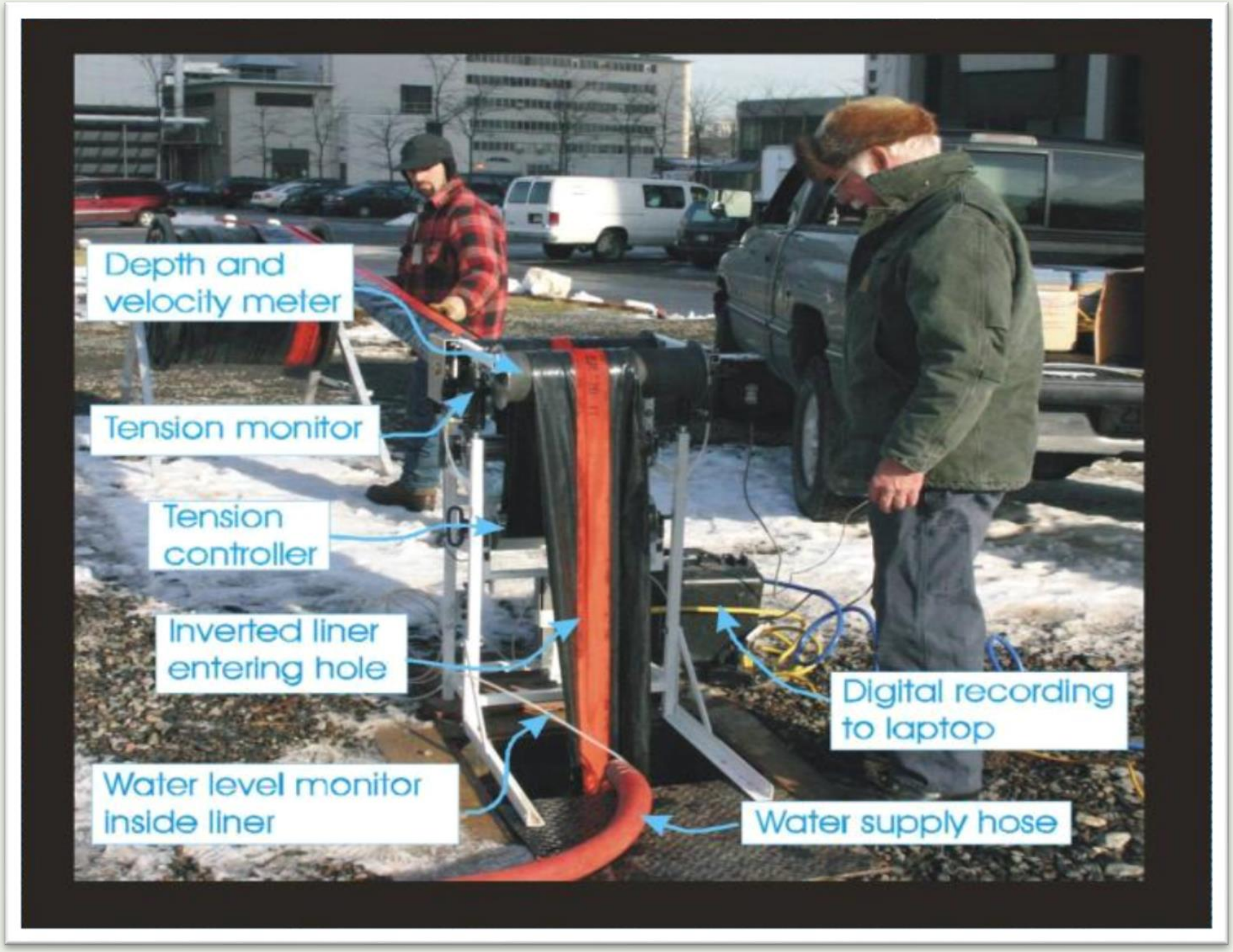


Not Cross-Connected

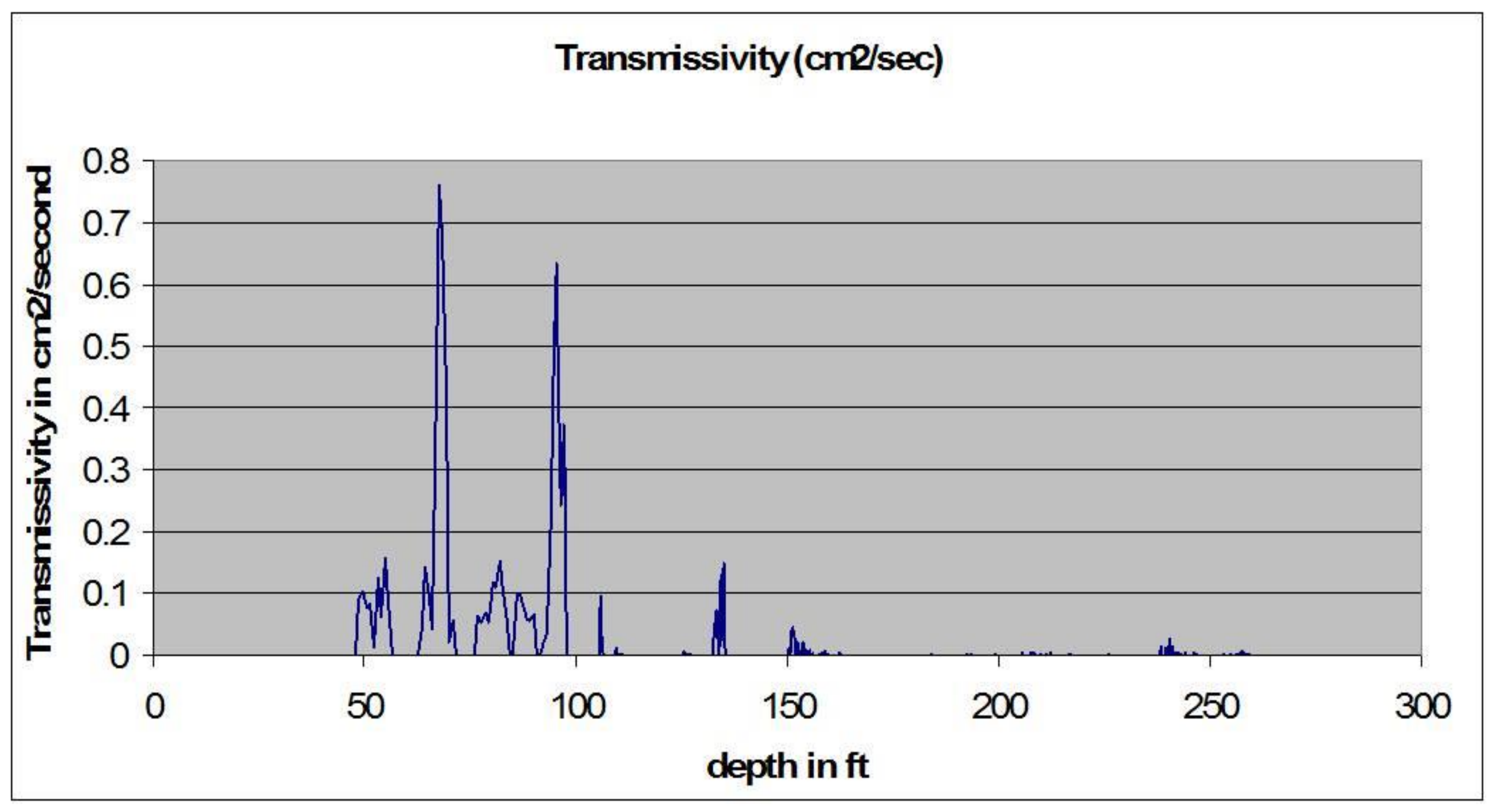


P. Pehme, 2006

FLUTe K – Profiling During Liner Installation

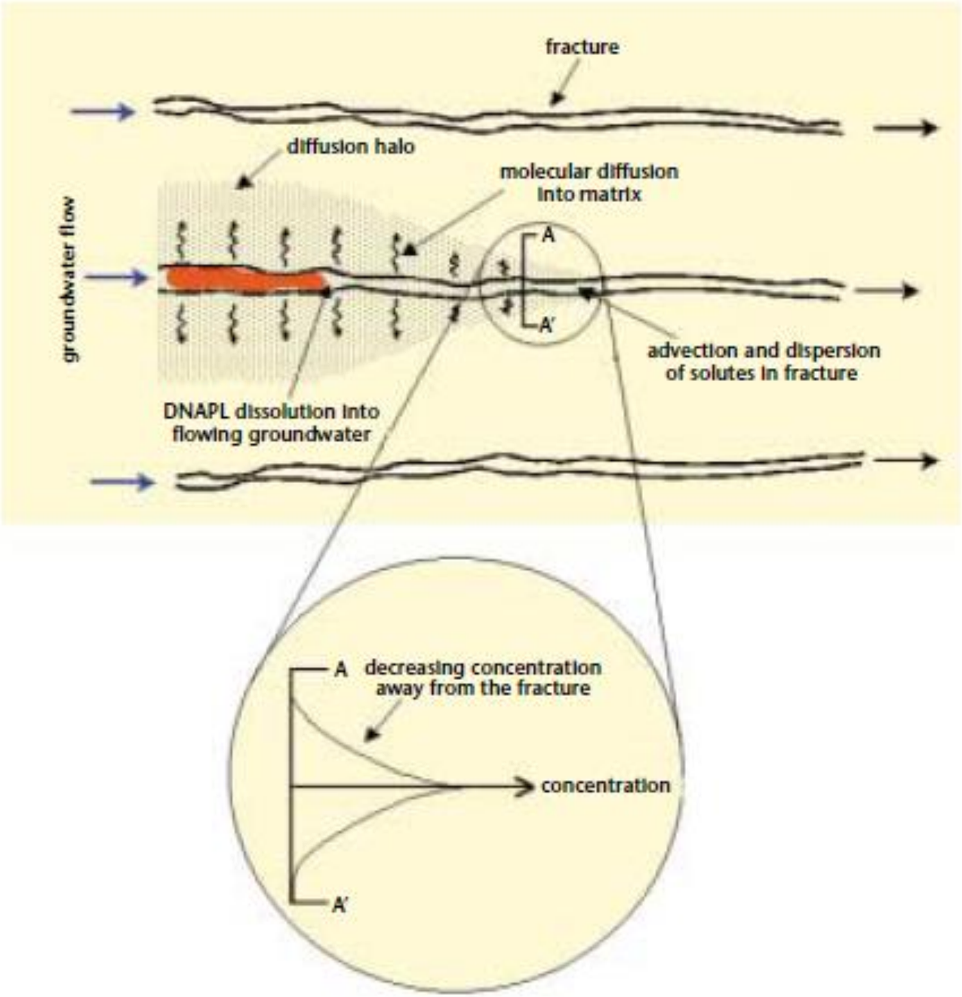


FLUTe Liner Profile Shows Transmissive Zones

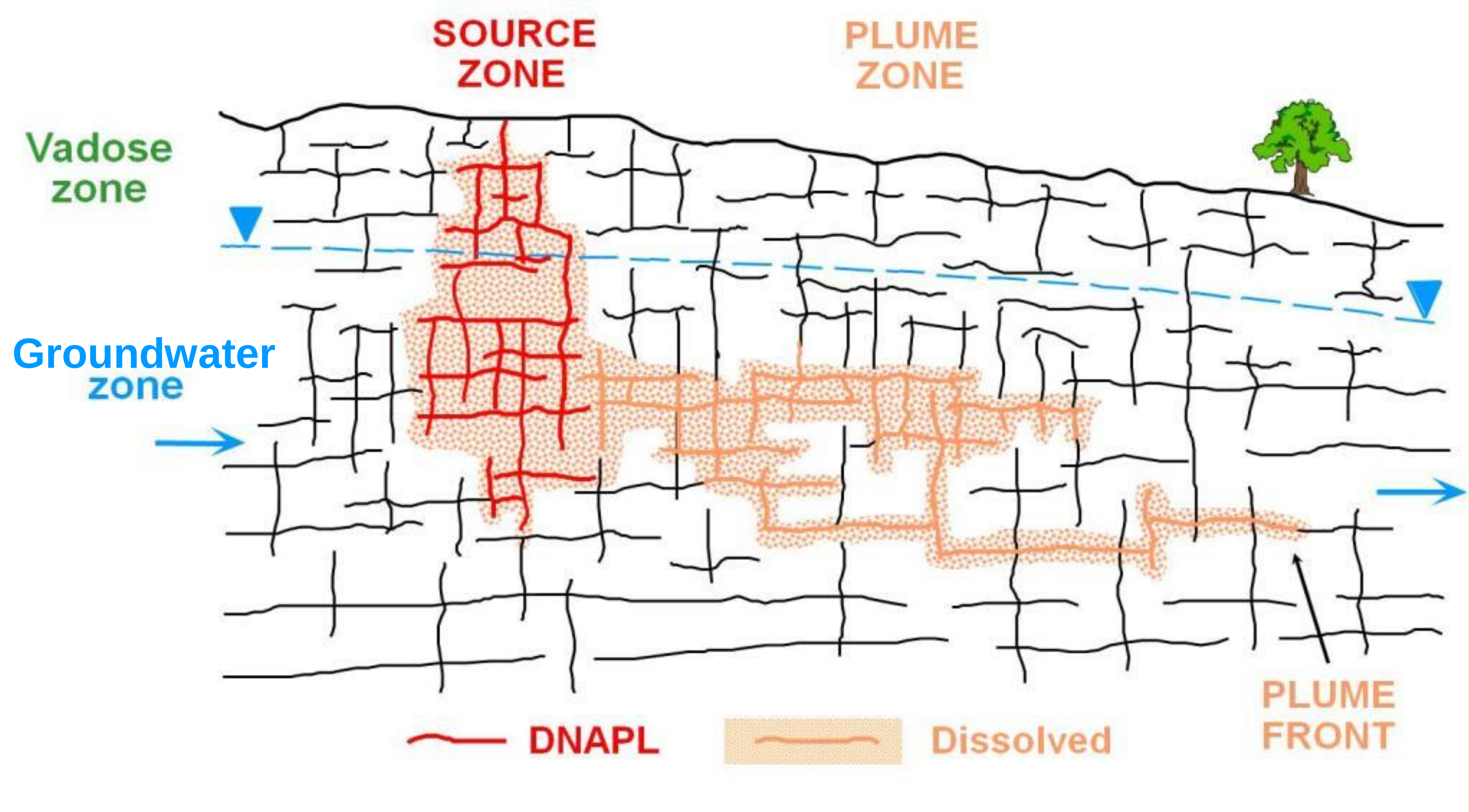


Guelph Site MW-26

Diffusion Into Rock Matrix



Contamination in Fractured Porous Media



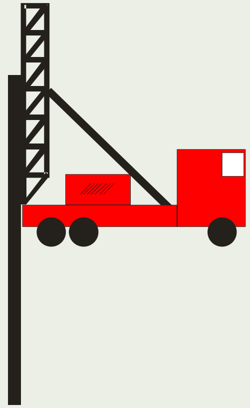
CORE DFN ™

DISCRETE FRACTURE NETWORK APPROACH

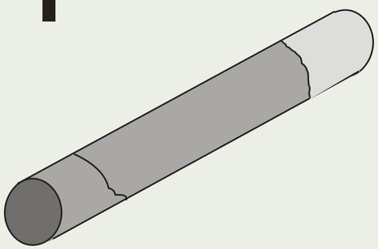
DFN Approach Process

Step 1. Core HQ vertical hole

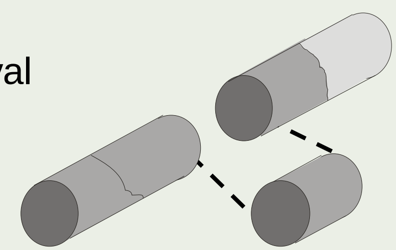
Sample length:
~1-2 inches



Step 2. Core logging and inspection

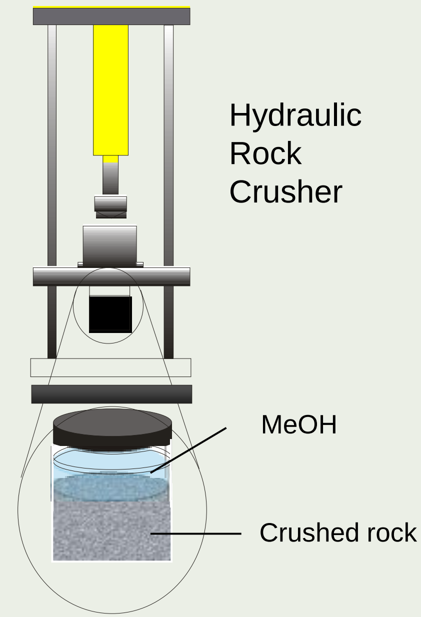


Step 3. Sample removal from core

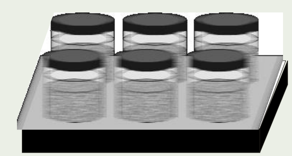


Step 4. Rock crushing

Step 5. Fill sample bottle with crushed rock and methanol



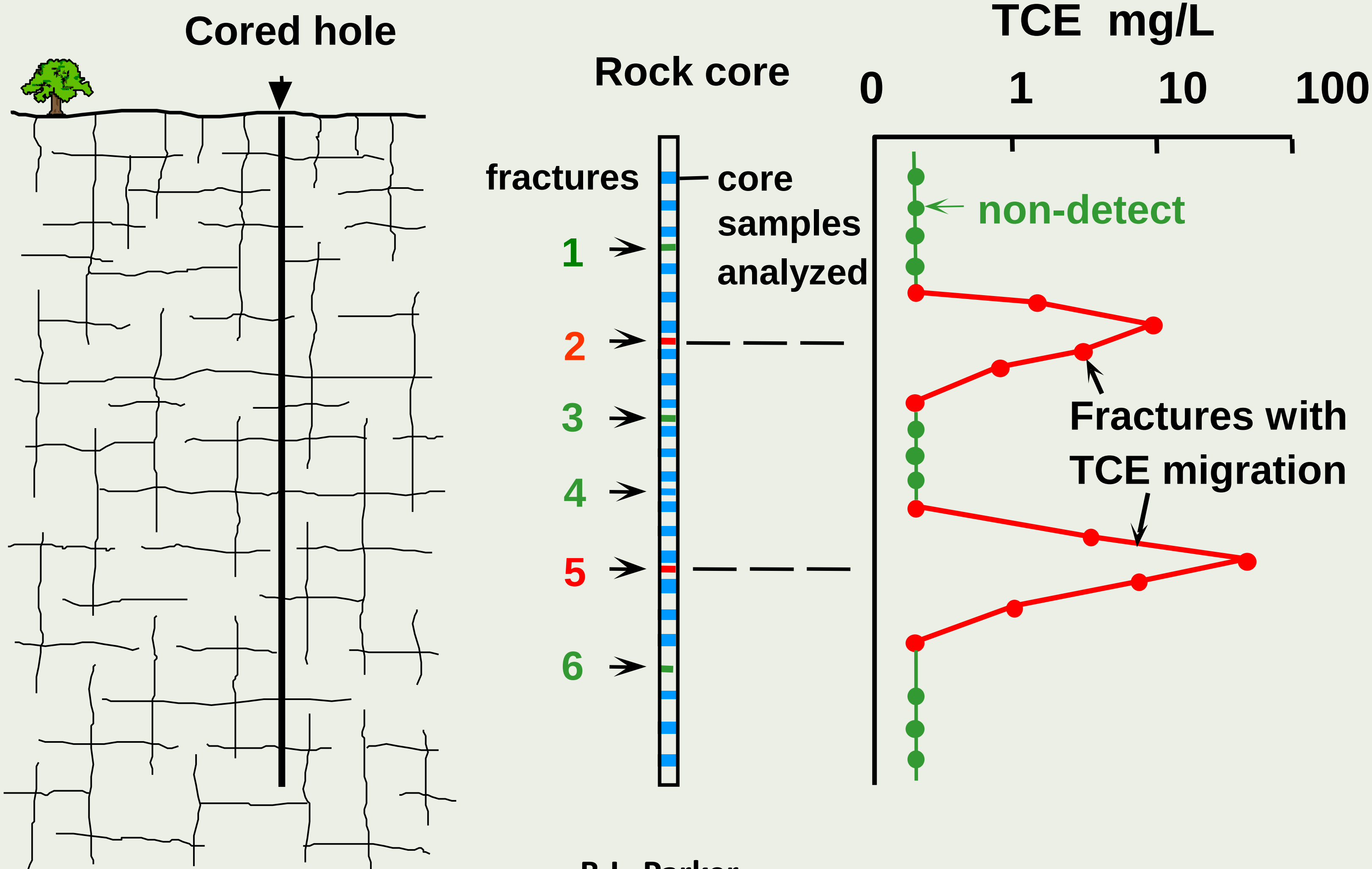
Step 6. Microwave assisted extraction (MAE)



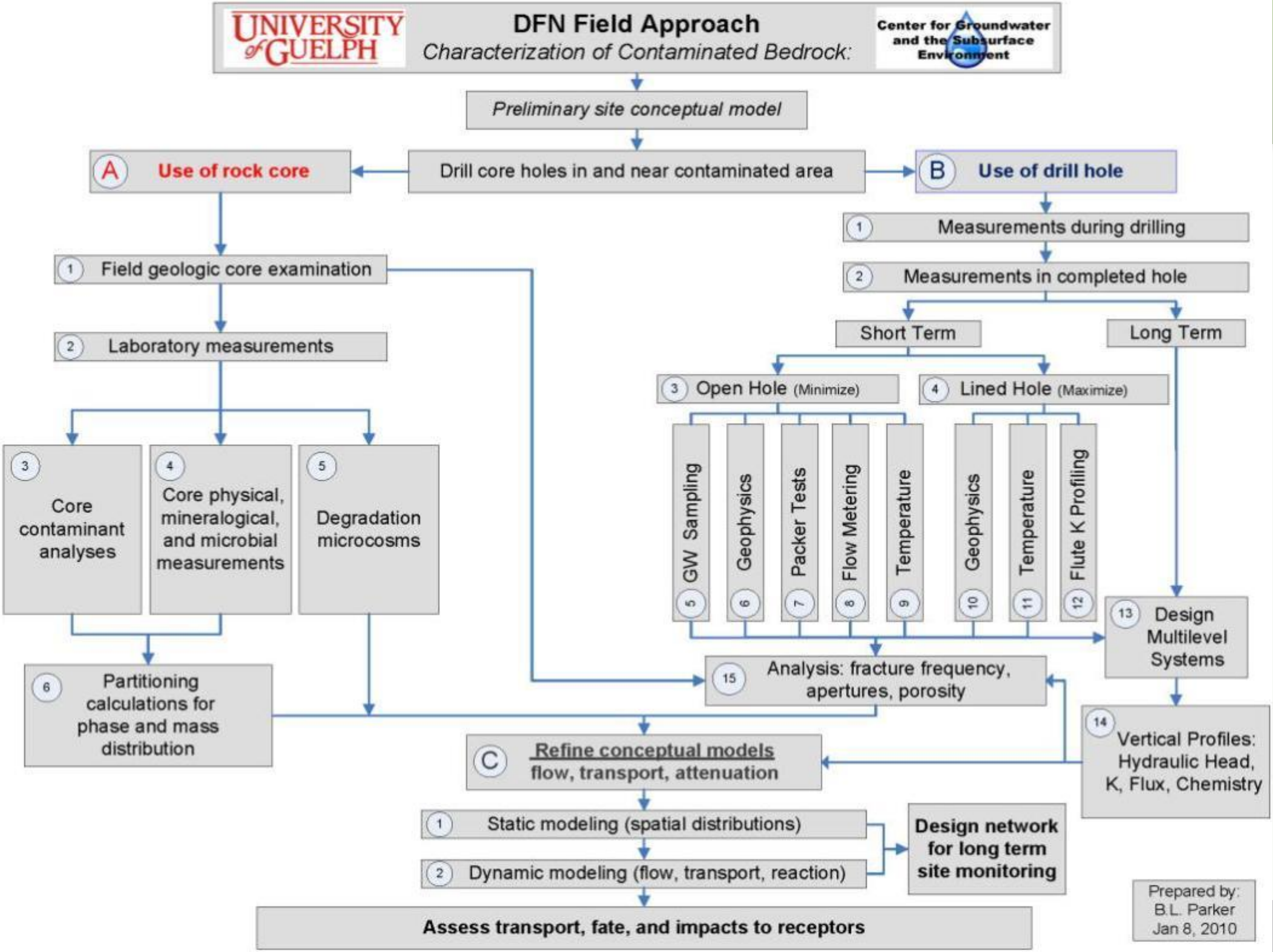
Step 7. Analysis and conversion of results to pore water concentration

B.L. Parker (Modified from Hurley, 2002)

Mass Distribution and Migration Pathway Identification



B.L. Parker

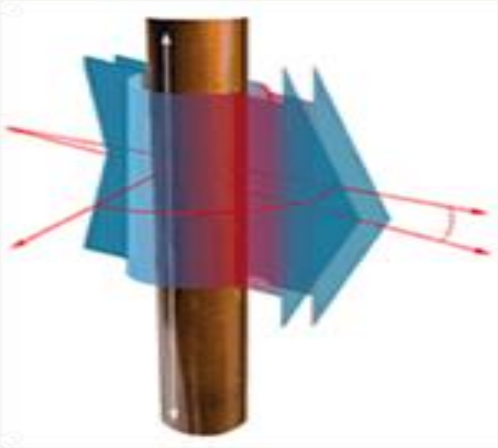

UNIVERSITY of GUELPH
DFN Field Approach
Characterization of Contaminated Bedrock:
Center for Groundwater and the Subsurface Environment
Preliminary site conceptual model
Drill core holes in and near contaminated area
A Use of rock core
1 Field geologic core examination
2 Laboratory measurements
3 Core contaminant analyses
4 Core physical, mineralogical, and microbial measurements
5 Degradation microcosms
6 Partitioning calculations for phase and mass distribution
B Use of drill hole
1 Measurements during drilling
2 Measurements in completed hole
Short Term
Long Term
3 Open Hole (Minimize)
4 Lined Hole (Maximize)
5 GW Sampling
6 Geophysics
7 Packer Tests
8 Flow Metering
9 Temperature
10 Geophysics
11 Temperature
12 Flute K Profiling
13 Design Multilevel Systems
14 Vertical Profiles: Hydraulic Head, K, Flux, Chemistry
15 Analysis: fracture frequency, apertures, porosity
C Refine conceptual models flow, transport, attenuation
1 Static modeling (spatial distributions)
2 Dynamic modeling (flow, transport, reaction)
Design network for long term site monitoring
Assess transport, fate, and impacts to receptors
Prepared by: B.L. Parker Jan 8, 2010

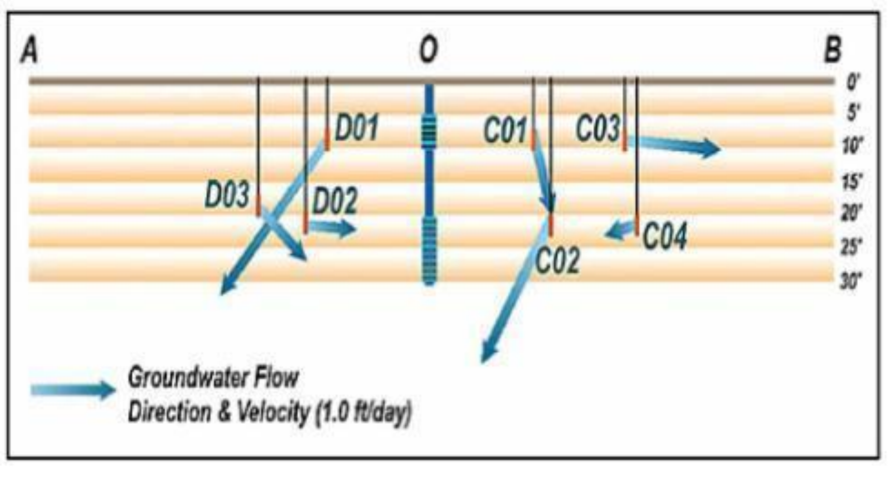
Tools for Non-Depth-Specific Applications

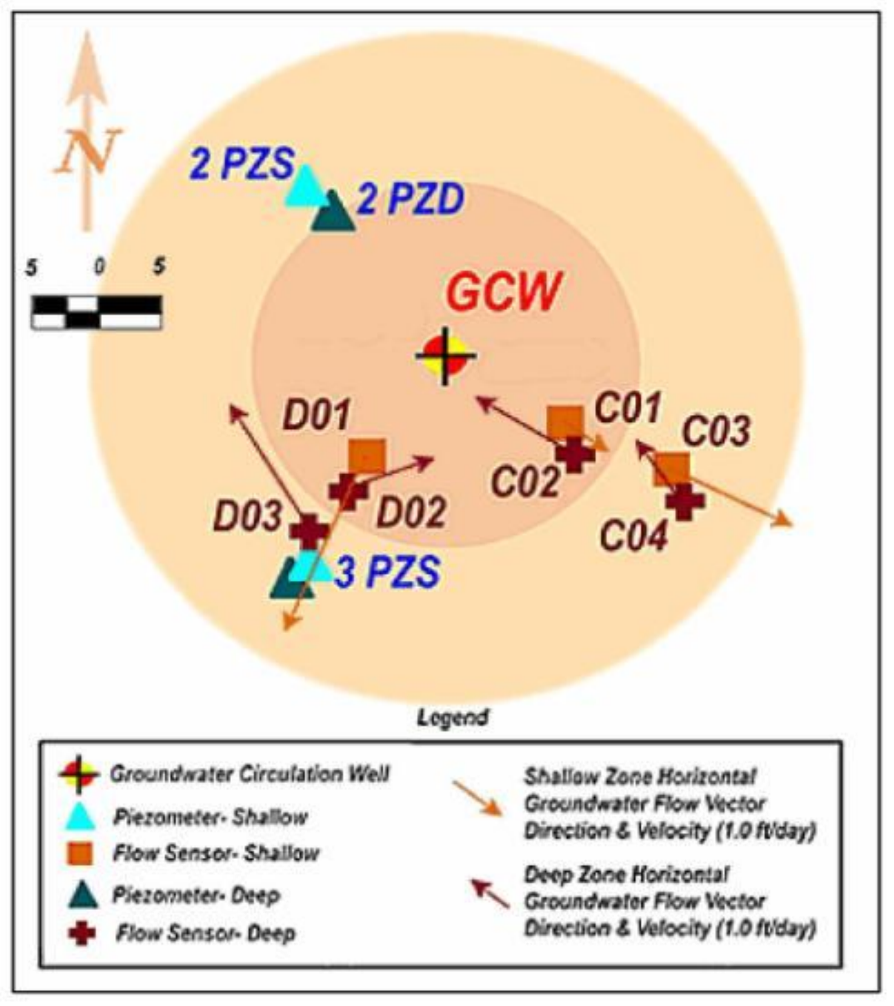
<u>Preview</u>

- *In situ* characterization
  - Flow velocity
  - Temperature
  - Passive flux

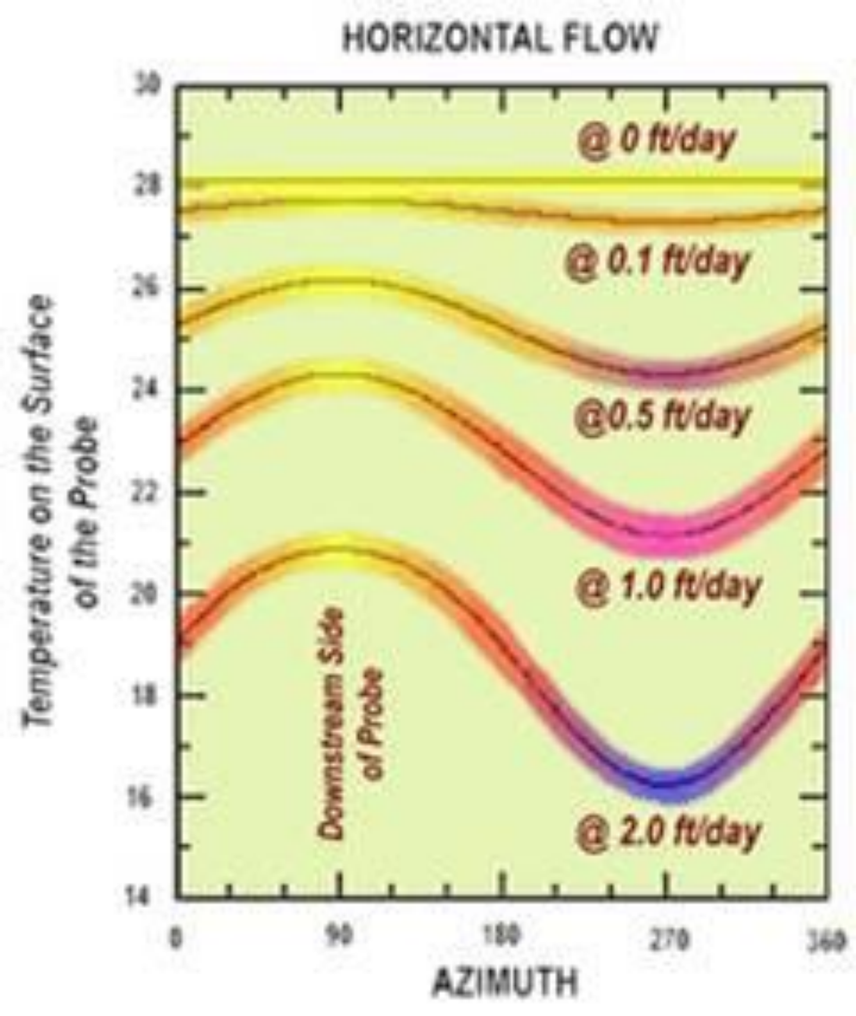
Flow Velocity Sensors







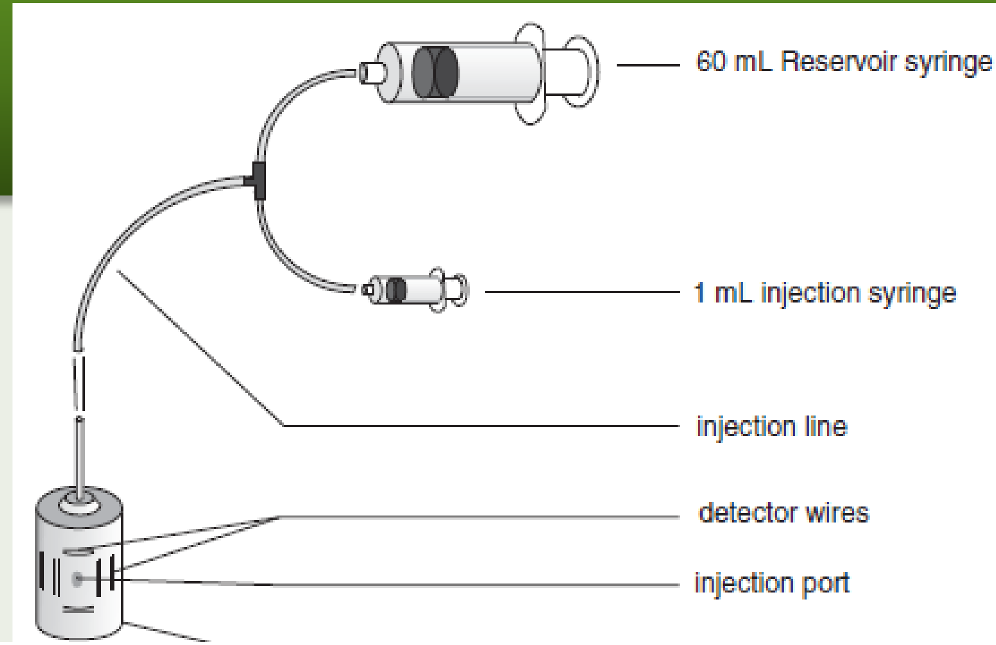
Sensor Temperature and Flow Rate

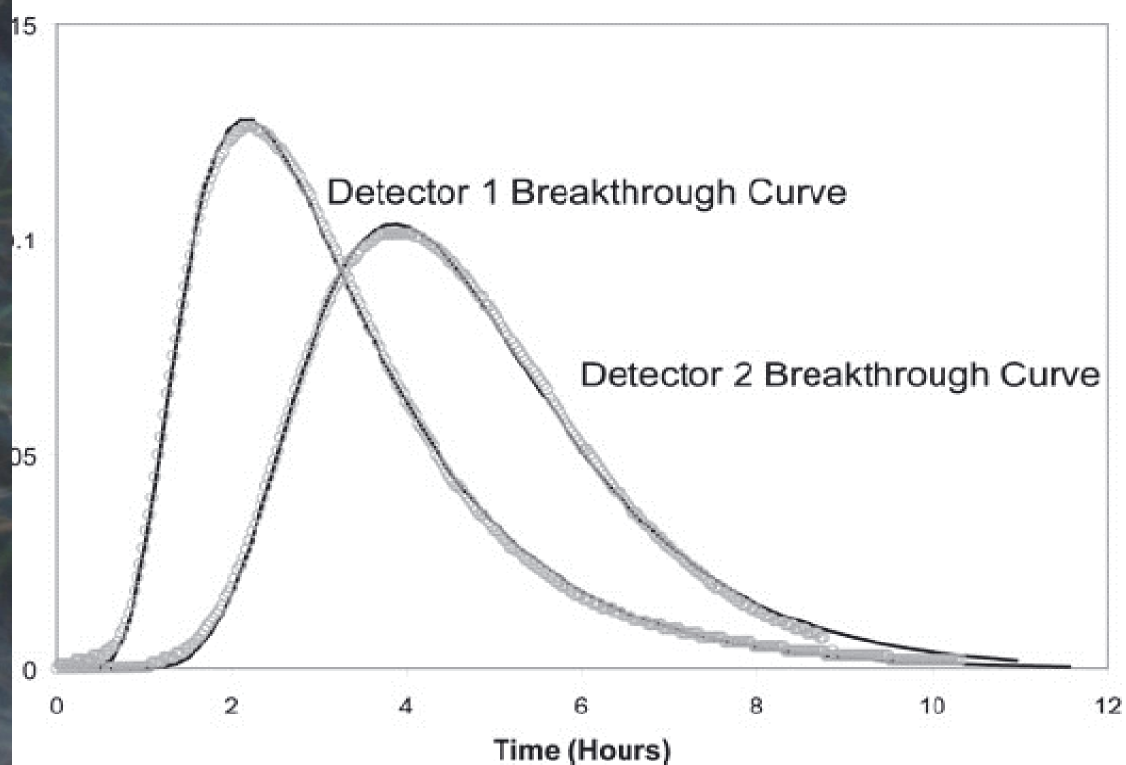


Uses of Point Velocity Probes

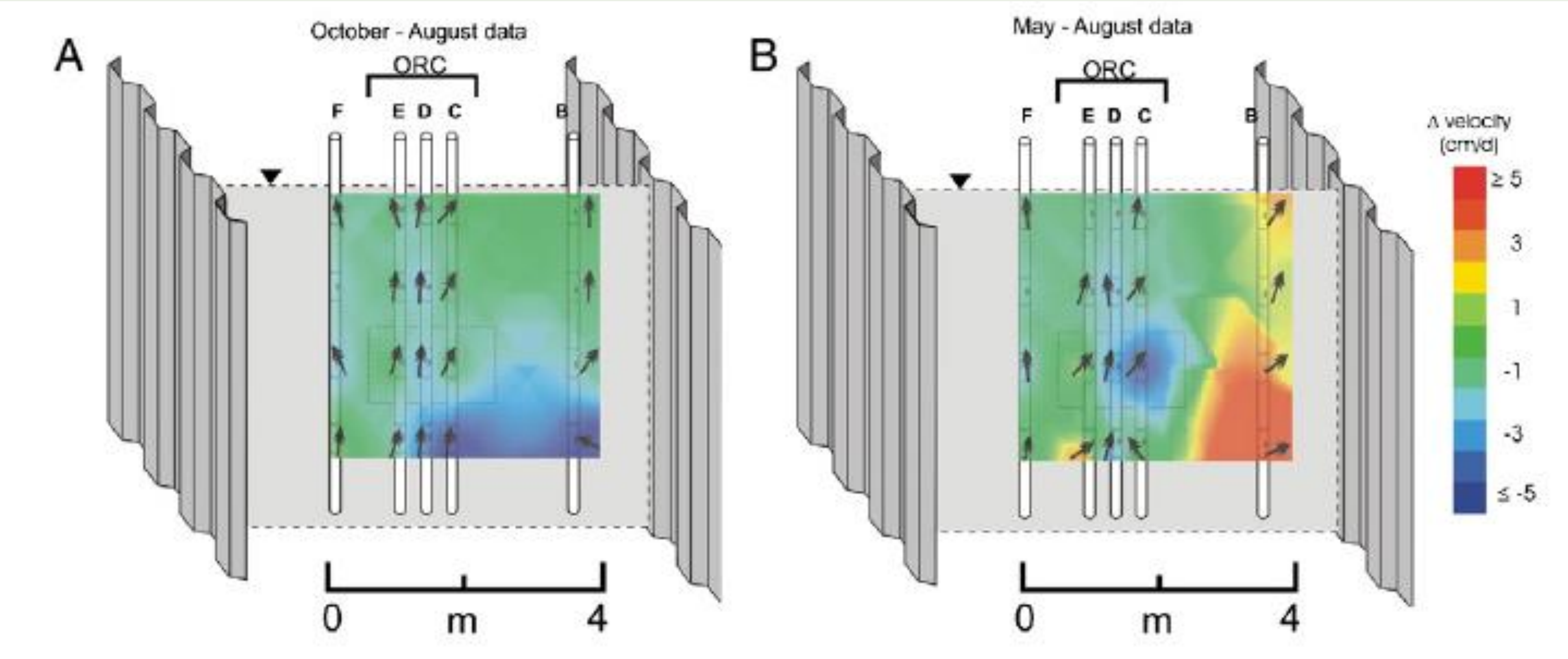
- ♦ K is invariably uncertain (n, gradient?)
- ♦ Small areas
- ♦ High permeability aquifers
- ♦ Near boundaries
- ♦ Thin strata – discovery and characterization
- ♦ Flow through NAPL zones
- ♦ Velocity changes over time at selected locations
- ♦ Assessment of hydraulic control

Devlin, J.F., et. al. Applications and Implications of Direct Groundwater Velocity Measurement at the Centimetre Scale. Journal of Contaminant Hydrology 127 (2012) 3 - 14

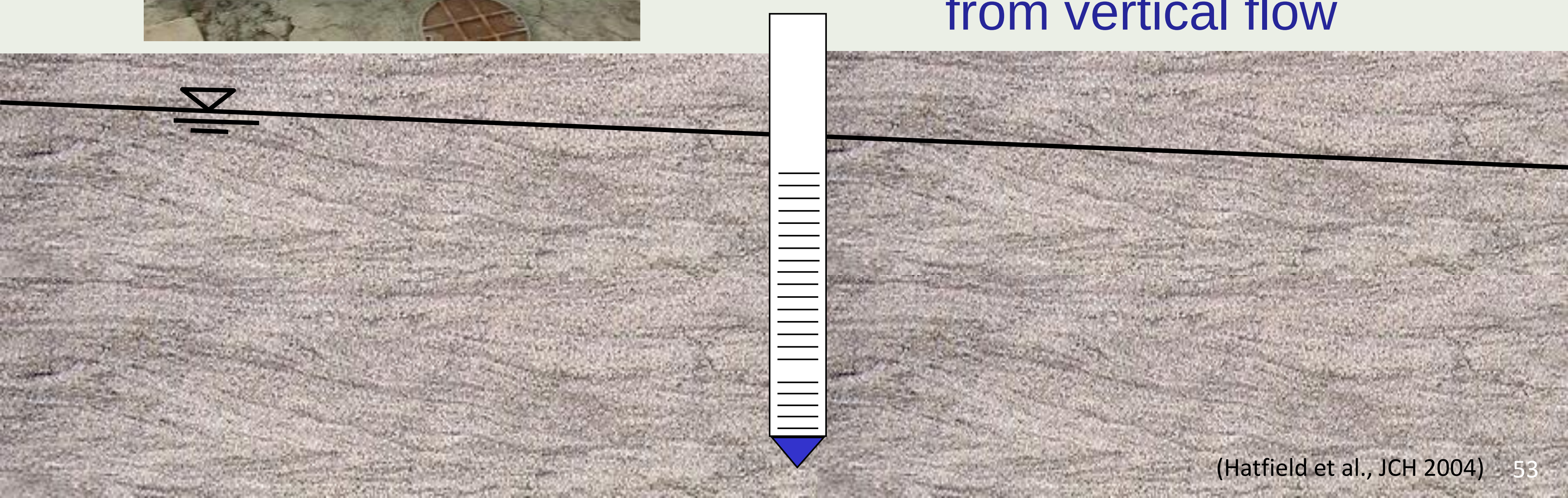




Mapping Velocity Changes Over Time during Enhanced Bioremediation



Passive Flux Meter Technology



Retrieval wire

Tube for flow bypass

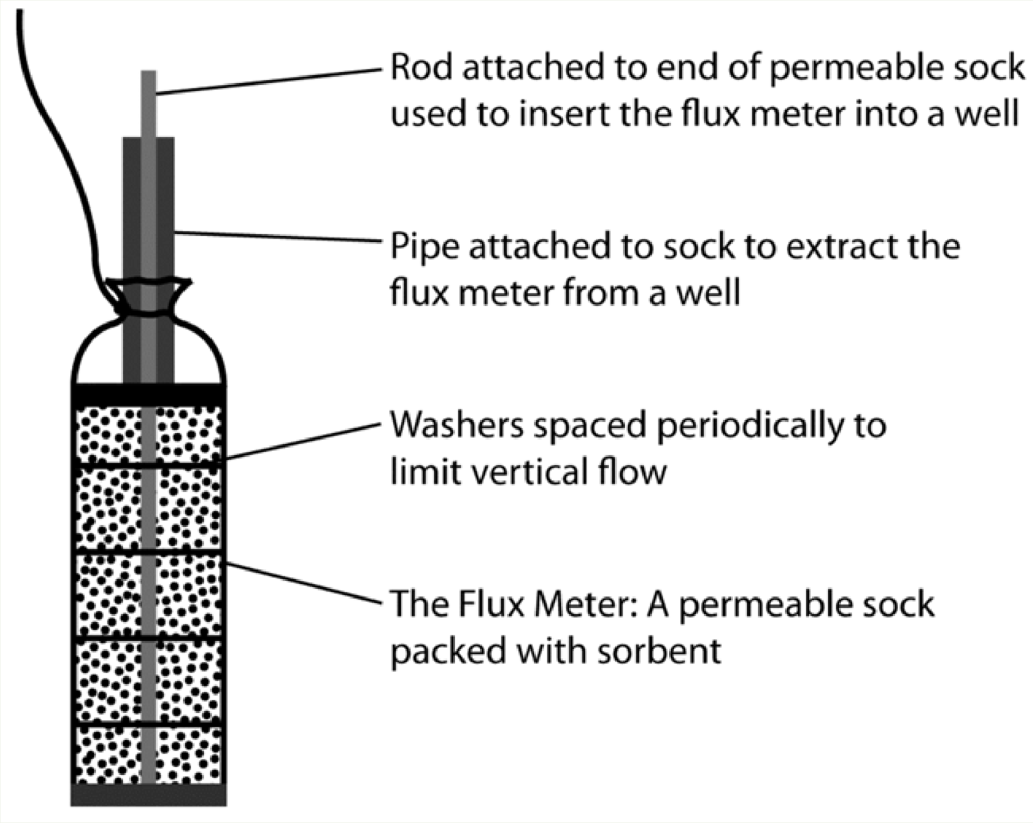
Sorbent with several tracers on activated carbon

Viton washers to minimize impacts from vertical flow

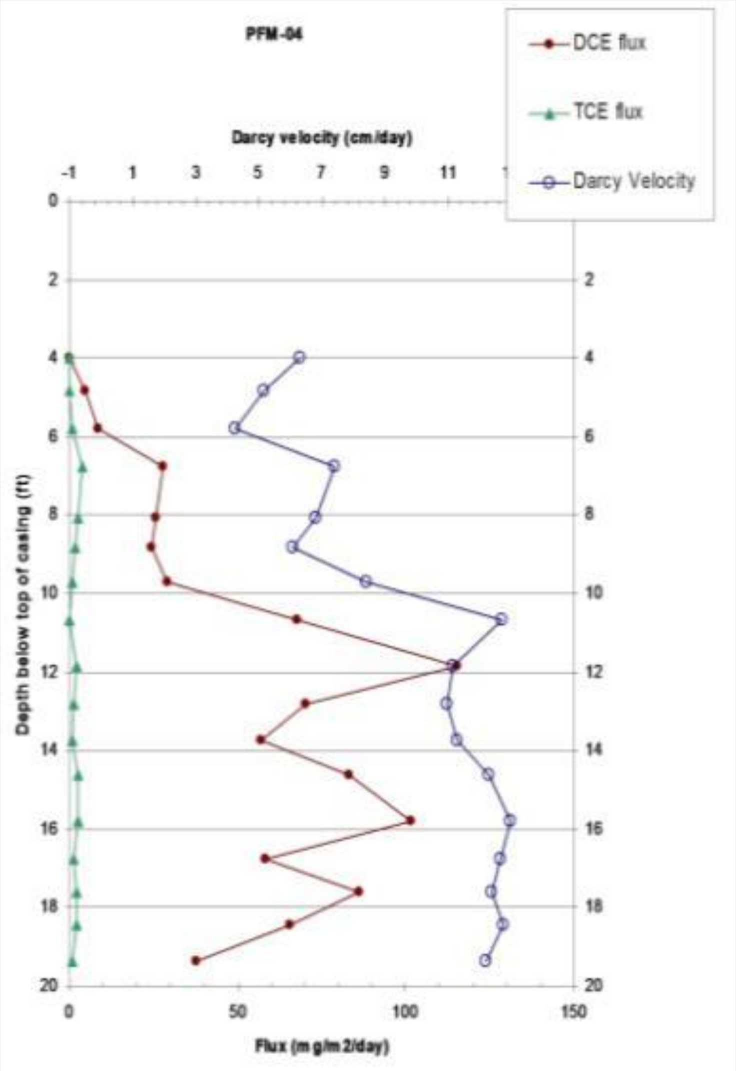
(Hatfield et al., JCH 2004)

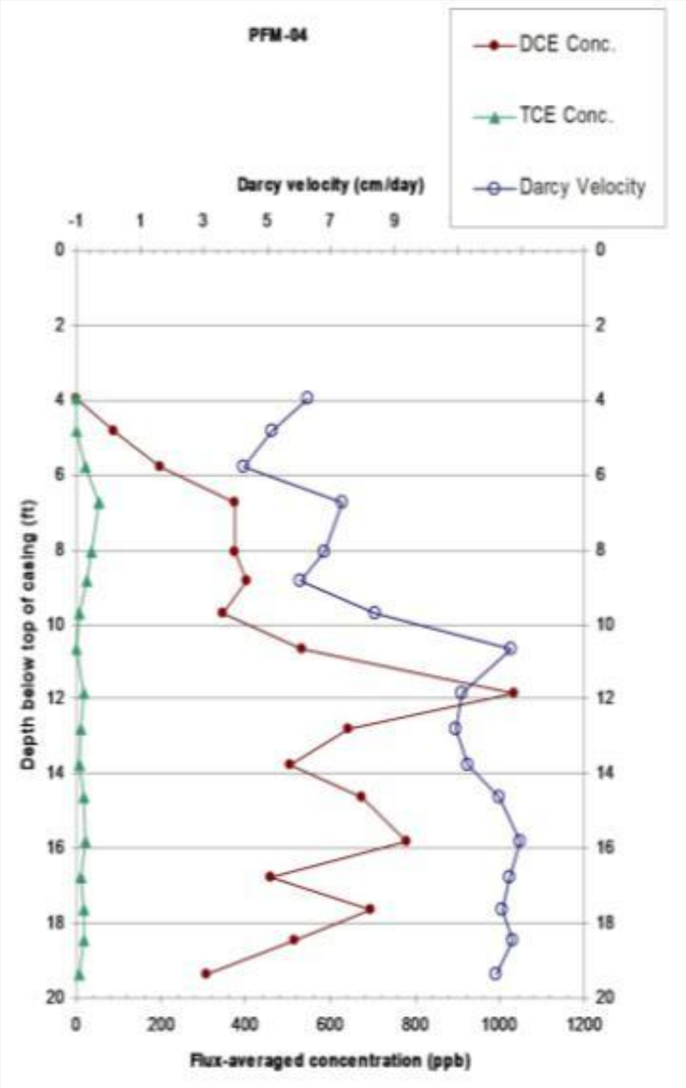
Limitations and Applications of Passive Flux Meter

- **Sizing well bores to actual flow conditions**
- **Measuring groundwater and contaminant flux**



Case Example – Passive Flux Meter Results





Questions?

Disclaimer

- Information presented in this presentation represents the views of the author(s)/presenter(s) and has not received formal U.S. EPA peer review.
- This information does not necessarily reflect the views of U.S. EPA, and no official endorsement should be inferred.
- The information is not intended, nor can it be relied upon, to create any rights enforceable by any party in litigation with the United States or any other party.
- Use or mention of trade names does not constitute an endorsement or recommendation for use.