High Resolution Site Characterization Supporting Focused Combined Remedies

- Seth Pitkin

- Combined Remedies: The Time Has Come
- April 23, 2014

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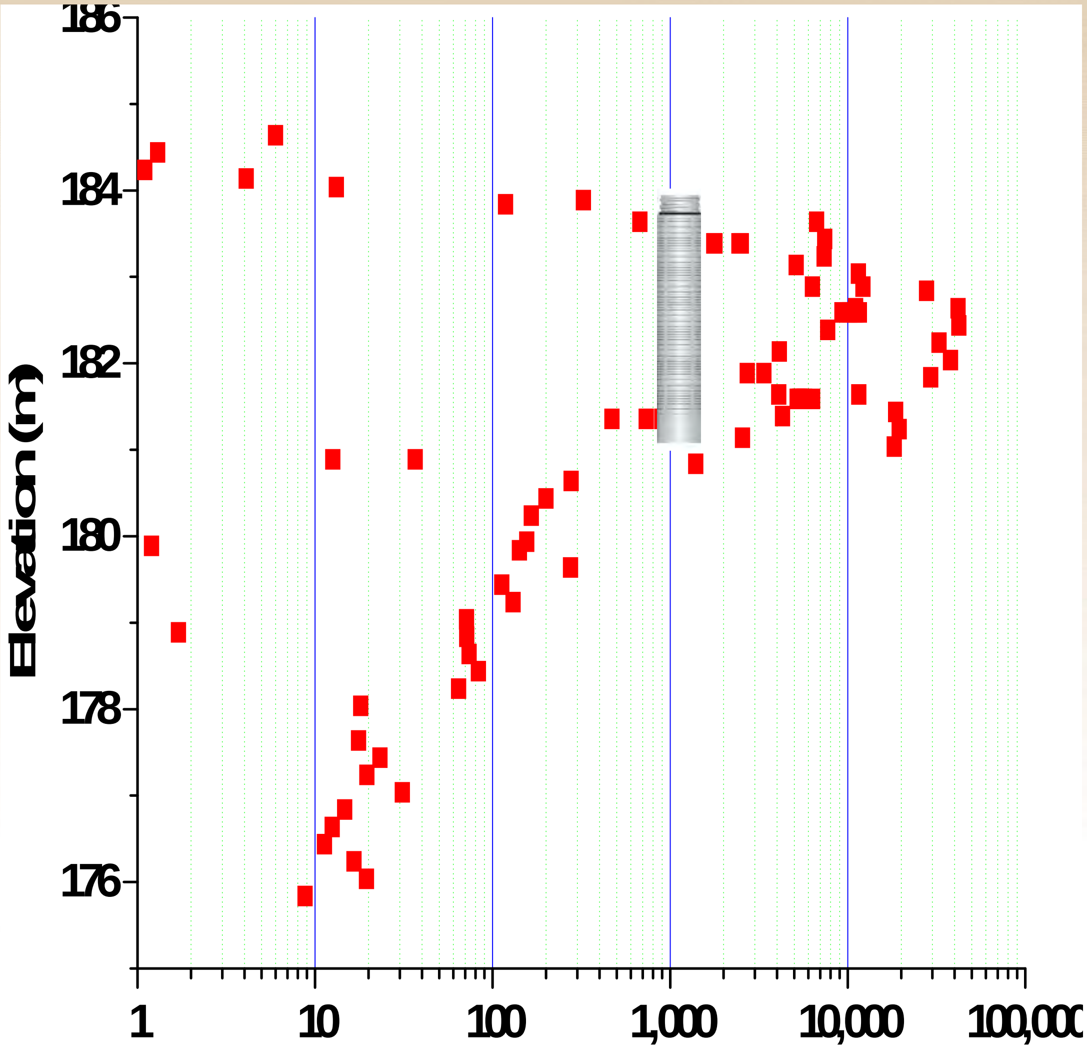
Components of a Successful Investigation in Support of Multiple Remedies

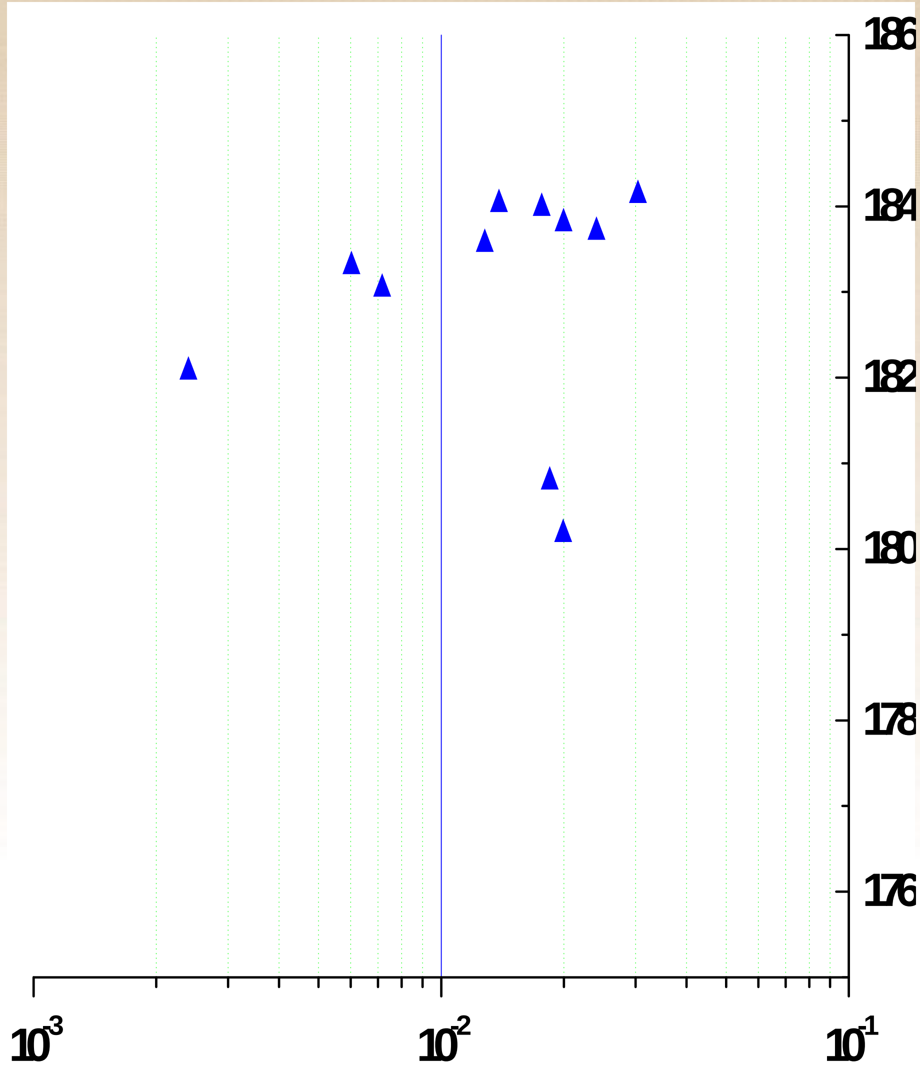
High Resolution Methods

- Understand the phases in which contaminants occur
  - NAPL, Solute, Gas, Sorbed
- Understand contaminant mass distribution spatially
- Understand the hydrostratigraphy controlling contaminant movement
  - Dual porosity systems: source zone and dissolved plume
  - Understand mass flux distribution (by phase and by zone – 14 compartment model)
- Unsaturated Zone (Grids)
  - Soil gas (passive or active)
  - Screening tools (e.g., MIP)
  - Soil Coring
- Saturated Zone (Transects)
  - Screening tools (e.g., MIP)
  - Profiling tools in the permeable zones: hydrostratigraphic and sampling (e.g., WaterlooAPS, Geoprobe HPT – GW)
  - Soil Coring in low K zones: subsample profiling for contaminant distribution additional samples for other properties

Monitorting Wells: Depth-Integrated, Flow Weighted Averaging

Not High Resolution





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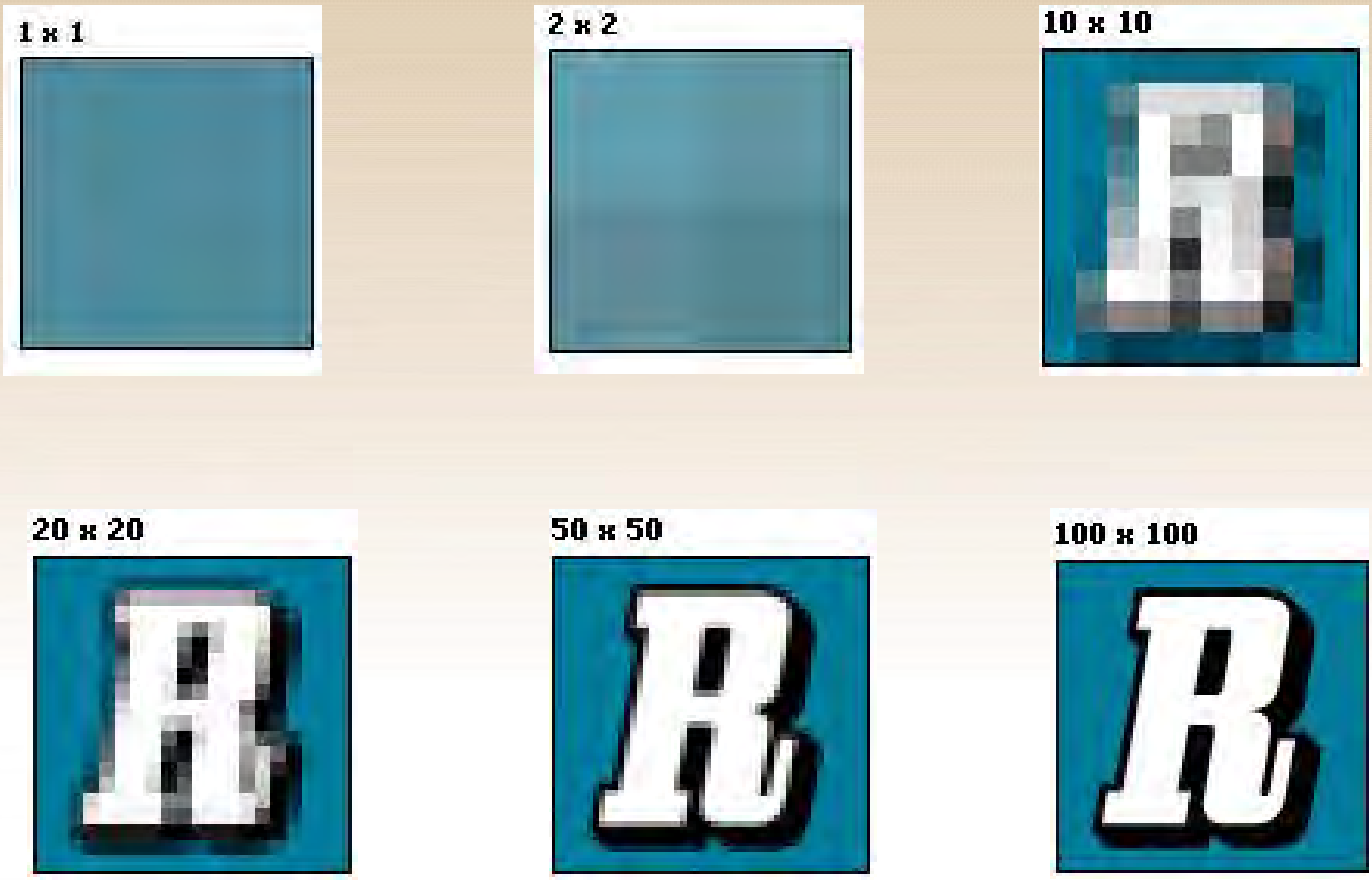
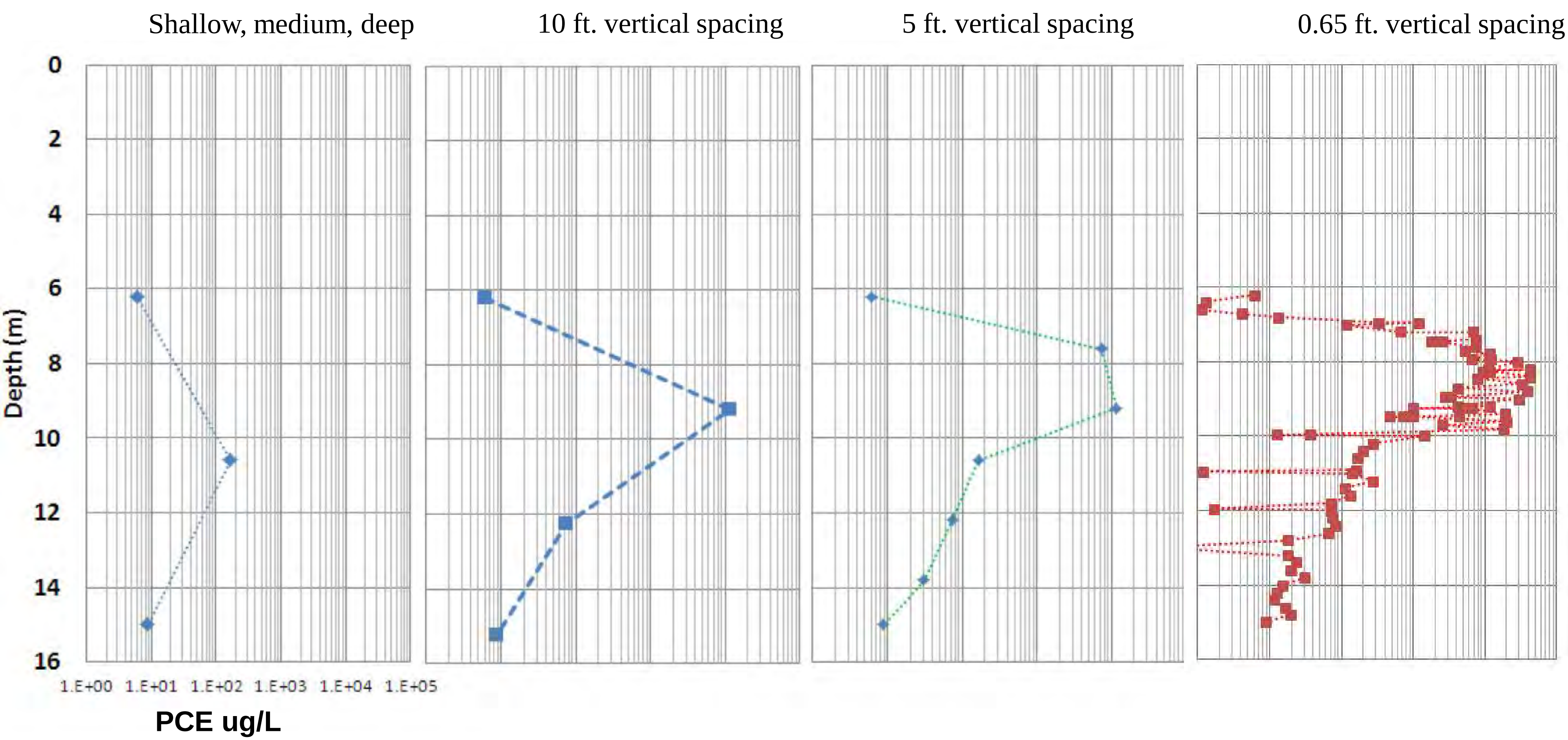
High Resolution (more pixels): Sampling Scale and Averaging



How Much is Enough?
What is Right Vertical Spacing?

A Profile Through PCE Plume in Sandy Aquifer



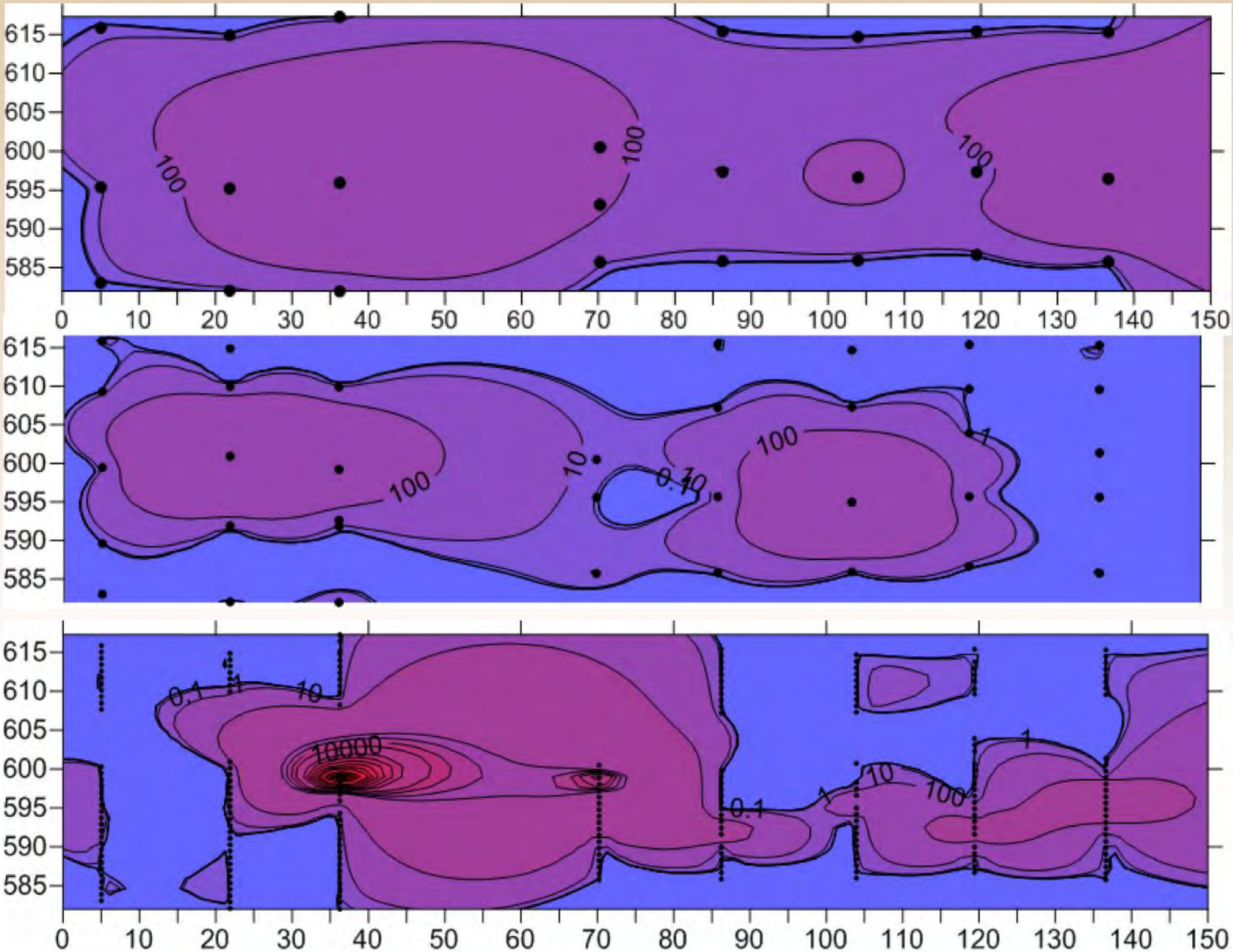
Key Point The vertical spacing you use determines whether you understand the nature of the plume or not

Multi-Level Sampling Transect
PCE in a Sandy Aquifer

Shallow, medium, deep

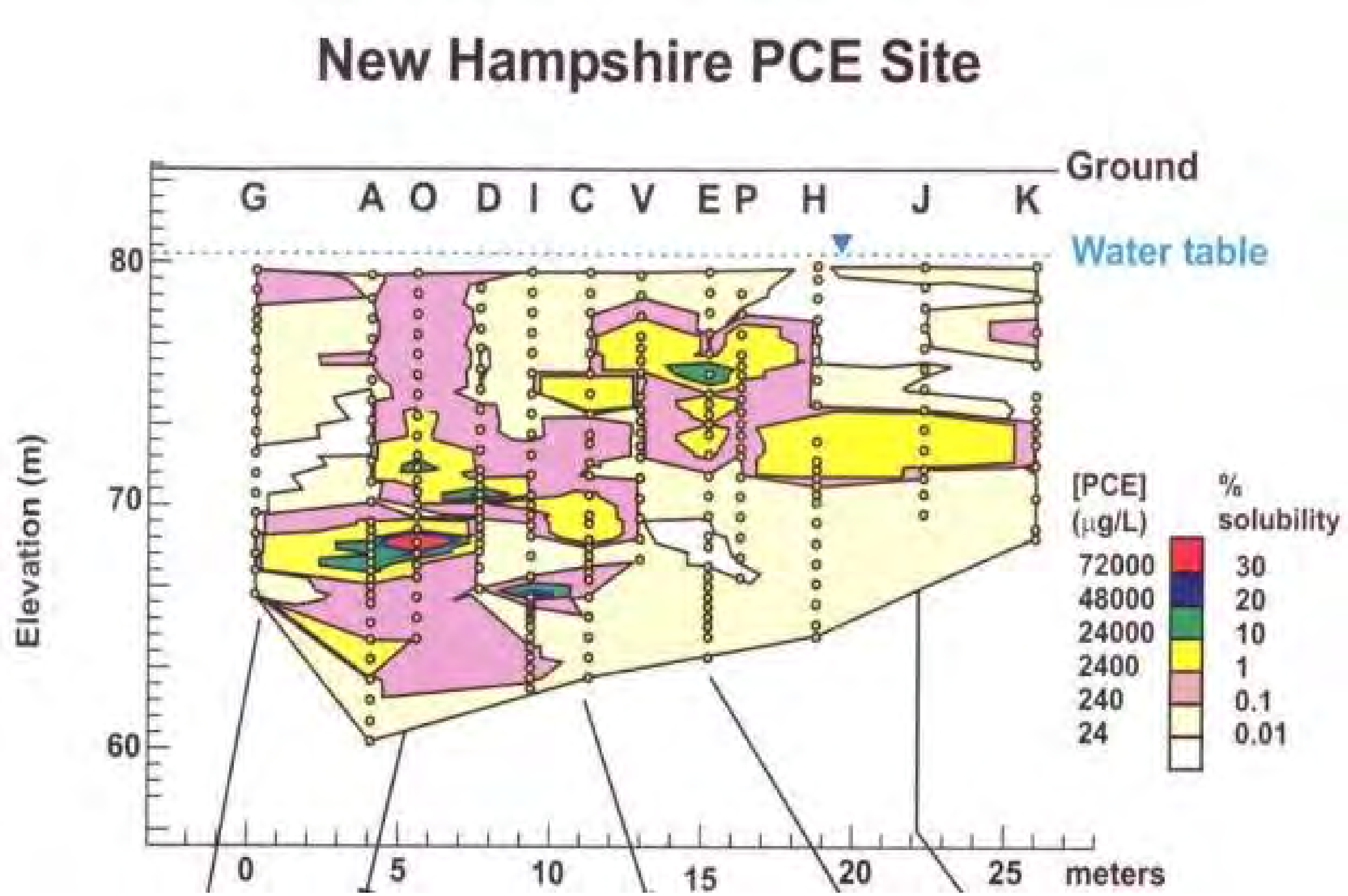
10-ft vertical spacing

0.8-ft vertical spacing



Mass Flux Distribution

Guilbeault et al. 2005



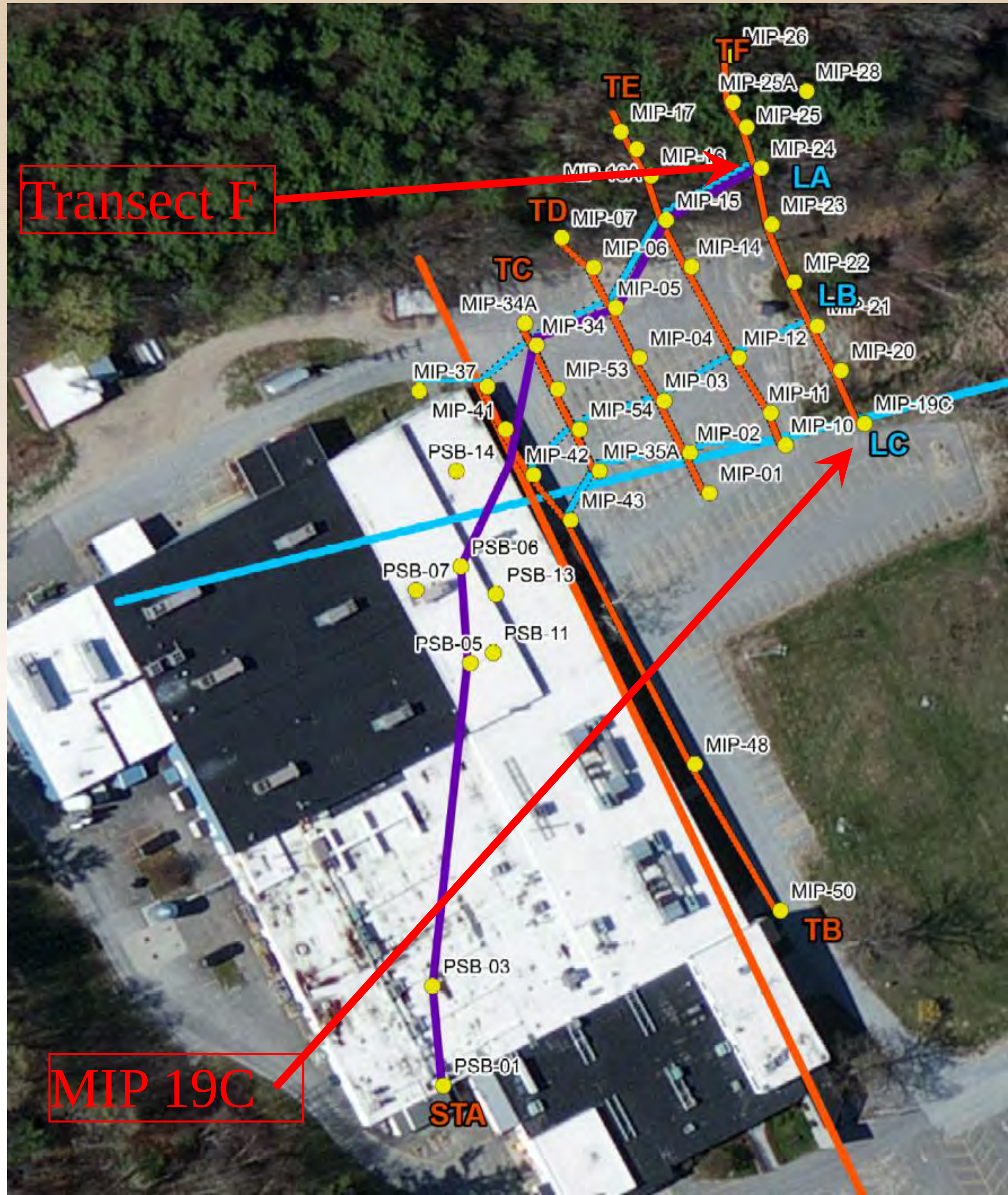
Optimal Vertical Sample Spacing is ~0.5 m

Key Point

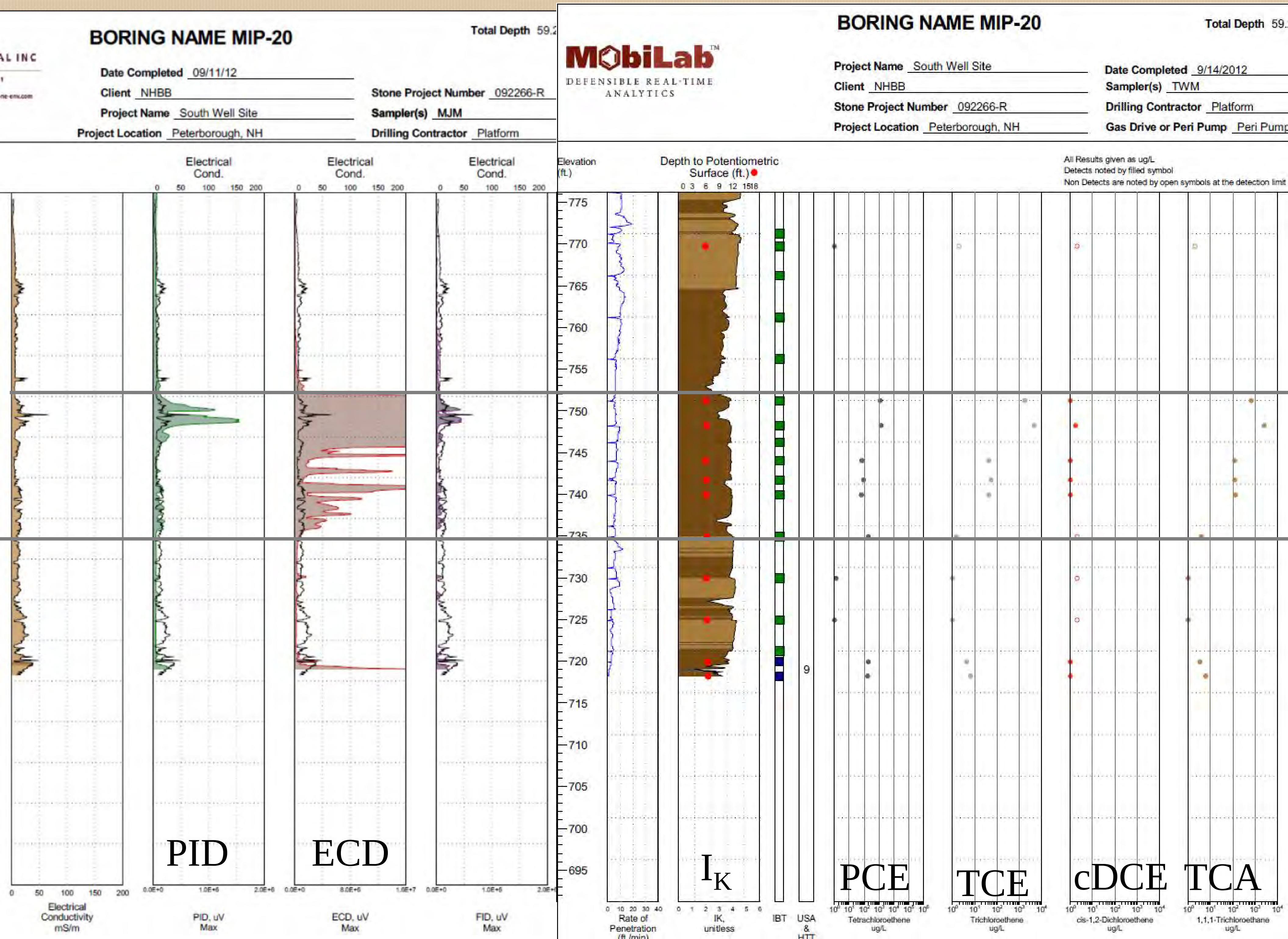
75% of contaminant mass discharge occurs through 5% to 10% of the plume cross sectional area

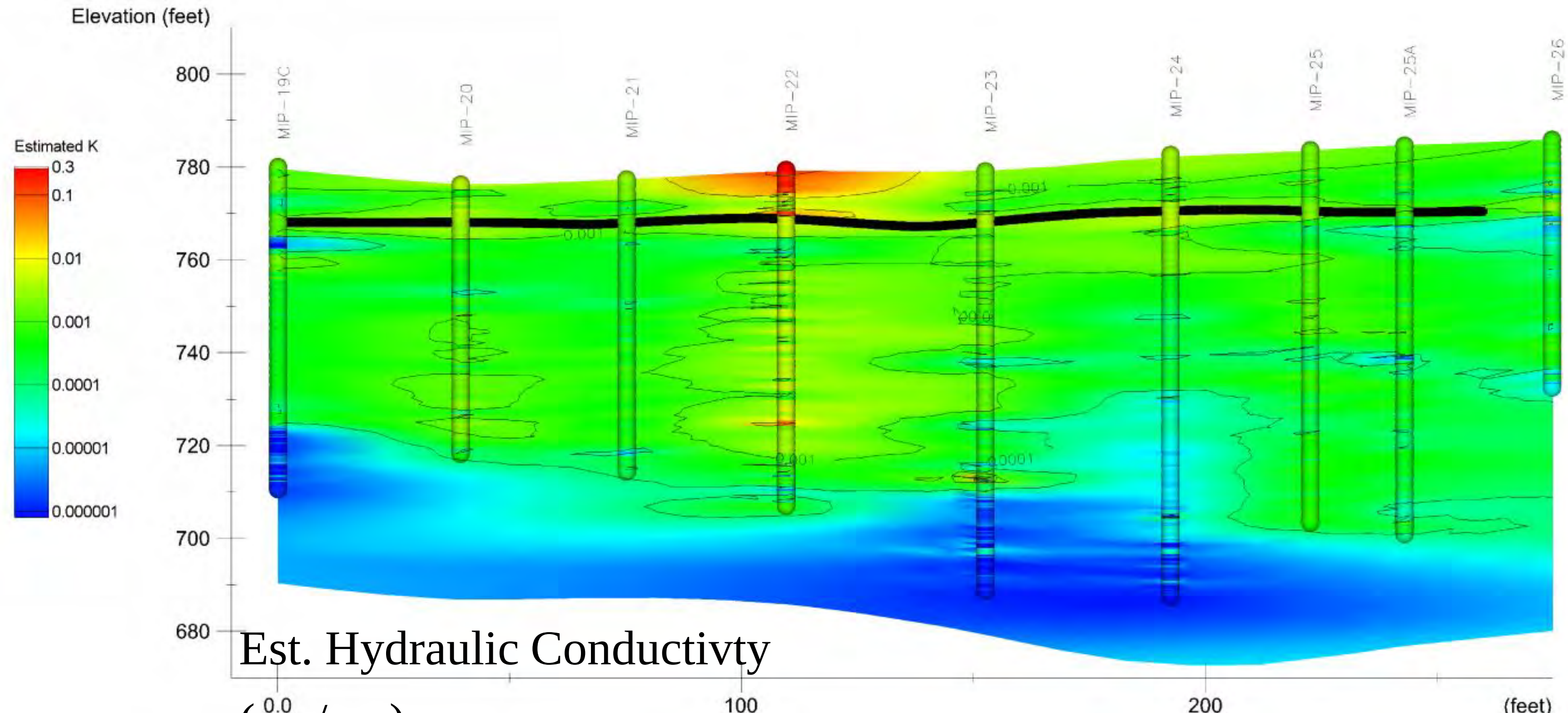
Assess Mass Flux Across a Transect

- High Resolution Investigation at a manufacturing plant
- Unconsolidated porous media
- Tools
  - MIP
  - Wateloo^{APS}
  - DPT Soil Coring
  - On Site Laboratory

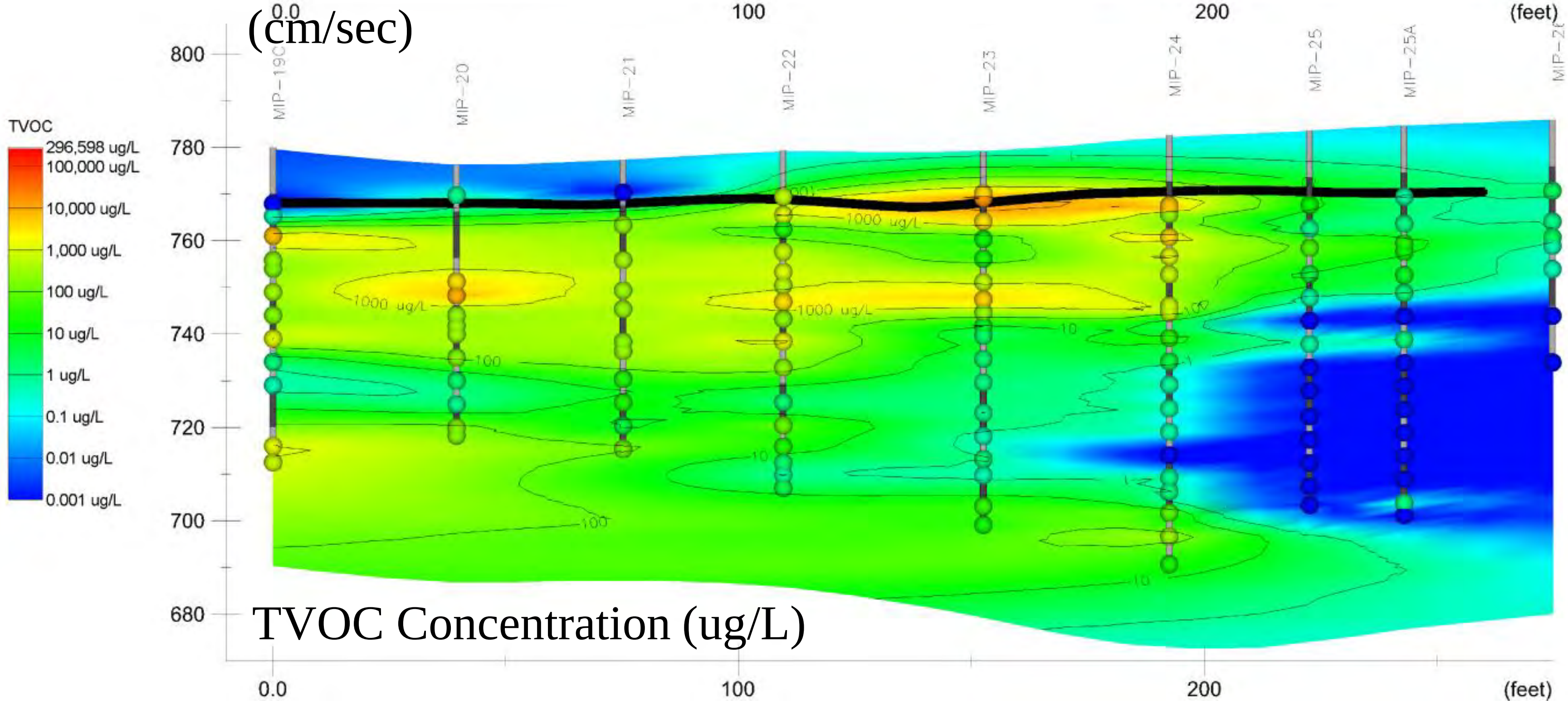


MIP Data Location MIP-20 Waterloo^APS Data





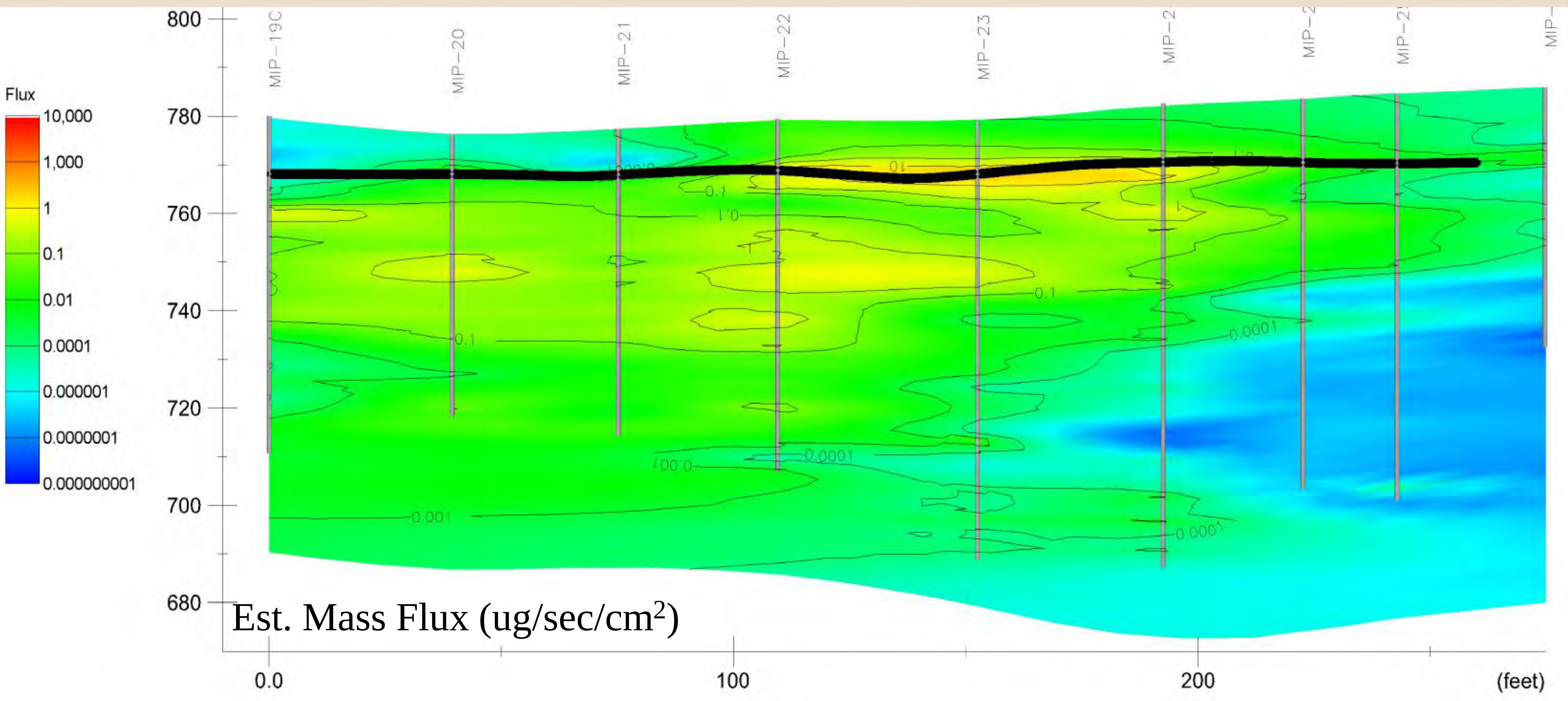
Est. Hydraulic Conductivty (cm/sec)



TVOC Concentration (ug/L)

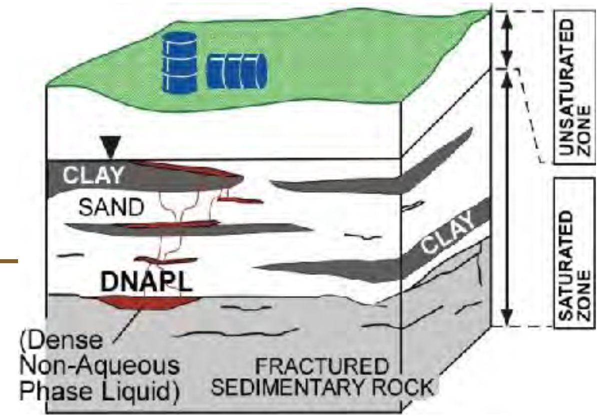
Estimated Mass Flux Distribution on Transect F

- Simplified Flux estimate:
  - Assume variability of i is negligible and assume unit area of 1 cm2
  - Interpolate K in 3D and C in 3D; The multiply the meshes to get 3D flux field in ug/sec/cm^2



Est. Mass Flux (ug/sec/cm^2)

Dual Porosity Systems:
17 potentially relevant fluxes

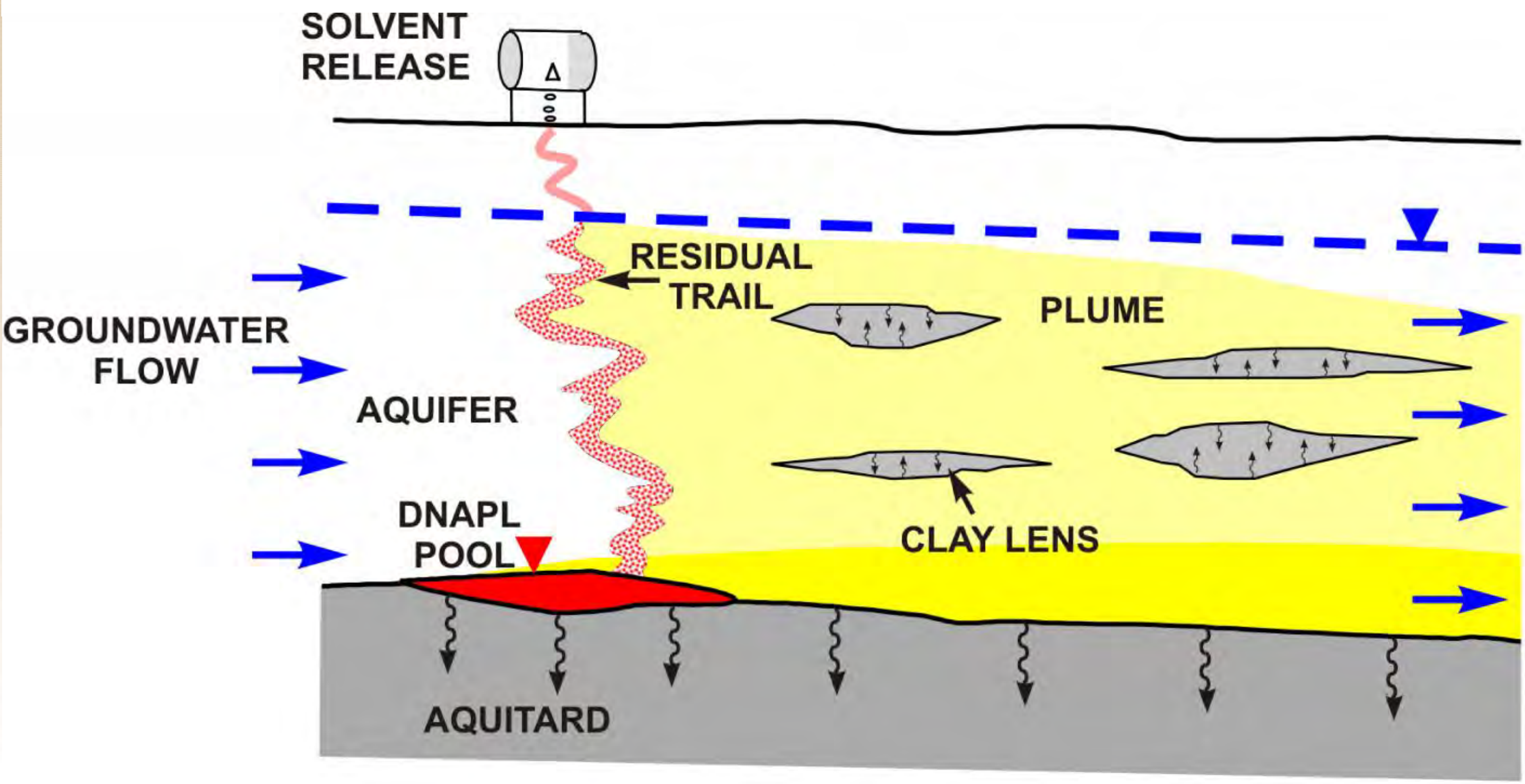


	Source Zone		Plume	
Phase/Zone	**Low Permeability**	**Transmissive**	**Transmissive**	**Low Permeability**
Vapor				
DNAPL			NA	NA
Aqueous				
Sorbed				

Dual Porosity Systems

Sale et. al., 2007

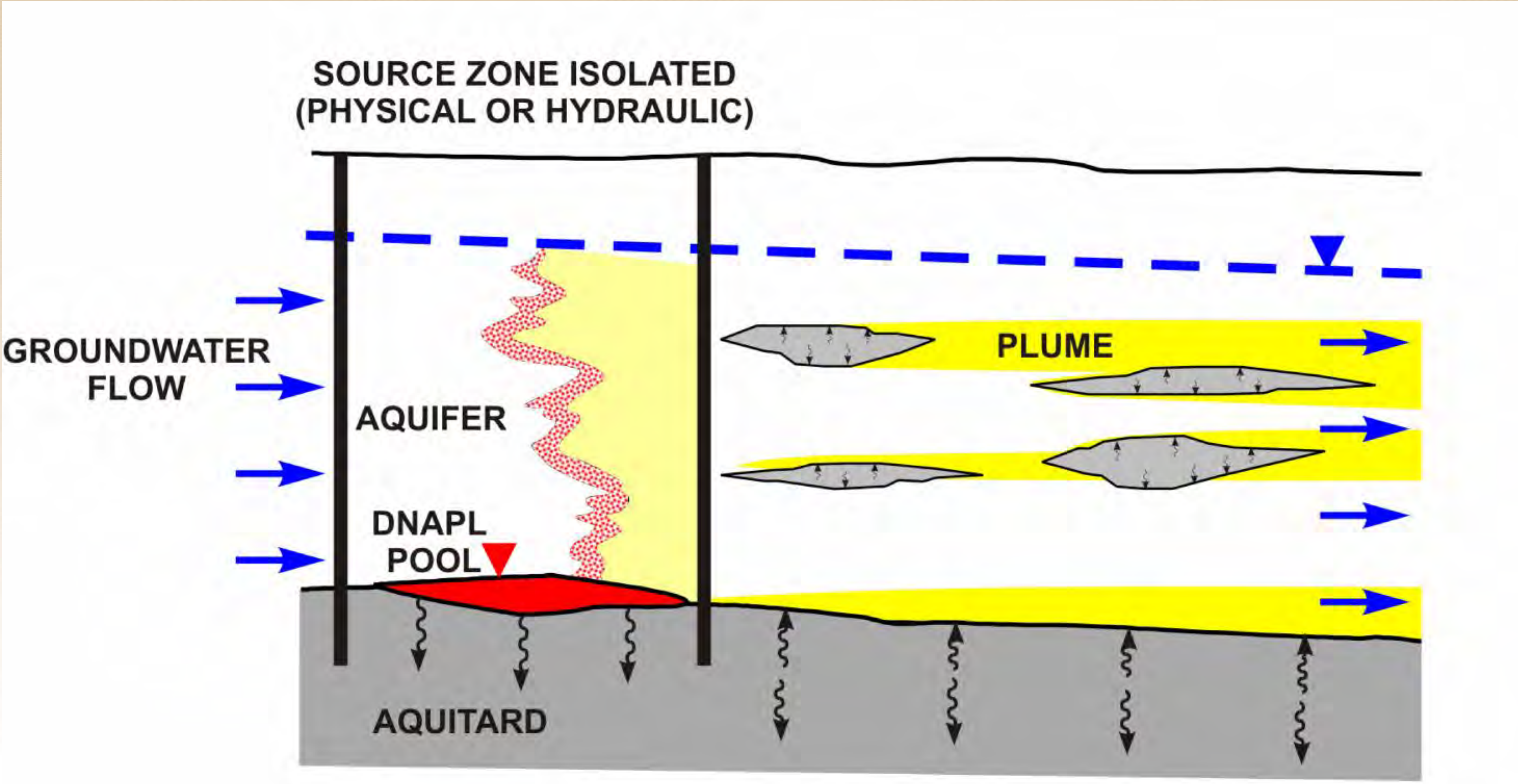
Sand Aquifer with Clay Lenses and Underlying Aquitard



Key Point Solute mass diffuses into low K zones in the source area and throughout the dissolved plume

Steve Chapman –University of Guelph

Persistent Plume after Source Isolation due to Back Diffusion



Key Point

Solutes diffuse back out of low K zones following source area isolation/remediation. The whole dissolved plume footprint becomes the source.

Steve Chapman –University of Guelph

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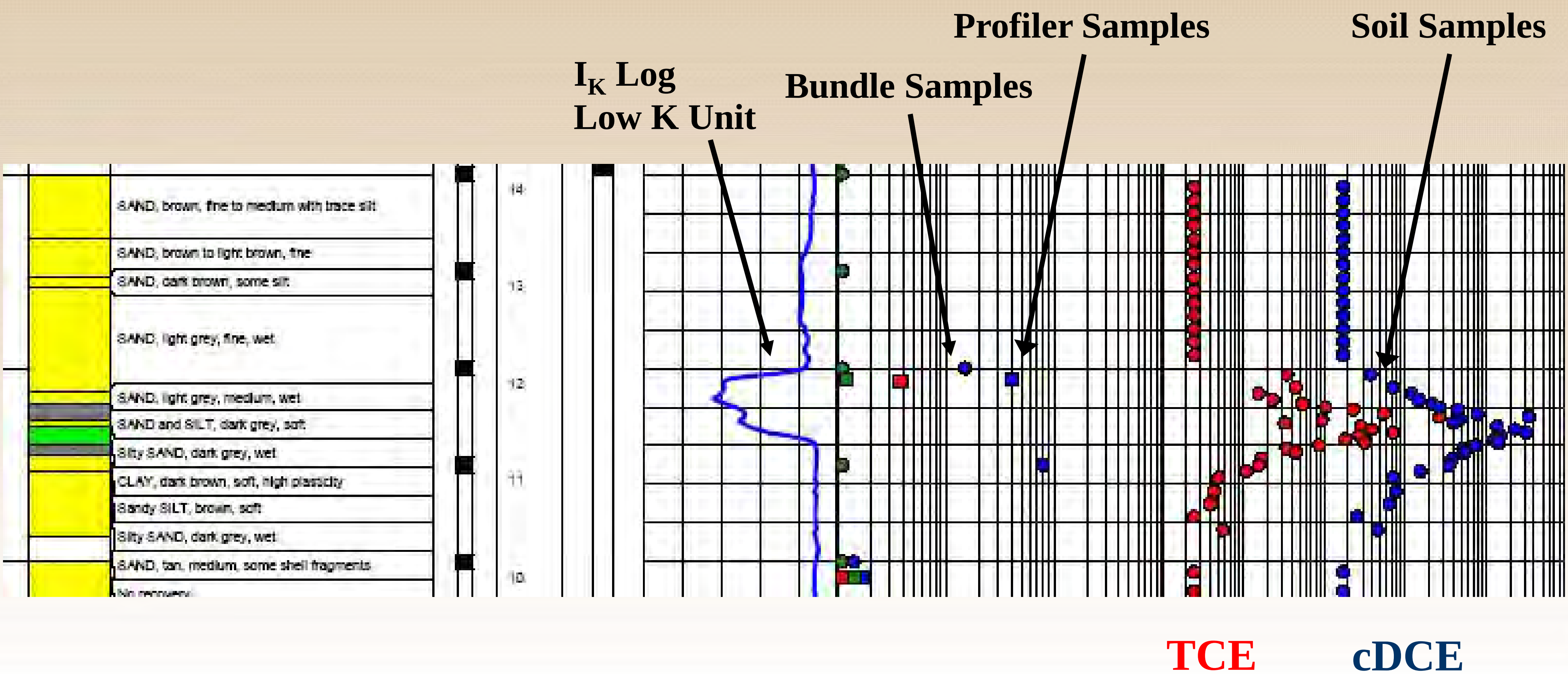
Where the Mass is
Cocoa, FL



Key Point

Contaminant mass mostly in low K layers creating thin plumes in high K layers throughout the dissolved plume

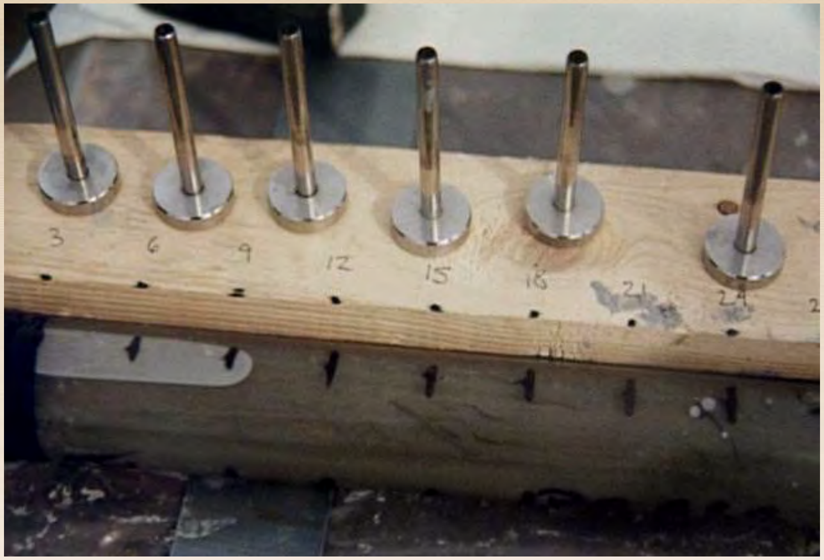
The Matrix Diffusion Challenge

- Low K zones serve as ongoing sources of contamination separate from the initial source and throughout the plume footprint
- This source persists for long time periods
- Concentrations in permeable zones rebound following remediation of those zones
- Introduction of remedial agents into the low K zones is controlled by the rate of diffusion and takes a very long time.

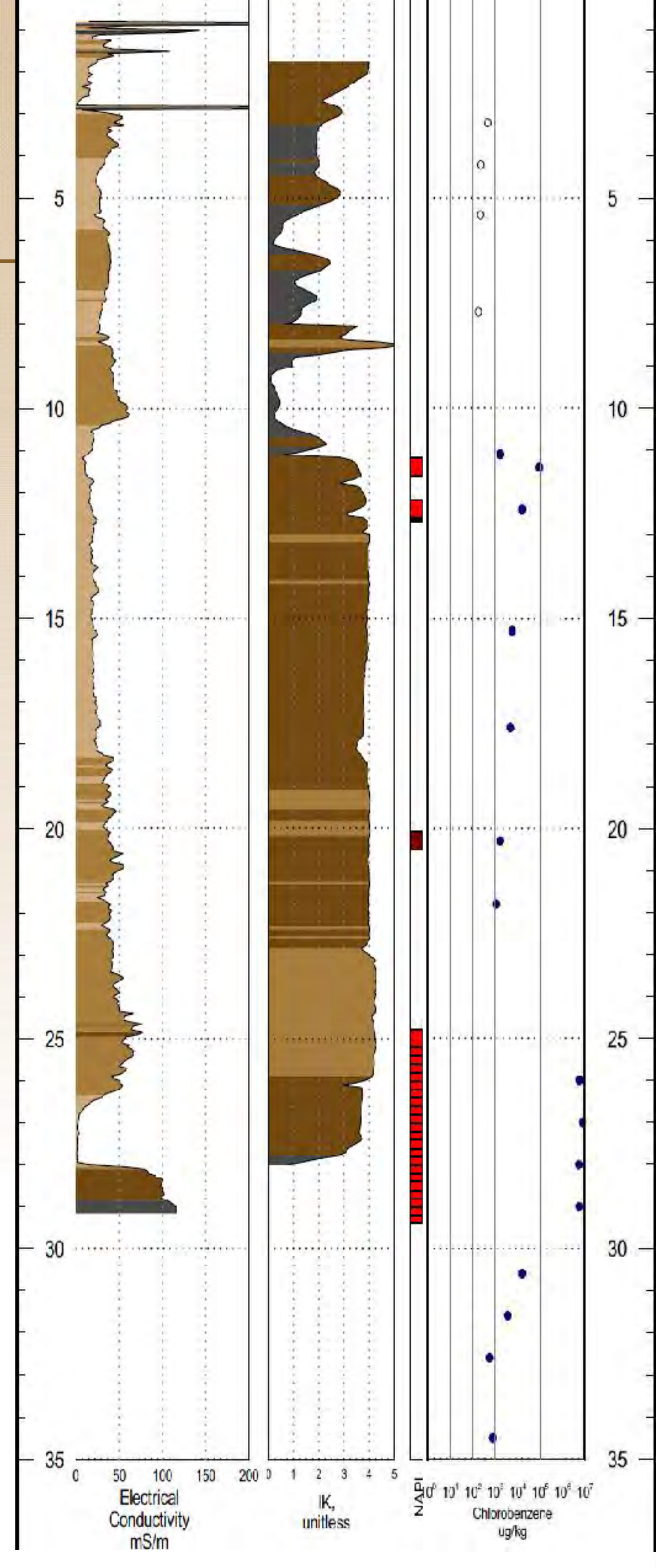
Developing Approaches to Mass in Low K Units

- Molecular Biological Techniques
  - Used to establish microbial activity and presence and nature of biodegradation in the immobile porosity (low K zones)
- Remedial Techniques for Low K units
  - Thermal methods (e.g., electrical resistance heating)
  - Electrokinetics rapid transport of remedial agents into low K layers (to be discussed in the Case Study)

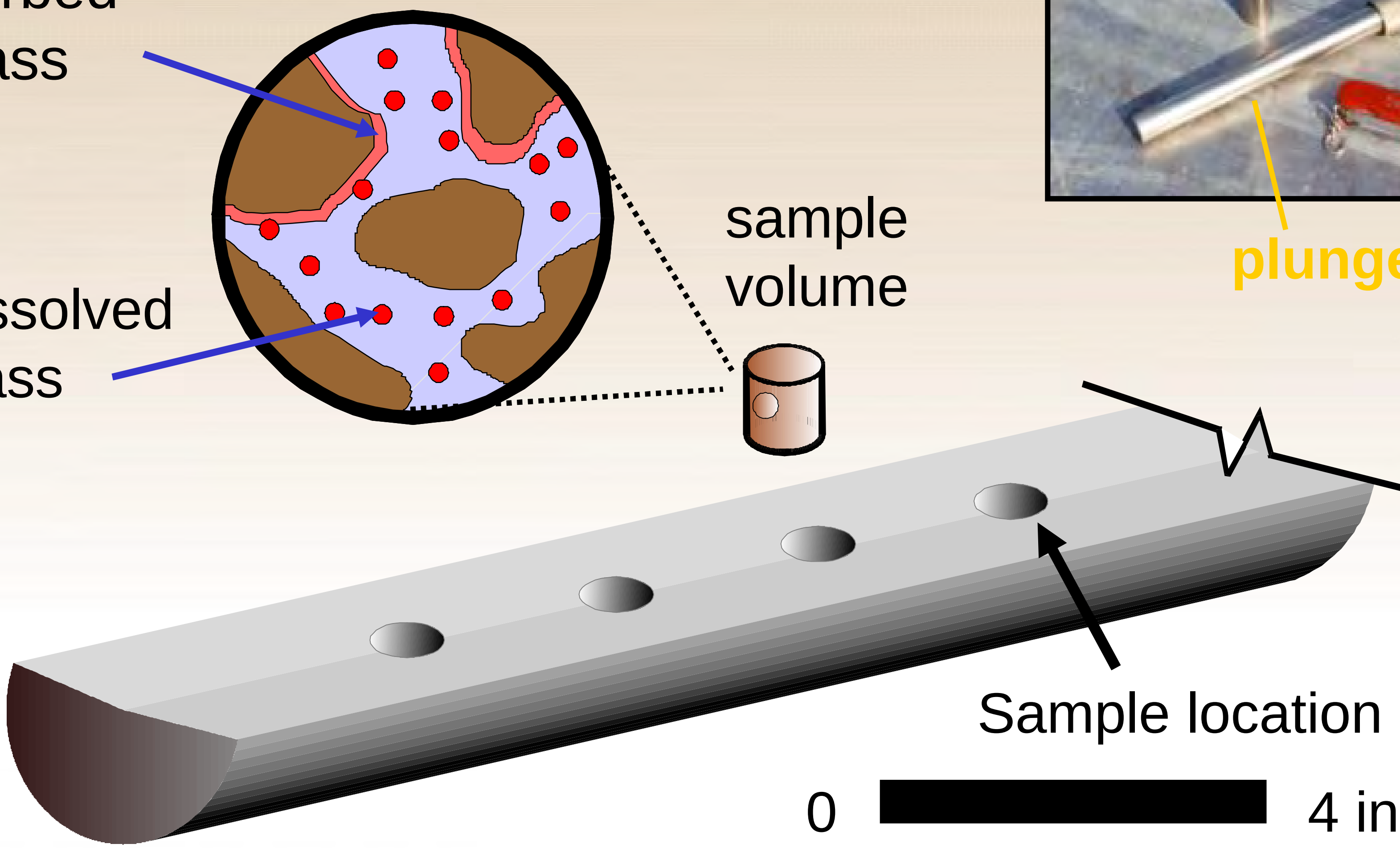
Essential Information from Cores



- Geologic/hydrogeologic features
- Physical, chemical & microbial properties
- Contaminant mass distributions (high & low K zones)
- Concentration gradients/diffusive fluxes
- Effectiveness of remedial technologies

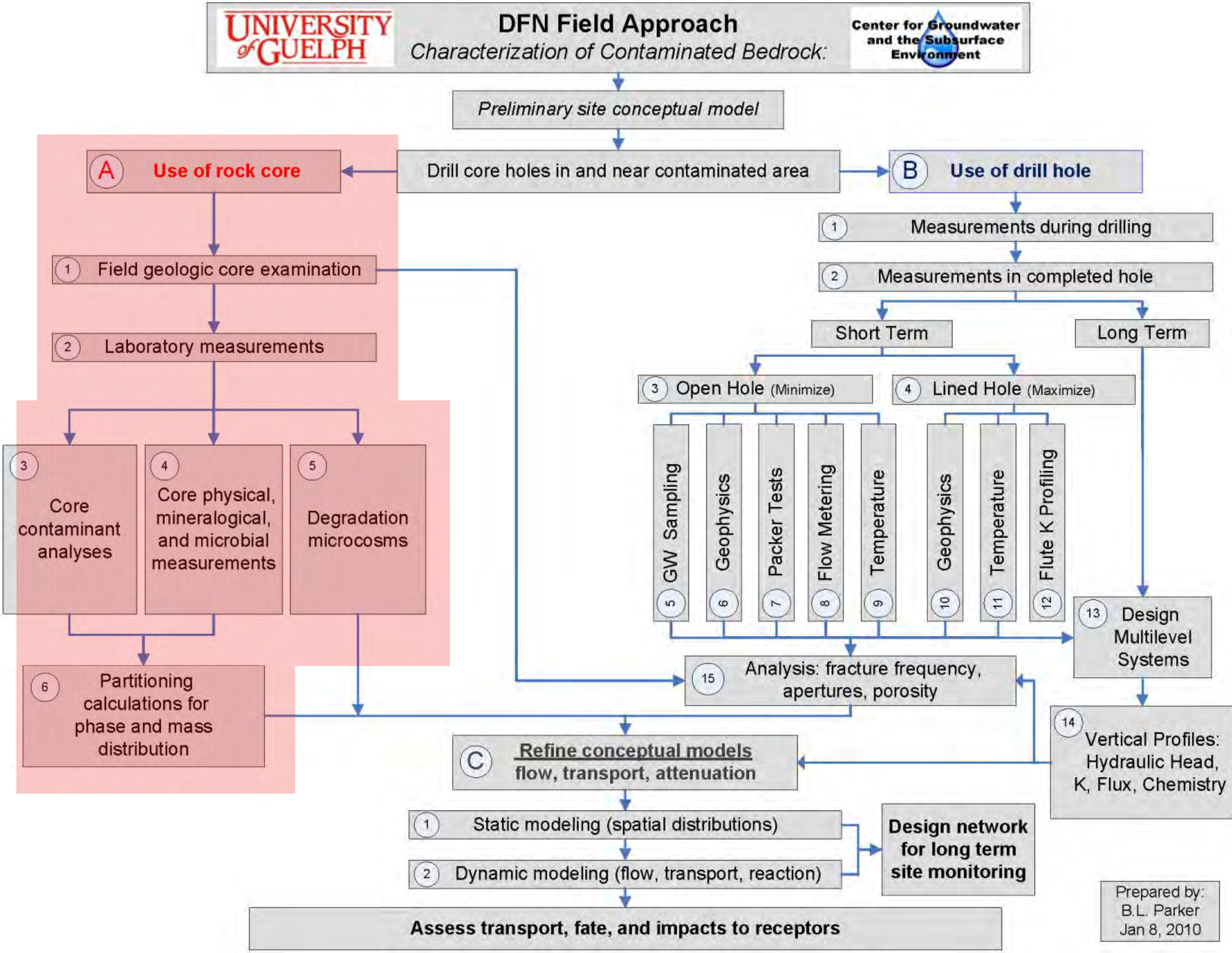


Subsampling (Profile Sampling) for VOCs




Sudan IV Dye

Guilbeault, 1999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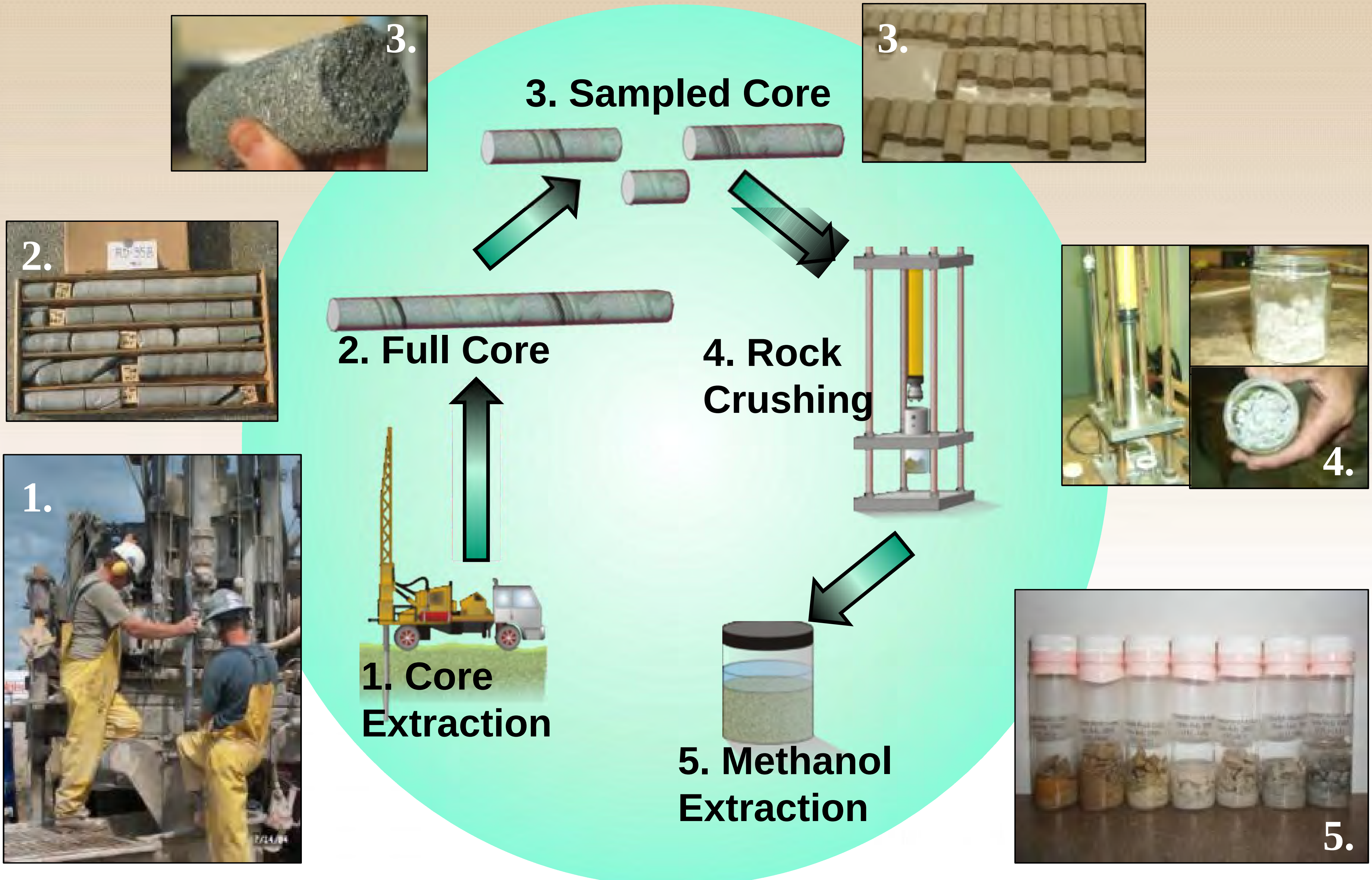
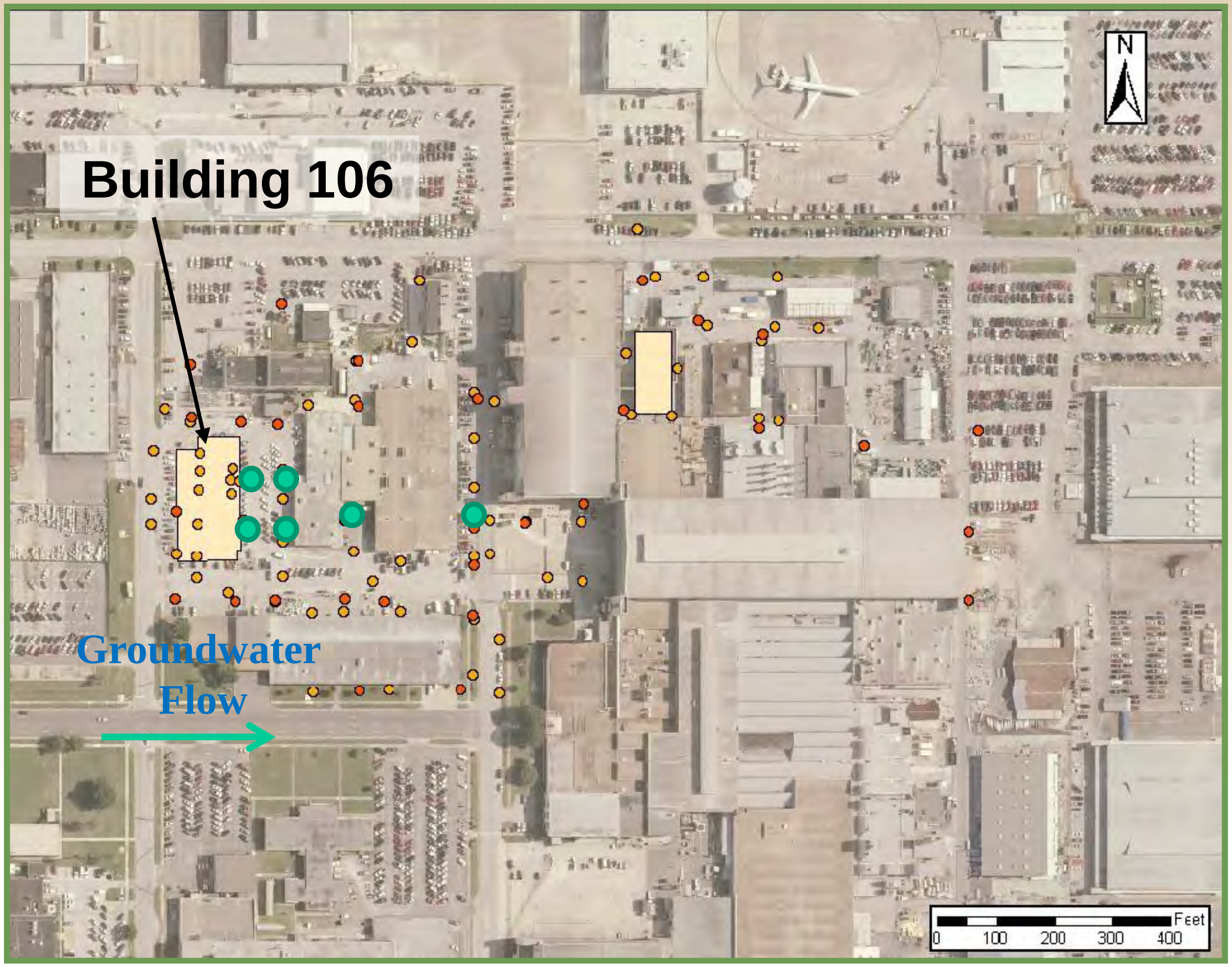
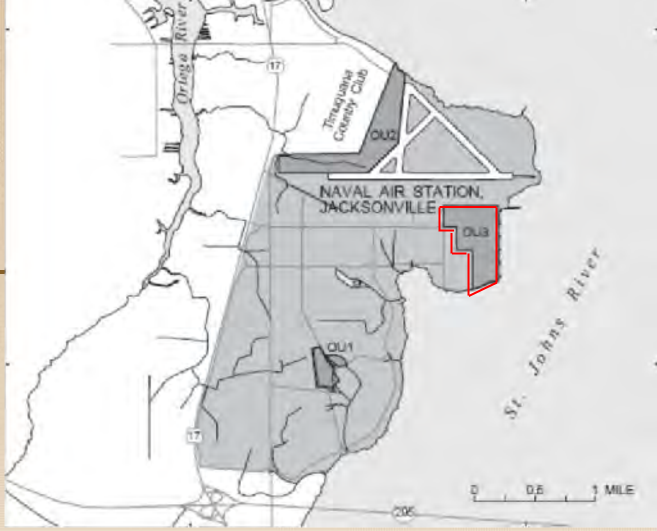
DFN Field Approach
Characterization of Contaminated Bedrock:
Center for Groundwater and the Subsurface Environment
Preliminary site conceptual model
Drill core holes in and near contaminated area
A Use of rock core
1 Field geologic core examination
2 Laboratory measurements
3 Core contaminant analyses
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)
GW Sampling 5
Geophysics 6
Packer Tests 7
Flow Metering 8
Temperature 9
Geophysics 10
Temperature 11
Flute K Profiling 12
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

CORE^{DFN} Sampling and Preservation



NAS Jacksonville Investigations (Jul / Aug 2011)





OU3 Building 106

- Former dry cleaner (1962 – 1990)
- PCE and TCE released to shallow aquifer
- Building removed
- Interim remedies (AS, SVE) have been discontinued after 5-yr review (2005)
- Strong interest in evaluating MNA as long-term remedy

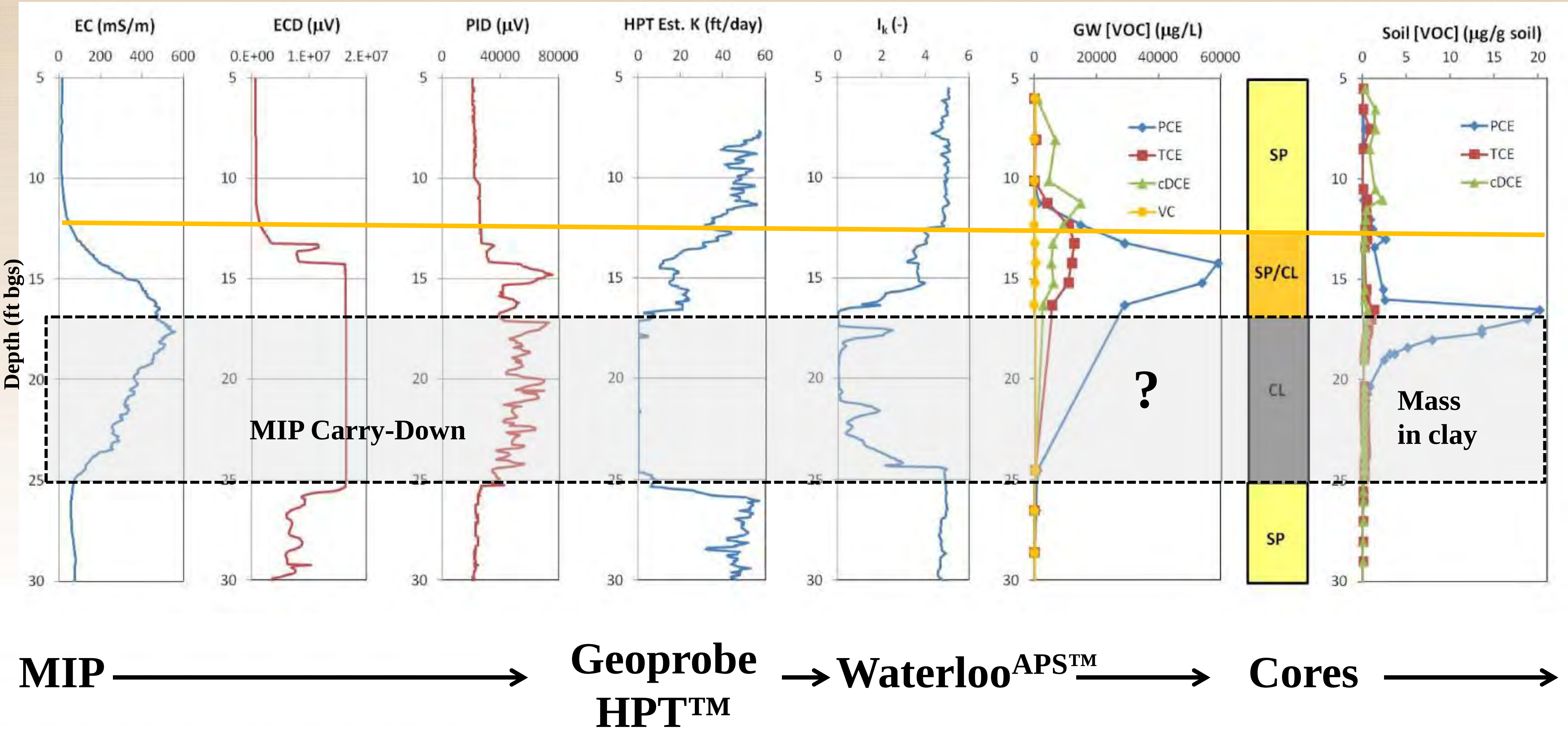
● Detailed study locations

NAS Jacksonville: Characterization Methods

- Membrane Interface Probe (MIP) screening
  - Rapid lithology (EC) and contaminant (ECD, PID) delineation -- qualitative
- Waterloo APS™ (Advanced Profiler System)
  - real-time hydrostratigraphy
  - targeted groundwater sampling of higher K zones / interfaces
- GeoProbe HPT ™ (Hydraulic Profiling Tool)
  - real time hydrostratigraphy
- Continuous cores (Geoprobe DT system)
  - detailed lithology delineation
  - Subsampling for mass distribution (targeted to lower K zones)
- Onsite Laboratory
  - For soil and groundwater samples

Thanks to:
Steve Chapman – University of Guelph
Dave Adamson – GSI
Mike Singletarry - NAVFAC

NAS Jacksonville Composite Dataset (OU3-3, Near Source)



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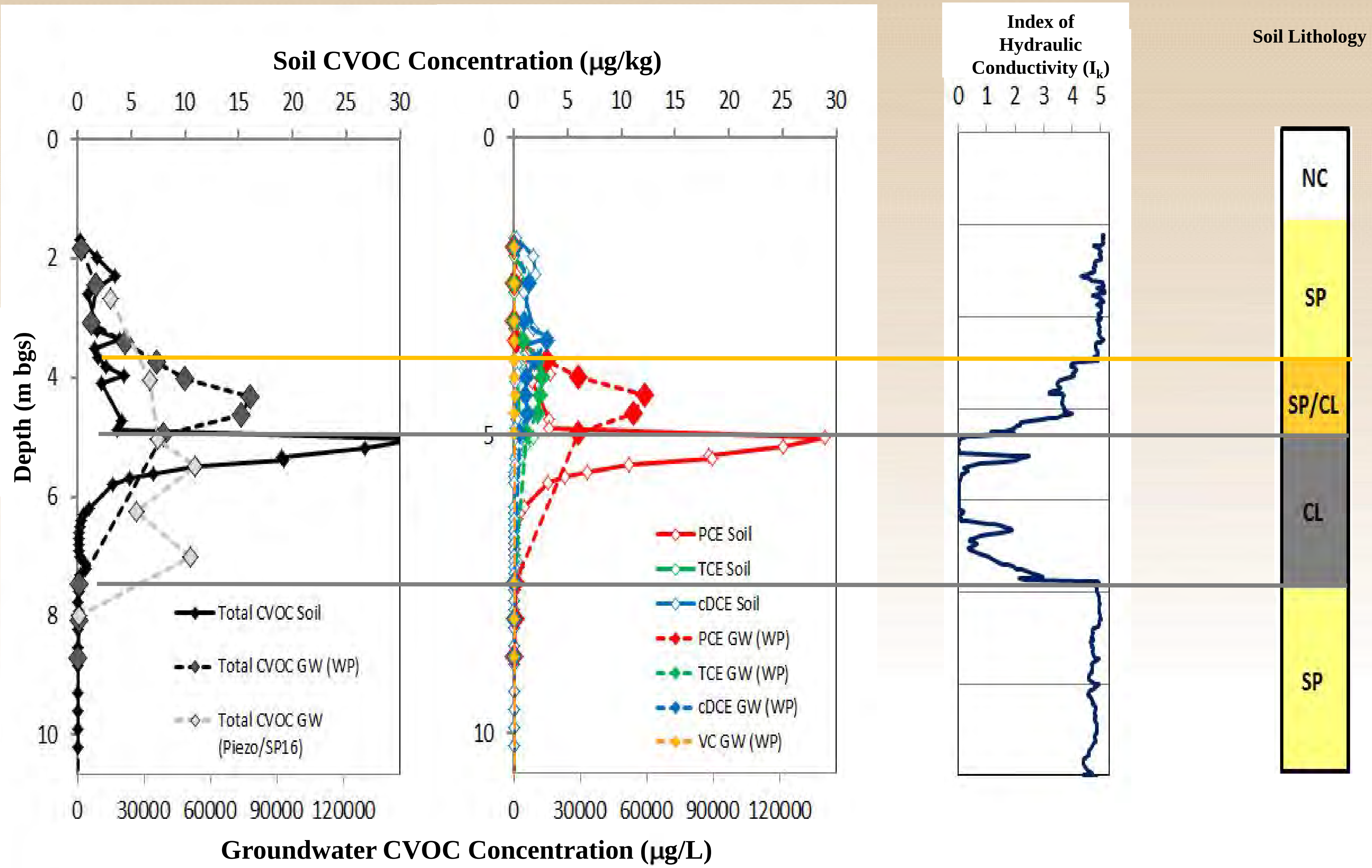
OU3-3: Soil and Groundwater Concentrations



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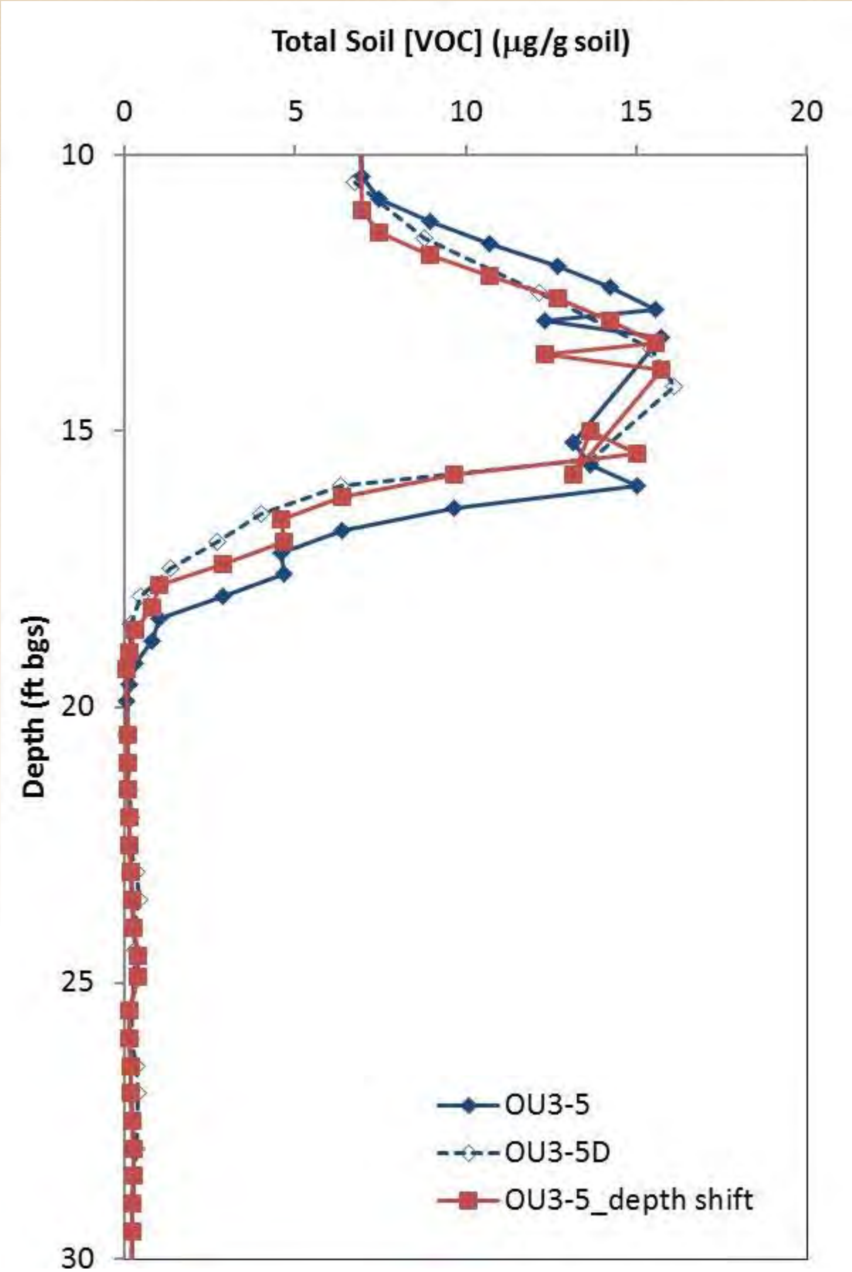
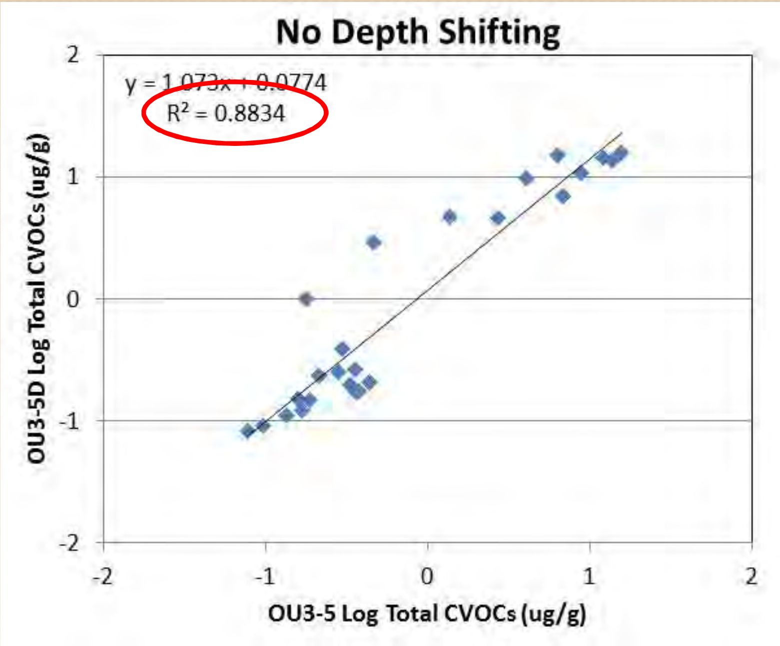
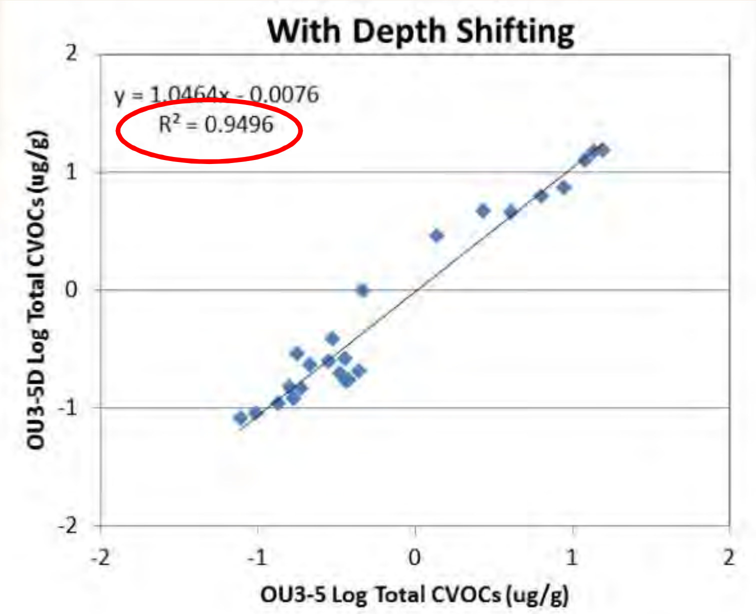
Collocated Soil Cores Demonstrate Good Correlation

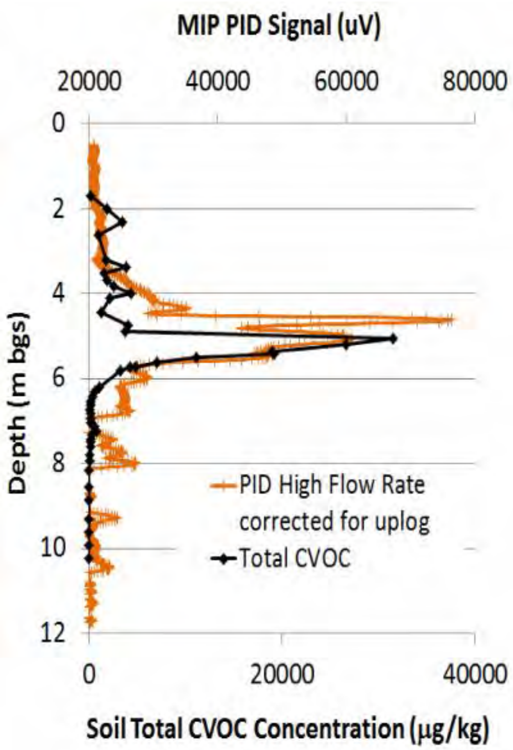




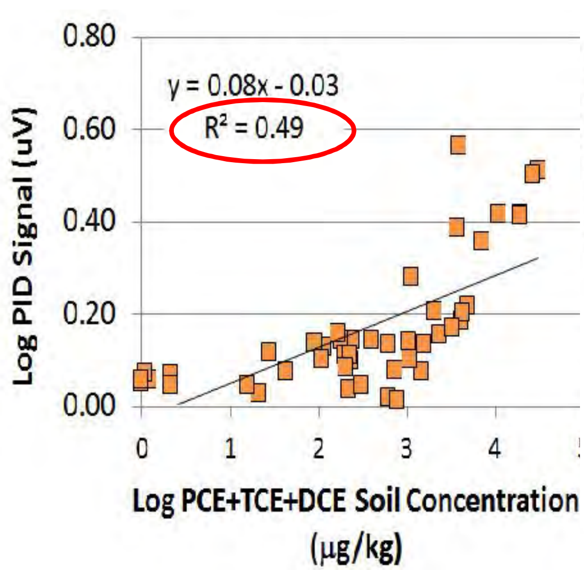


MIP Provides Mass Location
But Not Concentration Correlation

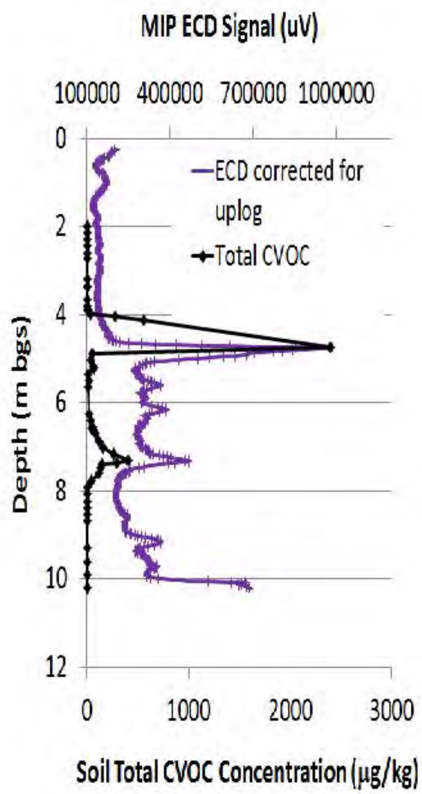
MIP:SOIL AT LOCATION OU3-3 (HIGH CONCENTRATION) USING OPTIMIZED SOP



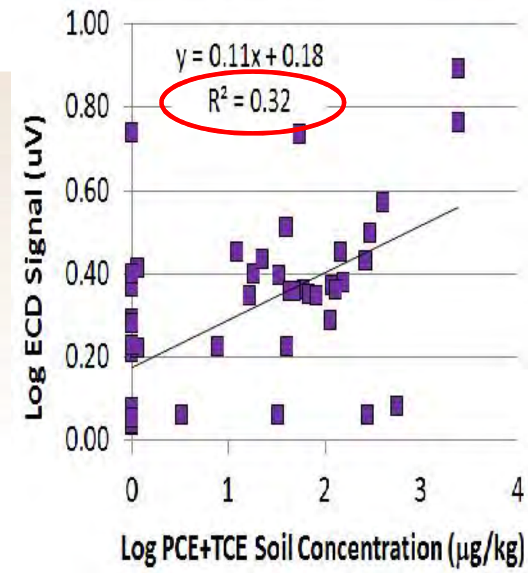
REGRESSION



MIP:SOIL AT LOCATION OU3-6 (LOW CONCENTRATION) USING OPTIMIZED SOP

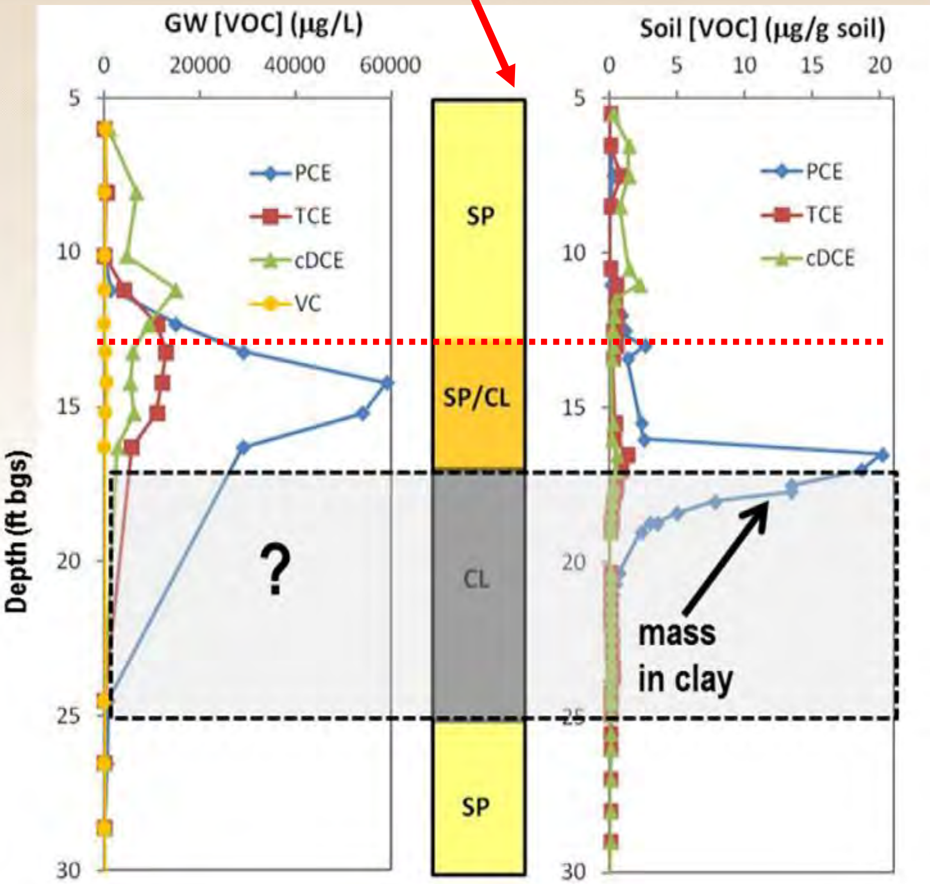


REGRESSION

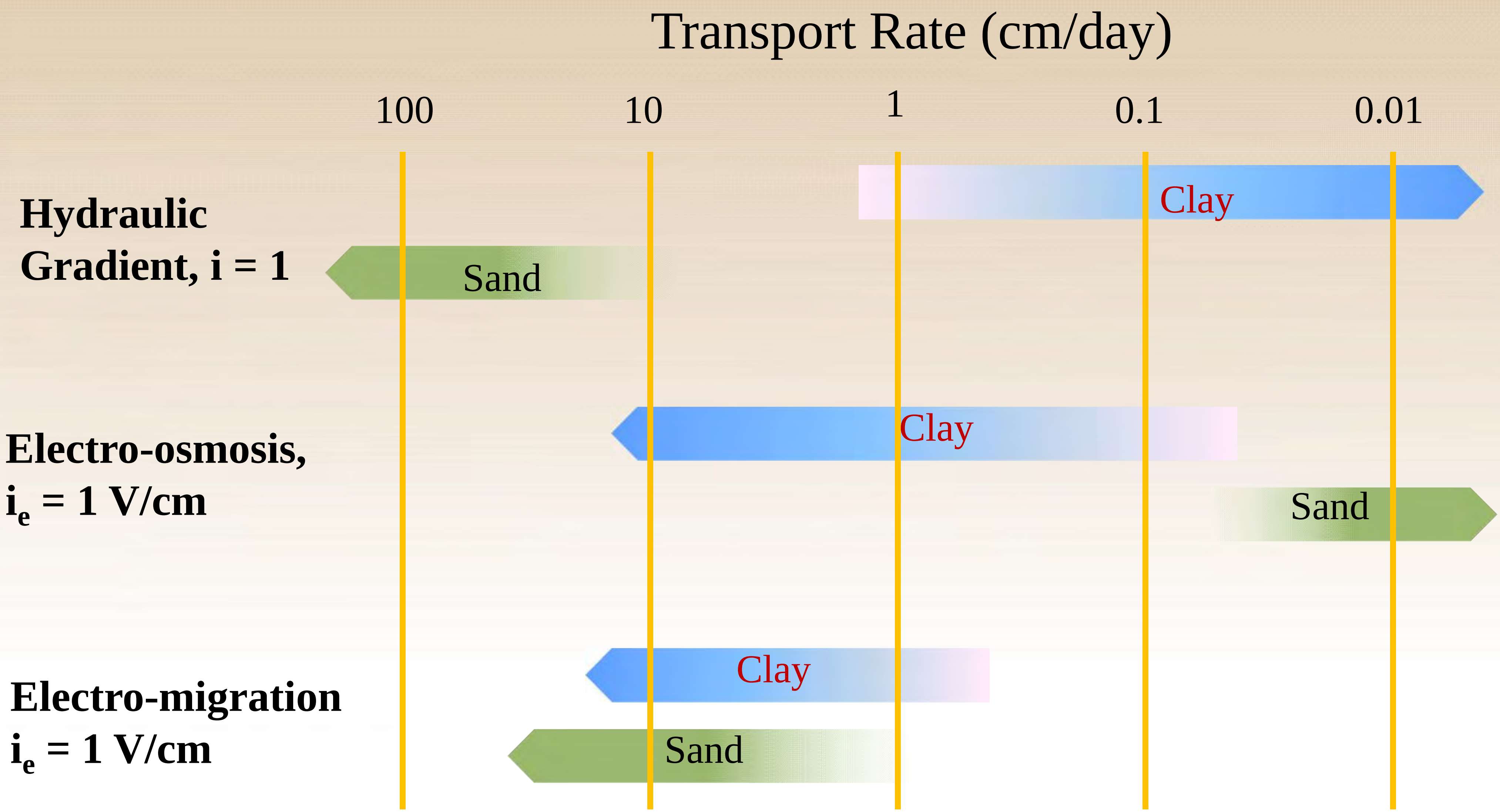


The Remediation Challenge

- Much of remaining contaminant mass is in low permeability layers
- Mass diffuses out slowly and represents a long term source of contamination
- Injections do not distribute remedial agents well in low permeability layers
- How to enhance biodegradation in low K layers?

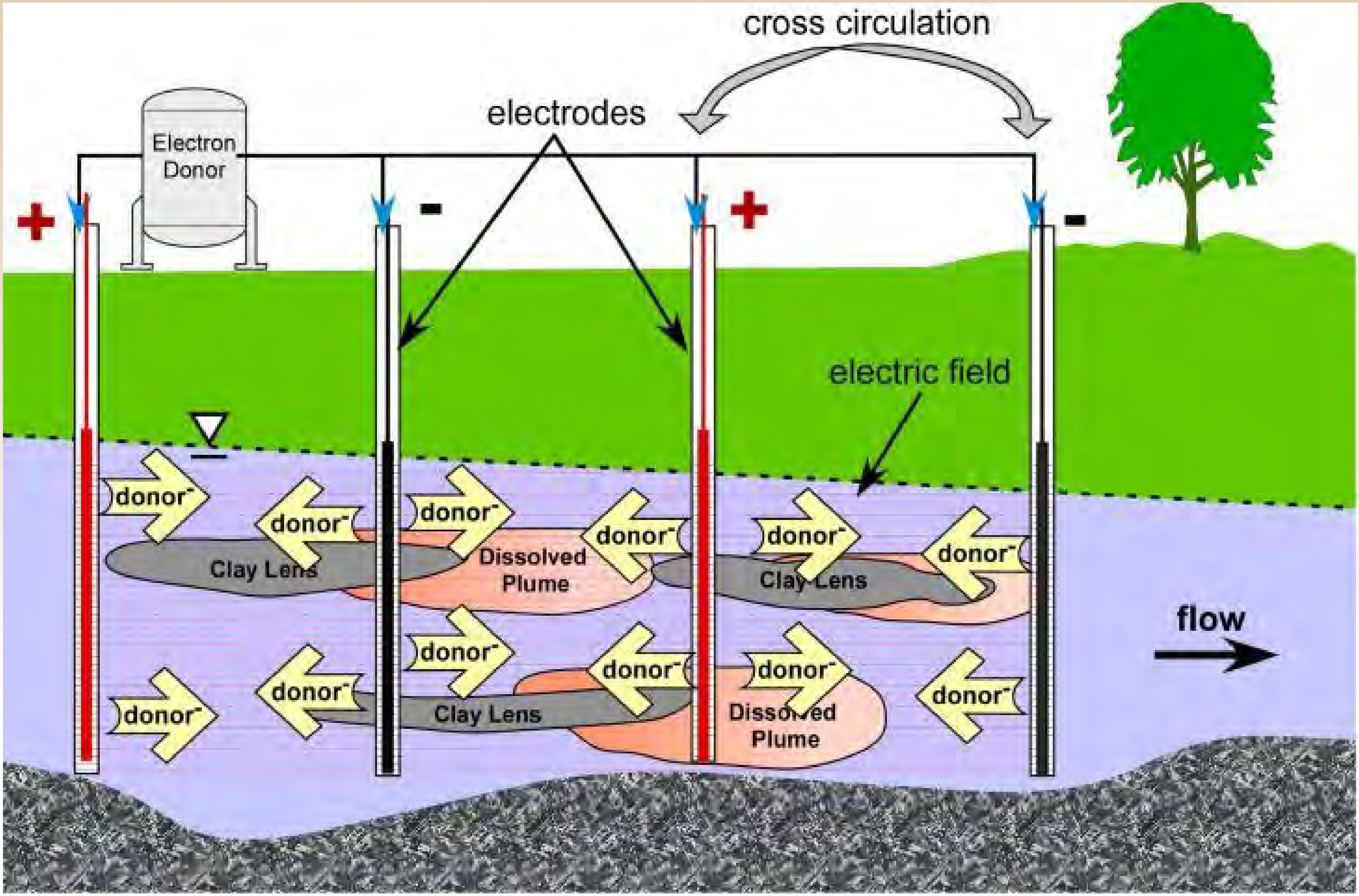


Electrokinetics: Relative Rates of Transport



Courtesy of Geosyntec

Electrokinetic (EK)-Bio Field Application Concept



Courtesy of Geosyntec

EK Treatability Testing at OU3

- DPT soil core from OU3
- Migrated lactate through core for 28 hours
- Thin-sectioned core, froze sections, analyzed for lactate
- Calculated lactate migration rate of 3 – 5 cm/day

Courtesy of Geosyntec





Thank You!

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