COLUMBIA TECHNOLOGIES

Rapid, Real-Time High Resolution Site Characterization

Effective Use of High Resolution Tools for LNAPL Cost Management

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Our Mission?


Efficient
Sustainable
Social
Economic
Environment

Our industry spends over $1 BILLION each day assessing, remediating, and making decisions on information that is incomplete, inaccurate, and too late.

Where does all the money go?

Historical Approach

Fieldwork → Office → Repeat

Drill → Sample → Lab → Data Evaluation → Map → Reports → Data Gaps

Remobilization

Repeat

Drill → Sample → Lab → Data Evaluation → Map → Reports → Data Gaps

Remobilization

Repeat

$ → $ → $ → $ → $ → $ → $

Cycle Time = Years

Expensive

Why?

80% of the errors, waste, and resources are spent on the wrong and insufficient samples.

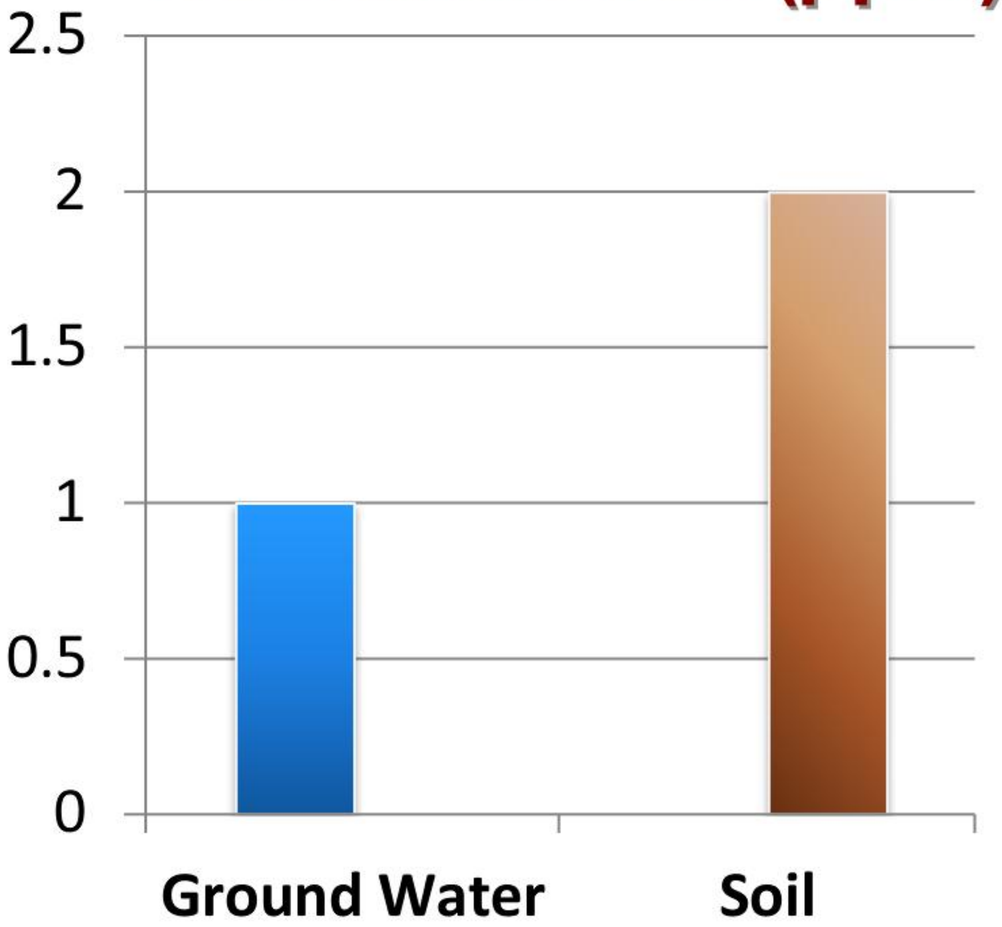
The GOALS of RDC

A Proper RDC Tells Us Where and How Much (Dissolved Phase & Adsorbed Phase)

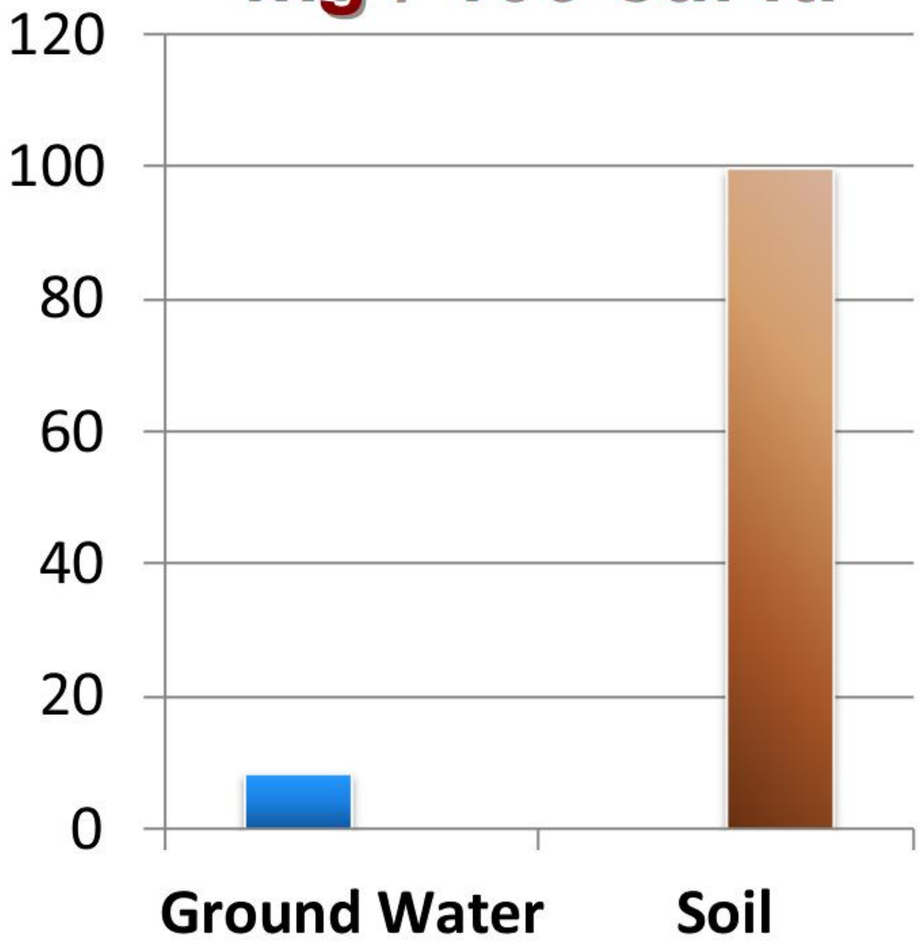
- Where the Contamination is Located
  - Vertical and Horizontal Distribution
- How Much Mass is There to Treat (Dosing)
- Other Physical & Chemical Parameters as Needed for Specific Treatments. (SOD, COD, etc.)
- If Back Diffusion Affects the Choice of Methods
- Soil/Rock Types for Delivery Mechanisms
- = Targeted and Accurate Injection Design Plan

Adsorbed Phase vs. Dissolved Phase Contaminant Loading

Soil and Ground Water Contamination (ppm)



Contaminant Load mg / 100 cu. ft.



If you design to only treat the dissolved phase contaminant, you get REBOUND

Vista GeoScience

Representative Sampling from Continuous Soil Cores

(Remember: A saturated soil sample includes the pore water, and therefore the combined adsorbed and dissolved phase)

Sub-Sampling Continuous Cores for VOCs Using Plugs

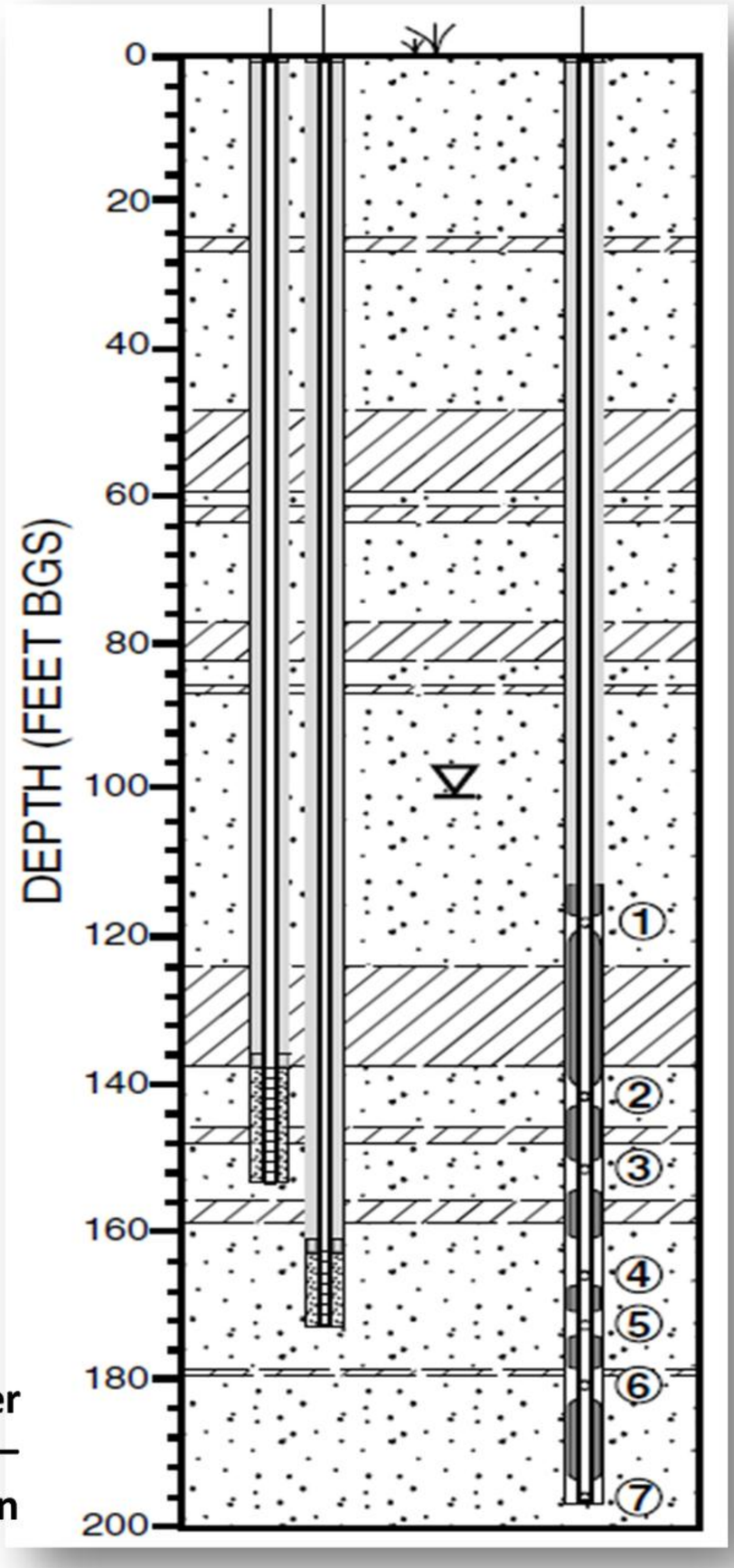
Cutting a Composite "Wedge" from the Continuous Core

ITRC (Interstate Technology & Regulatory Council). 2012. *Incremental Sampling Methodology. ISM-1. www.itrcweb.org.*

Tools for Discrete Ground Water Samples

- Discrete GW Sampling Tools
- Multiple Wells with Discrete Screens
- Single Well with Multi-Level Ports
- ….BUT REMEMBER: 80-90% of the mass resides in the saturated soils.

Geoprobe® Screen-Point Sampler



Practical Handbook of Environmental Site Characterization and Ground-Water Monitoring, Second Edition, Ed. David M. Nielsen – CH 11, Multi-Level Ground Water Monitoring, Murray Einarson

Use High Resolution Data to Create "Decision Units" for Treatment Dosing

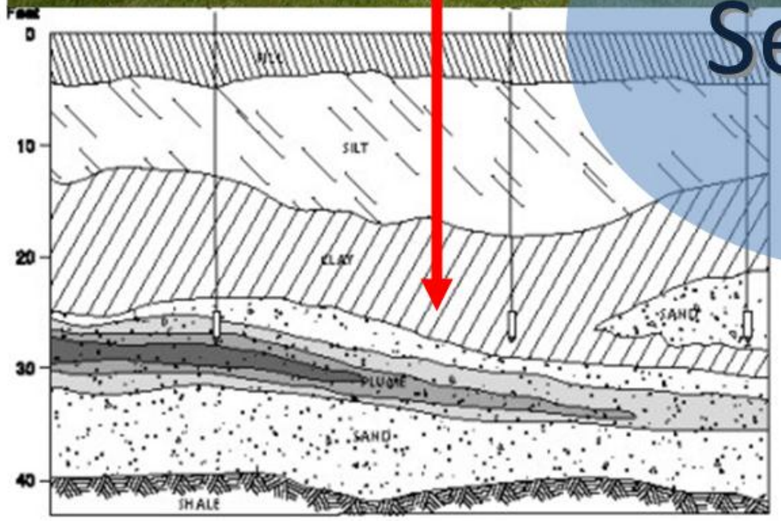
DEPTH

Injection Depth	Area A 500 sq. ft, 5 pts.	Area B 1,500 sq. ft, 15 pts	Area C 4,000 sq. ft. 40 pts.
12'			
14'	10 lbs	25 lbs	10 lbs
16'	40 lbs	40 lbs	25 lbs
18'	25 lbs	25 lbs	25 lbs
20'	10 lbs	10 lbs	10 lbs
22'			10 lbs

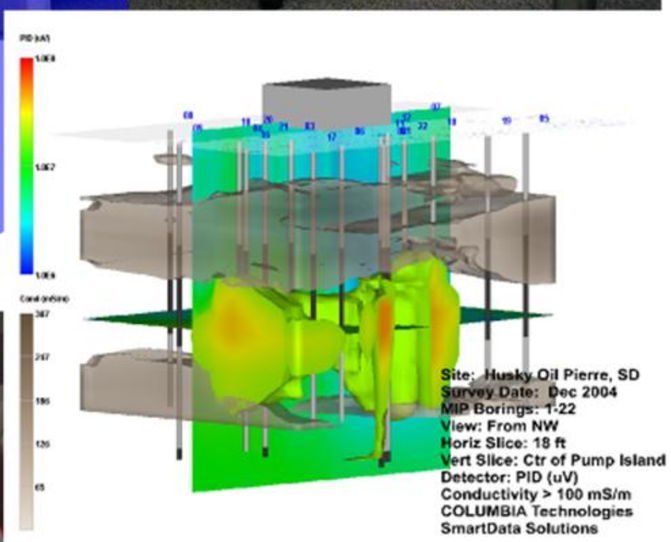
Vista GeoScience

Sensors

Advanced Analytics



Internet Delivery



Cycle Time = Minutes

Accurate, high definition and real time information

U.S. Patent No. 7,058,509

The NAPL Challenge

The NAPL Challenge

Oil
Soil
Water
Bugs
Vapor ??

The OIL Challenge

Where is it (really)?

Leaking or not?

Moving or not?

Transmissive (recoverable) or not?Above saturation or not?

Degrading – YES but how fast?

What is LNAPL?

NAPL = Non-Aqueous Phase Liquid

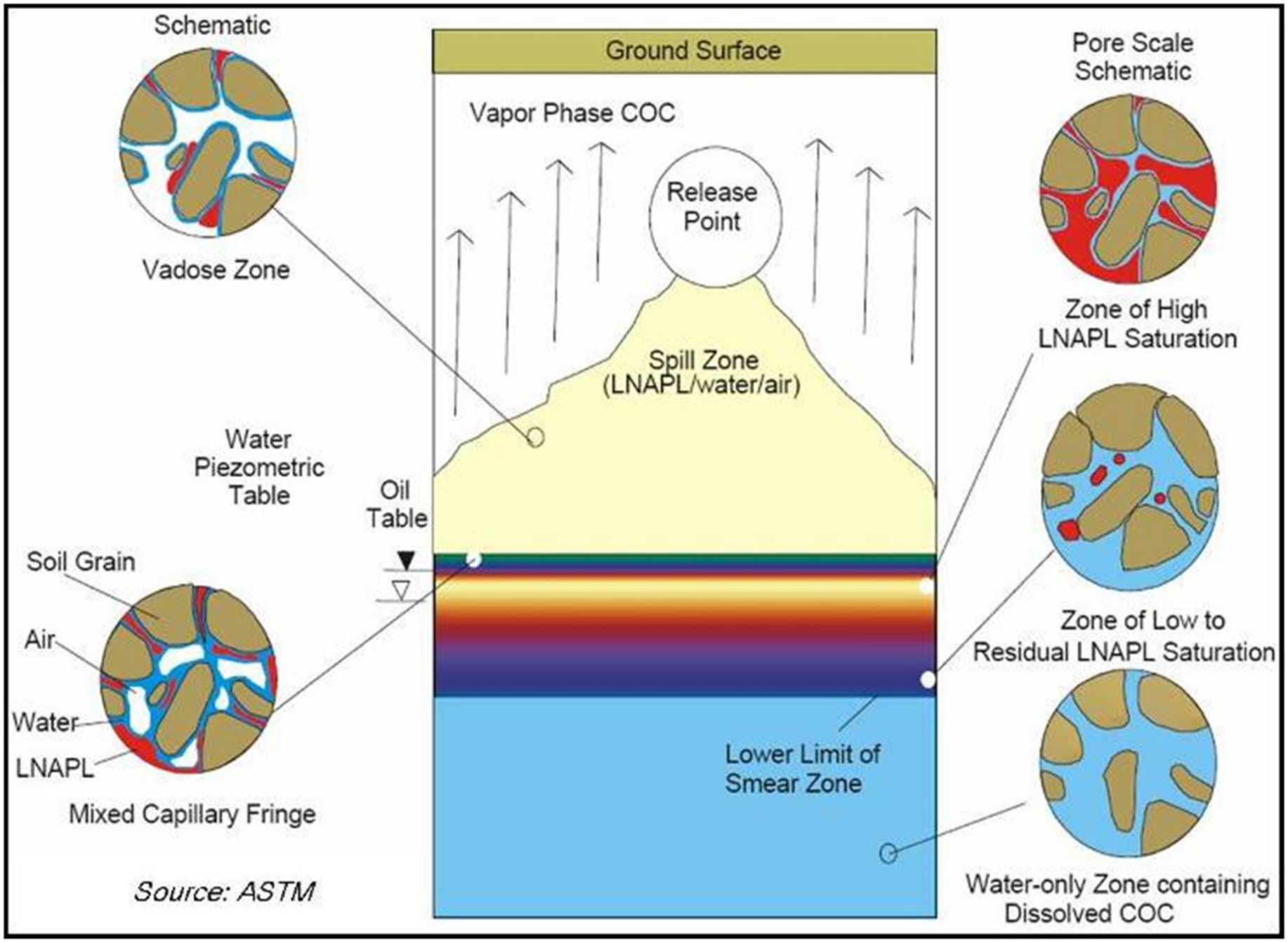
- Do not mix with water and remain as a separate phase
- Include petroleum hydrocarbons and chlorinated solvents

LNAPL = NAPL that is less dense than water

- Gasoline, diesel fuel, jet fuel, and crude oil
- Multi-component mixtures

Courtesy of:

Underground – It's Complicated



Courtesy of:

The SOIL Challenge

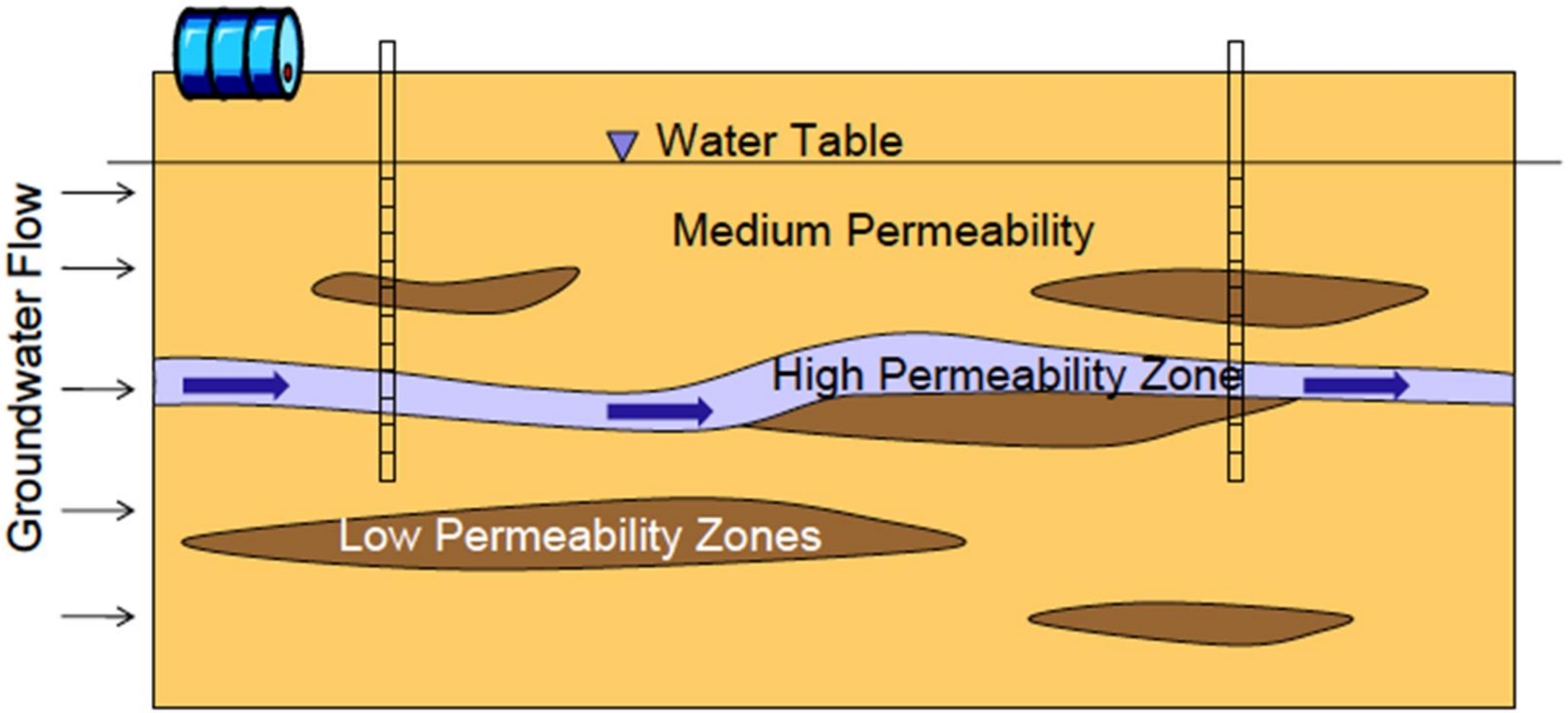
Is it sand or clay?

Or should we measure whether it is permeable or non-permeable?

VIDEO

Geologic X-Section: Setting the Stage for a DNAPL Release

Key Point: Groundwater flux is dominant in high-permeability zones
Groundwater velocity in high-permeability zones >>> average value



Highly simplified illustration of heterogeneous geology

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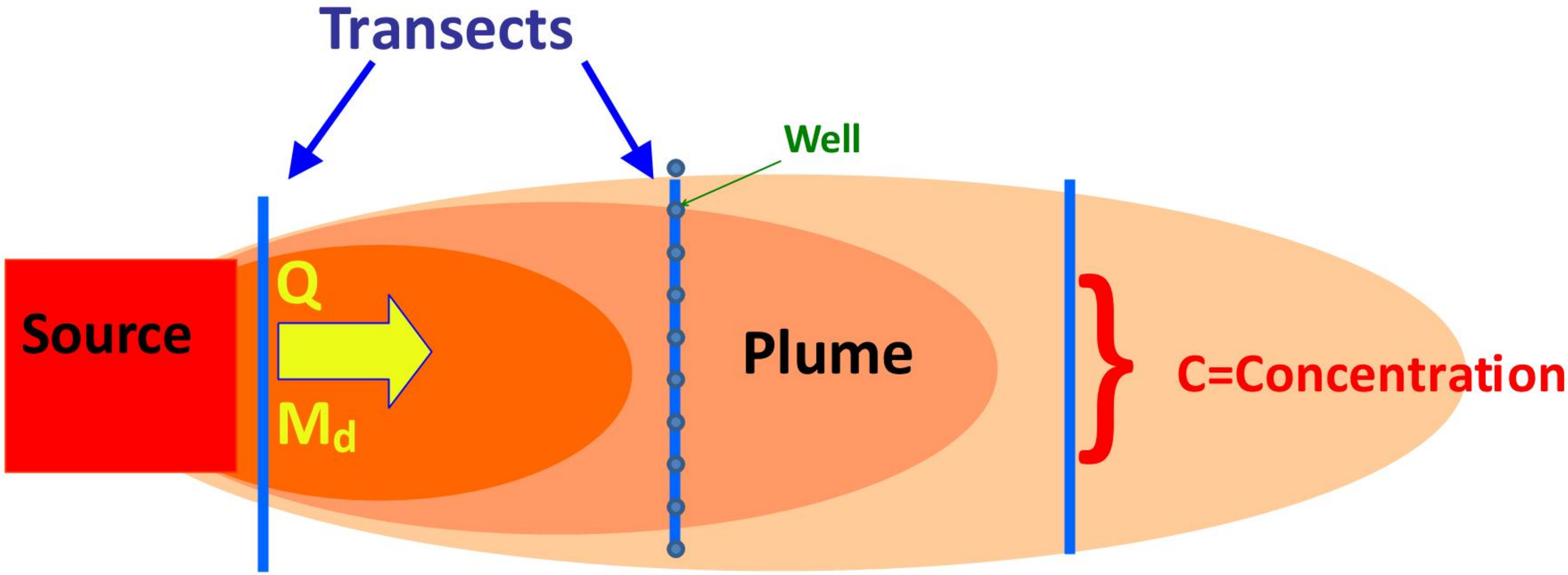
Courtesy of: INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

Mass Discharge: Chemical Mass and Transmissivity



Across any Transect, a Contaminant Plume Conveys:

Groundwater Discharge, **Q** (e.g., L/day)

Contaminant **Mass Discharge**, M_d (e.g., g/day or kg/year)

Figure 2-1

$$M_d = Q \times C \qquad \text{(L/day x mg/L = mg/day)}$$

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Courtesy of: INTERSTATE COUNCIL ITRC TECHNOLOGY REGULATORY

It's a Science Based Decision

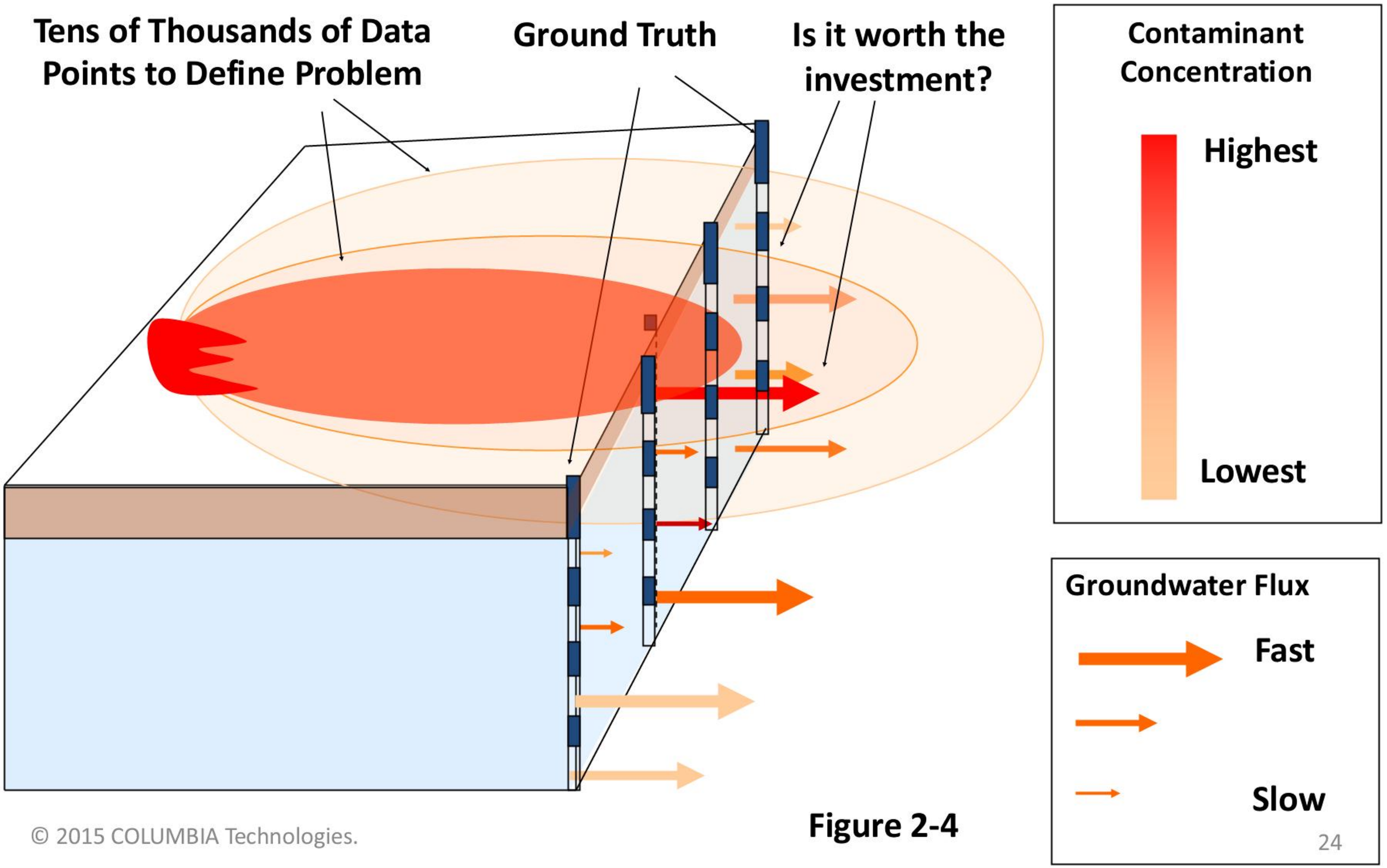
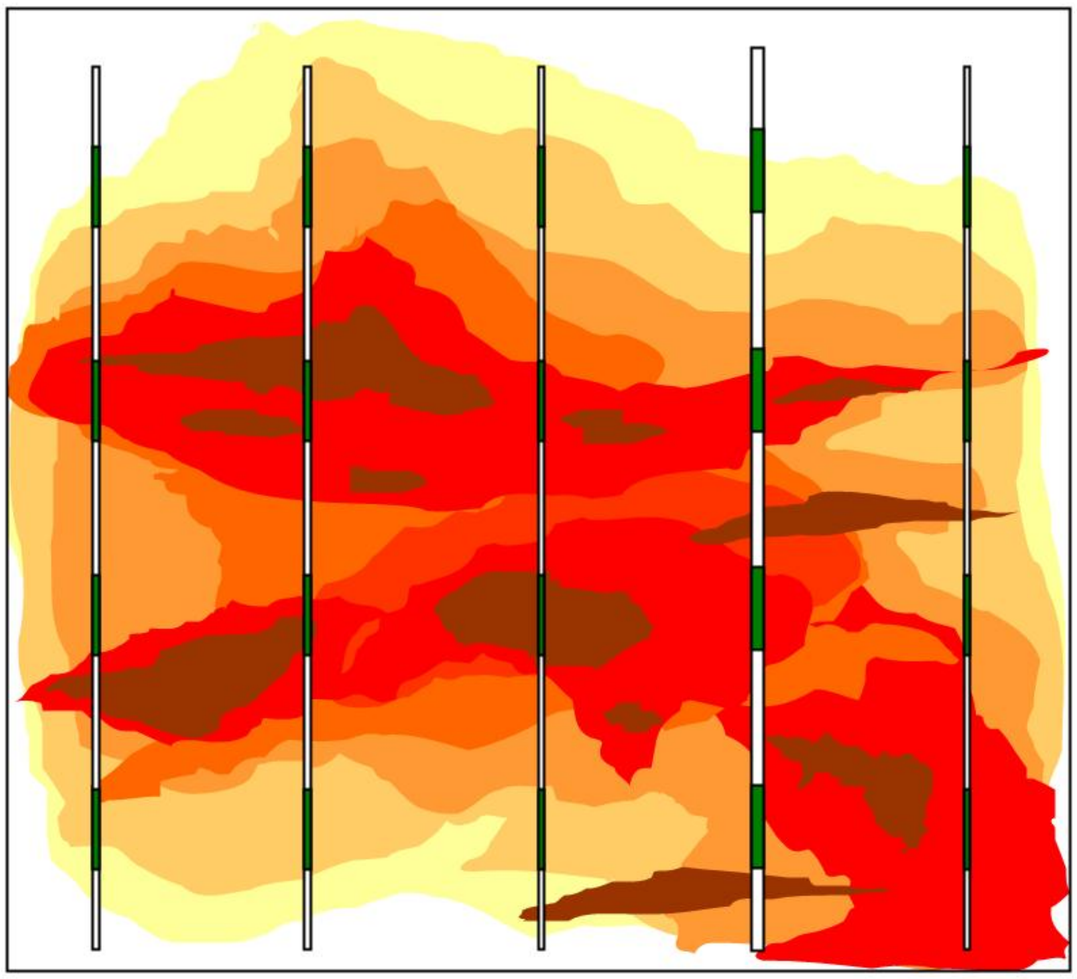


Figure 2-4

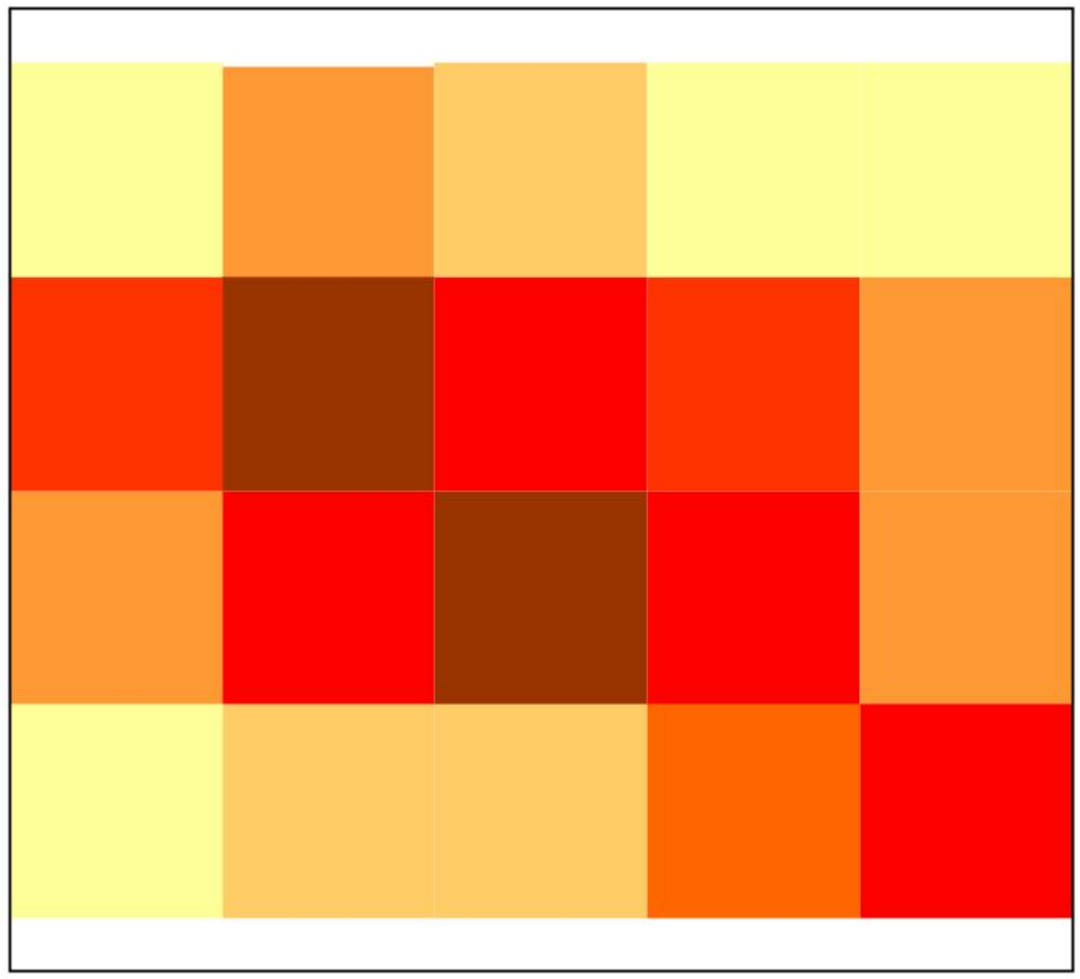
Courtesy of:

Heterogeneity Measured

Power of High Resolution



Clarity of Typical Site Characterization



- Scale matters – what needs to be measured
- How to interpolate between highly variable data
- Most transects sample < 1% of the groundwater

80-90% of the contaminant mass is moving or stored within 10-20% of the geospatial volume

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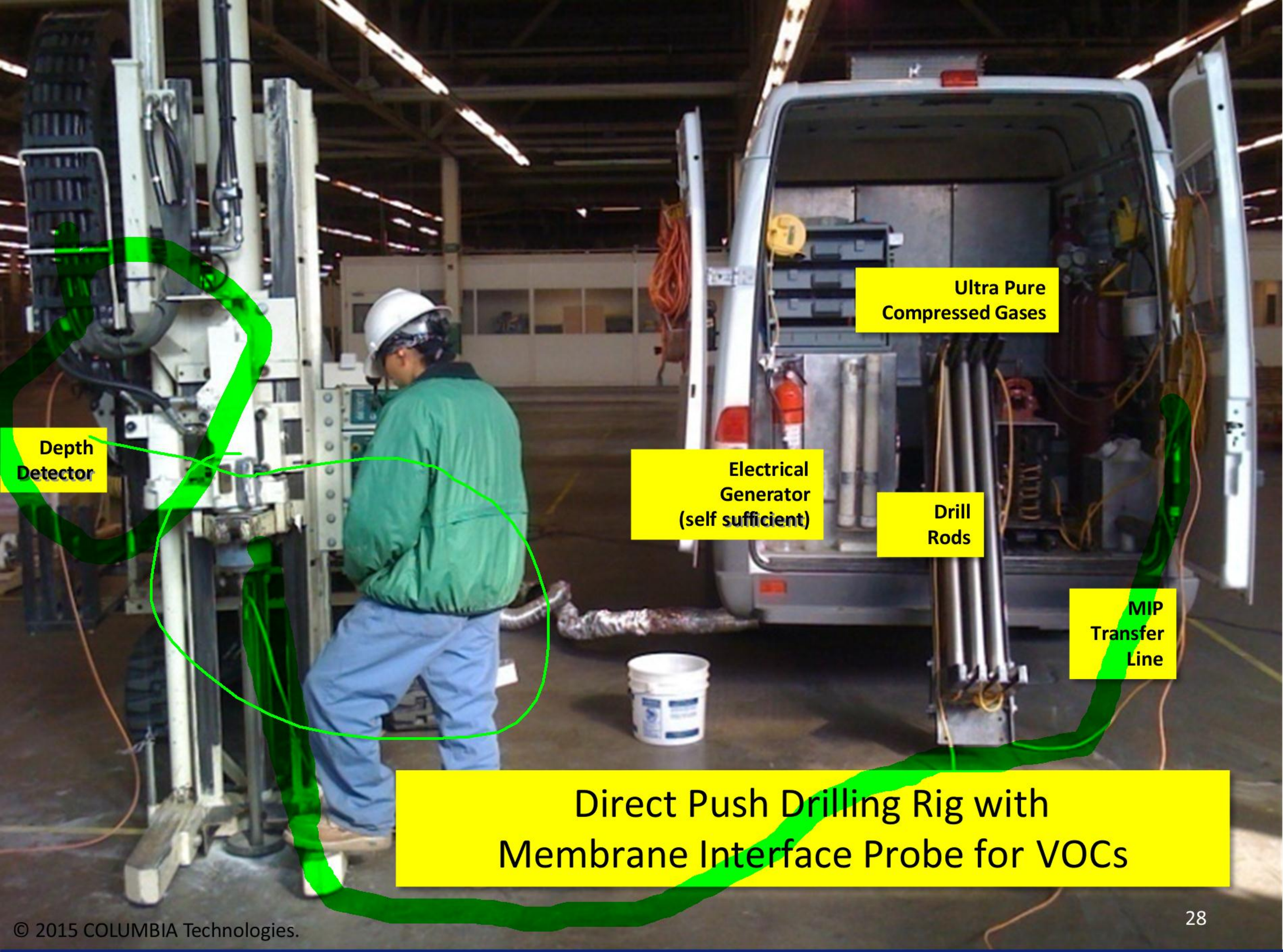
High Resolution Systems

Method	Target Data
MIP (Membrane Interface Probe) **(MIP-EC, MiHPT, MIP-HTL, LL MIP, MIP-XSD)**	**Volatile Organic Compounds (VOCs)** **(Dissolved phase petroleum and/or Solvents)**
LIF (Laser Induced Fluorescence) **(UVOST®, ROST®, TarGOST®, FFD)**	**LNAPL/Residual phase petroleum** **Light petroleum fuels to coal tars**
HPT (Hydraulic Profiling Tool)	**Soil hydraulics (pore pressure, soil permeability)**
PST (Pneumatic Slug Test)	**Soil characteristic - permeability**
EC (Electrical Conductivity)	**Soil characteristic - electrical**
CPT (Cone Penetrometer)	**Soil characteristic, behavior type**
Discrete Groundwater Profiling *Short, discrete screen interval (0.2 – 1.0 meter)*	**VOCs, SVOCs, Metals, Biologics, Gases**
Onsite Laboratory Analyses *Rapid Laboratory grade GC, GCMS, HPLC, other*	**VOCs, SVOCs, Metals, Gases**
Real Time Data Management *Mapping and vertical profile charts*	**Quality Assurance and Decision Making** **Results presented via Internet in real time**



Direct Push Drilling Rig with Membrane Interface Probe for VOCs

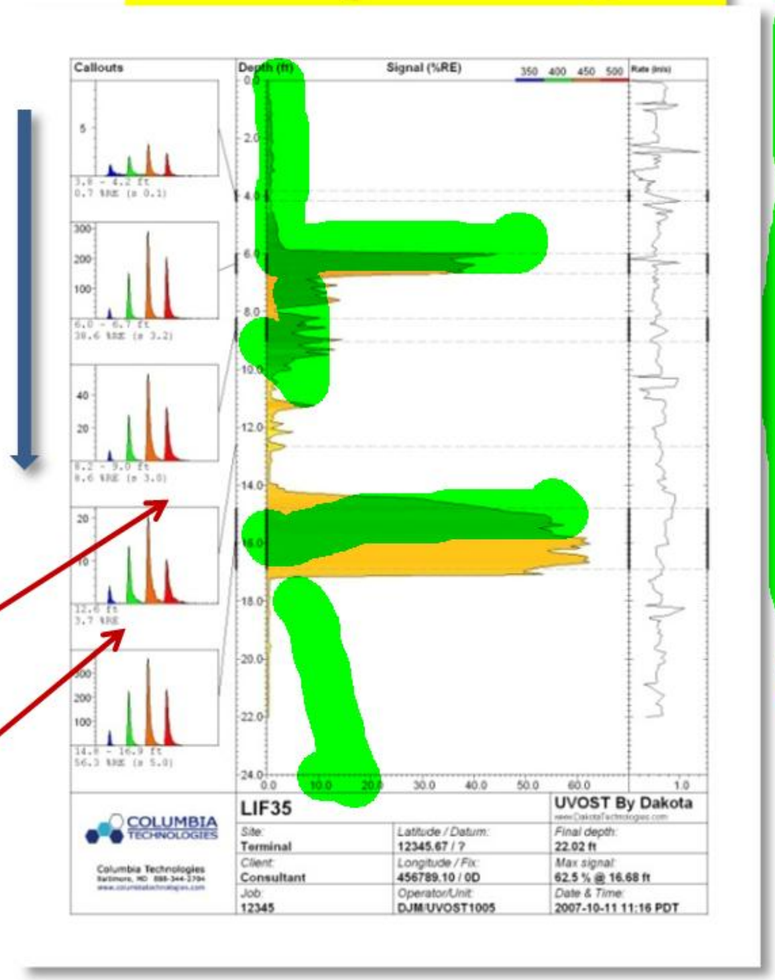
Laser Induced Fluorescence (LIF)

UltraViolet Optical Screening Tool®(UVOST®)

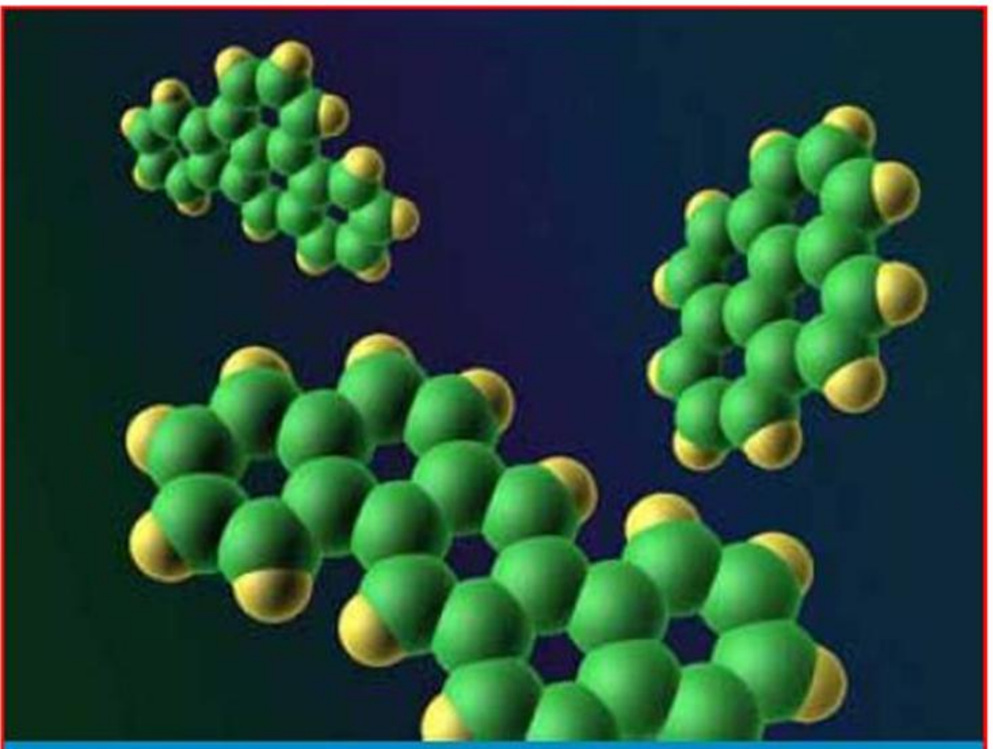
Quick Notes:

- Responds to PAH containing compounds
- Residual Phase Petroleum Hydrocarbons
- Excellent mapping of NAPL
- Matrix effects
- Reference Emitter (RE) source test required

Sample LIF Log

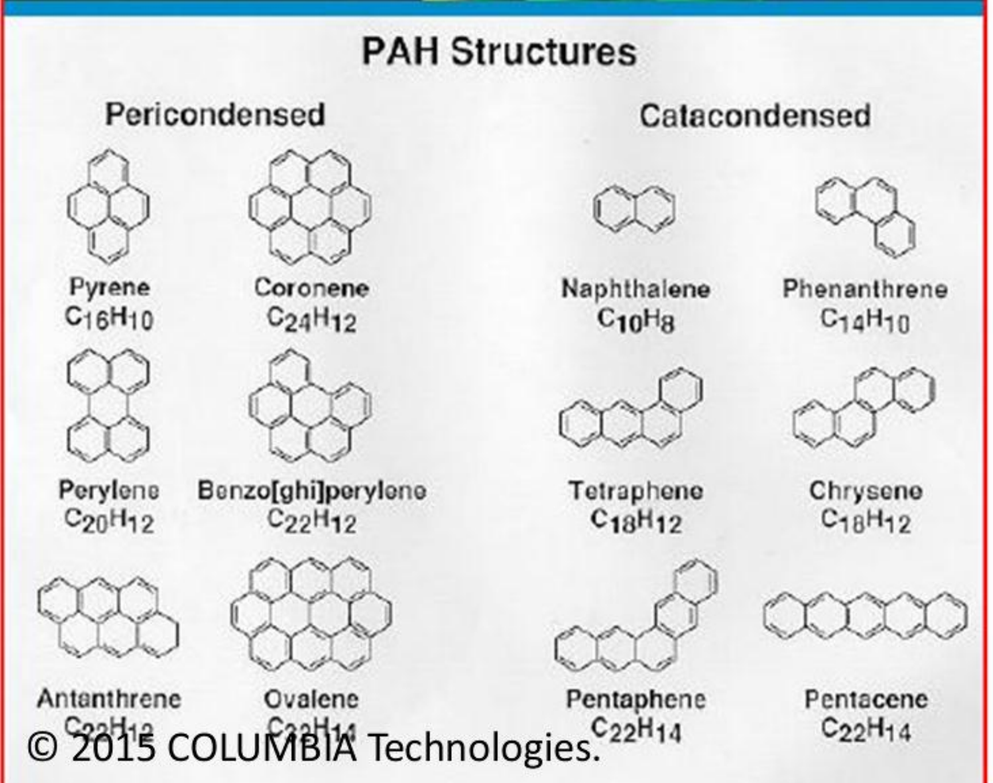


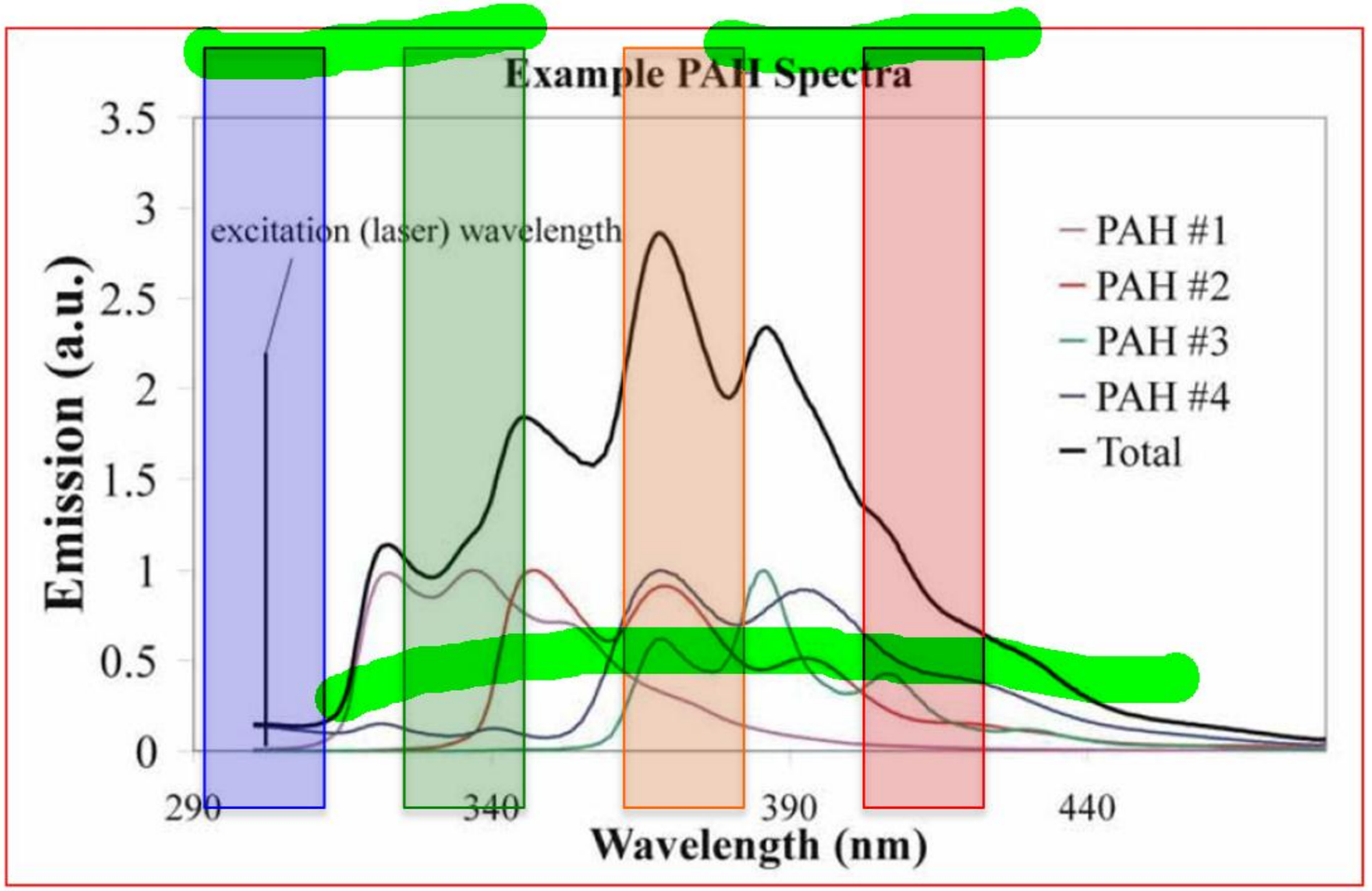
LIF Principles of Operation



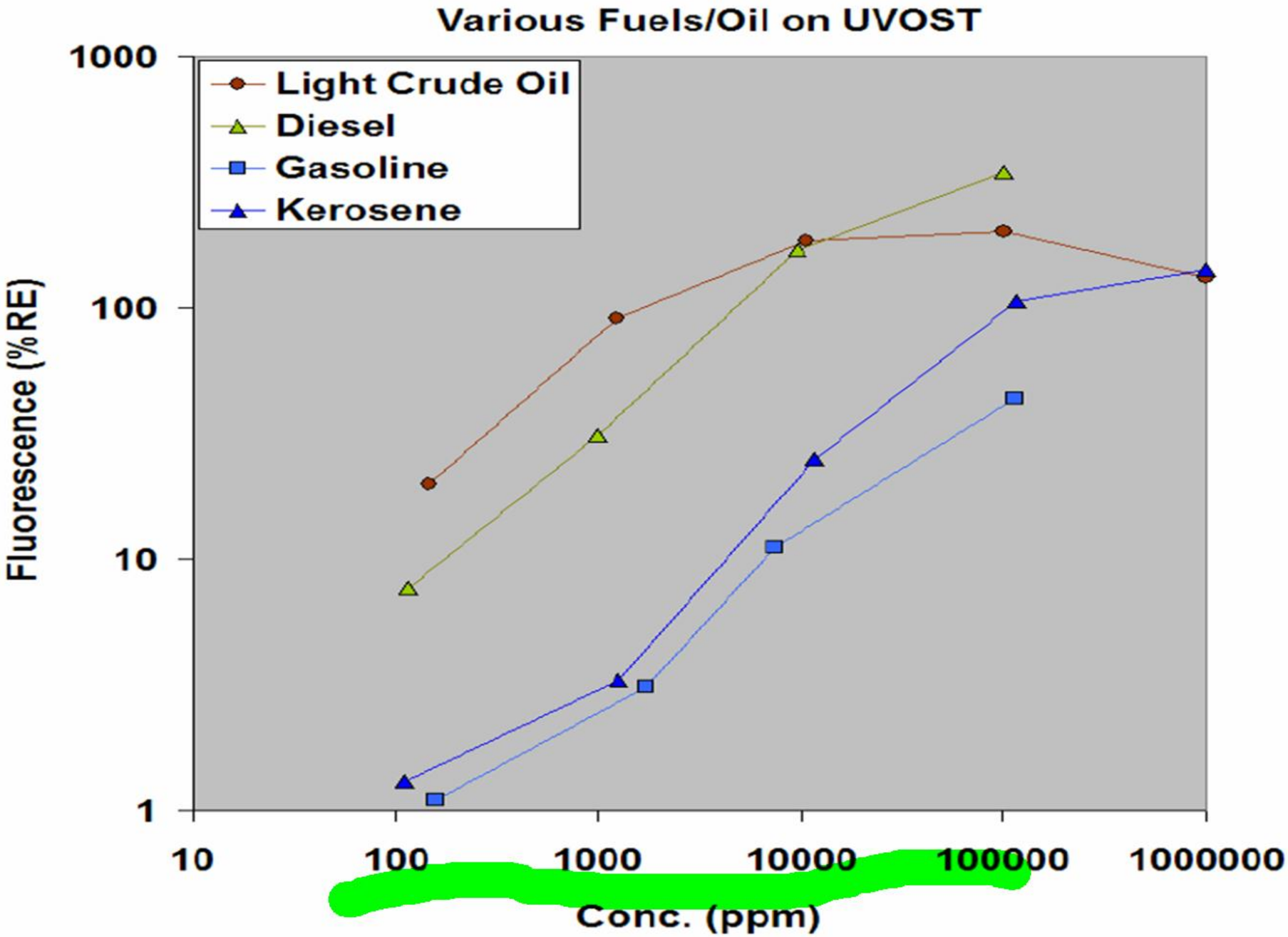
LIF responds to free-phase PAHs – anything with more than one benzene ring

- PAHs fluoresce when struck with UV light
- Each PAH has a unique fluorescence spectrum
- Heavier PAHs are more red-shifted





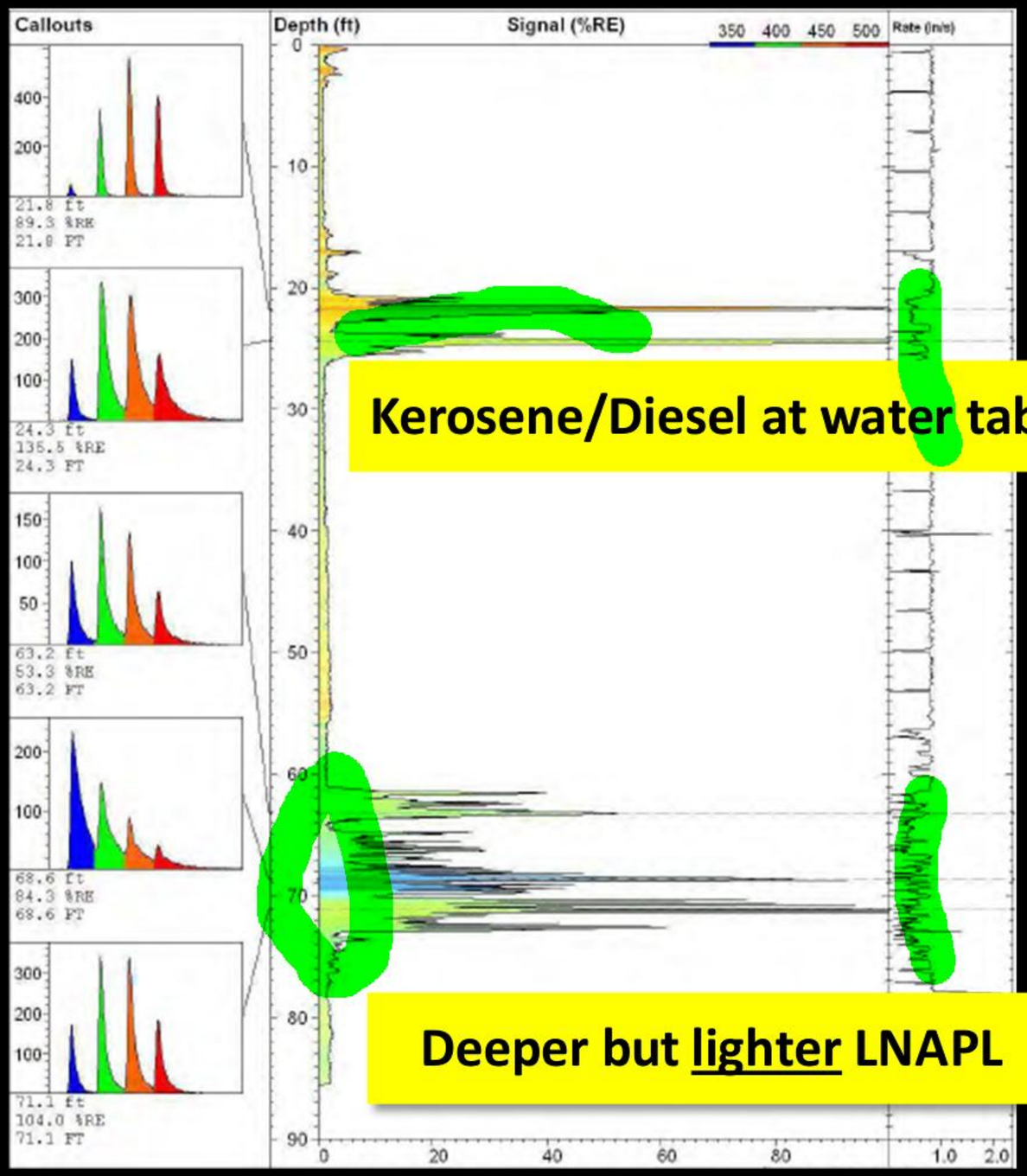
Linear Response Over Wide Range of Saturation



UltraViolet Optical Screening Tool®

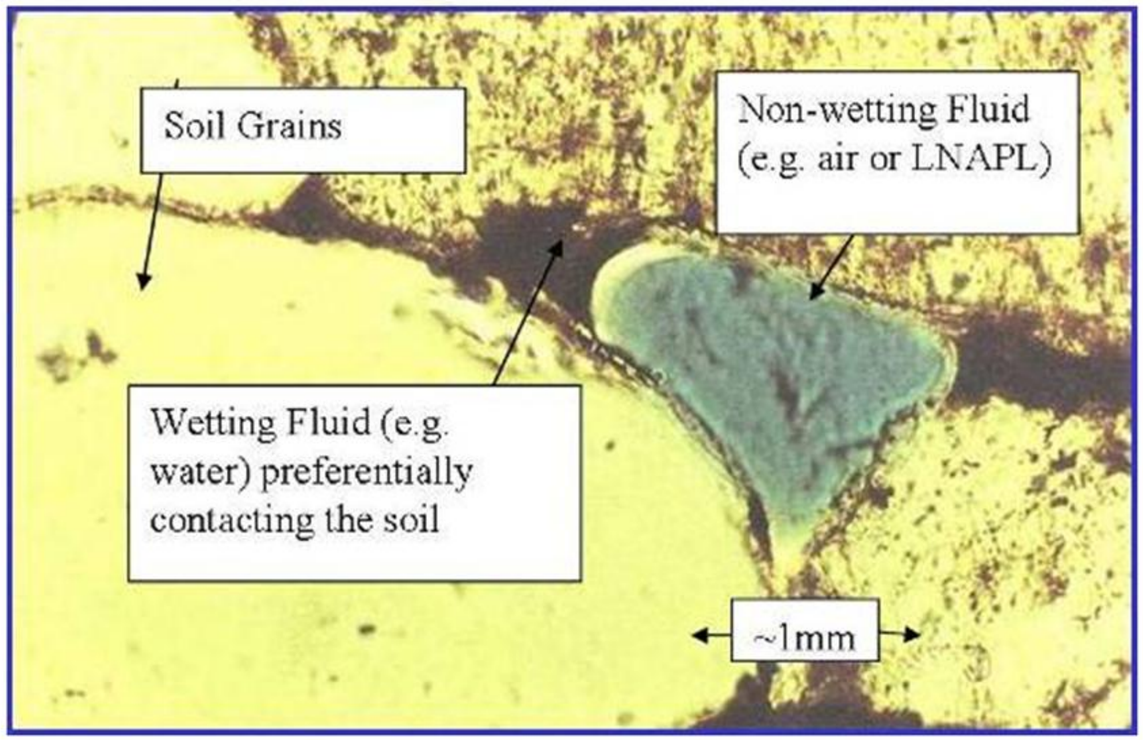
Optical Spectroscopy:

- FOUR different frequency bands
- Fluorescent light received from the down hole window
- Lighter, shorter chain hydrocarbons blue-green
- Heavier, longer chain hydrocarbons orange-red
- Matrix effects
- Reference Emitter (RE) source test required

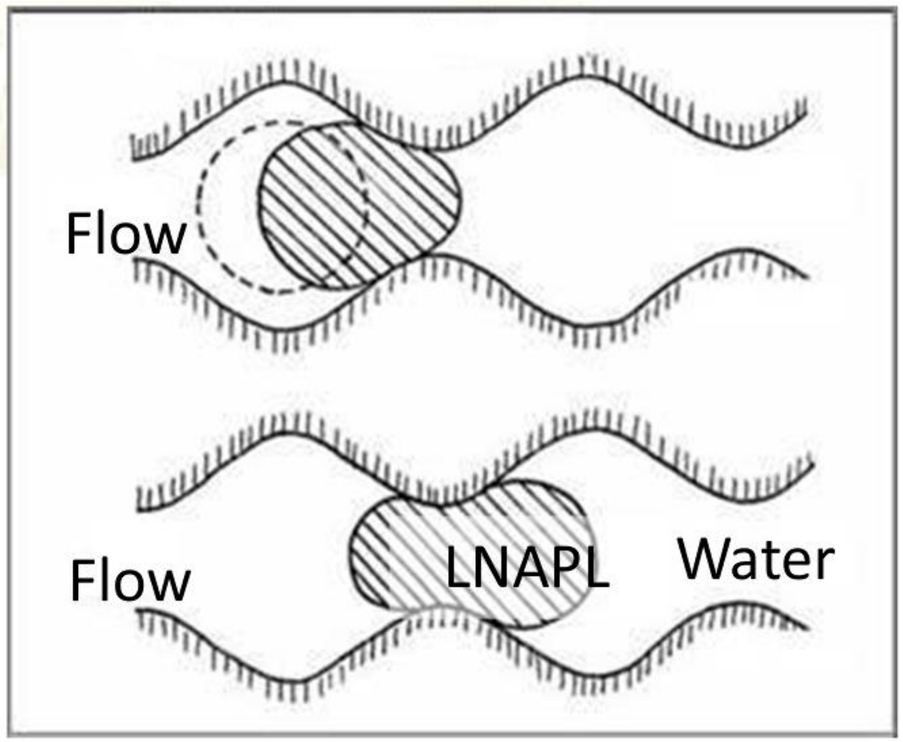



The WATER Challenge

Pores and Pore Pressure



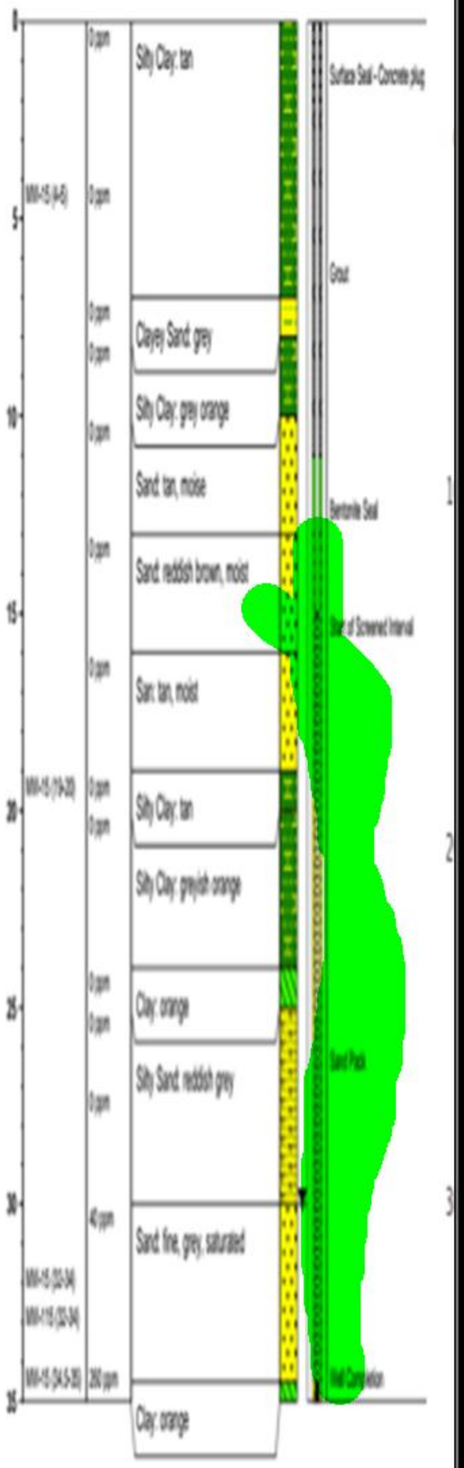
For water wet media



Quick Notes:

- LNAPL share pore space with other fluids including air
- The head pressure of the LNAPL must overcome the pore entry pressure for LNAPL migration

Courtesy of:



Screened Interval

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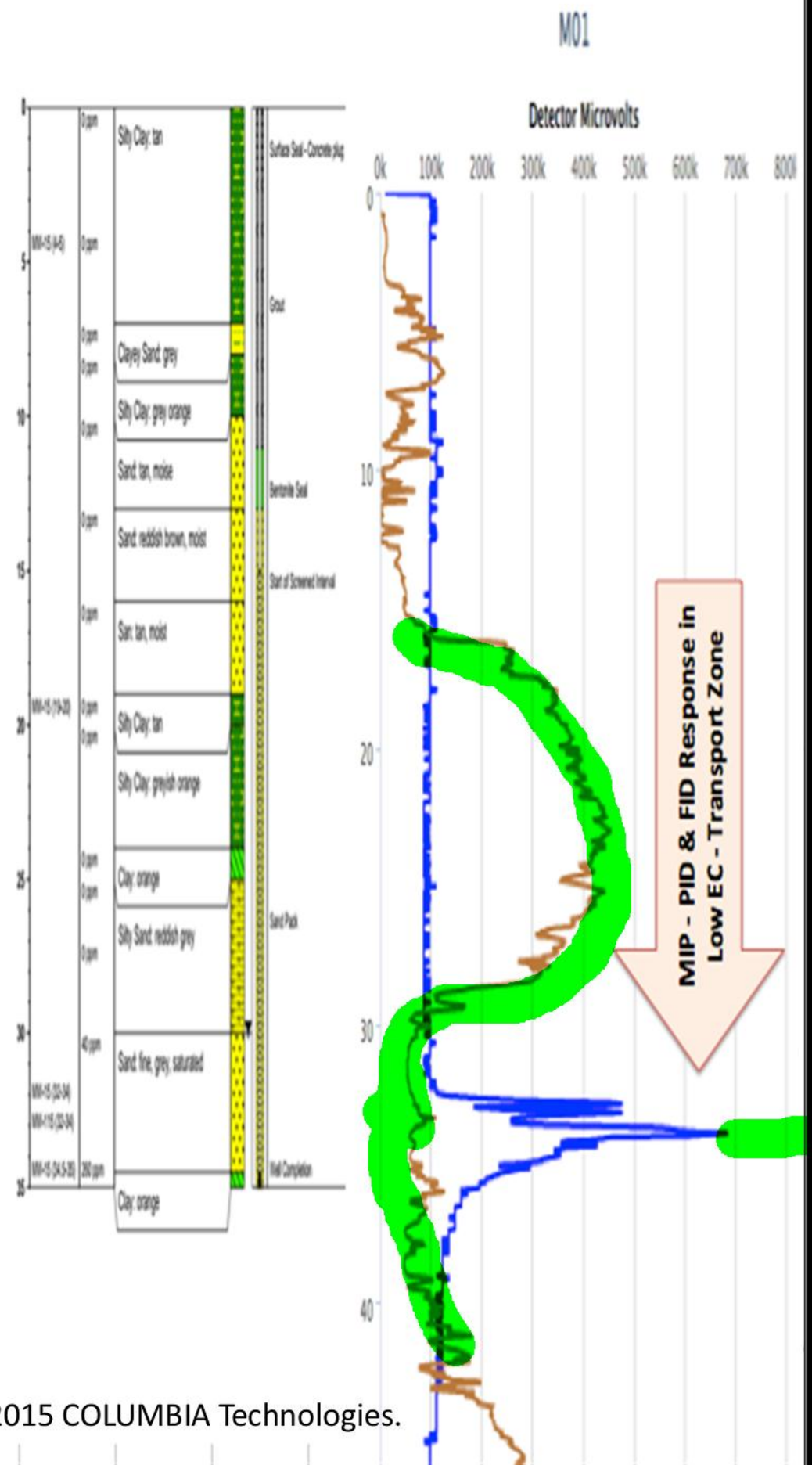
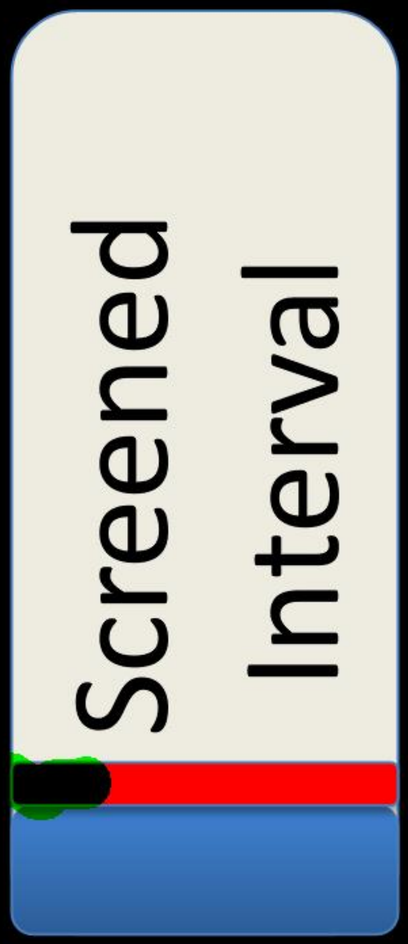
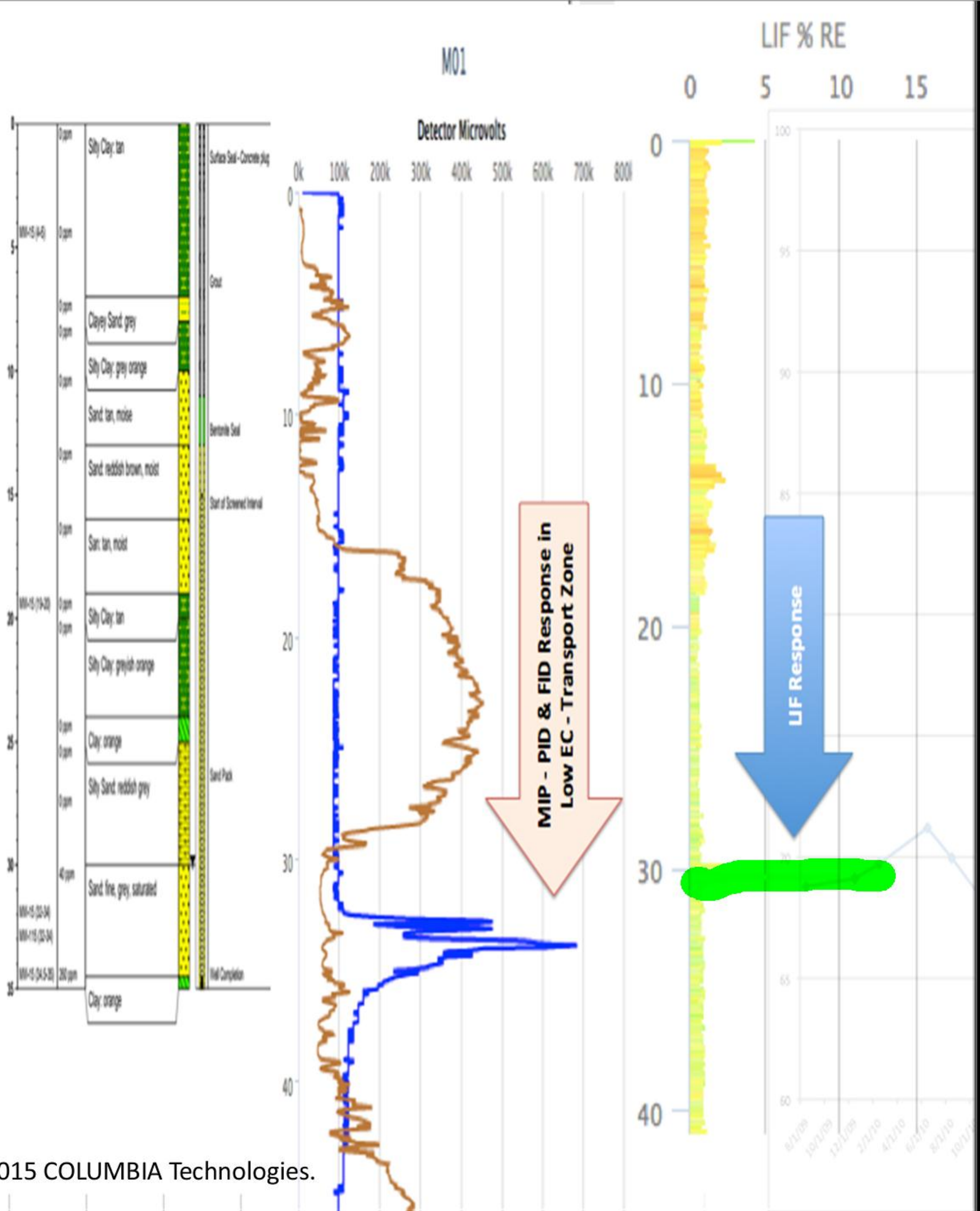
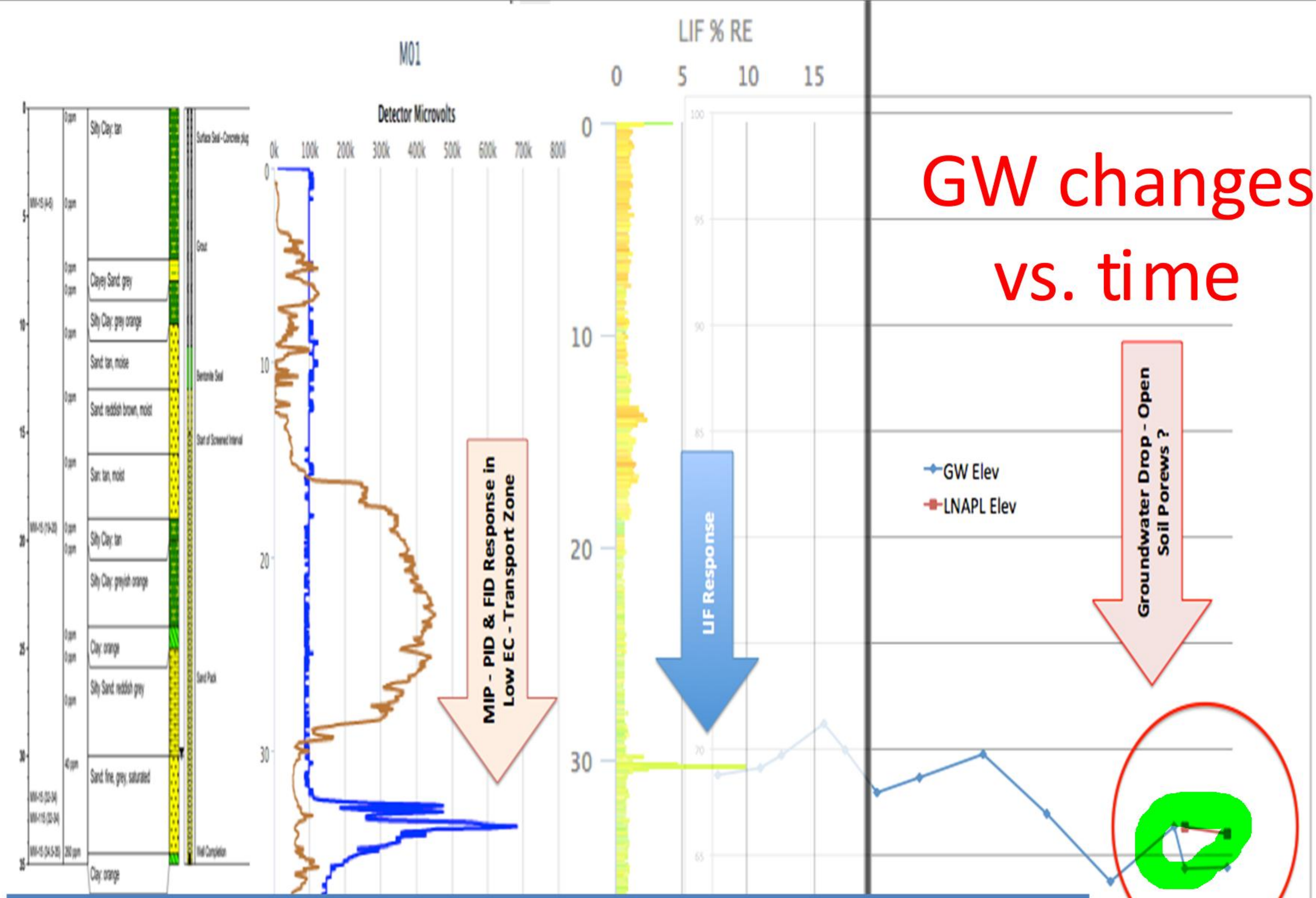




Fined Grained Soil



"Upgradient" Transect



The WATER Challenge

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Laser Mapping of Petroleum Pipeline Leakage

Pipe

NAPL Distribution

"Direction" of Groundwater Flow

$$ of Monitoring Wells

Cost-effectively characterize Contaminated sites

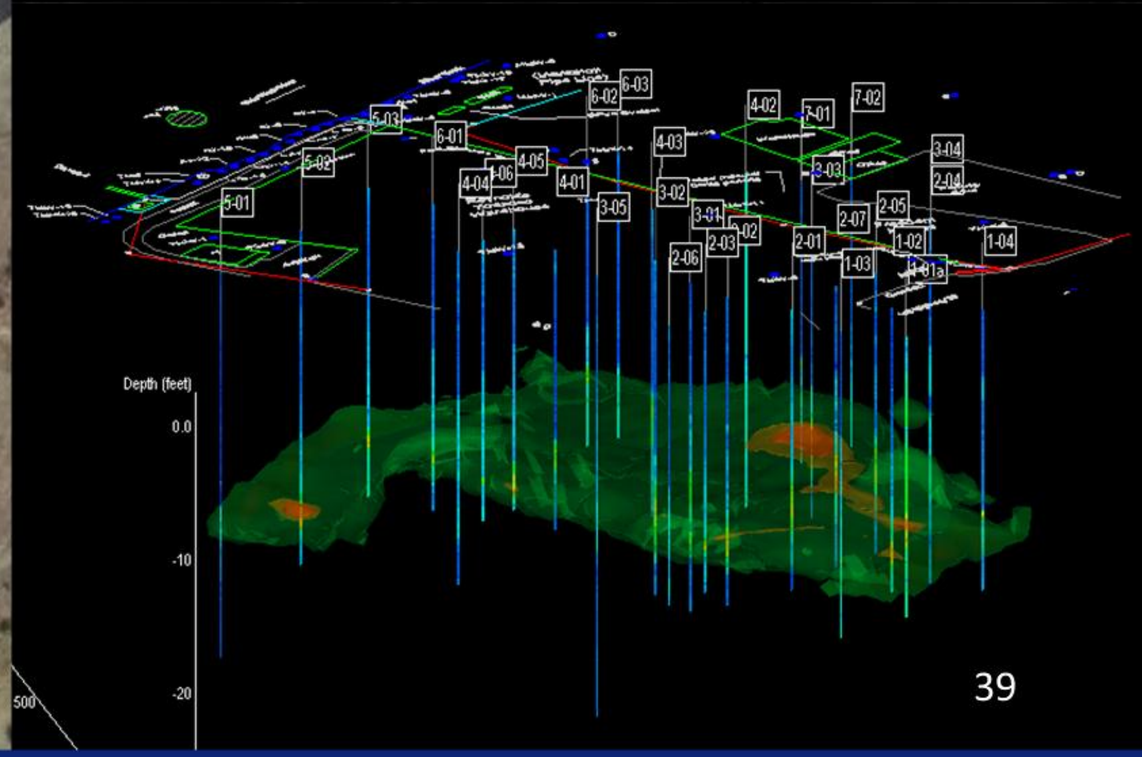
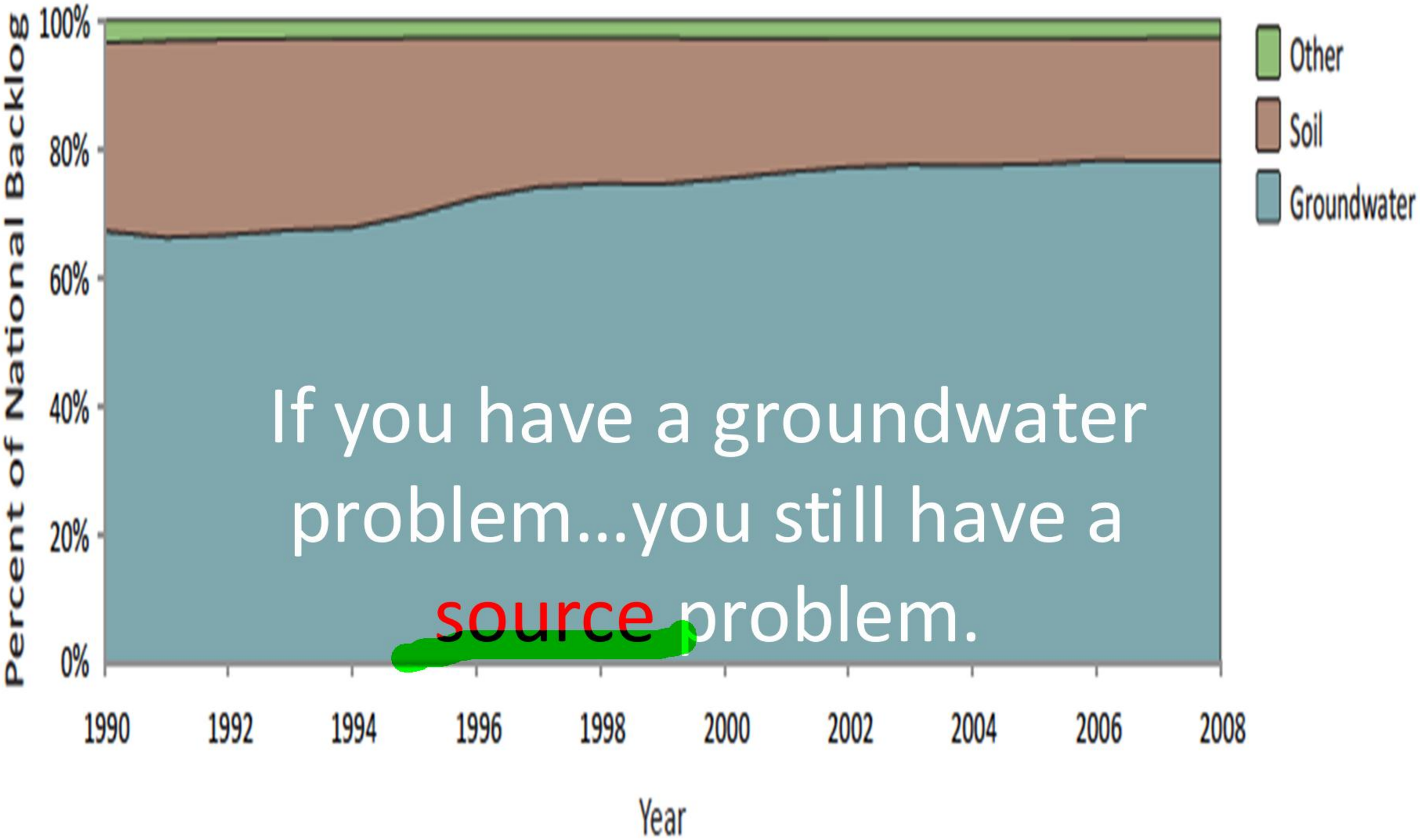


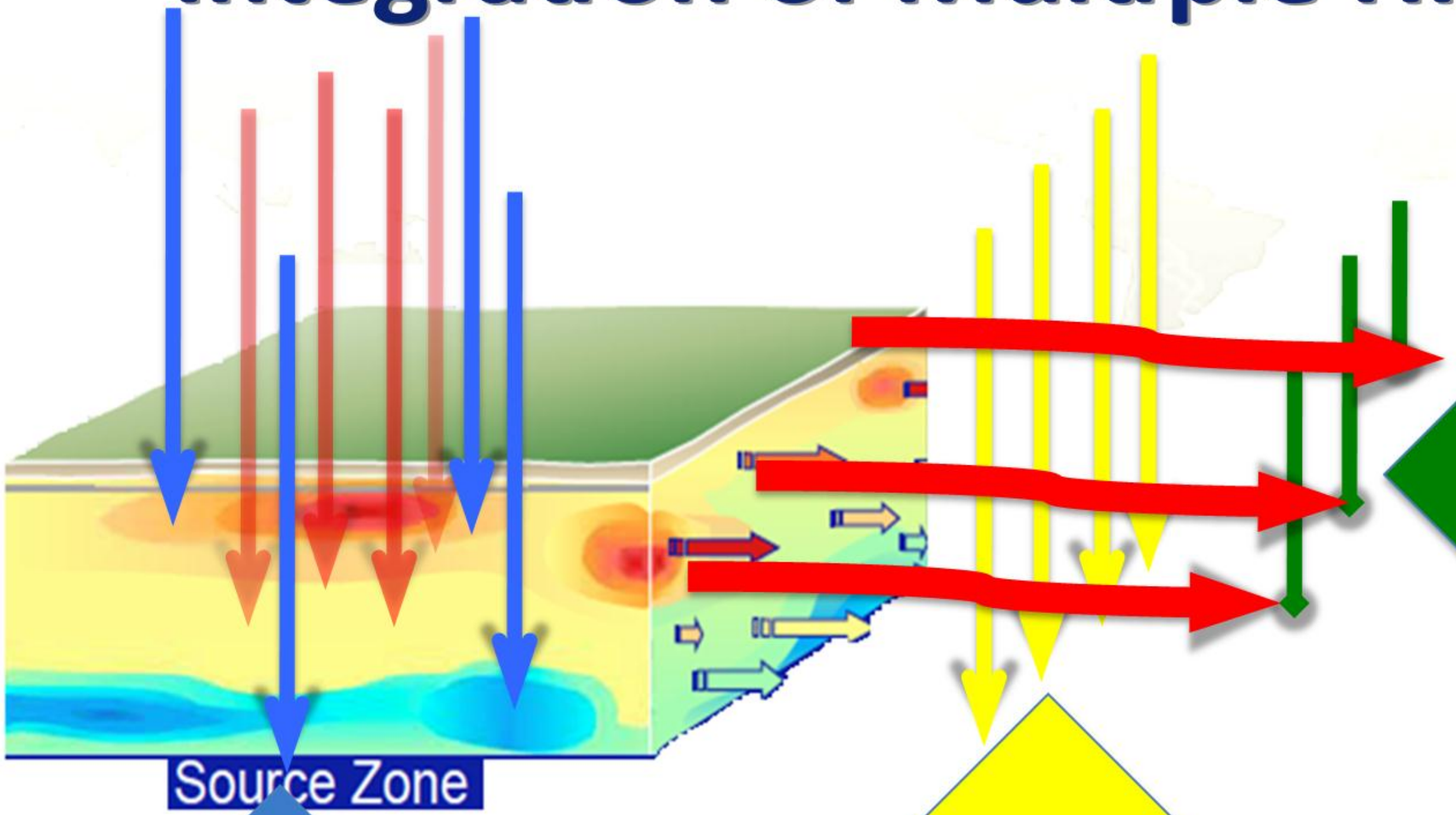
Figure 21. Distribution of Open LUST Releases per Year in 11 States, by Known Media Type (1990 – 2008)



The answer is not likely in the monitoring well.

Multiple Lines of Evidence

Integration of Multiple HRSC Tools



1. Isolate and Refine the Source Area

2. Determine pathways of permeability

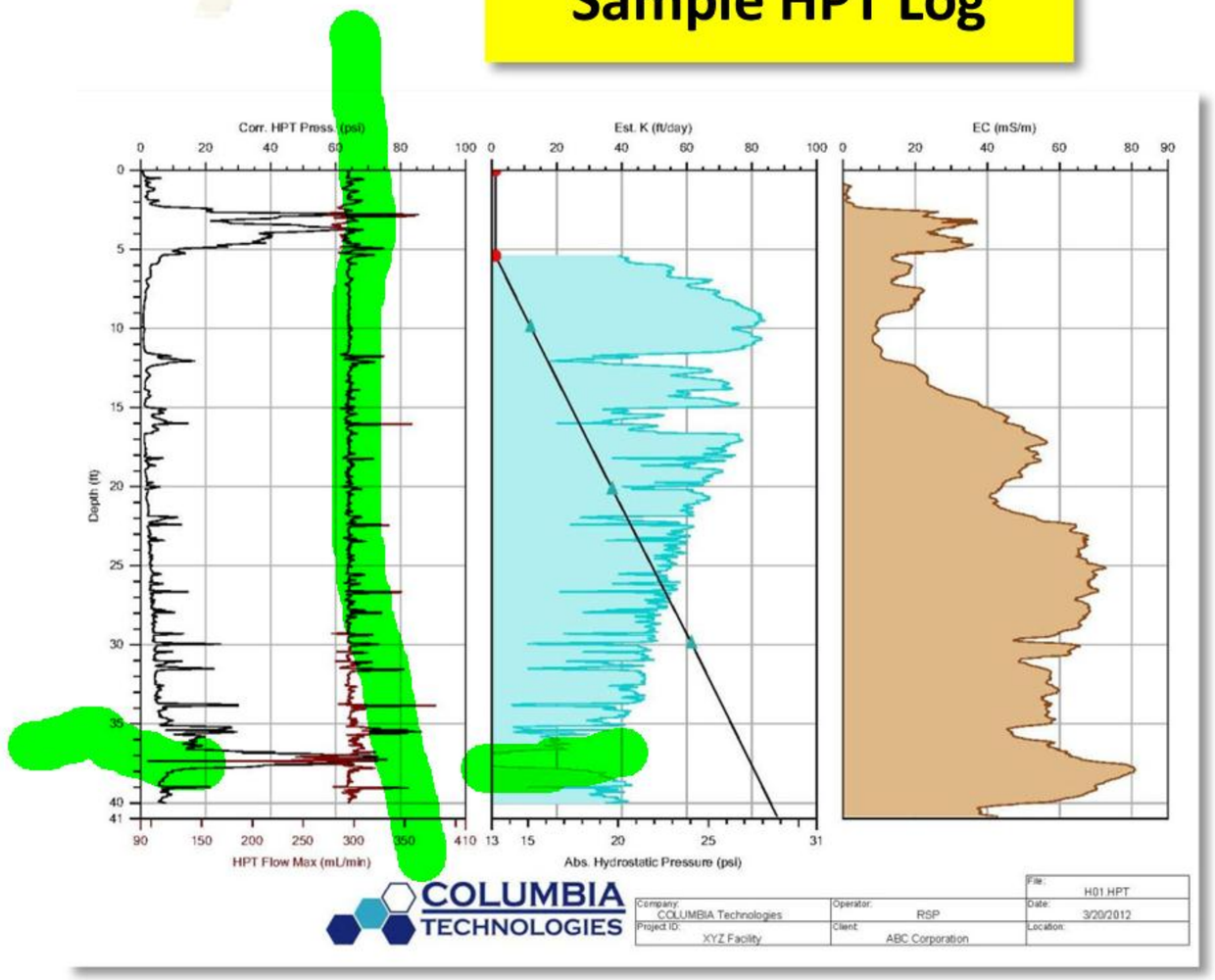
3. Sample to confirm mass and contaminant ID and remediation parameters

Hydraulic Profiling Tool (HPT)

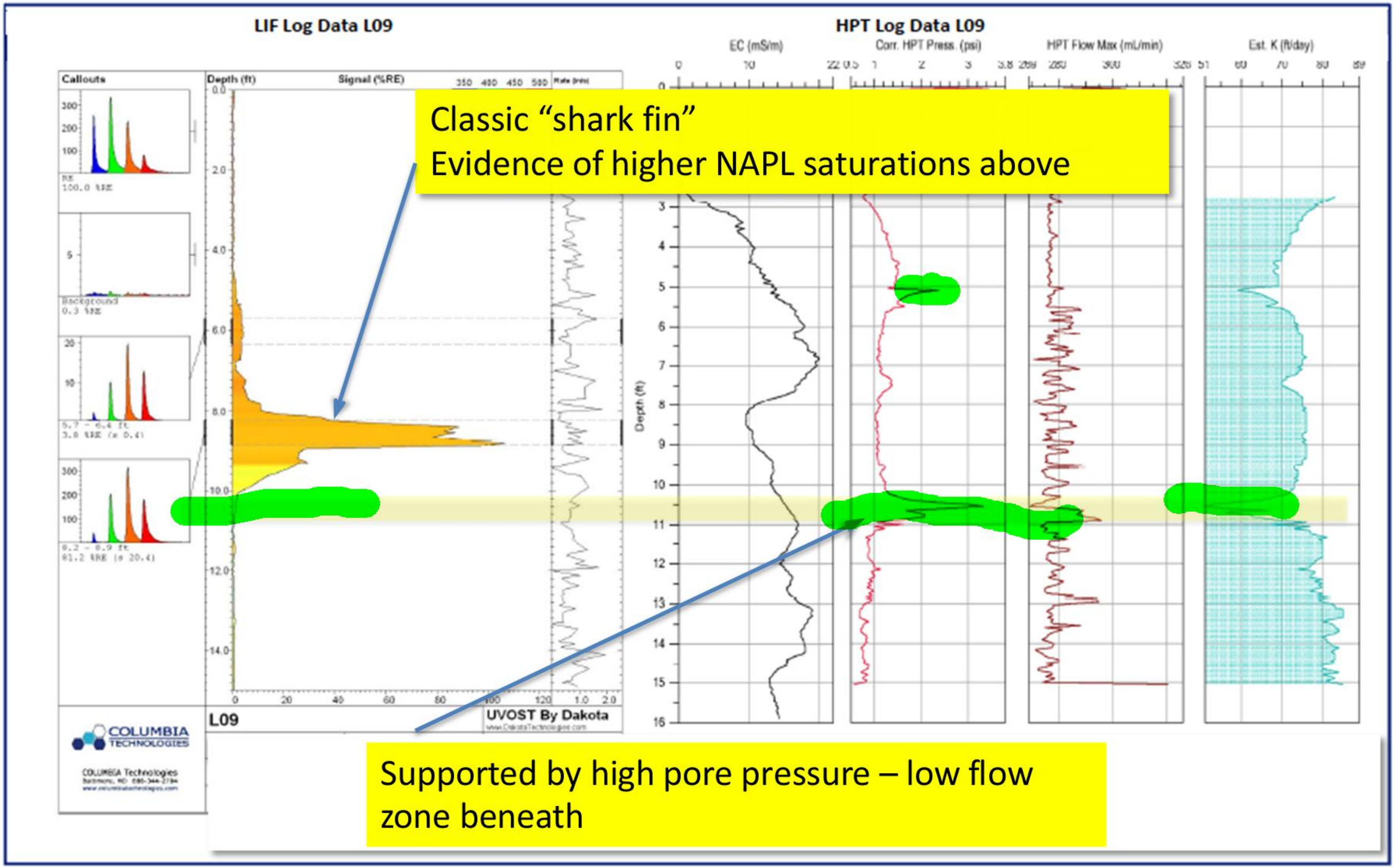
Quick Notes:

- Used to profile hydraulic pore pressure and permeability “effective K”
- Integrated EC
- Positive pressure flow of water supplied from surface
- Determine migration pathways, remediation injection regions, and placements for monitoring wells

Sample HPT Log



Combined HPT and LIF

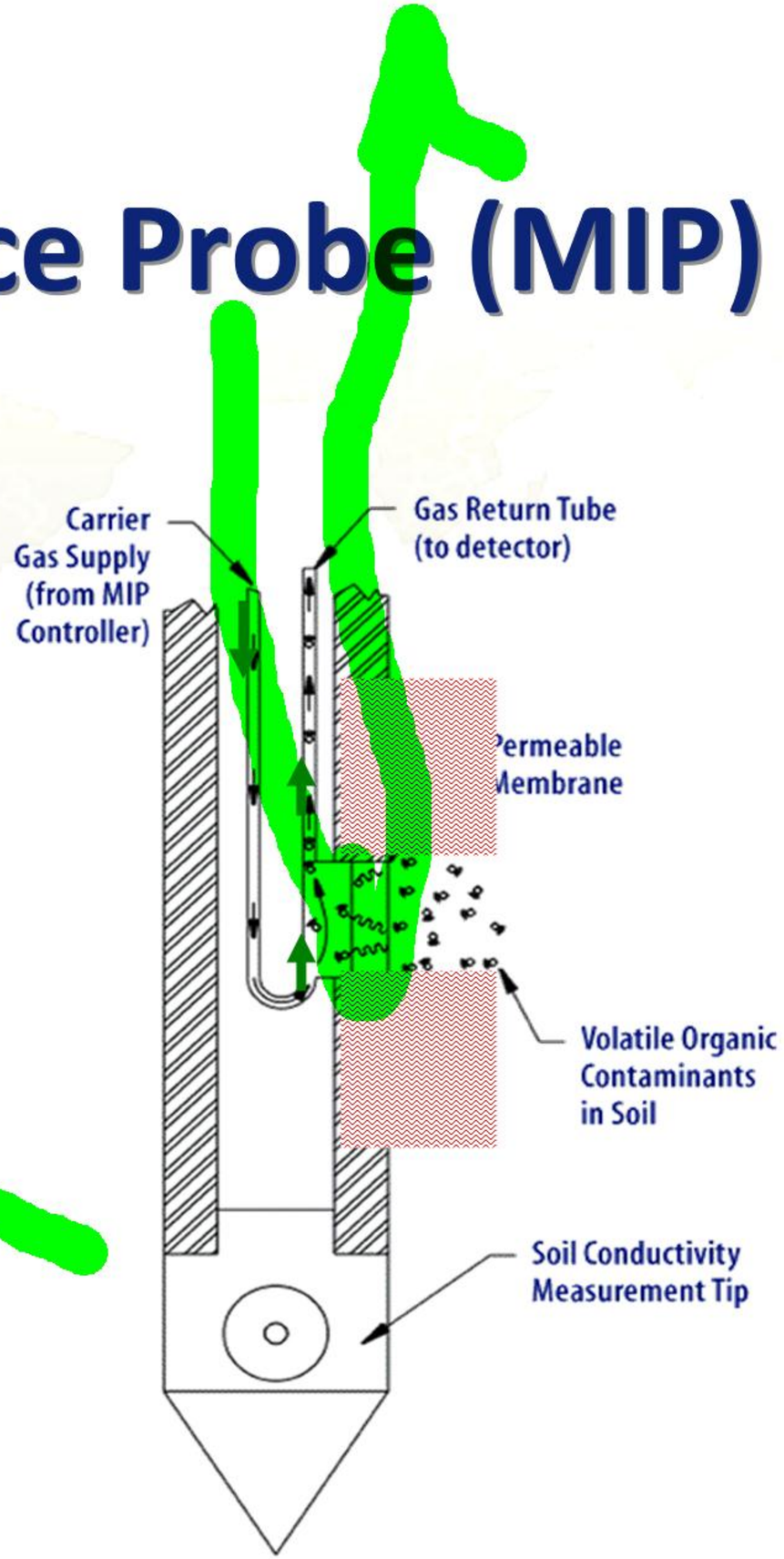


Log data collected by COLUMBIA Technologies, LLC

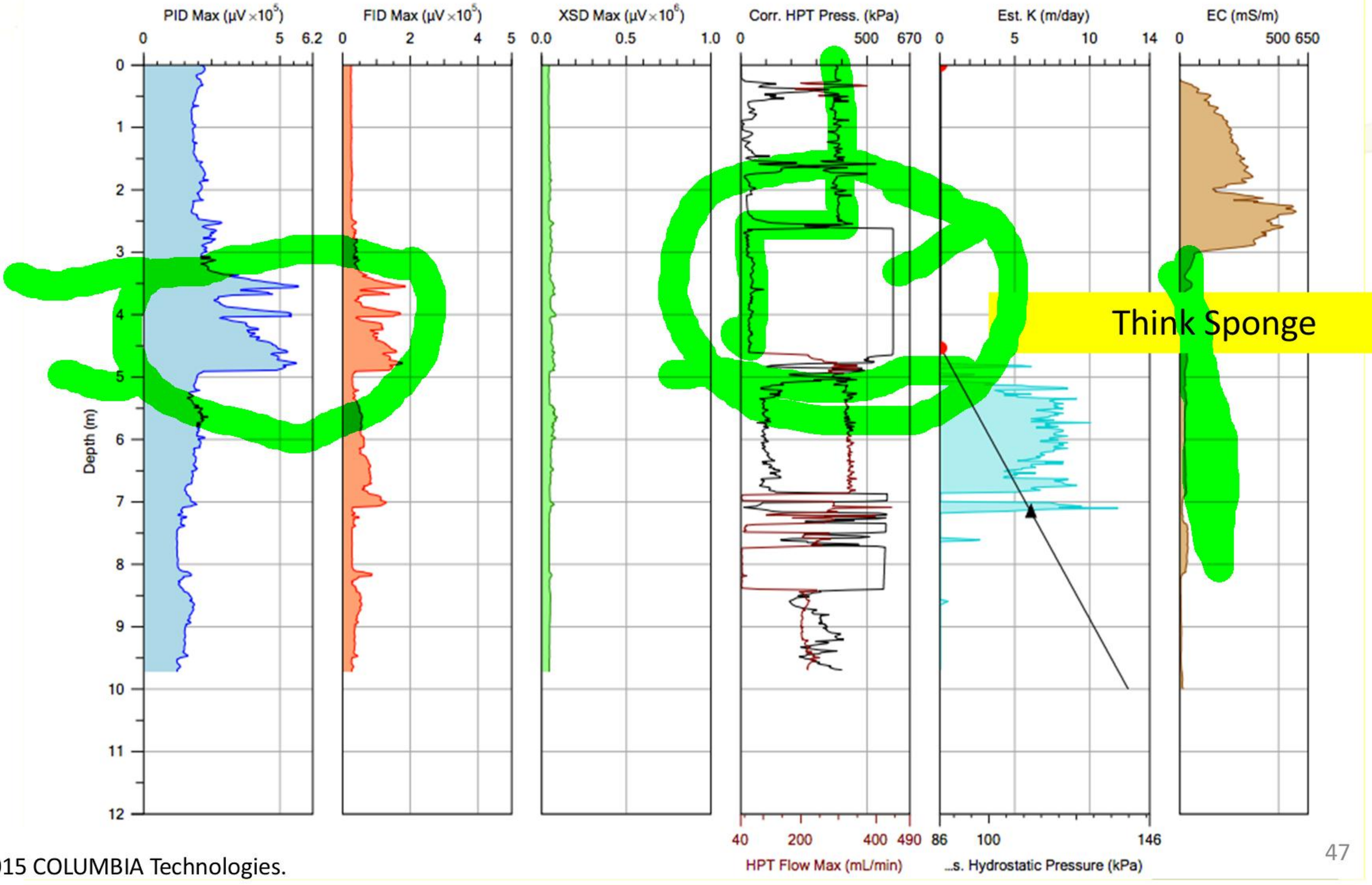
Membrane Interface Probe (MIP)

Quick Notes:

- Volatile Organic Compounds (VOCs)
- Vapor, Dissolved Phase, Sorbed Phase, some NAPL
- Typical DL: 1 ppm fuel / 200 ppb solvent (can be lower with special procedures)
- Integrated Electrical Conductivity and/or
- Hydraulic Profiling Tool
- Optional Heated Trunk Line
- Matrix effects
- Performance Test Required!



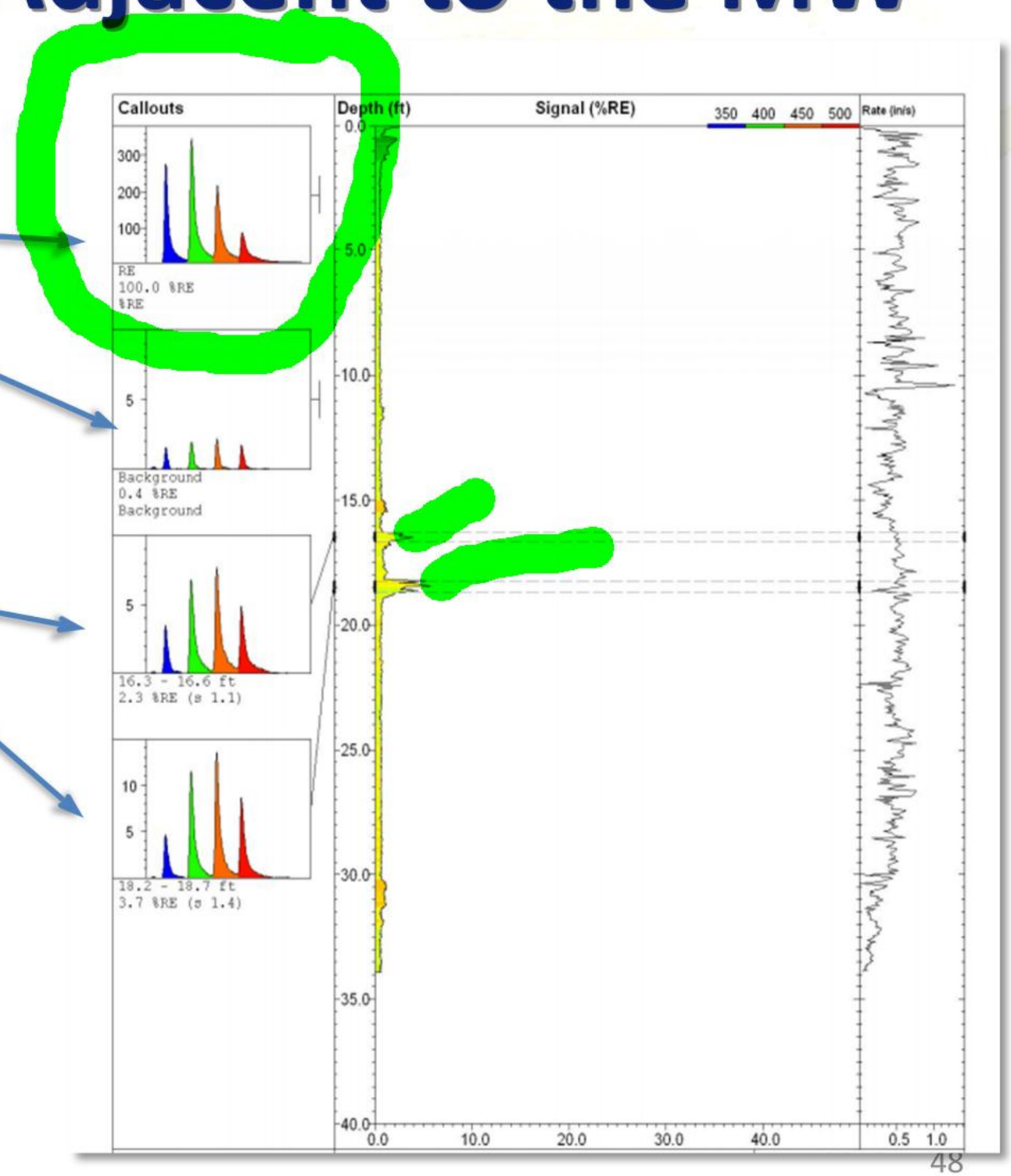
MiHPT Response to LNAPL – Unsaturated Zone



Initial LIF Profile Adjacent to the MW

Quick Notes:

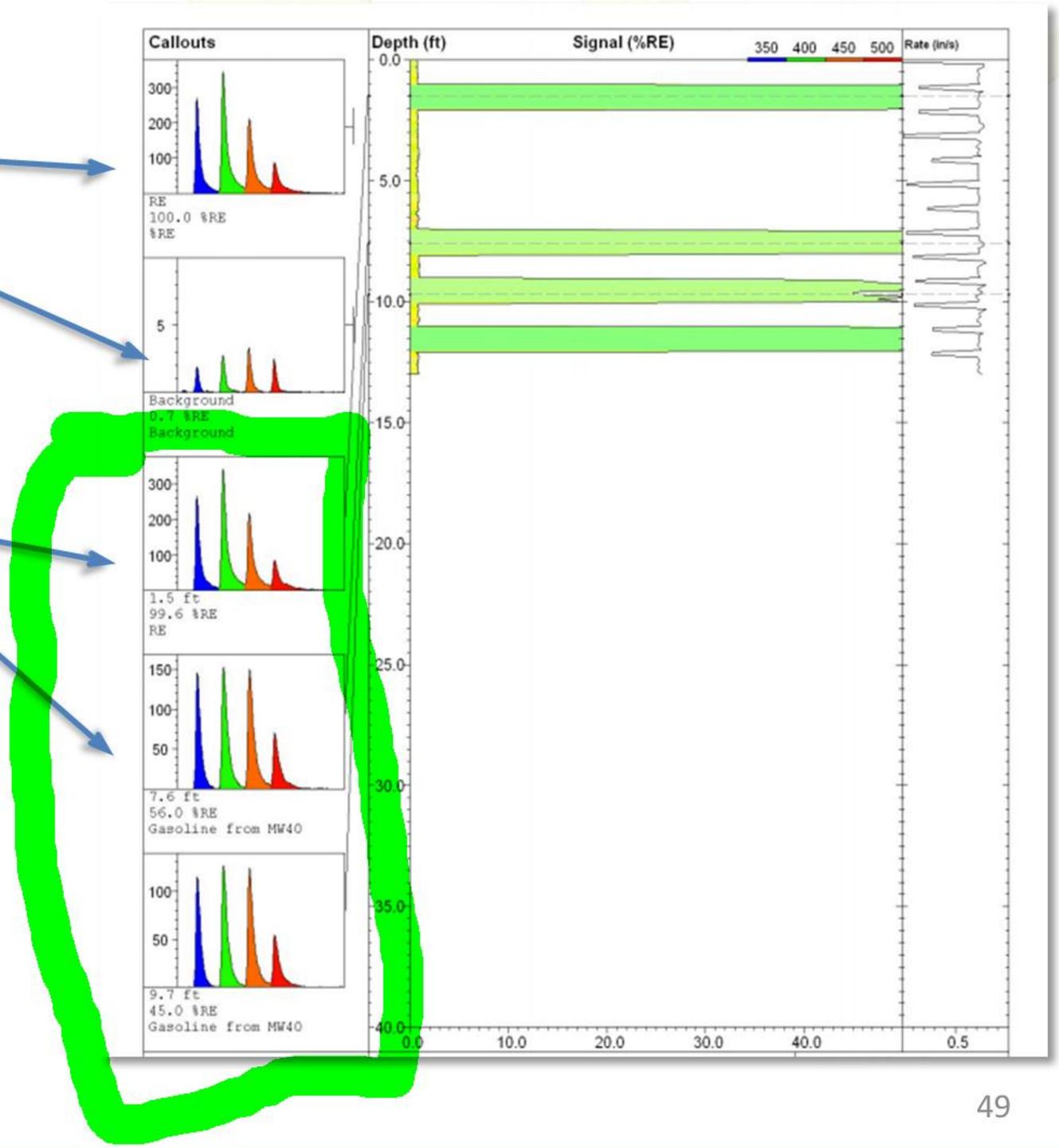
- Performance test is GOOD
- Background check is GOOD
- Material in the formation is different than performance test standard and repeatable
- Material is at 17 and 19 feet below grade



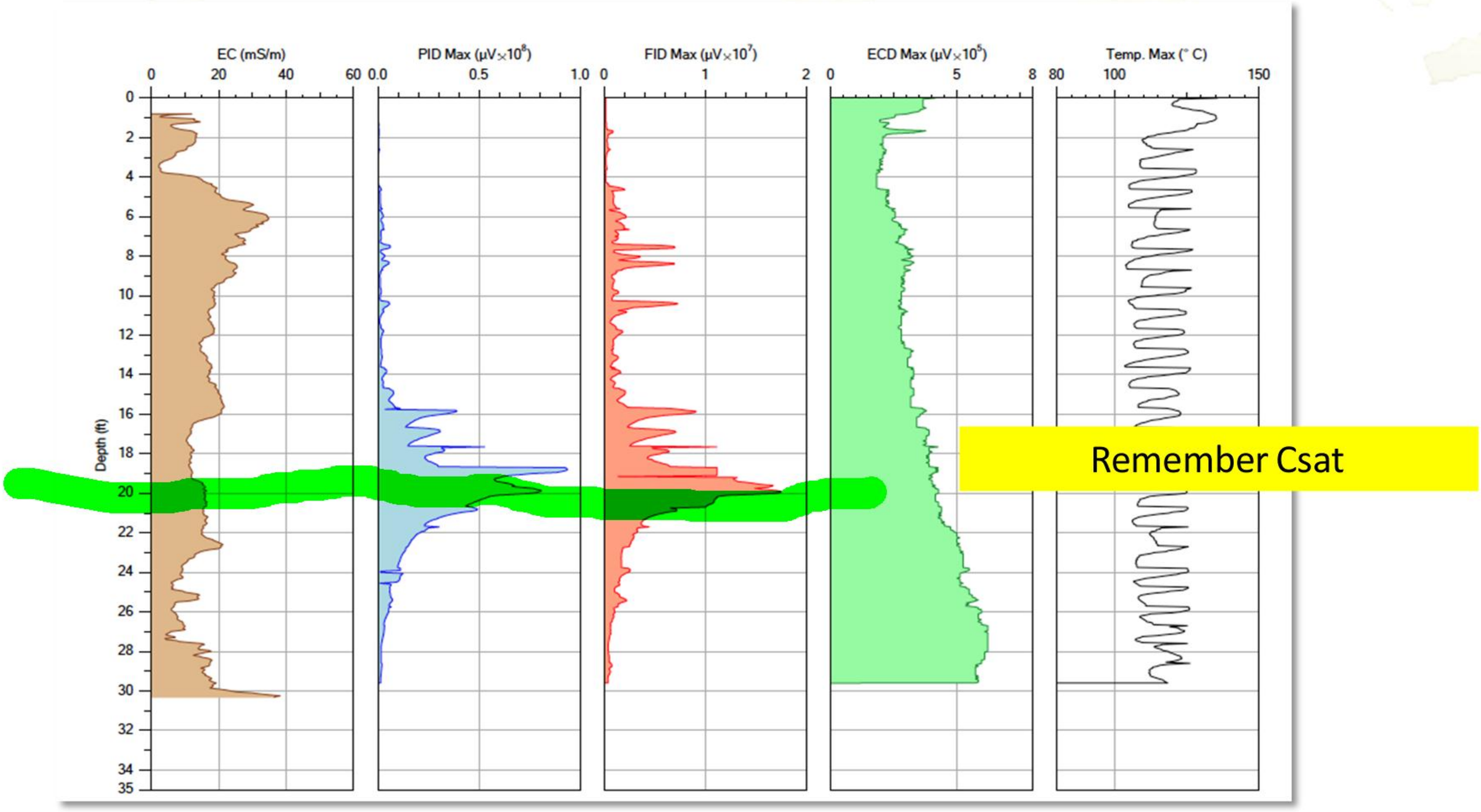
LIF Profile of Product in the MW

Quick Notes:

- Performance test is GOOD
- Background check is GOOD
- Material in the well is lighter (more fresh, less degraded) than product in the formation
- Material in the well is different than the performance test standard
- Response is repeatable



MIP Response Adjacent to the MW



The answer is not likely in the monitoring well.

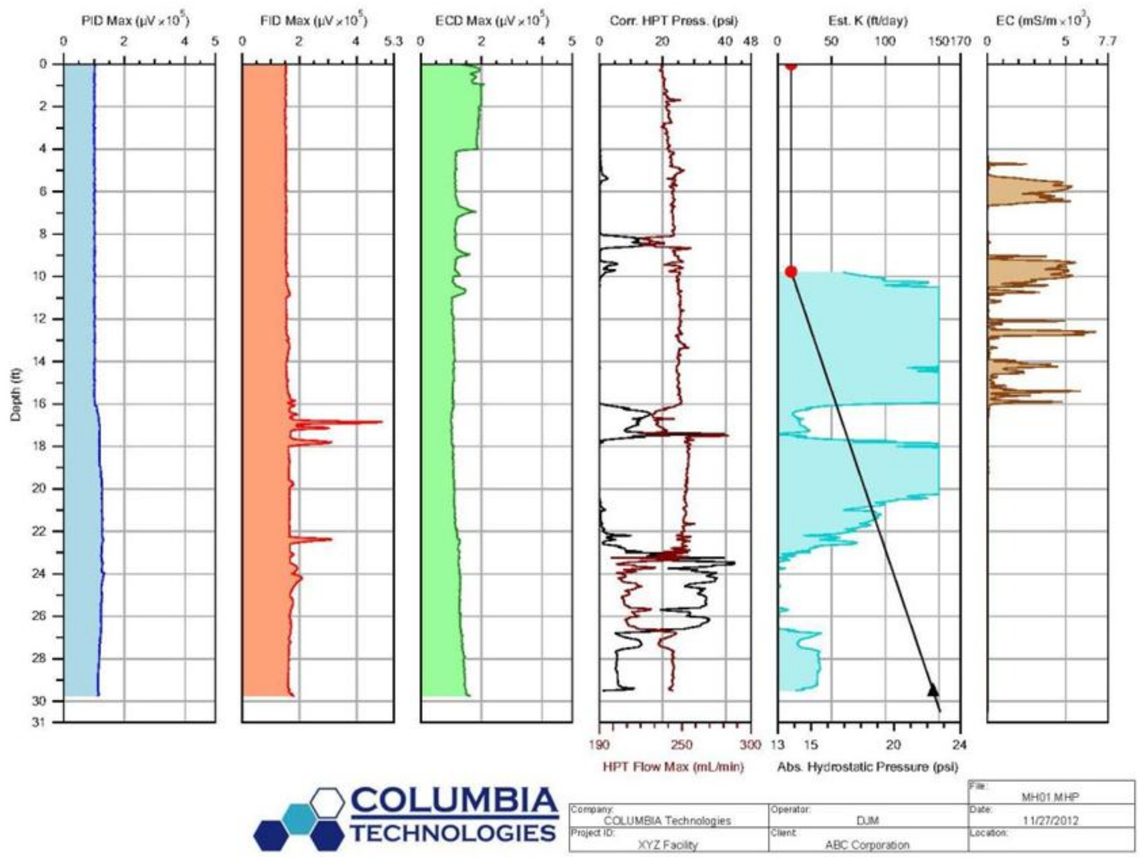
Combination Membrane Interface Probe-Hydraulic Profiling Tool (MiHPT)

Combined MIP-HPT Probe – multiple lines of evidence in the same push!

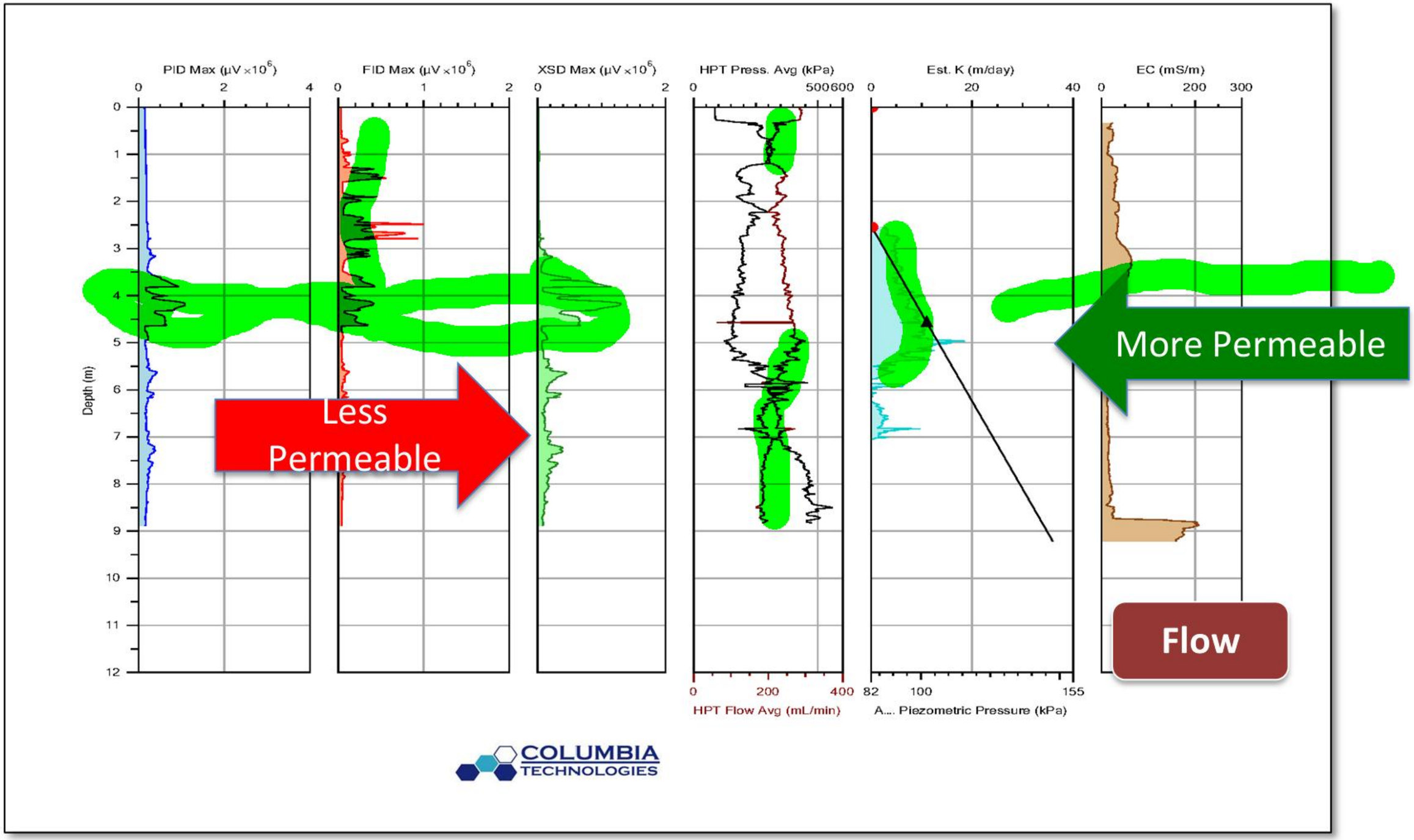
- Contaminant distribution of VOCs
- Measurements of EC
- HPT pore pressure and Effective “K”

Probable storage **zone**

Sample MiHpt Log

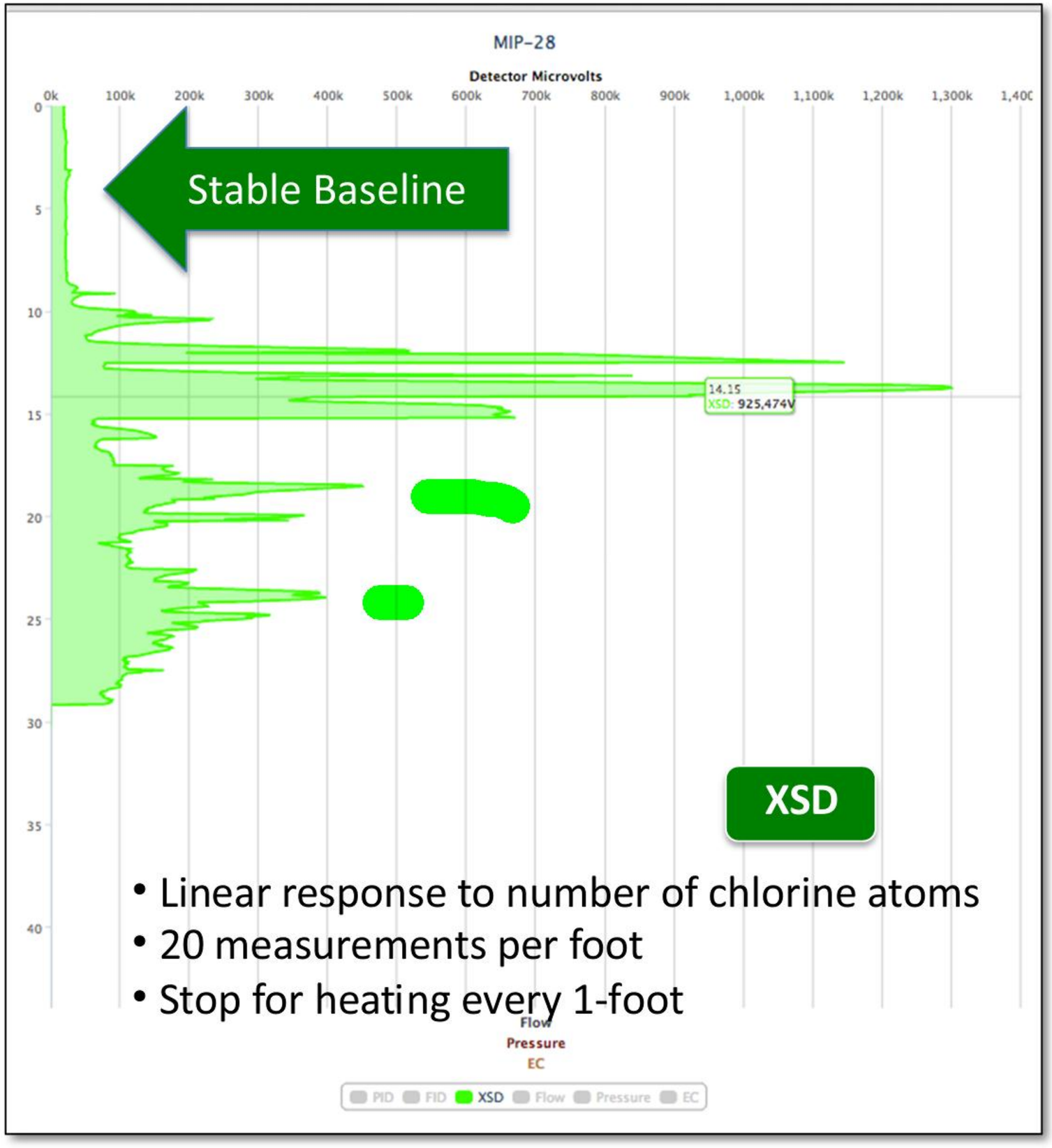


Standard MiHpt Profile with Estimated "K"



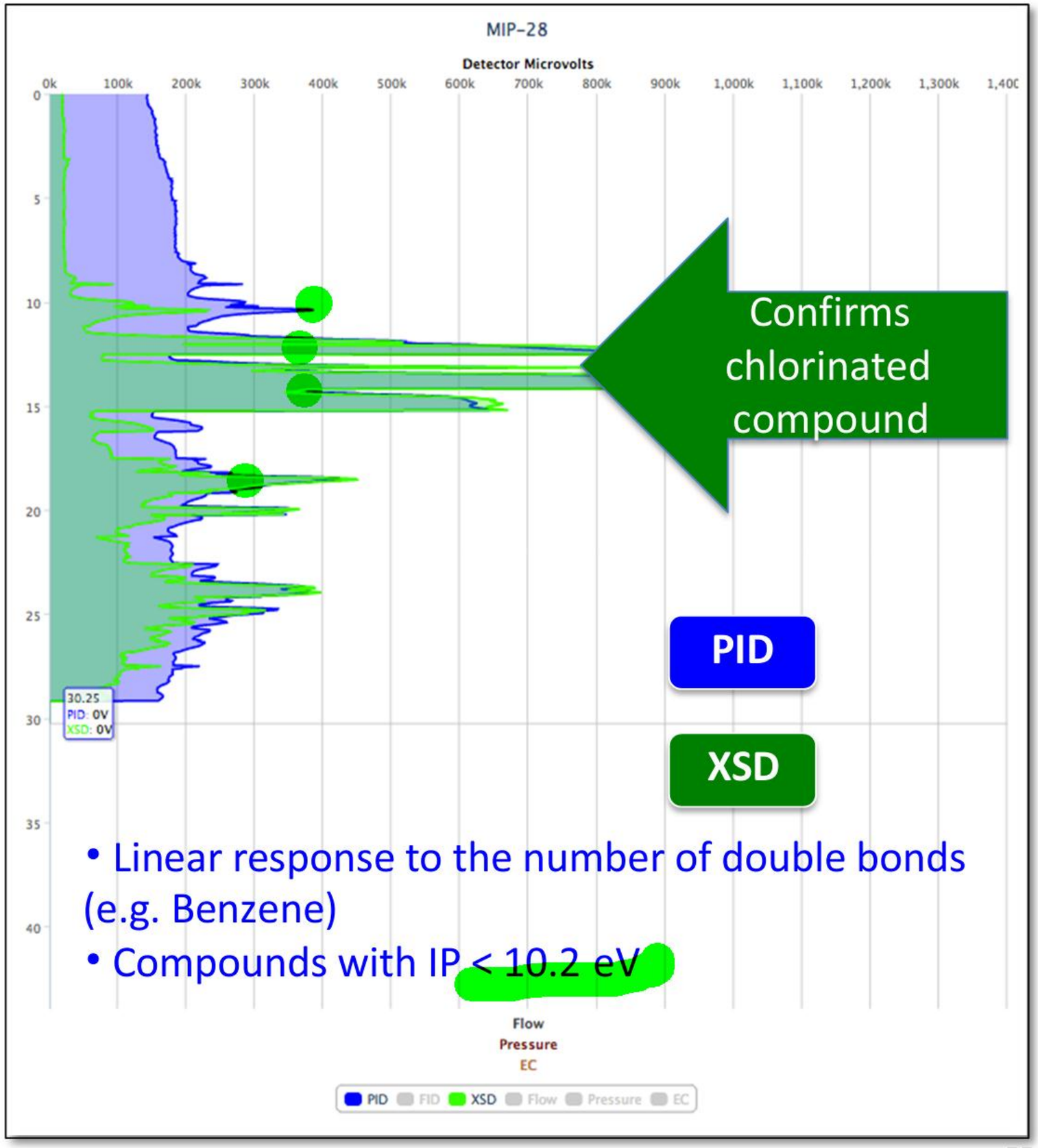
Membrane Interface Probe (MIP)

Halogen Specific Detector (XSD)



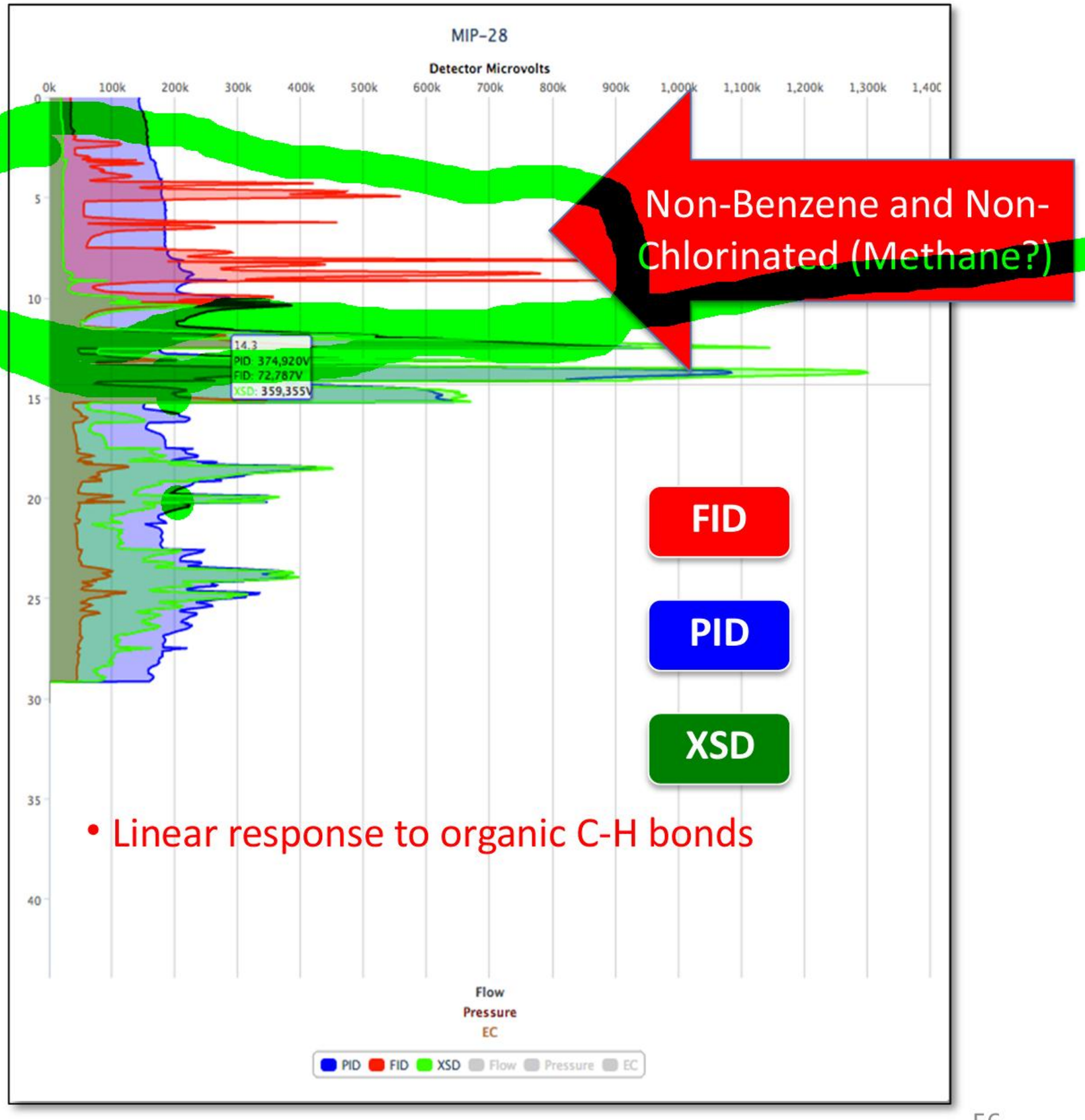
Membrane Interface Probe (MIP)

Photo Ionization Detector (PID)



Membrane Interface Probe (MIP)

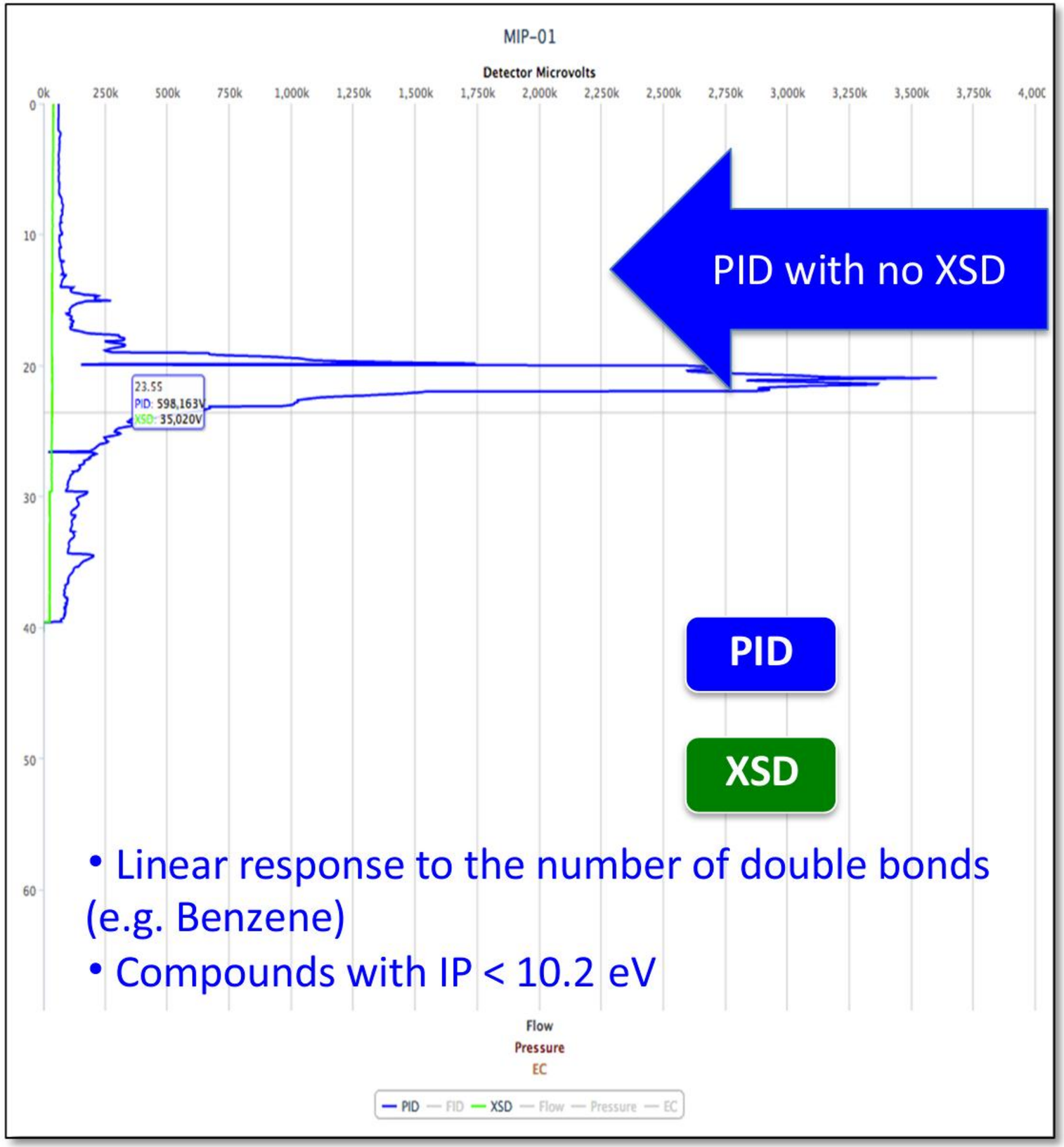
Flame Ionization Detector (FID)



- Linear response to organic C-H bonds

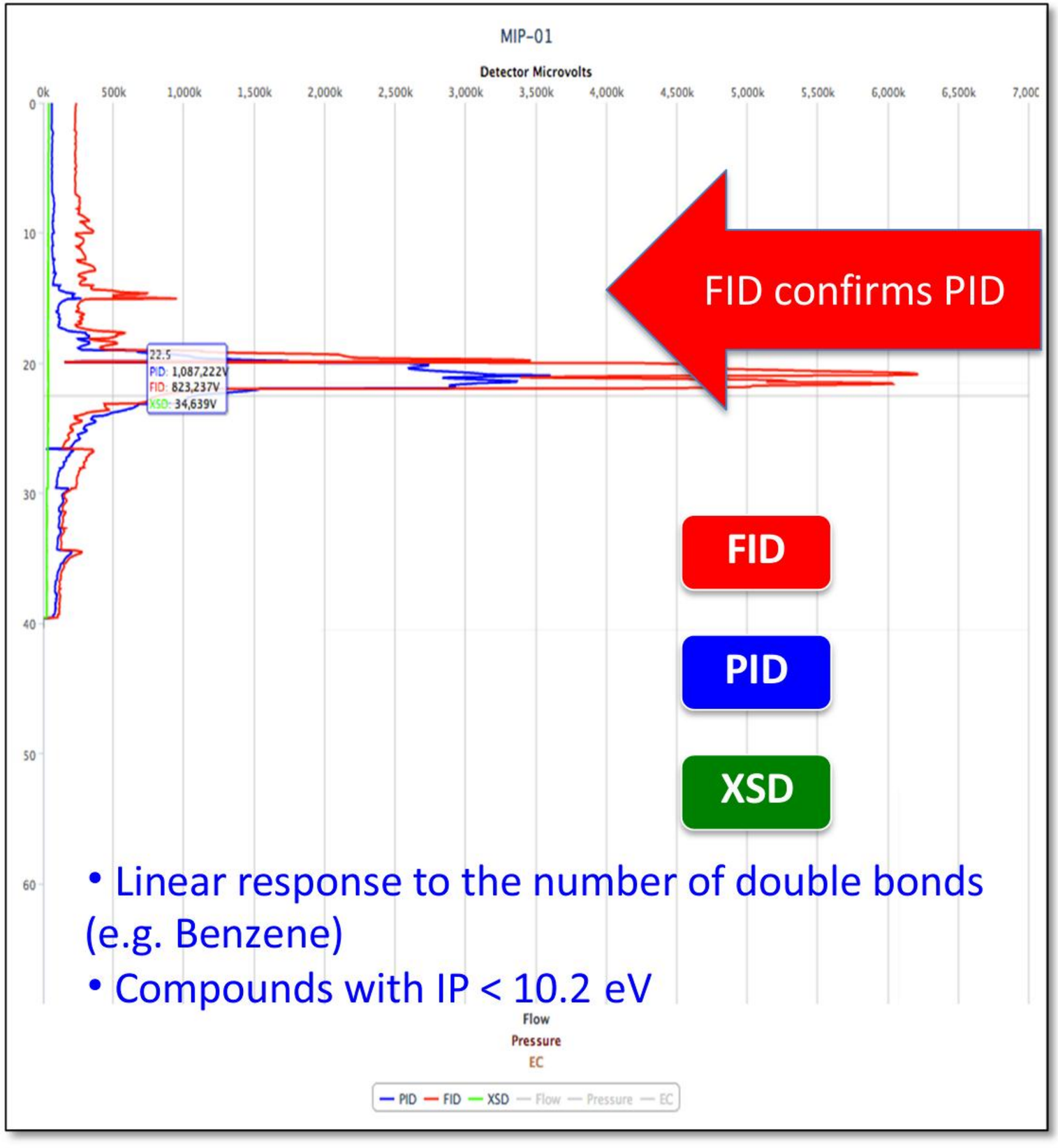
Membrane Interface Probe (MIP)

Photo Ionization Detector (PID)

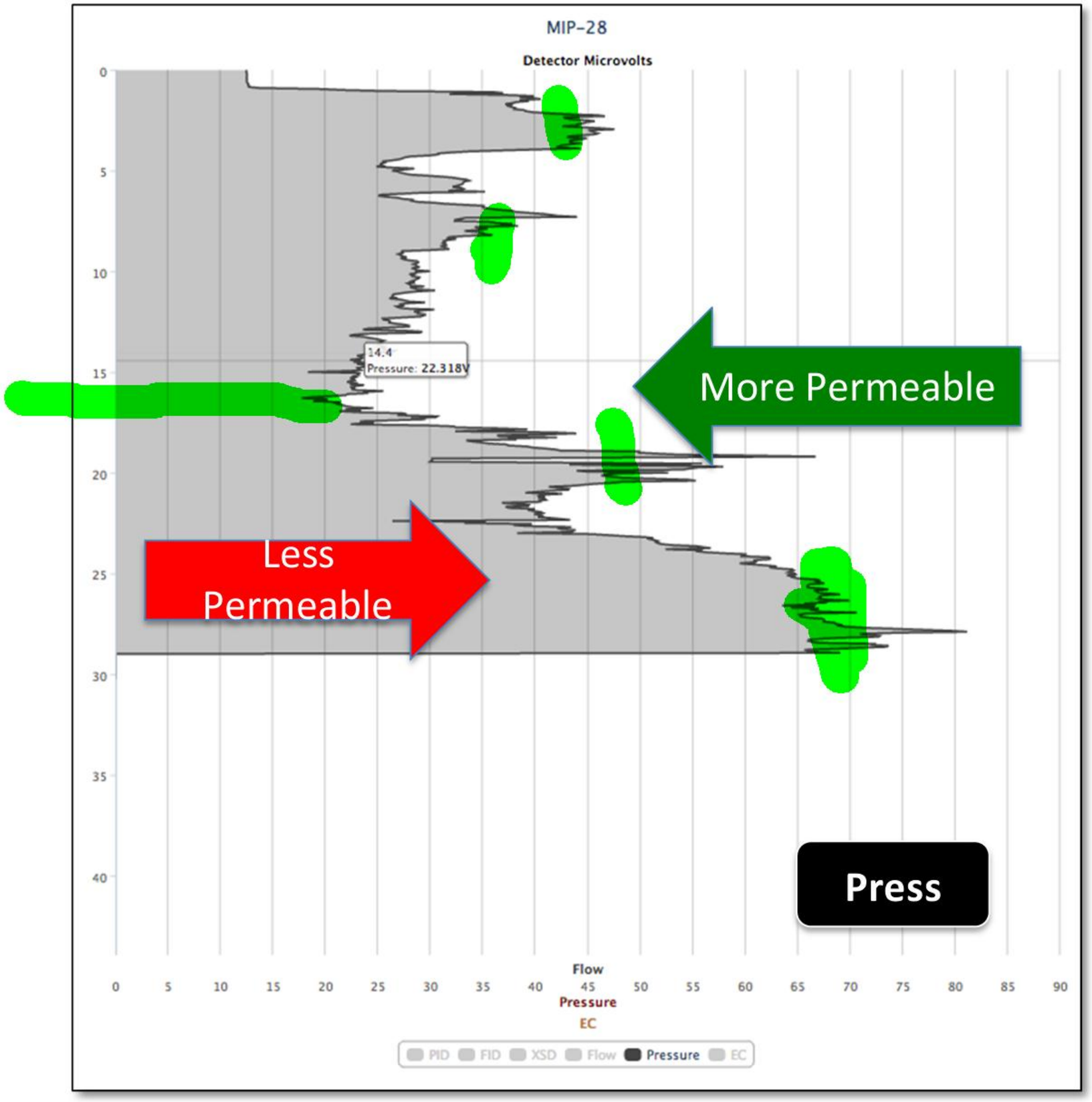


Membrane Interface Probe (MIP)

PID + FID

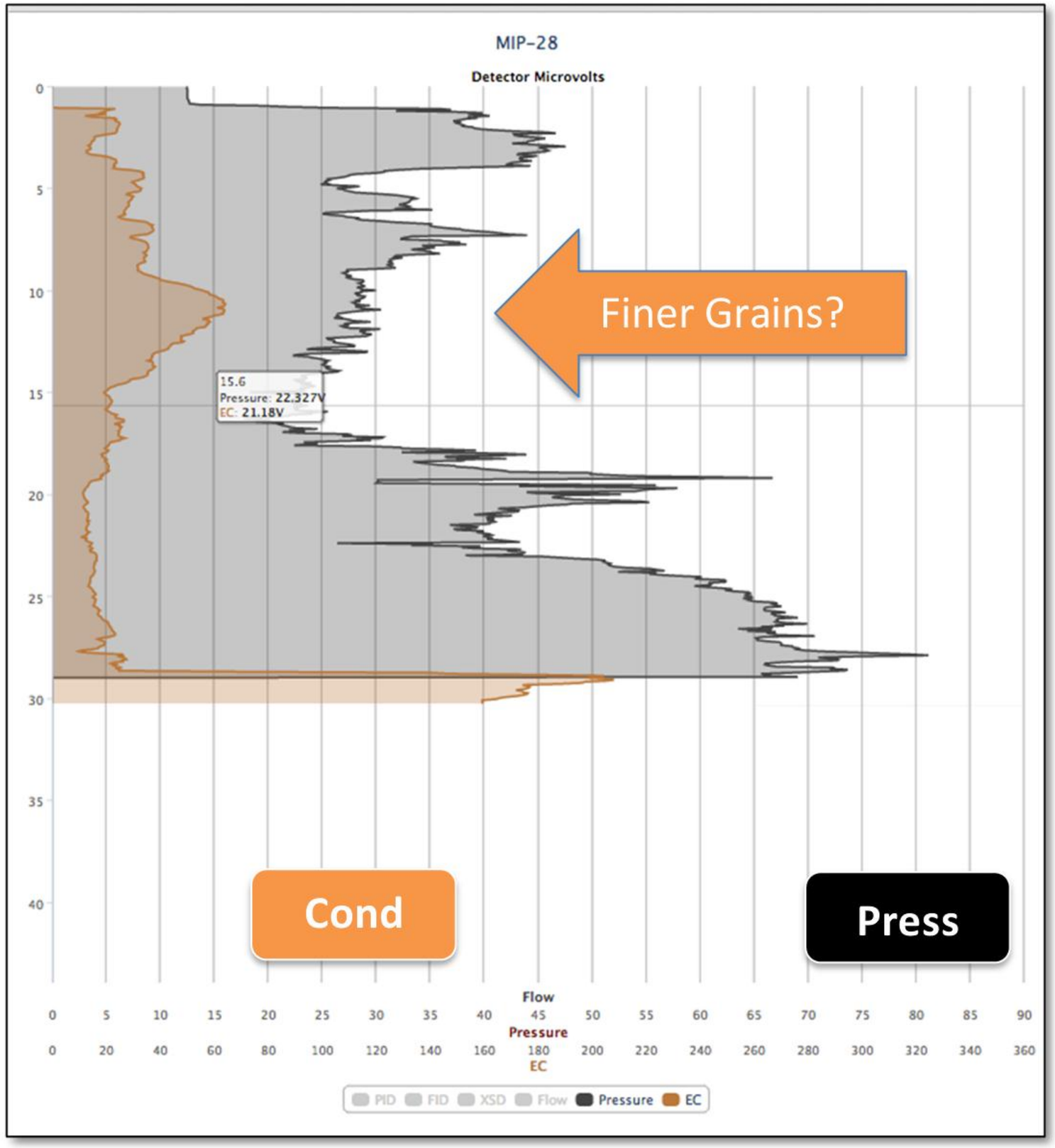


Hydraulic Profiling Tool (HPT) Hydraulic Pore Pressure

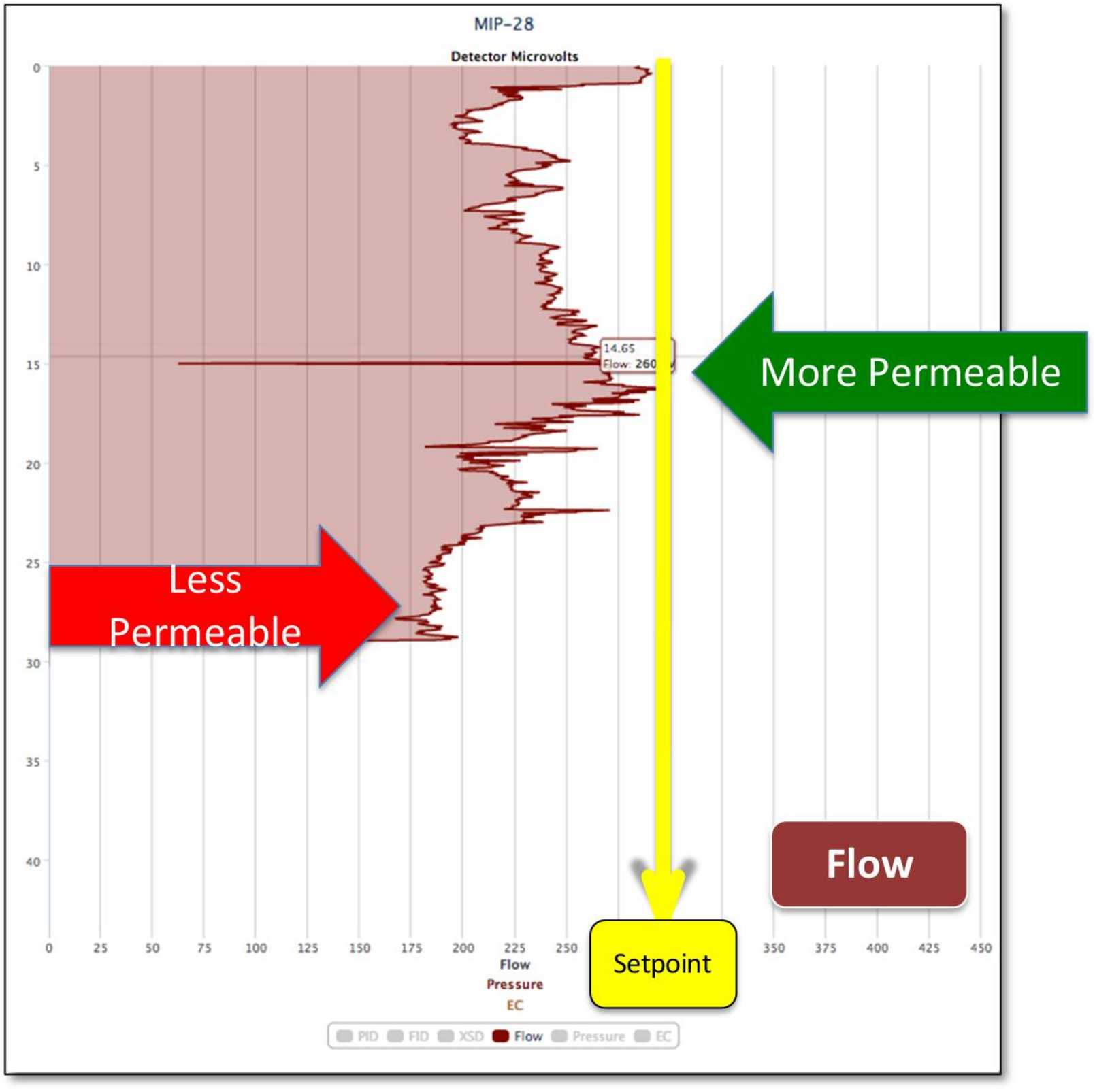


Hydraulic Profiling Tool (HPT)

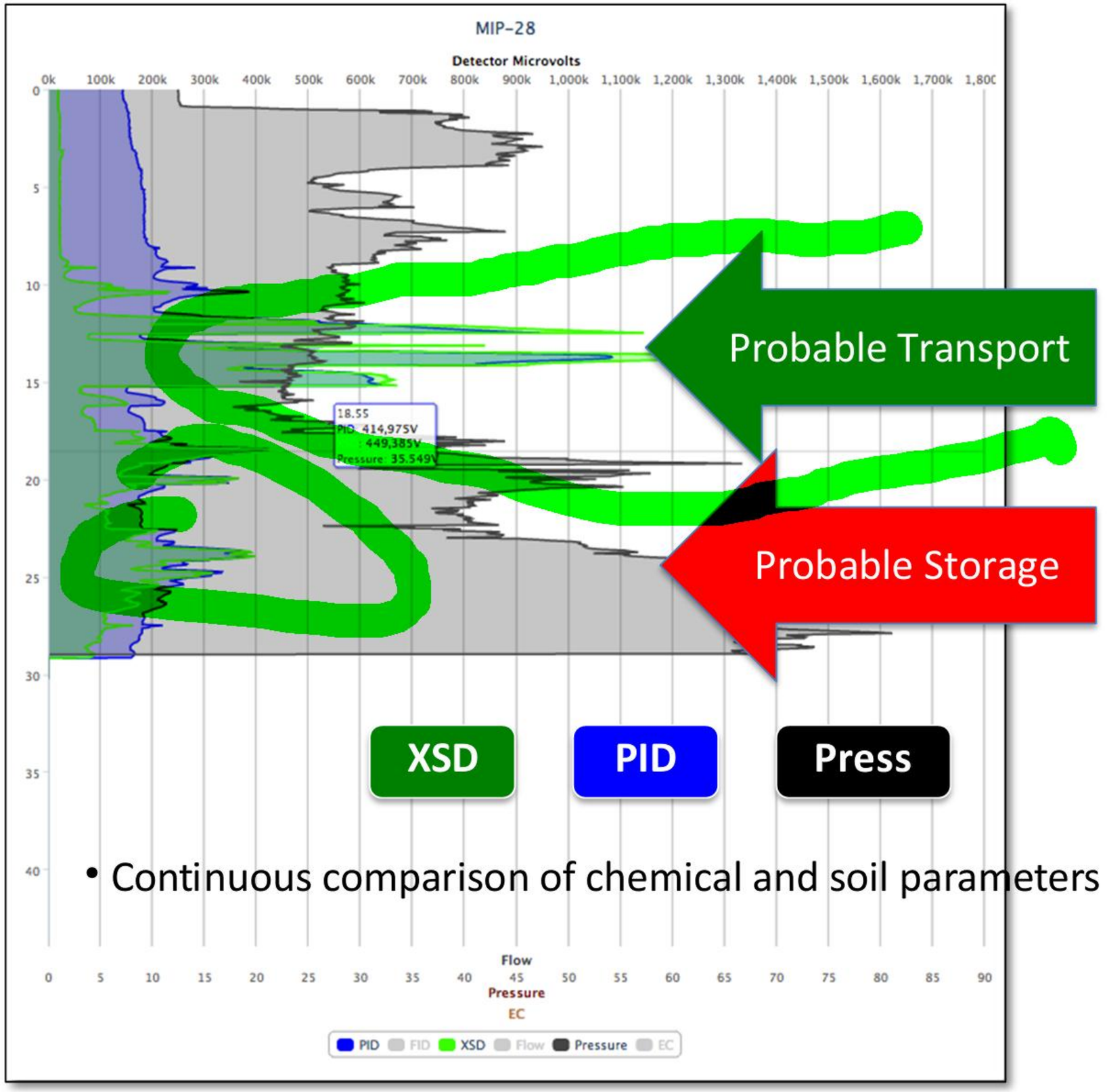
Electrical Conductivity and Hydraulic Pore Pressure



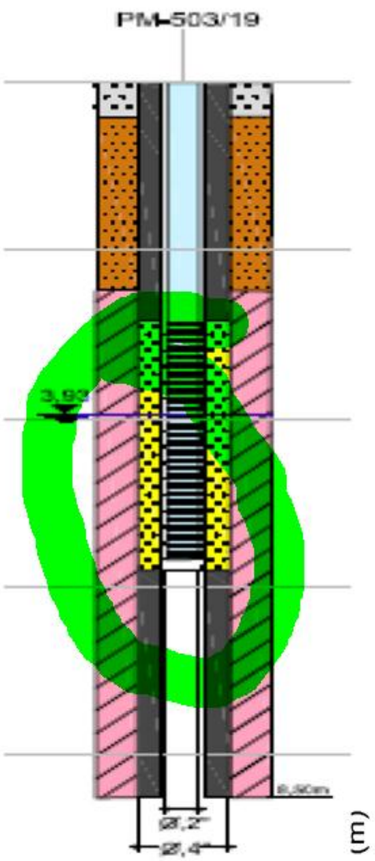
Hydraulic Profiling Tool (HPT) Hydraulic Flow



Combined Membrane Interface Probe and Hydraulic Profiling Tool (MiHpt)



- Continuous comparison of chemical and soil parameters



PID Max (µV x10⁵)

0.0 0.5 1.0 1.6

XSD Max (µV x10⁵)

0.1 5 8.1

HPT Press. Avg (kPa)

90 200 400 600 750

EC (mS/m)

0 20 40 58

Depth (m)

0 2 4 6 8 10 12 14 16 18 19

0.2 0.5 1.0 1.5

FID Max (µV x10⁵)

0 5 10

Est. K (m/day)

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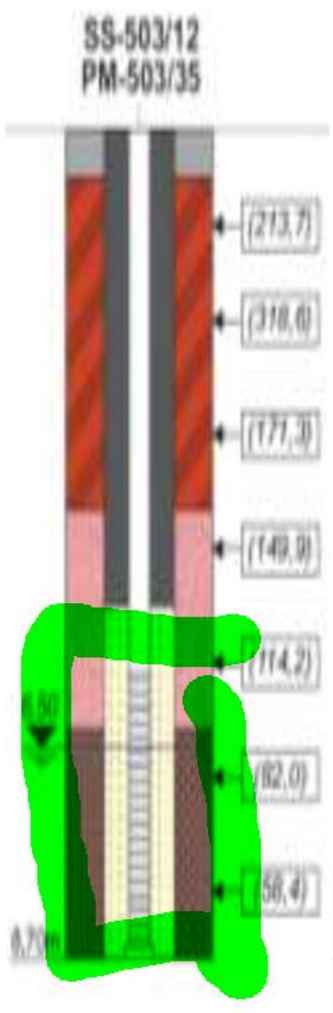
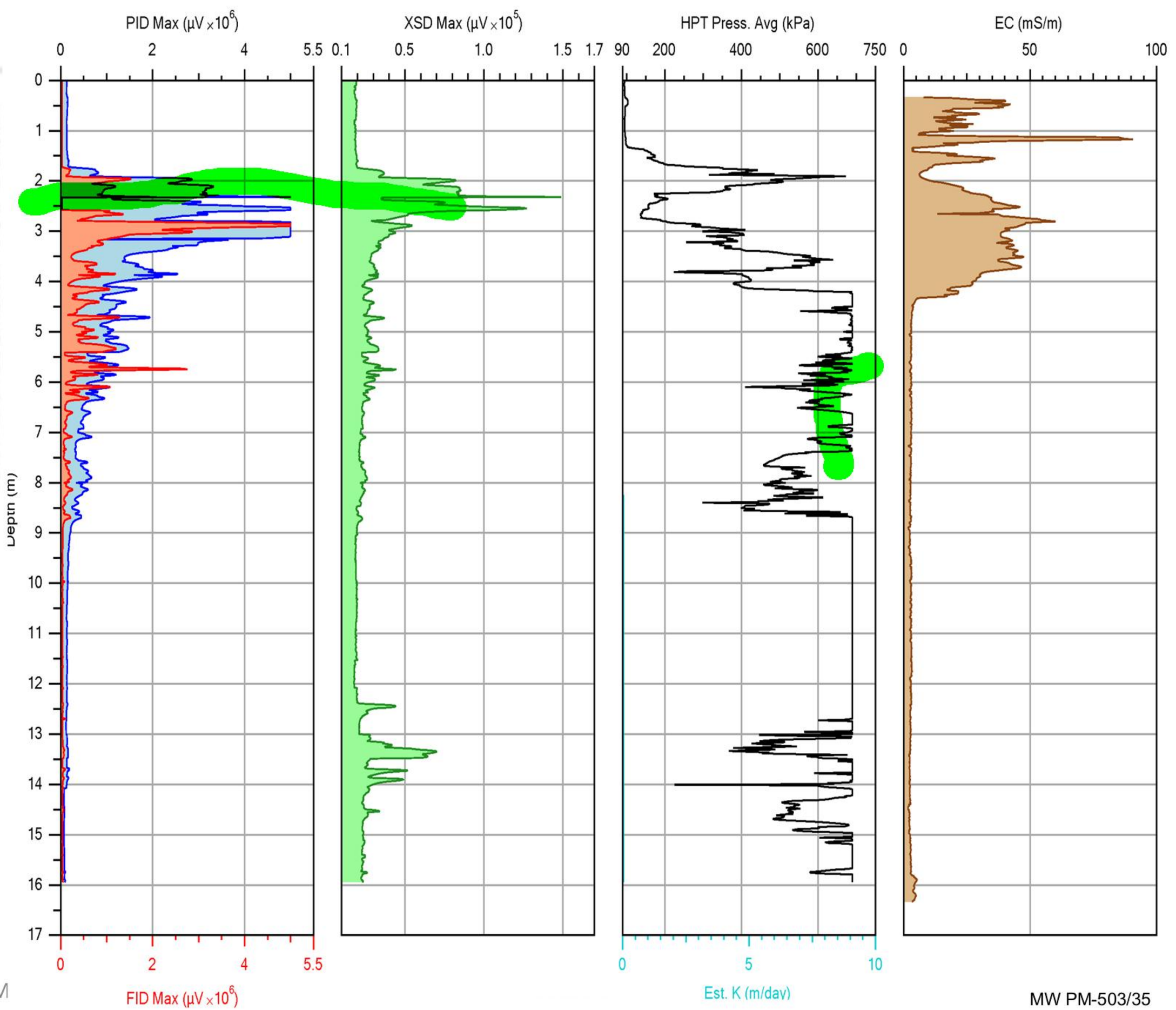
MW PM-503/19

File: MIHPT-02.MHP

Date:





MW PM-503/35

File:
MIHPT-03.MHP

SS-503/11
PMM-503/30.1

(0,0)
(0,3)
(0,2)
(0,6)
(0,1)
(0,3)
(0,5)
(8,5)

7,00

17,5m
18,2m

PID Max (μV x10^5)

0.6 1.0 1.5 2.0 2.5

XSD Max (μV x10^4)

1.4 4 6 8.6

HPT Press. Avg (kPa)

90 200 400 600 750

EC (mS/m)

0 10 20 30 35

Depth (m)

0 2 4 6 8 10 12 14 16 18 20

0.2 0.5 1.0 1.5

FID Max (μV x10^5)

0 2 4 6.1

Est. K (m/day)

MW PM-503/30.1

File: MIHPT-04.MHP

SS-503/11
PMM-503/30.1

(0,0)
(0,3)
(0,2)
(0,6)
(0,1)
(0,3)
(0,5)
(8,5)

7,00

17,5m
18,2m

PID Max (μV x10^5)

0.6 1.0 1.5 2.0 2.5

XSD Max (μV x10^4)

1.4 4 6 8.6

HPT Press. Avg (kPa)

90 200 400 600 750

EC (mS/m)

0 10 20 30 35

Depth (m)

0 2 4 6 8 10 12 14 16 18 20

0.2 0.5 1.0 1.5

FID Max (μV x10^5)

0 2 4 6.1

Est. K (m/day)

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ARAGON Perfurações e Sondagens

MW PM-503/30.1

File:
MIHPT-04.MHP

The answer is not likely in the monitoring well.

Starting with The “Monitoring” Well

Situation:

- Historical release
- Multiple MWs installed
- New or recurring free product thickness (1.5-ft) in one or more wells
- Investigate for unidentified source

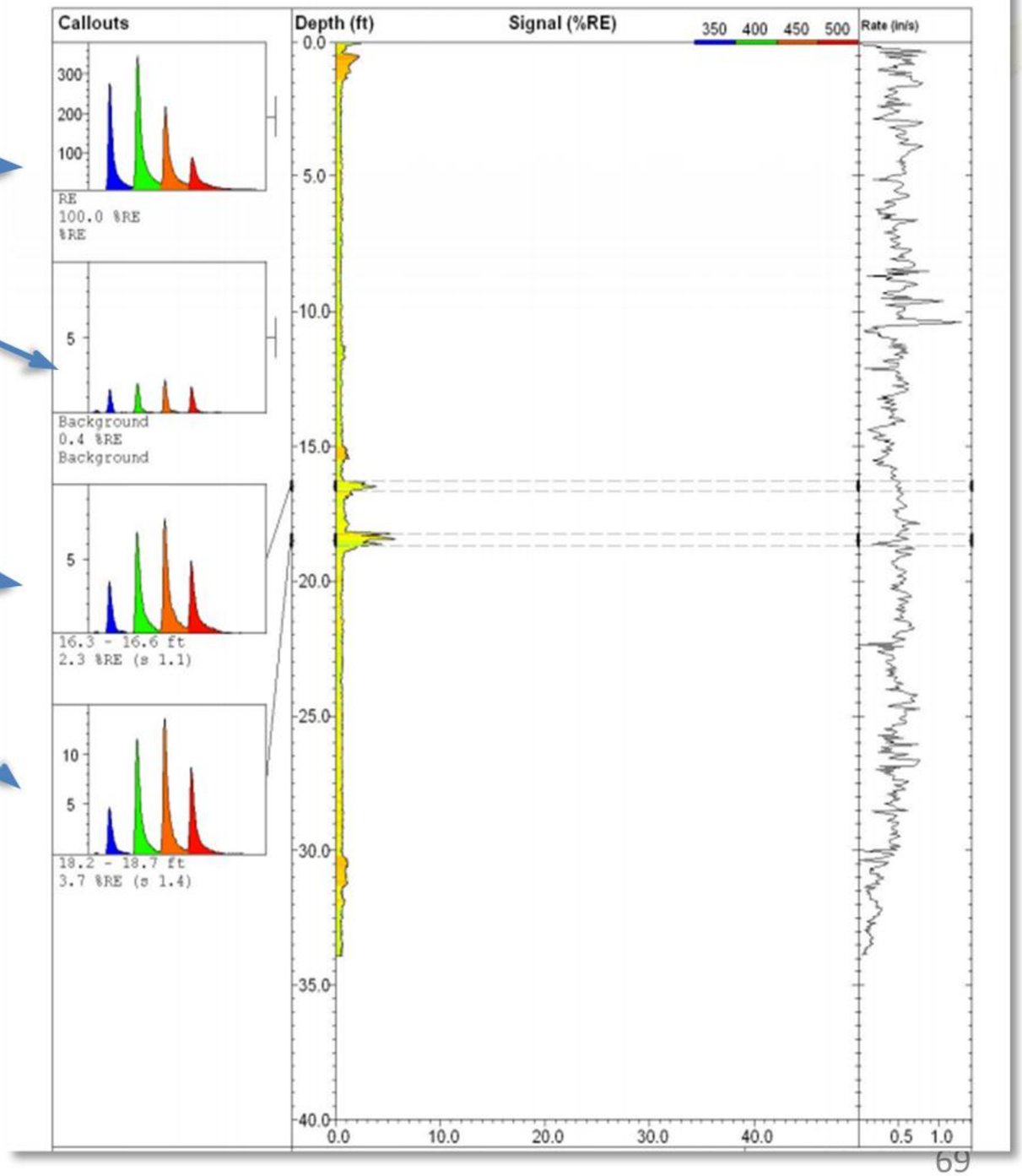
Fact:

- *Recurring presence of LNAPL in a monitoring well OR continued elevated groundwater concentrations of hydrocarbons are clear evidence of a remaining source…it just may not be mobile or moving*

Initial LIF Profile Adjacent to the MW

Quick Notes:

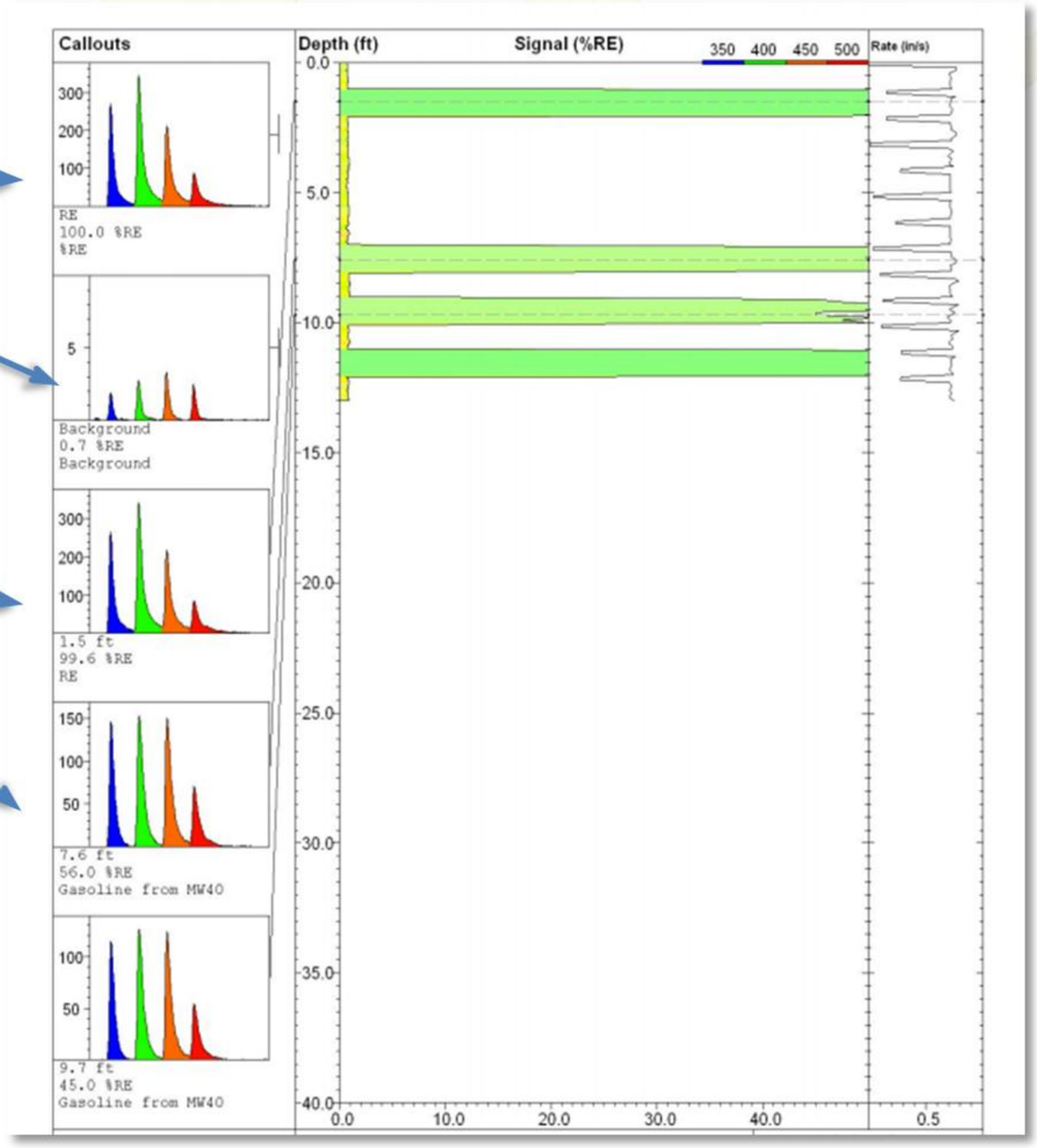
- Performance test is GOOD
- Background check is GOOD
- Material in the formation is different than performance test standard and repeatable
- Material is at 17 and 19 feet below grade



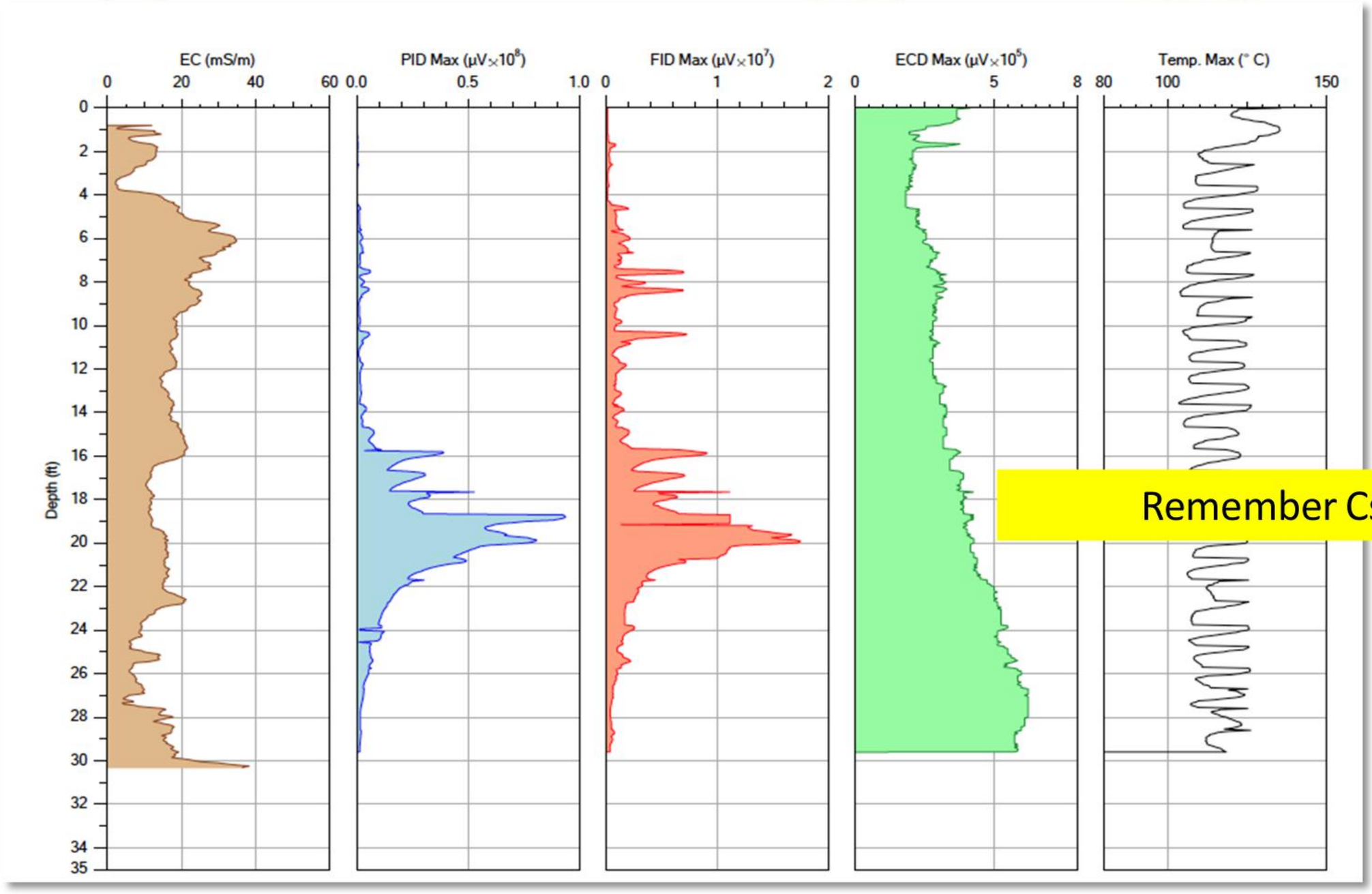
LIF Profile of Product in the MW

Quick Notes:

- Performance test is GOOD
- Background check is GOOD
- Material in the well is lighter (more fresh, less degraded) than product in the formation
- Material in the well is different than the performance test standard
- Response is repeatable



MIP Response Adjacent to the MW

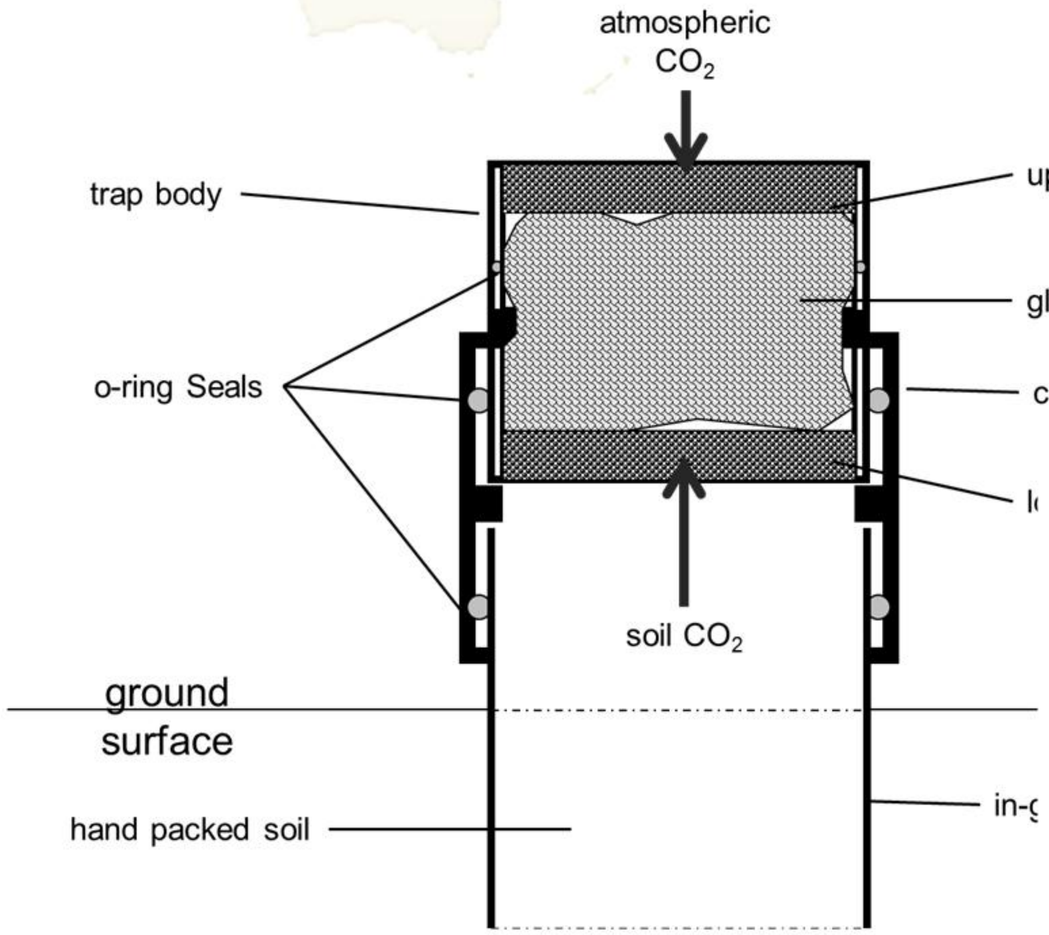


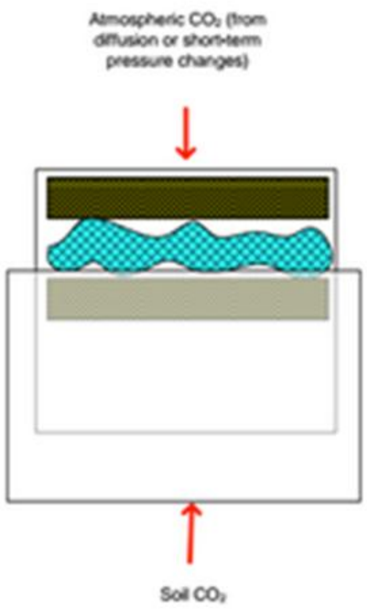
The answer is not likely in the monitoring well.

SmartData Solutions® Provides:

- Real Time Information
- Secure Cloud Platform
- Quality Assurance
- Collaboration
- Data Gap Analysis
- Global Reach

Measurement of Natural Source Zone Depletion

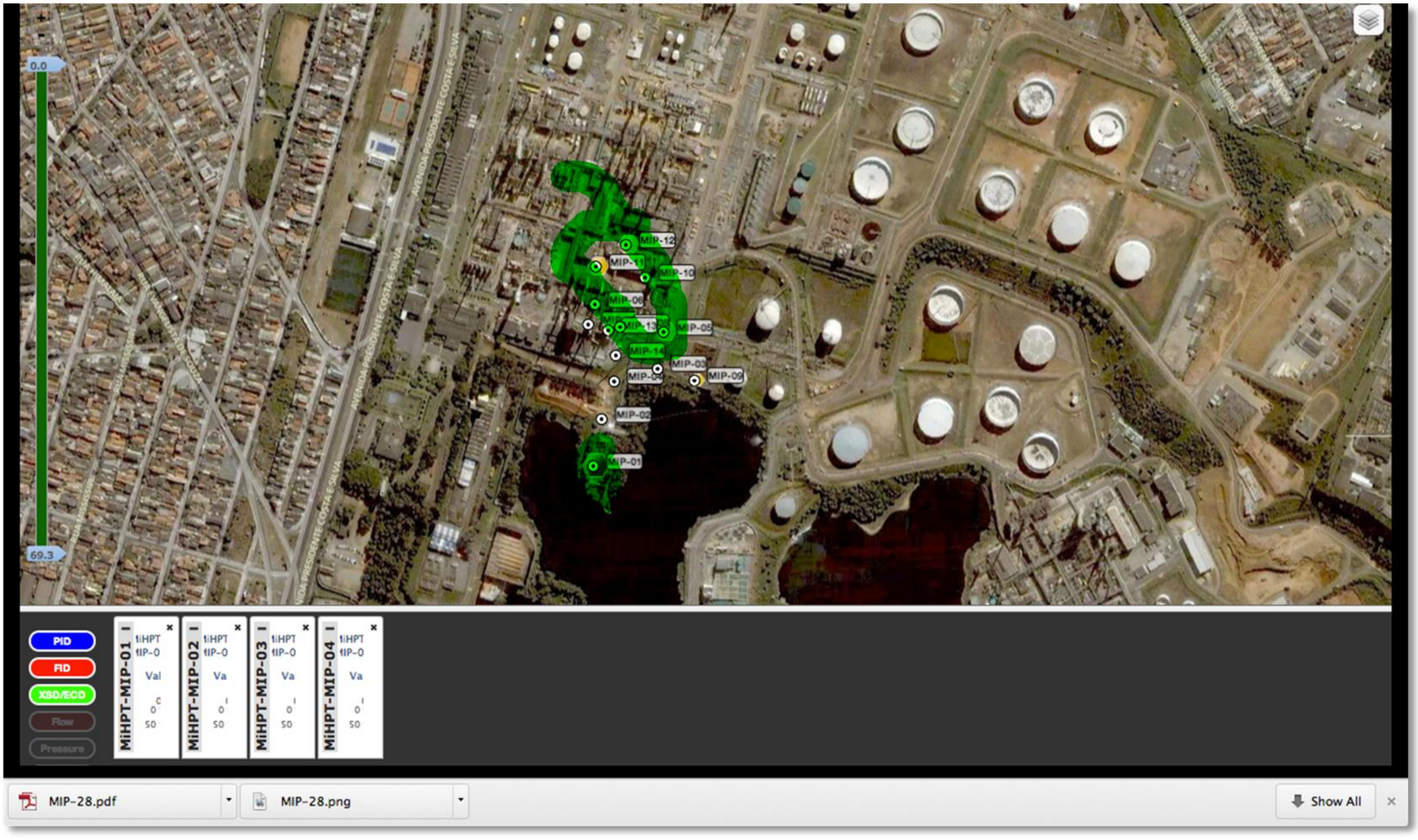




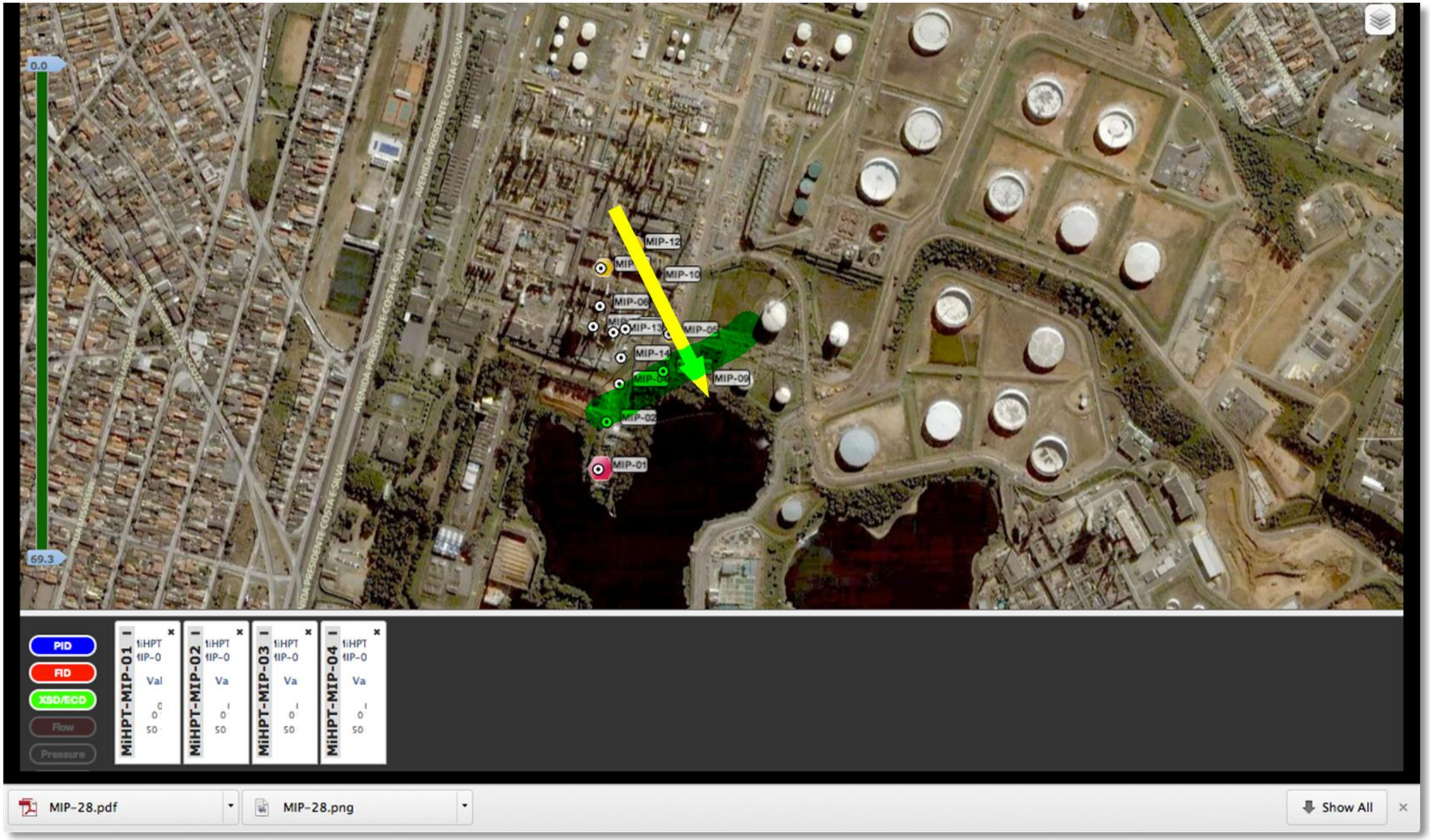
Case Example

Petroleum VOCs

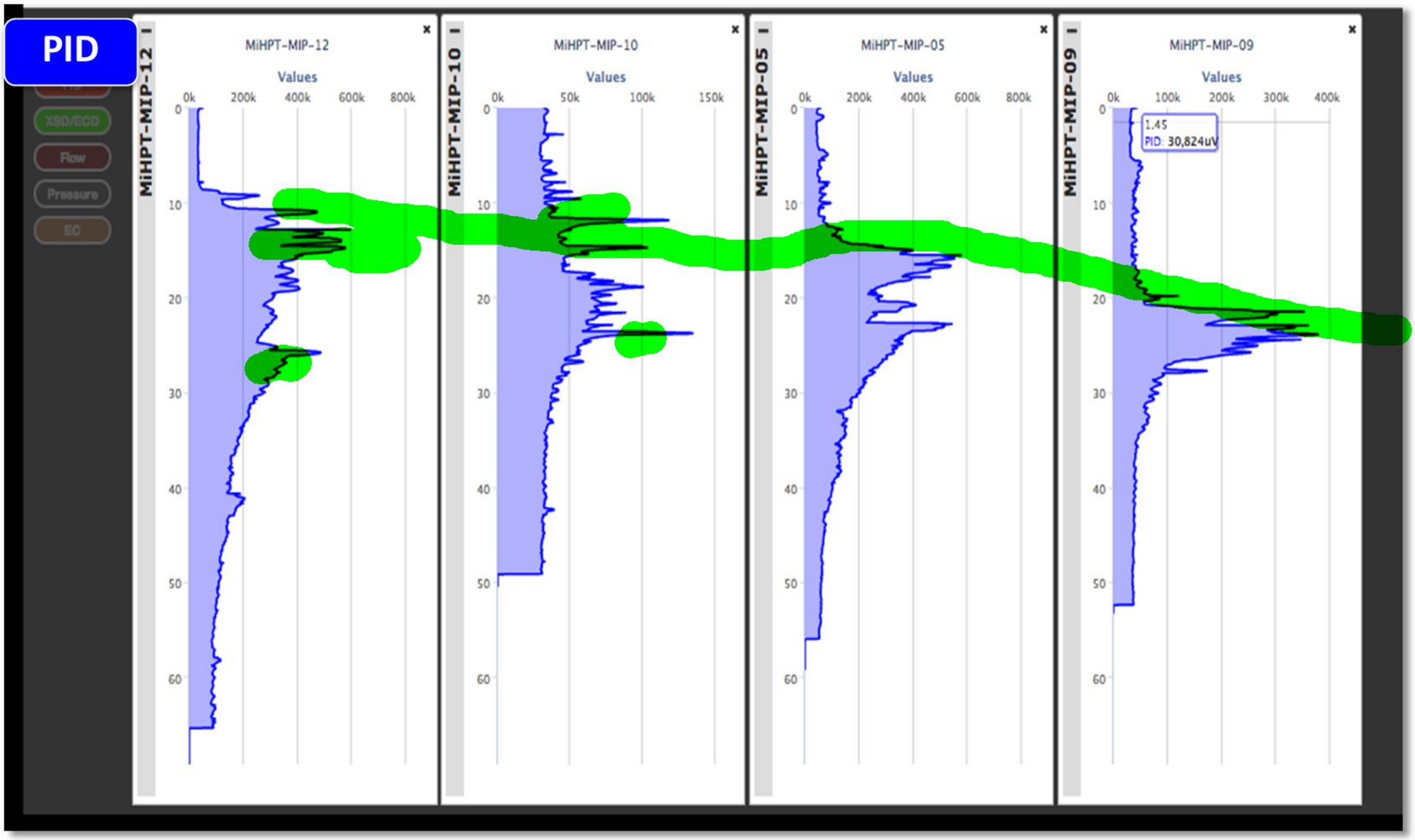
MIP Response to Petroleum VOCs



Transect 01 – Towards water body



Transect 01 – PID

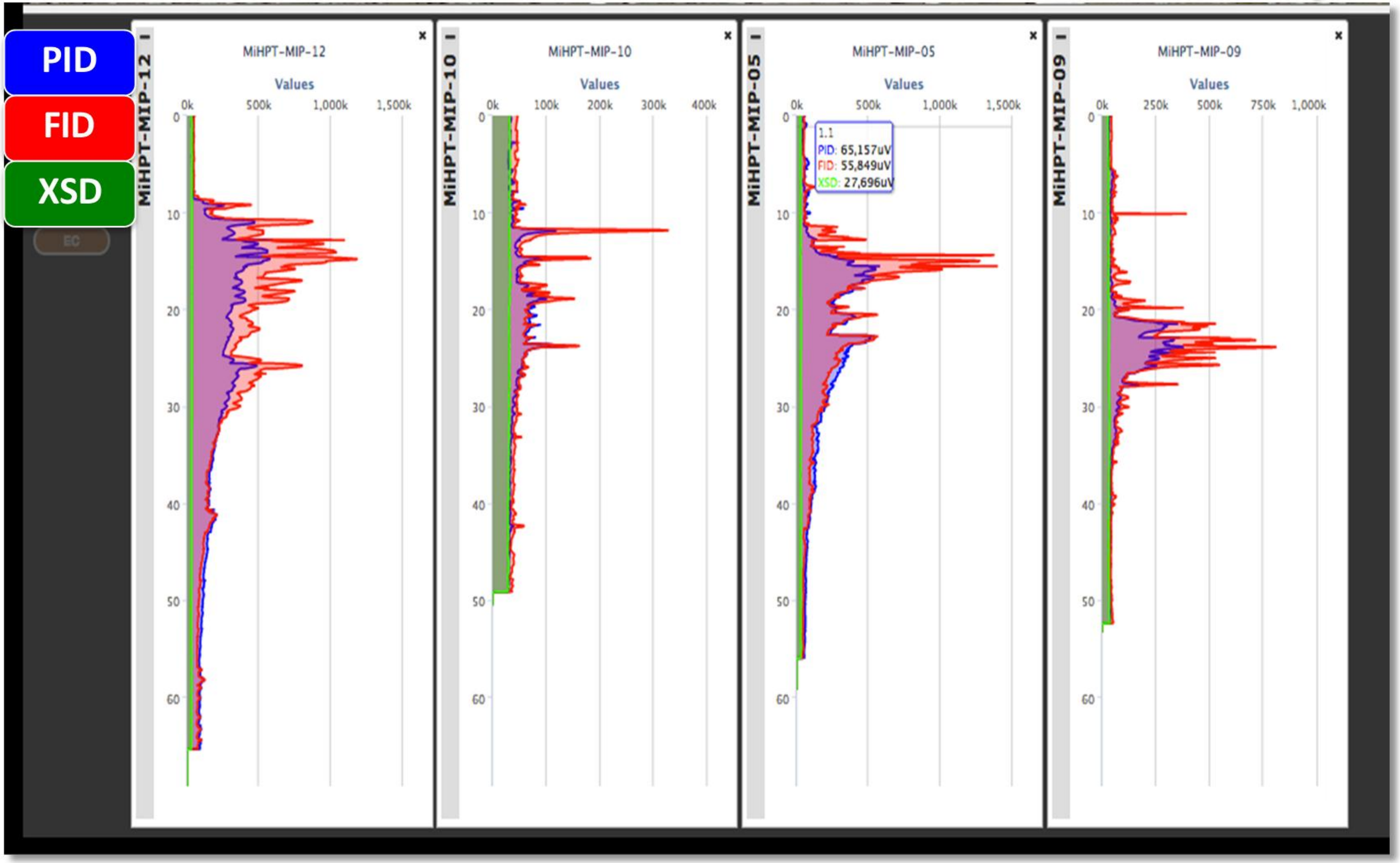


Transect 01 – PID w/ FID and XSD

PID

FID

XSD



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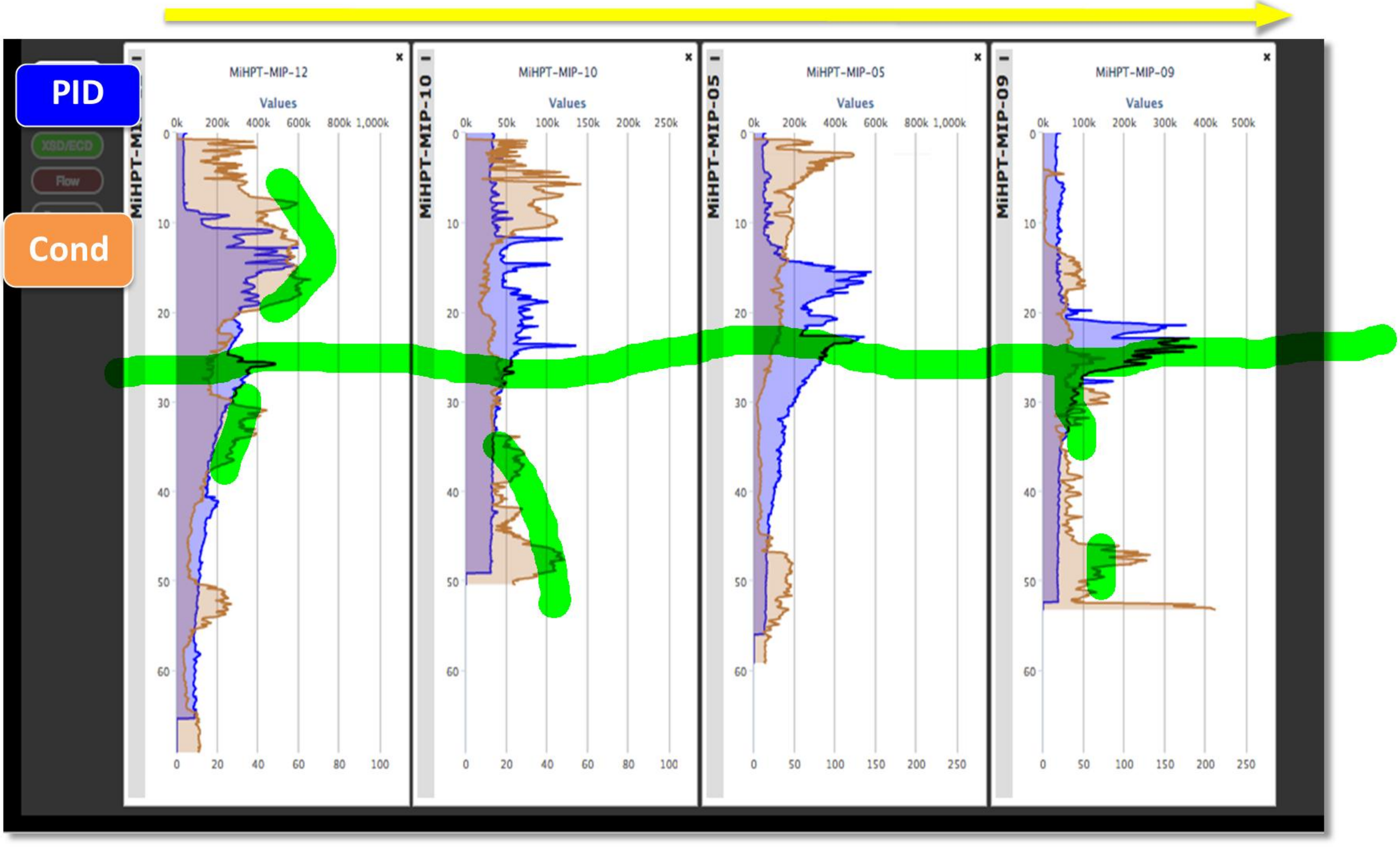
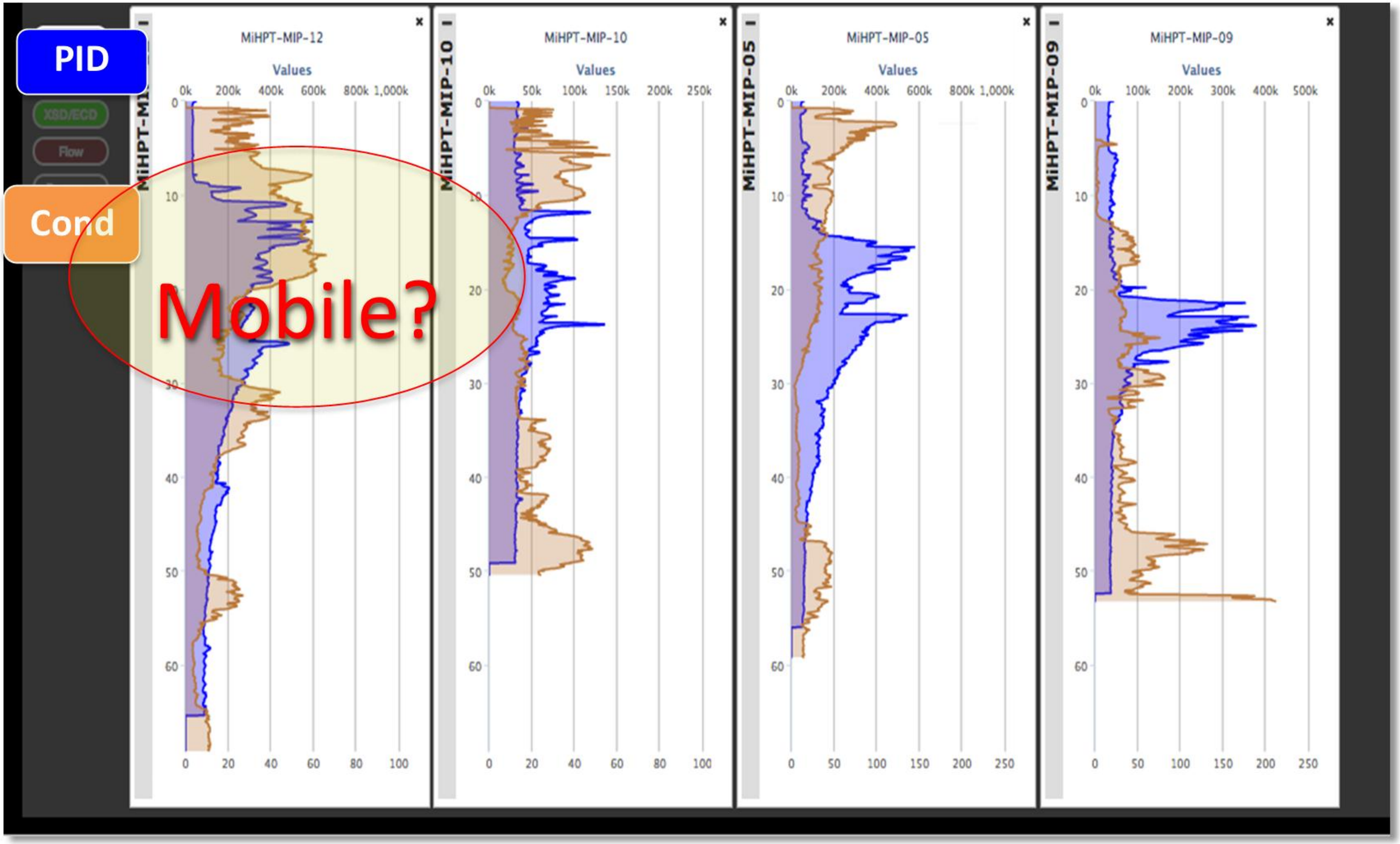
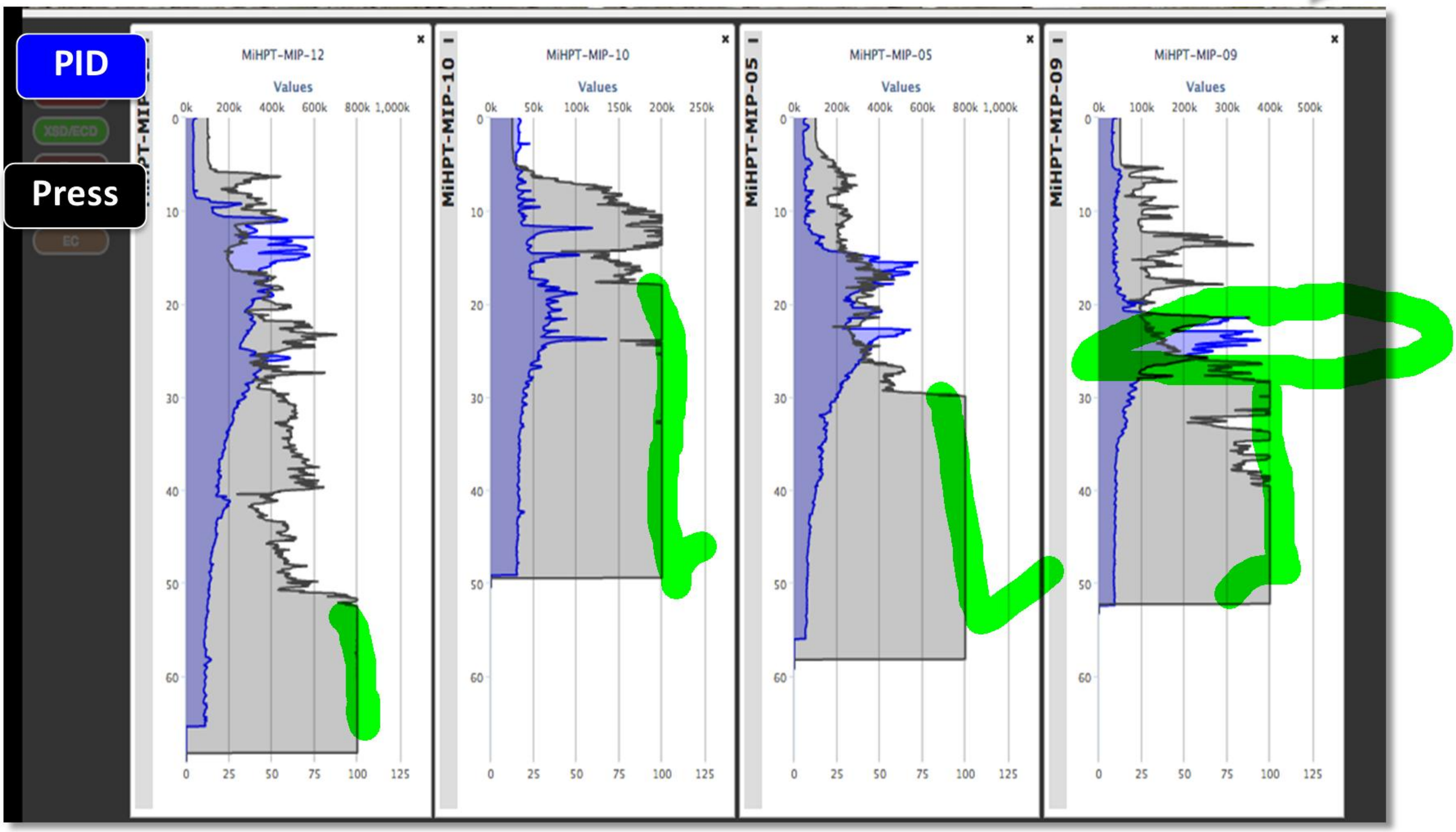
Transect 01 – PID with Conductivity



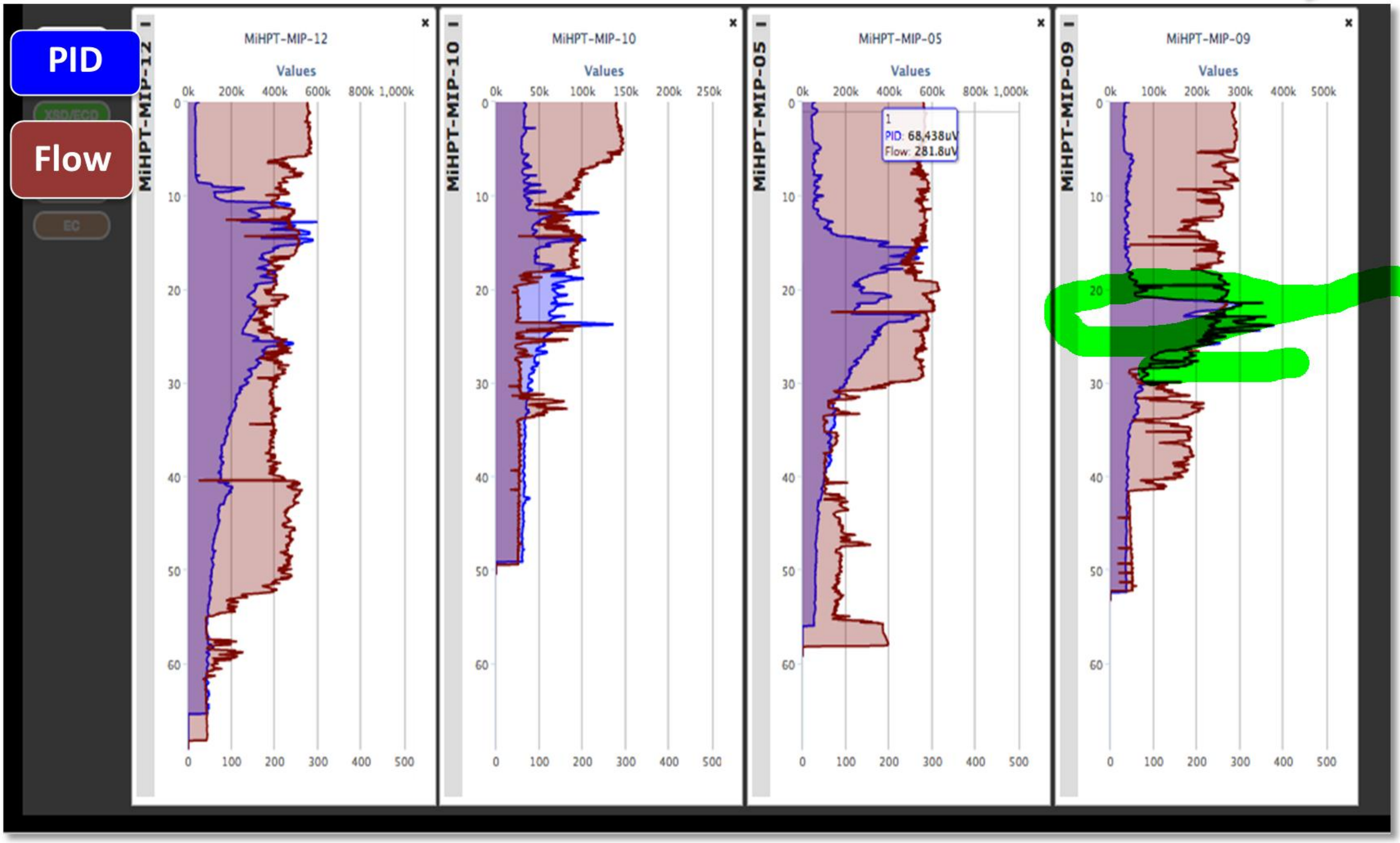
Transect 01 – PID with Conductivity



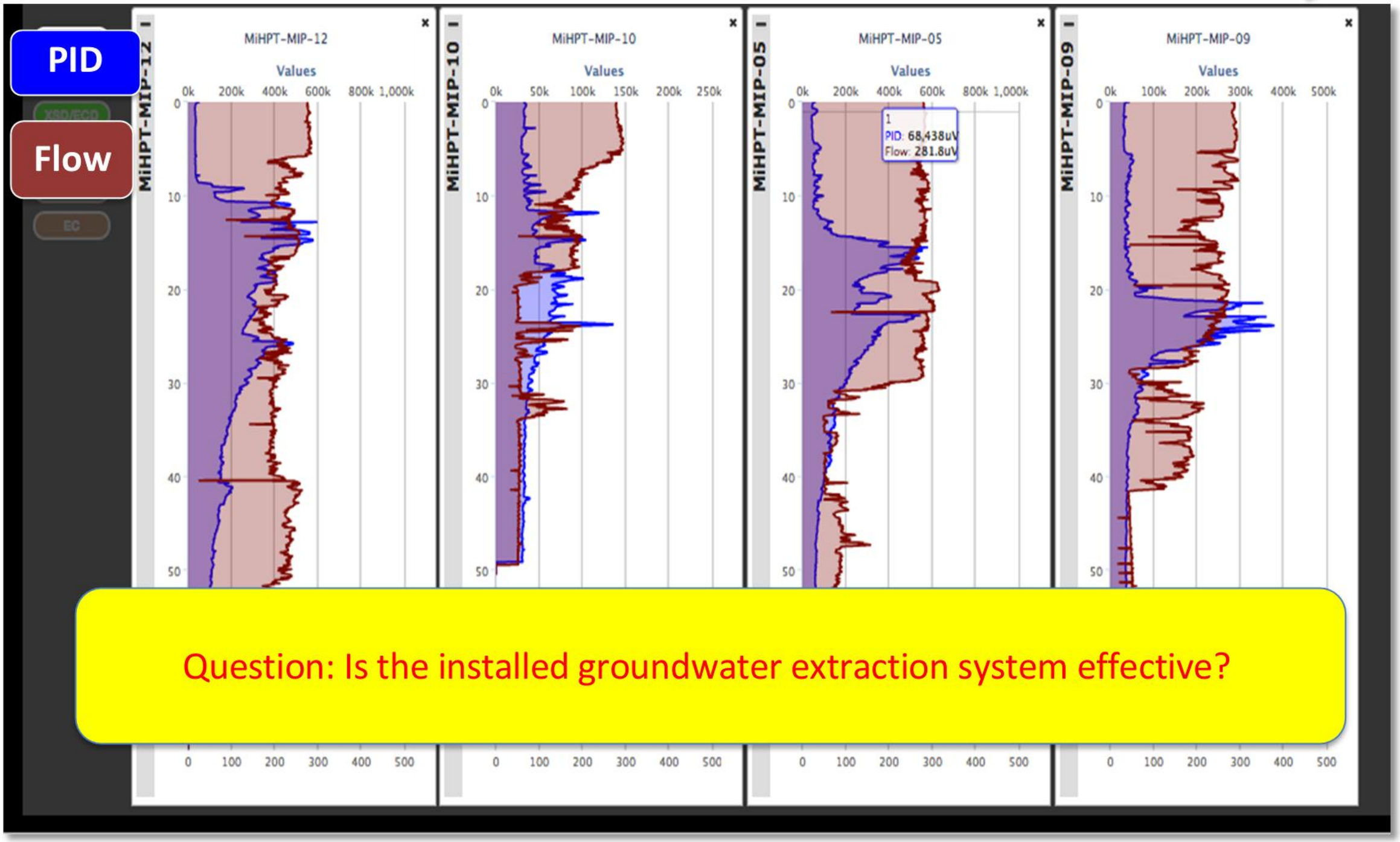
Transect 01 – PID with Pressure



Transect 01 – PID with Flow



Transect 01 – PID with Flow



Do we want to guess (and pay) for more hardware, chemicals, and lab analyses or do we want to pay for

results?

Think and Restore

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