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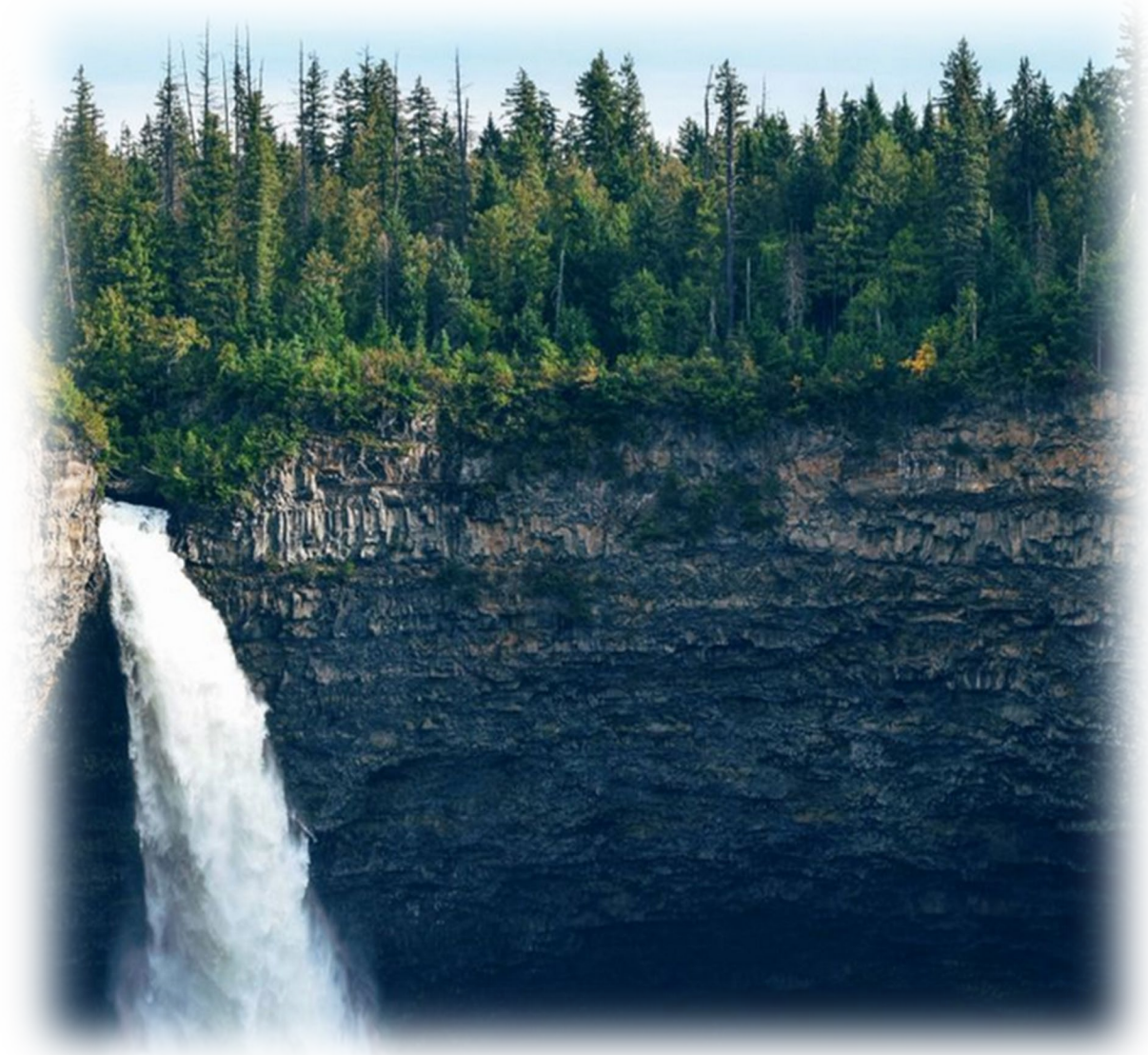


High Resolution Site Characterization (HRSC)

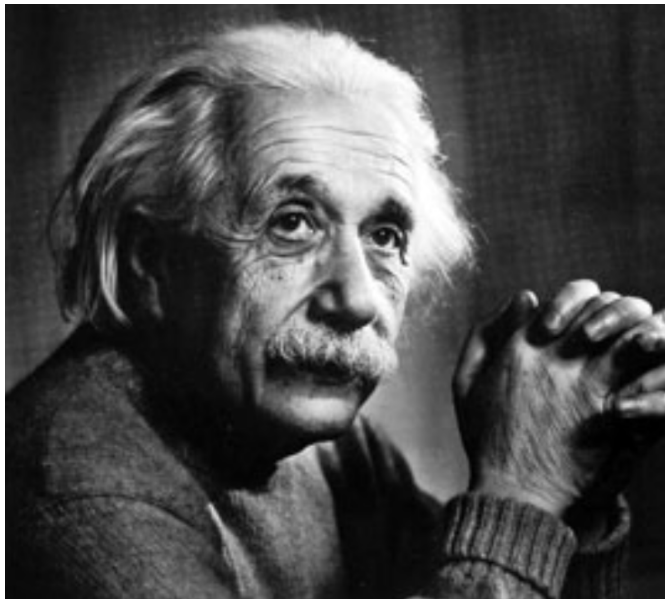
Janet L Castle, PG
President
jcastle@eaglesynergistic.com
ED-WOSB

Locations Nationwide:

CO, TX, GA, CA, PA, IL

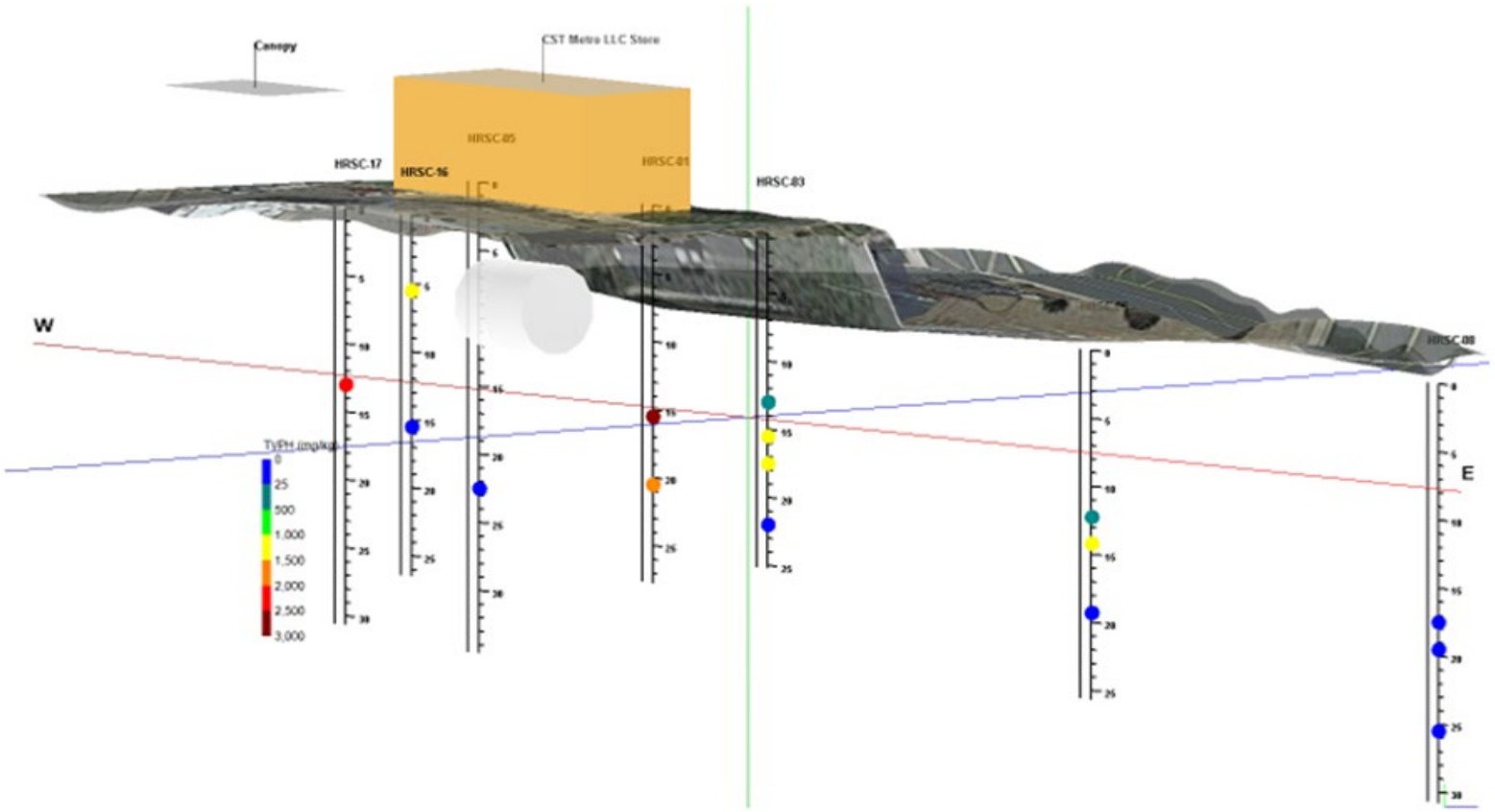
EPA United States Environmental Protection Agency

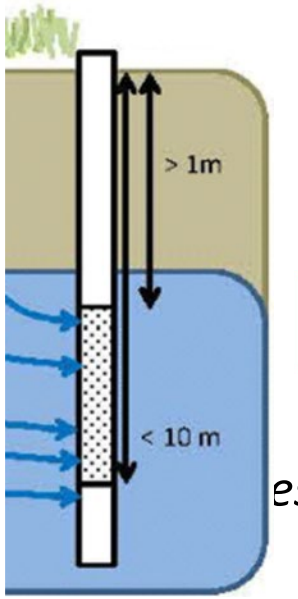
- One cannot effectively solve a problem which one has not adequately and accurately defined (CSM)
- Many remedies underperform or fail due to a lack of understanding of site conditions and processes
- The cost of these failed/ underperforming remedies is large
- The costs of excessive long term monitoring programs related to investigating sites with monitoring wells is large
- The costs of High Resolution Site Characterization, which allows one to avoid failed remedies, is small in comparison, but requires an up front investment to result in lower life cycle costs.



Einstein is quoted as having said that if he had one hour to save the world he would spend *fifty-five minutes defining the problem and only five minutes finding the solution*.

Historical Investigative Methods





es

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Historical Investigative Methods

Accurate Soil **Recovery**?
2’-3’ out of 5’?

Ah	0–25	dark reddish brown (5YR 3/4), loam, weak blocky subangular to moderate fine granular, soft fragile consistence, many very fine pores, many very fine and common medium roots, dry, non calcareous, clear wavy boundary to
AB	25–60	diffuse transitional horizon dark reddish brown (5YR 3/6), clay loam, moderate blocky subangular, broken thin clay cutans, many very fine pores, non-calcareous, diffuse boundary to
Bt	60–160	dark reddish brown (5YR 3/6), clay, strong very coarse subangular blocky, hard consistence, continuous moderately thick clay cutans, many very fine pores, non-calcareous, abrupt irregular boundary to

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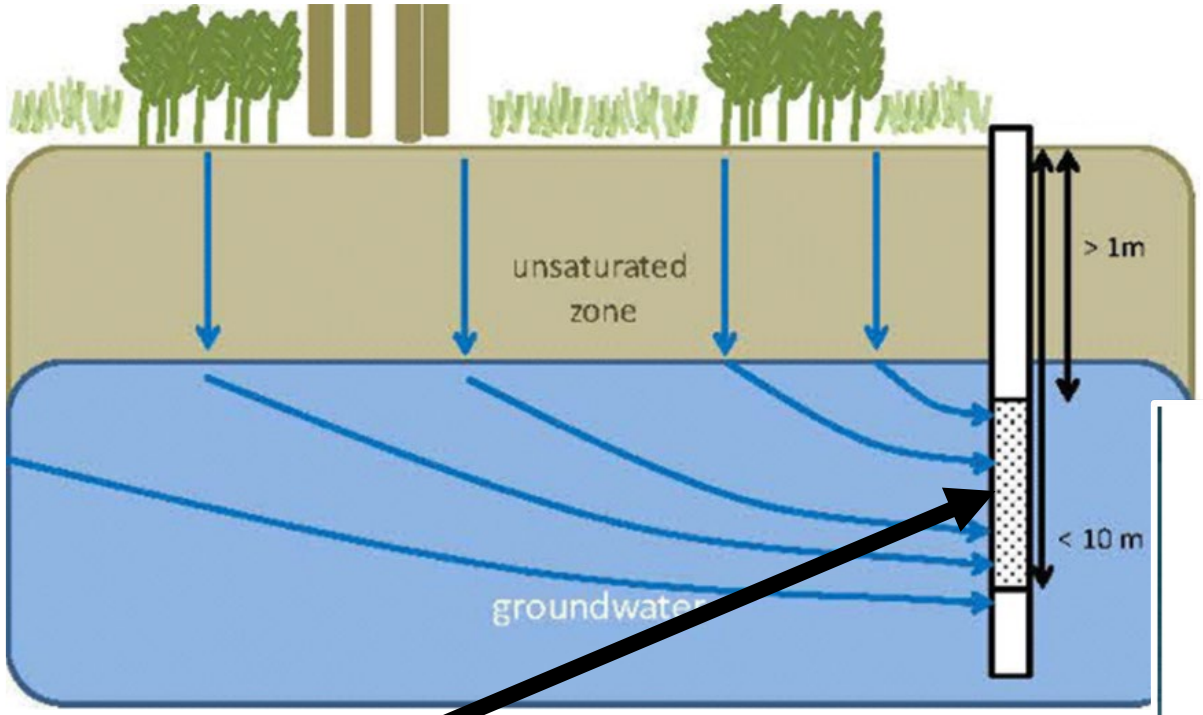
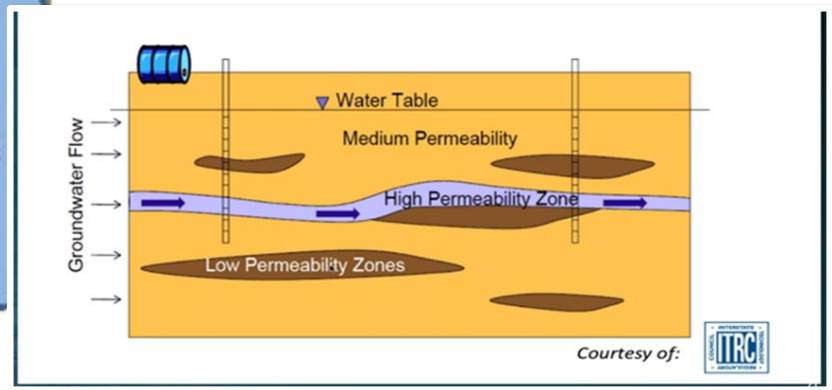
Historical Investigative Methods





Accurate Screened Interval
?

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High Resolution Site Characterization Technologies

*"The advent of innovative **site characterization technologies** and strategies and the development of more effective treatment methods provide new options for **faster and more effective site cleanup**. New approaches to site cleanup, based on the use of in situ treatment technologies, promote more targeted or "surgical" options. These targeted efforts require the best possible understanding of subsurface features, contaminant distribution, volume and mass."*

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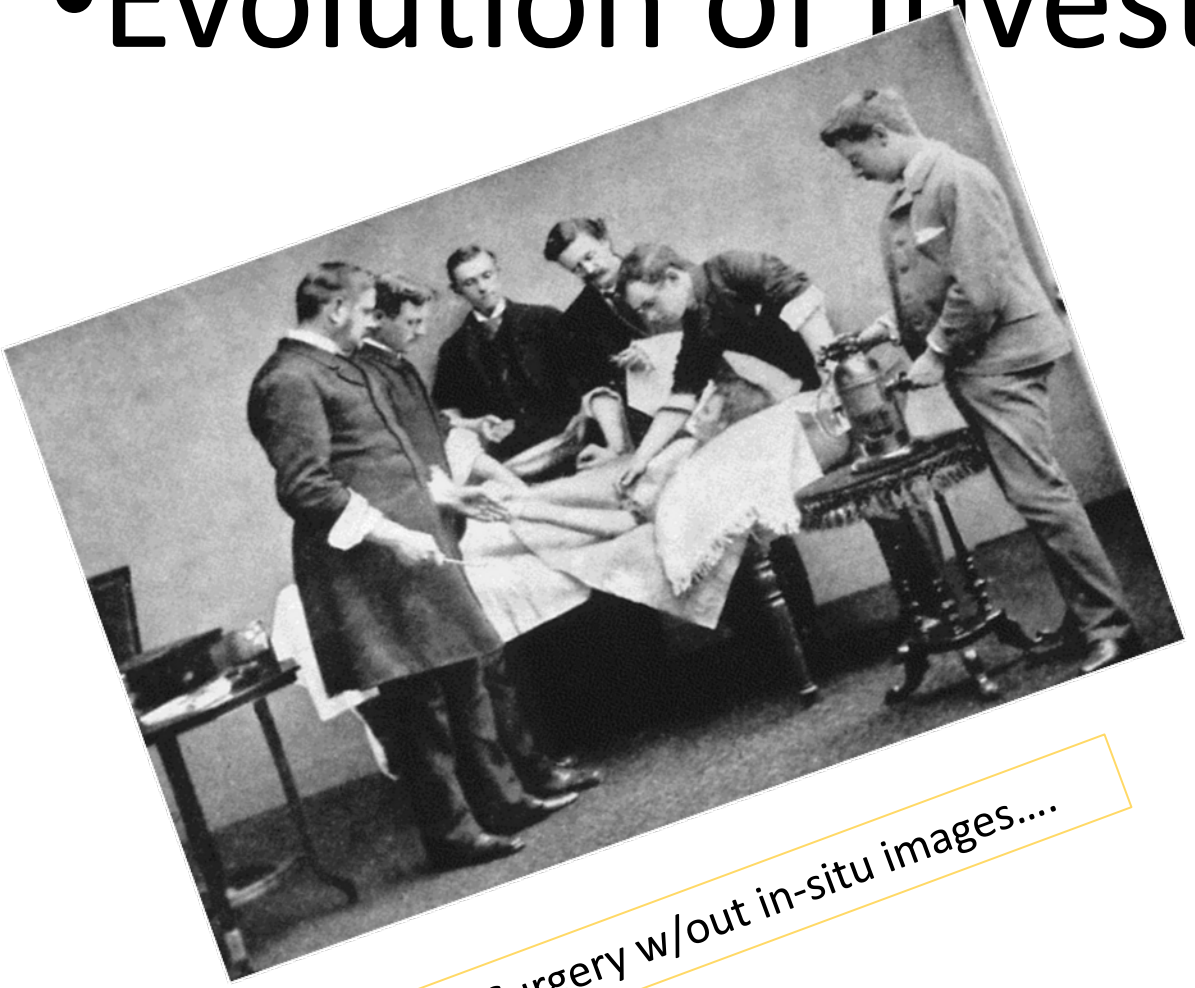
Evolution of Remediation Methods

- Excavation
- Physical containment
- In-situ soil mixing
- Natural source zone depletion (NSZD)
- Air sparging/soil vapor extraction (AS/SVE)
- LNAPL skimming
- Bioslurping/EFR
- Dual pump liquid extraction
- Multi-phase extraction, dual pump
- Multi-phase extraction, single pump
- Water/hot water flooding
- In situ chemical oxidation
- Surfactant- enhanced subsurface remediation
- Cosolvent flushing
- Steam/hot-air injection
- Radio frequency heating
- Three and six-phase electrical resistance heating

Courtesy of: ITRC

Remediation Methods

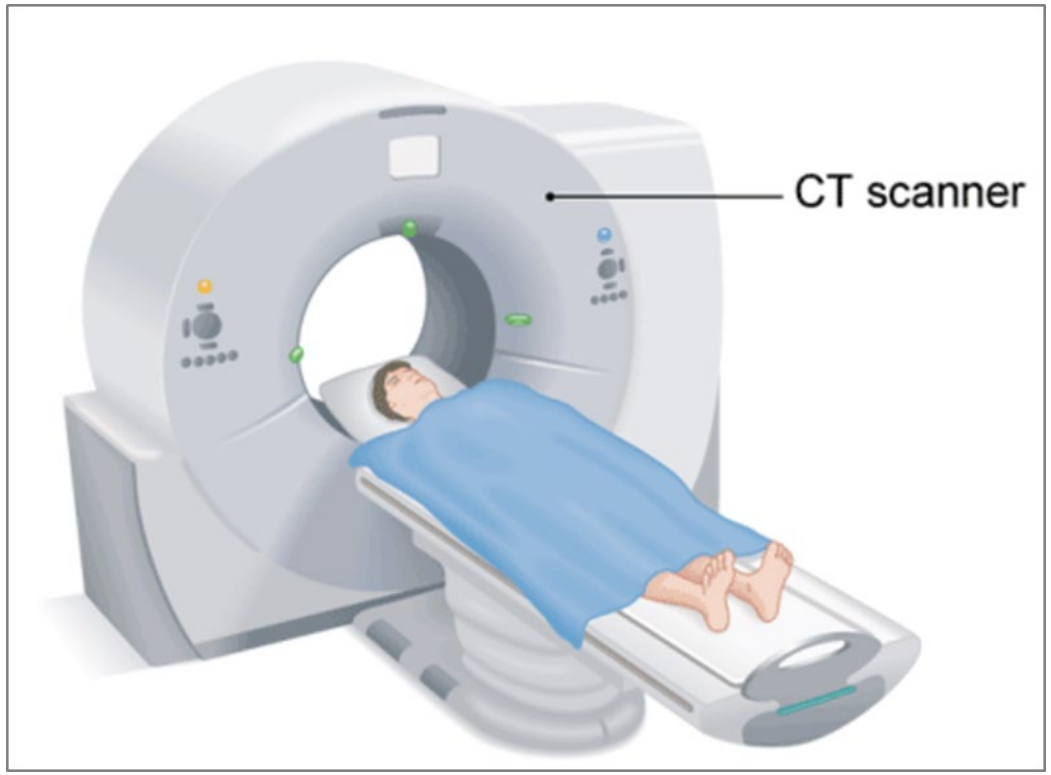
•Evolution of Investigative Technologies

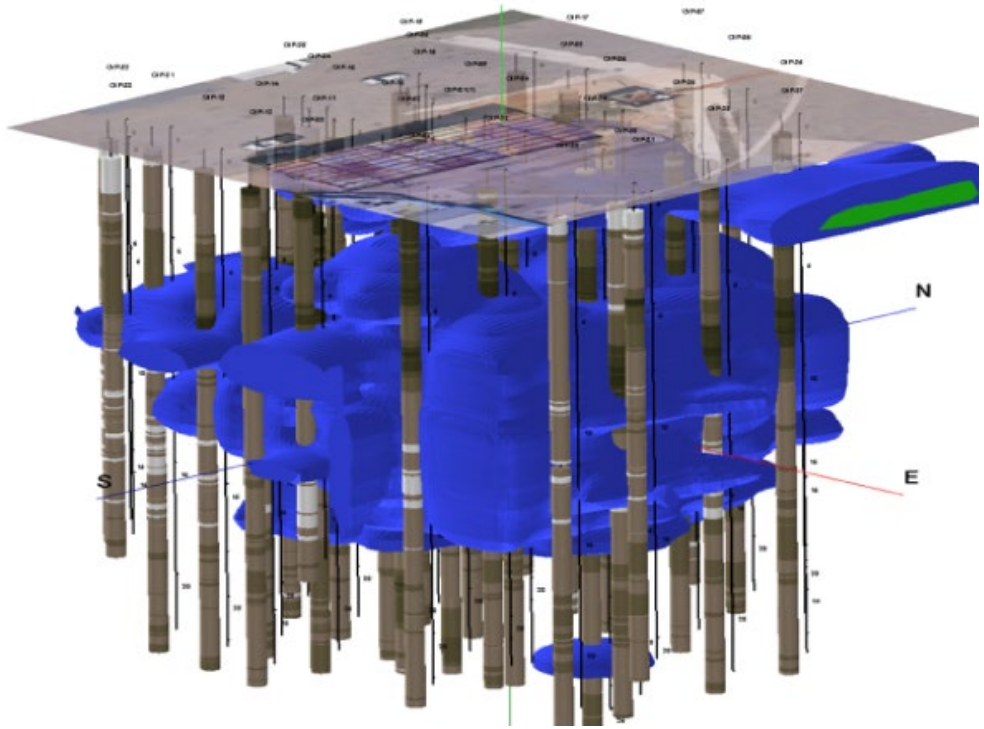


Surgery w/out in-situ images….

…and after in-situ images….

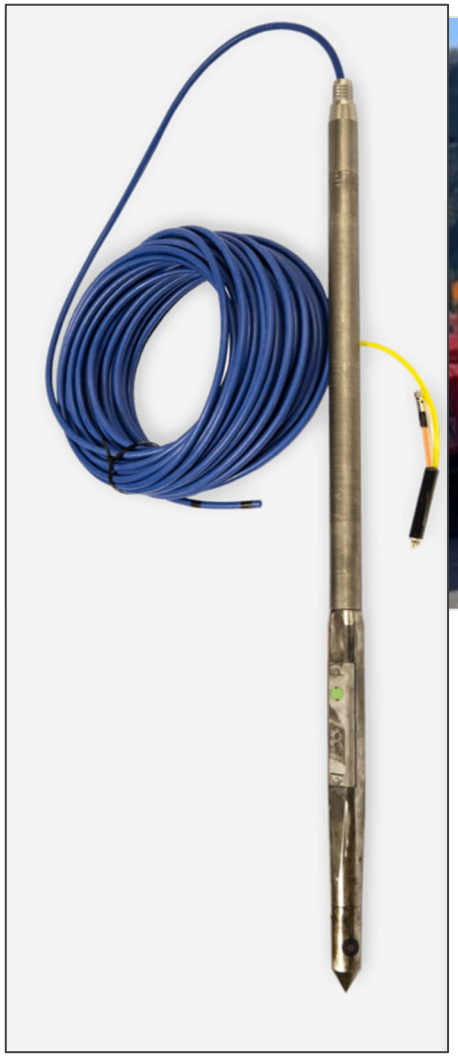
A Clear and Accurate Picture Now- To Target your Remediation





HRSC Overview

HRSC Mobile Command Centers Units:



HRSC Overview

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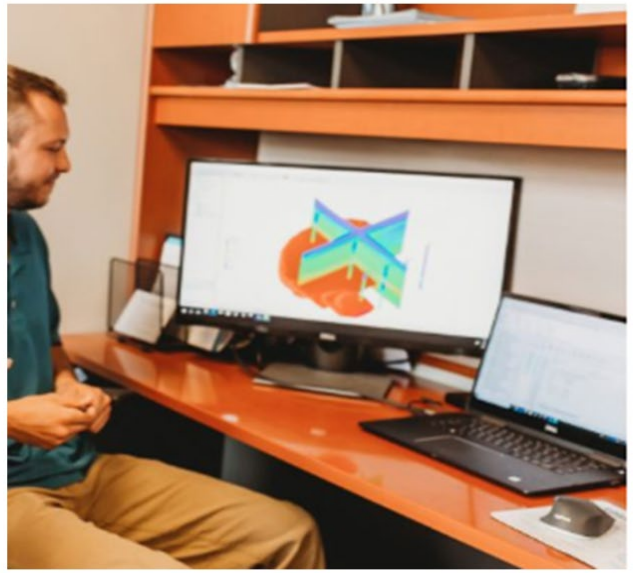
Strategic & Dynamic HRSC Investigative process– Critical for Targeted Remediation Success

Real Time Data

HRSC Specialists working dynamically with you in the field

& HRSC Scientists working with you virtually to optimize project



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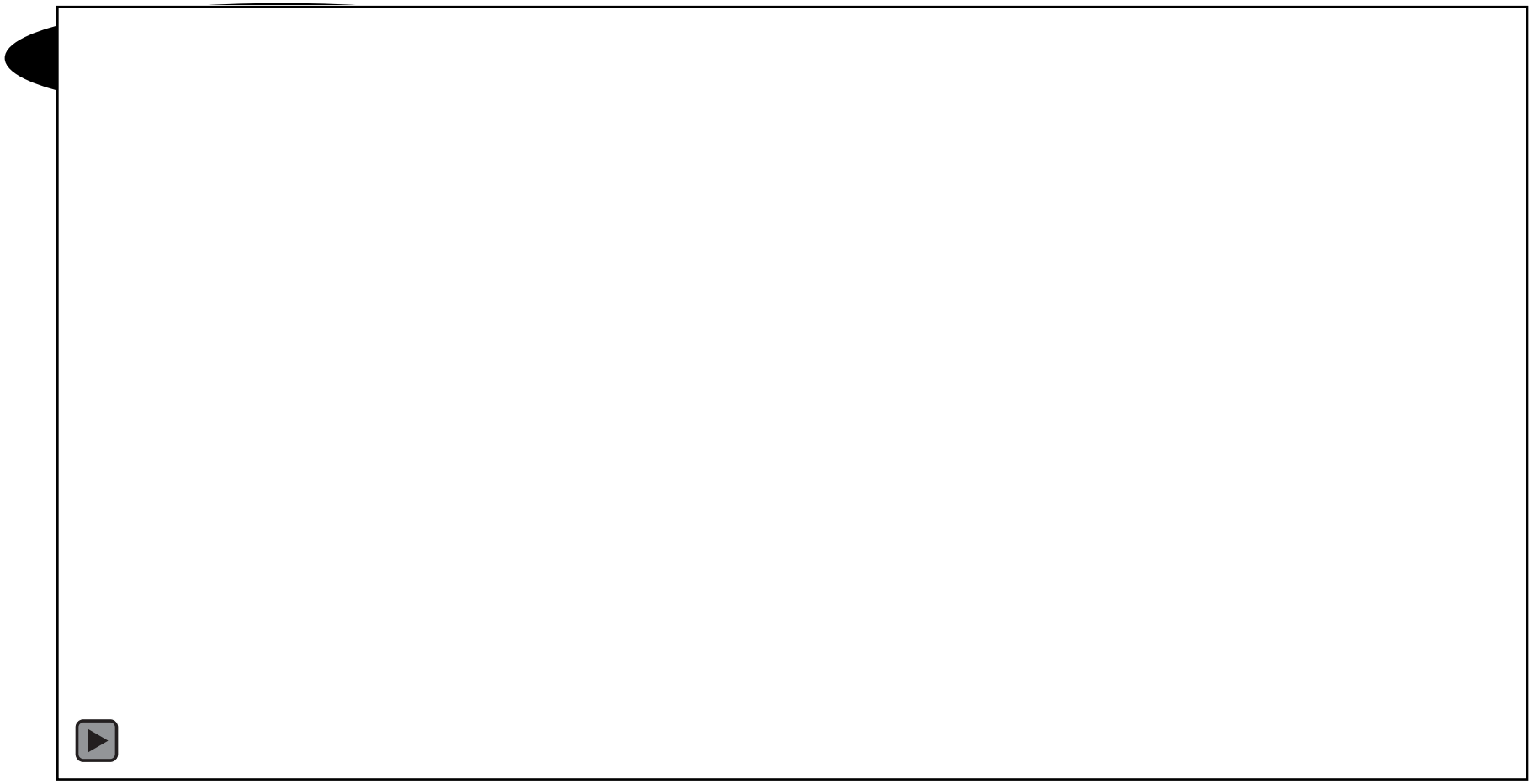
Strategic HRSC Investigative process– Critical for Targeted Remediation Success

Dynamic decisions possible due to real time data



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Strategic HRSC Investigative process– Critical for Targeted Remediation Success

Basic Overview of HRSC Technology – Understand Your Data

- Theory
- Equipment
- Data

Overview of HRSC Technology

MH6530 Combined MIP-HPT probe

Two Main Detection Methods:

MIP/HPT = **MIHPT**

- **Membrane Interface Probe**
- **Hydraulic Profiling Technology**
  - VOCs

OIP/HPT = **OIHPT**

- **Optical Imaging Profiler**
- **Hydraulic Profiling Technology**
  - LNAPLS

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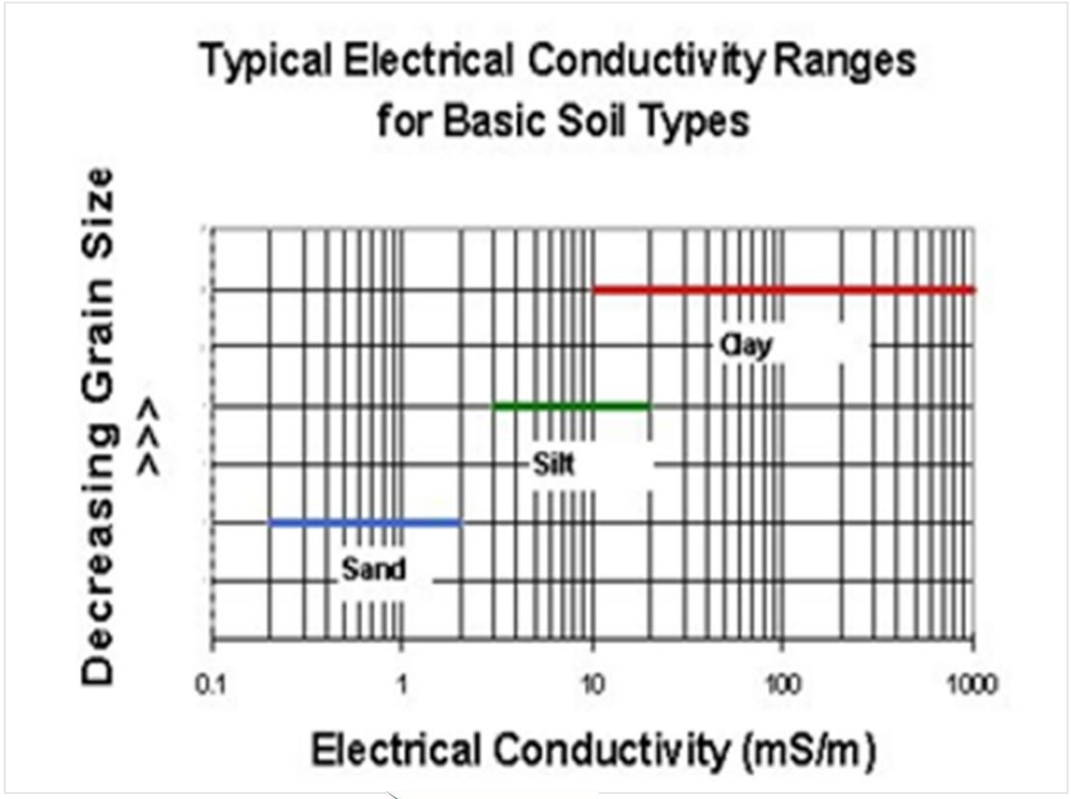
EC – Electrical Conductivity Detector

Soil Conductivity:

- Indicator of Grain Size
- Ionic Compounds/Salts
- Metals



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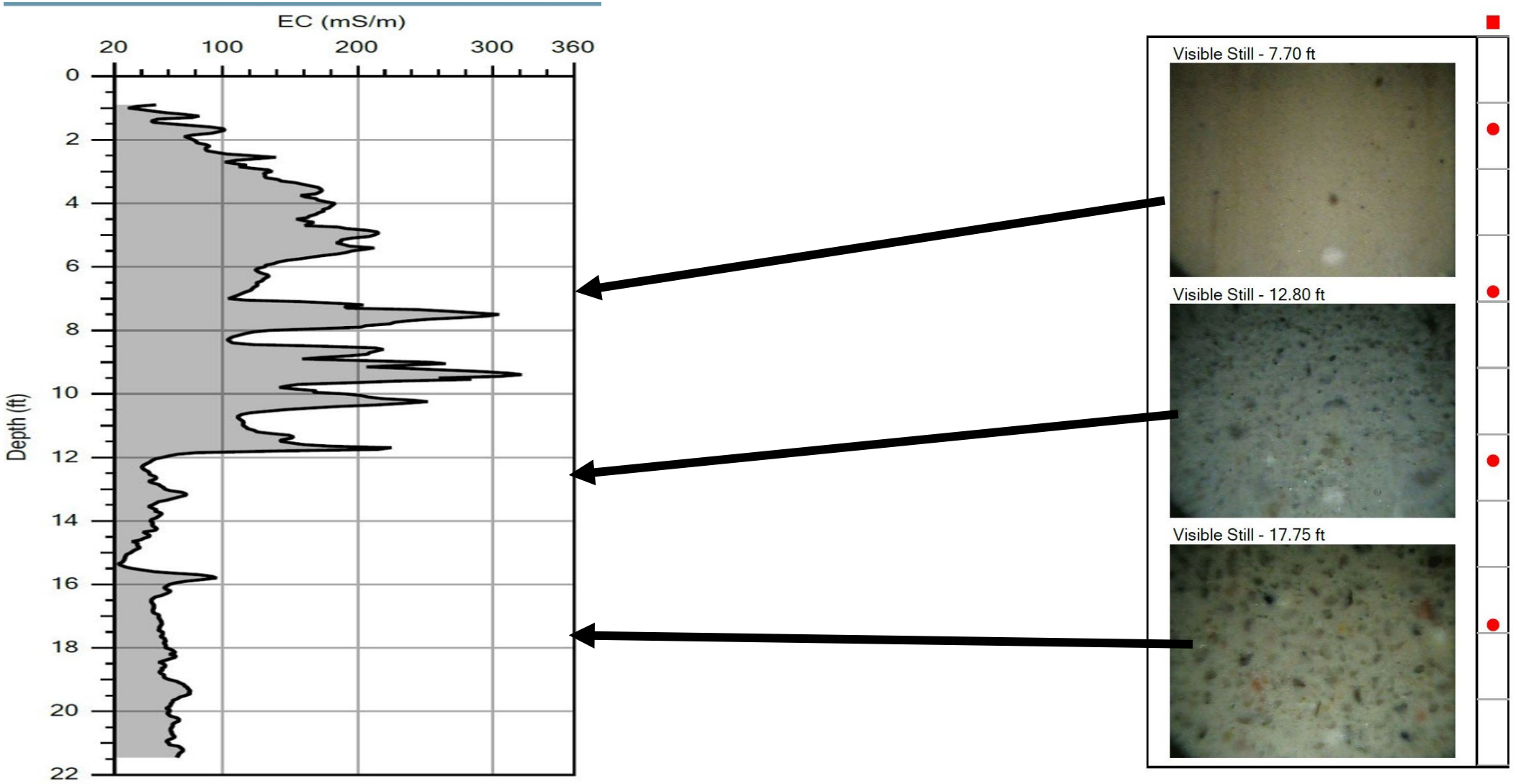
EC – Electrical Conductivity Detector



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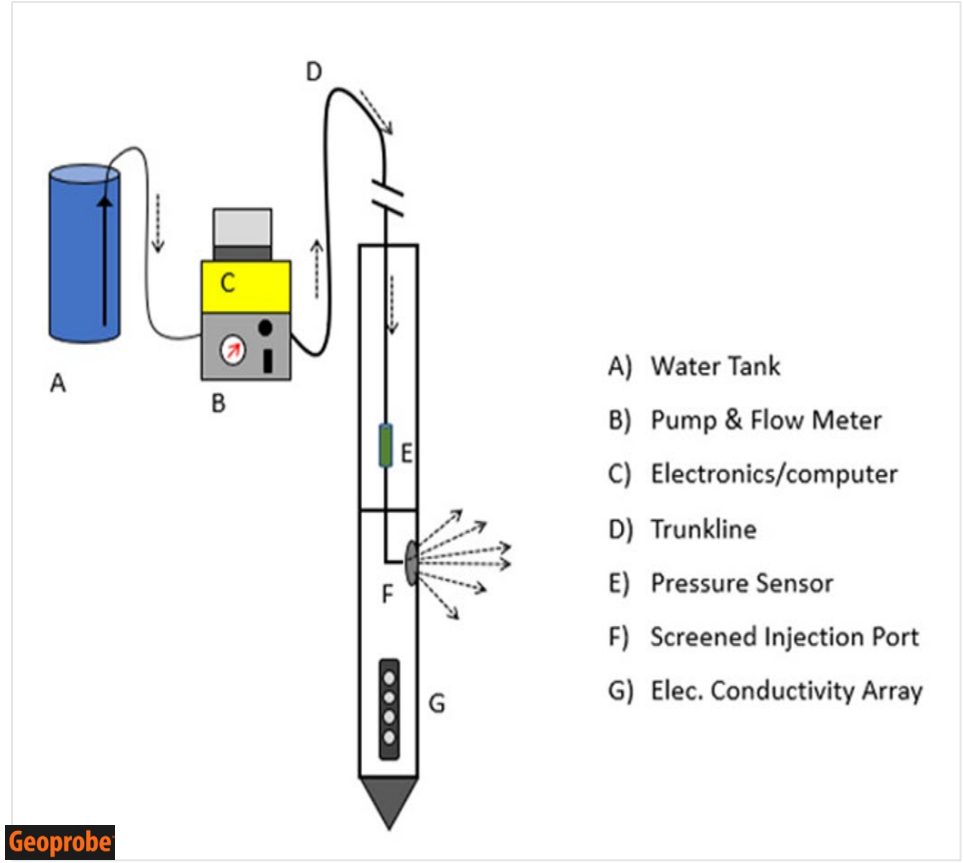
ogies, LLC

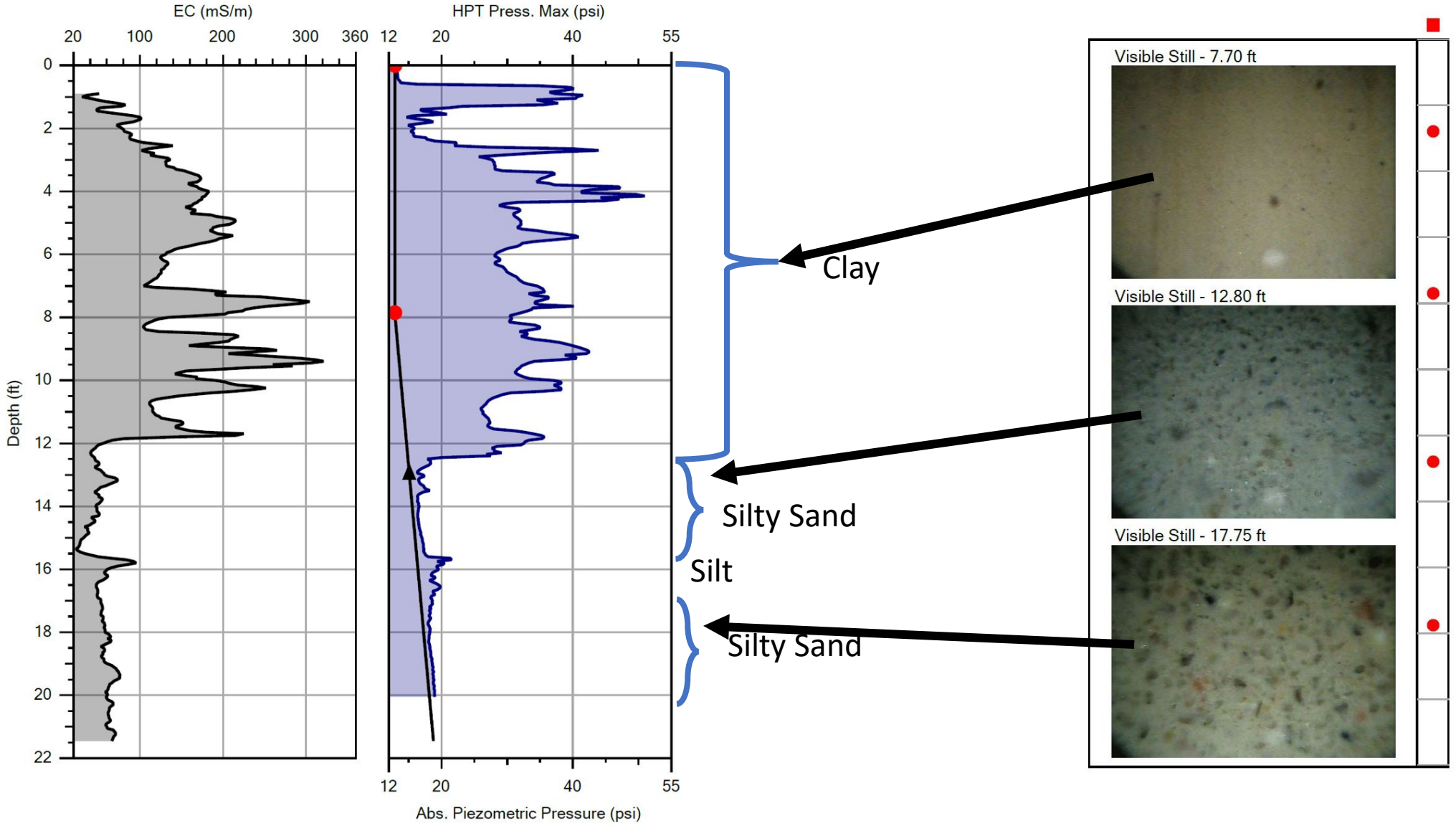
HPT – Hydraulic Profiling Tool

HPT Pressure:

- Indicator of Permeability
- Dissipation Test
  - Hydrostatic Head
- Estimated K values

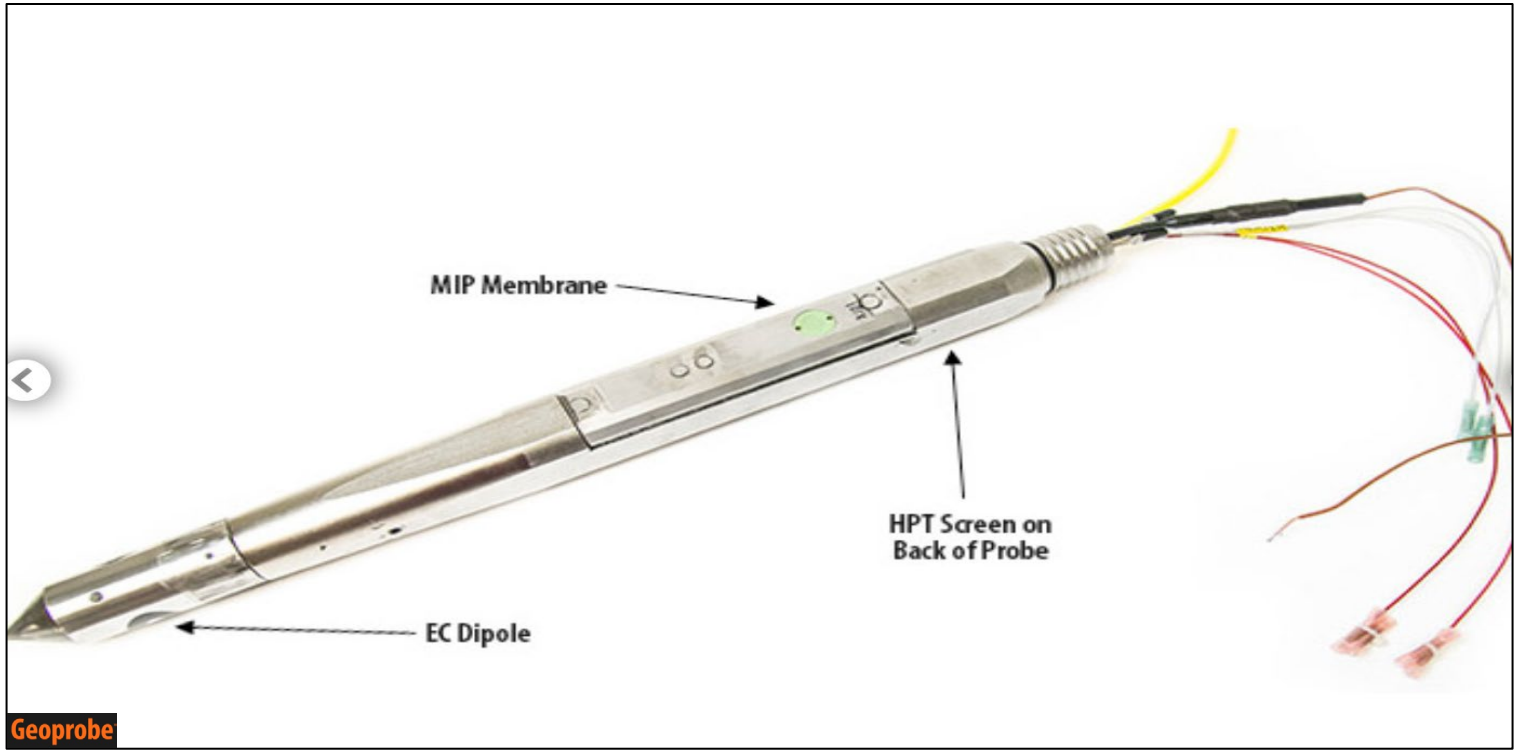


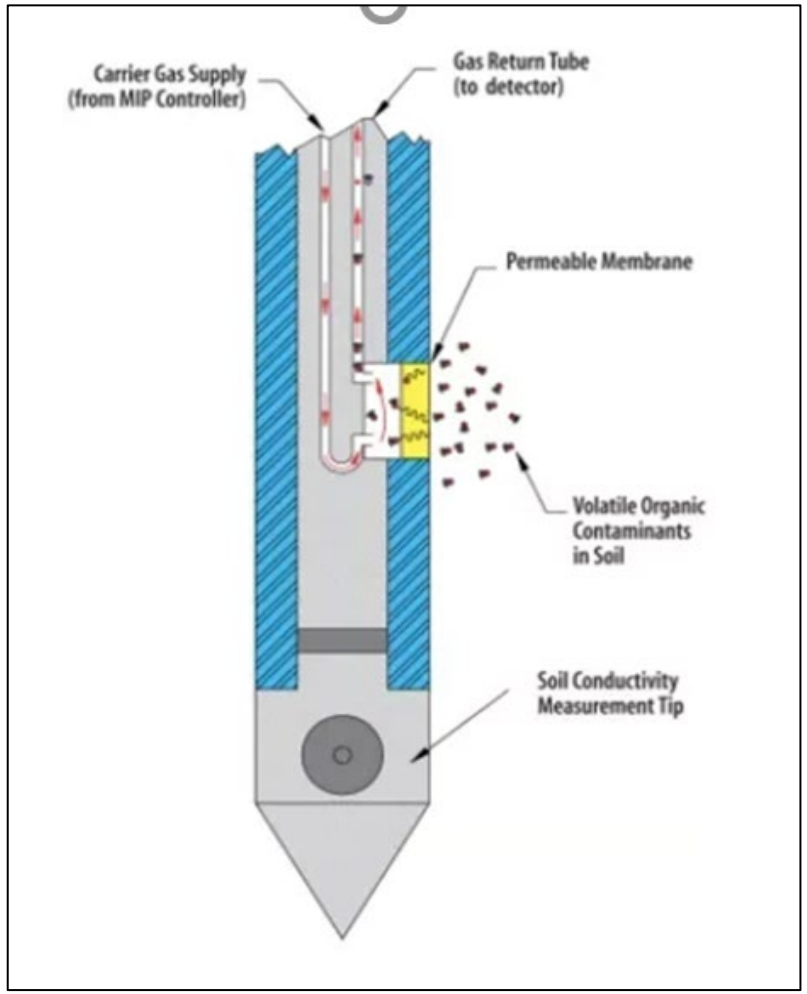
EC & HPT- Hydraulic Profiling Technology



MIP/HPT = MIHPT

- Heater block – 120C
- Pause 1’ intervals
- VOCs difuse through membrane
- Carried up to surface





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MIHPT Detectors/Equipment

Sample of Detector Equipment inside the Mobile Command Center Units :

MiHPT :

- GC
  - PID
  - FID
  - XSD

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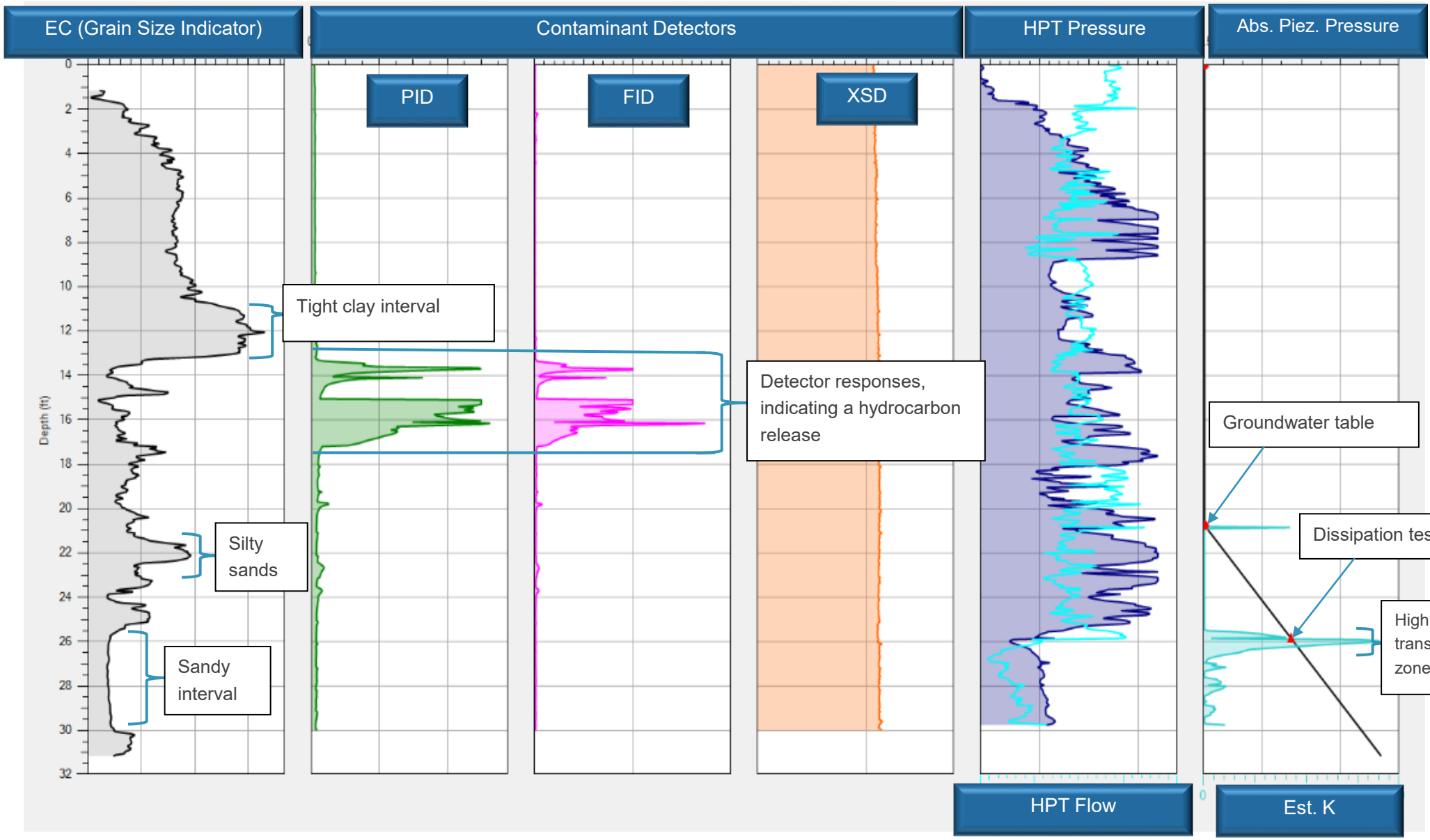
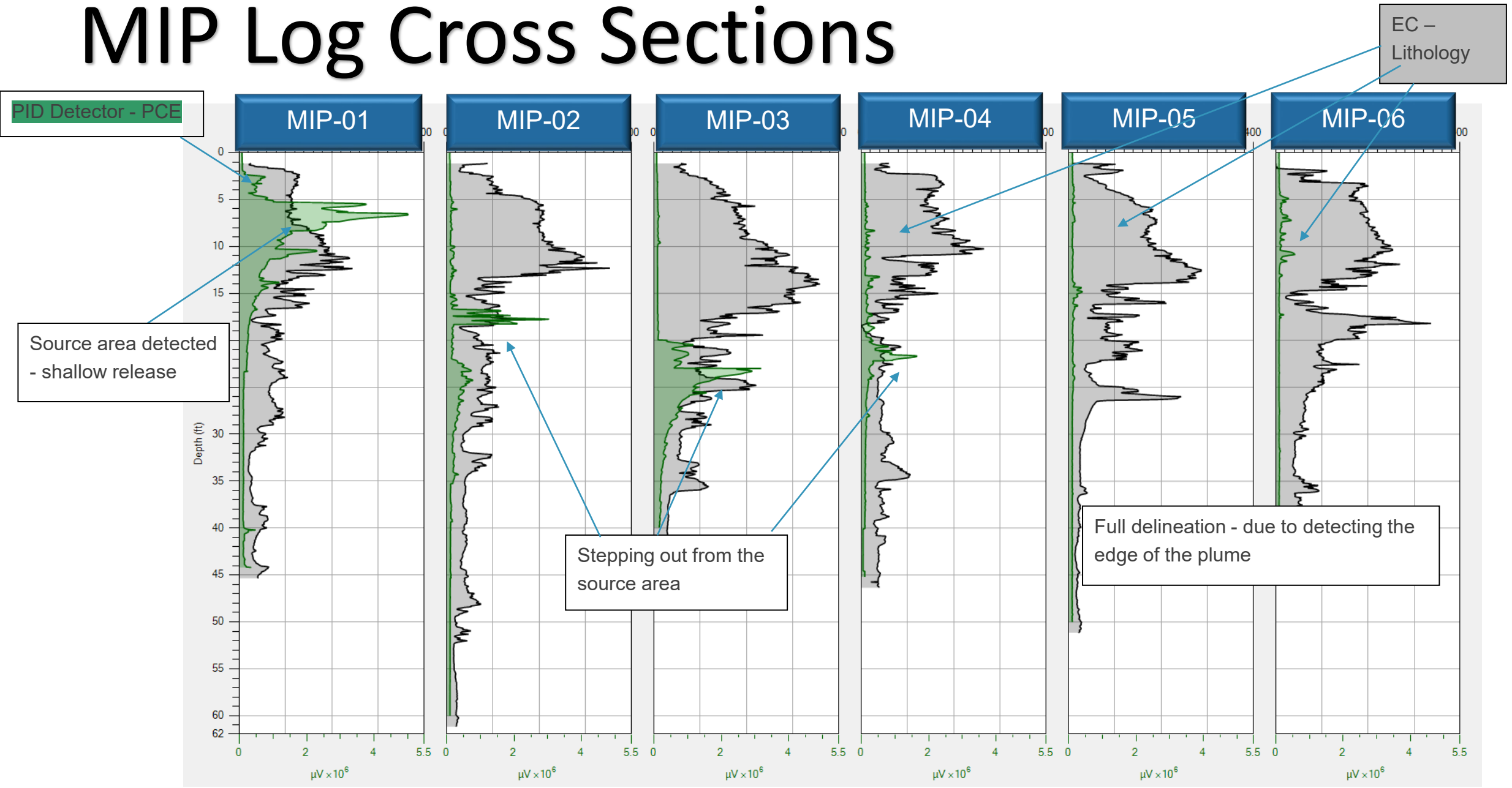
MIHpt Log

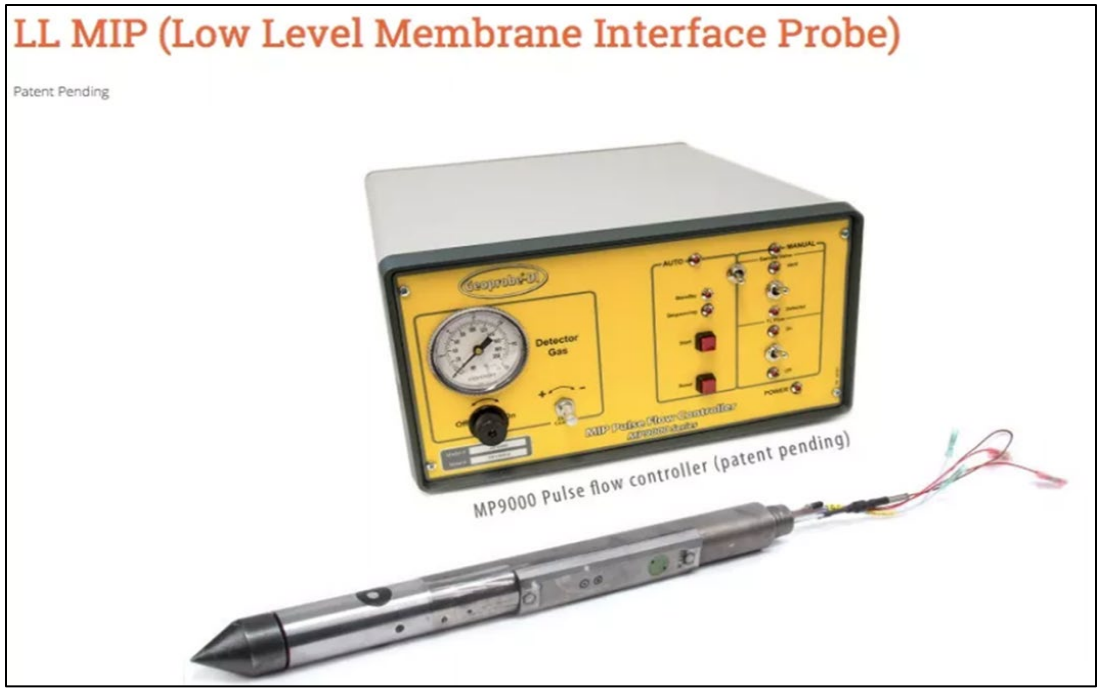

EC (Grain Size Indicator)
Contaminant Detectors
HPT Pressure
Abs. Piez. Pressure
PID
FID
XSD
Depth (ft)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
Tight clay interval
Detector responses, indicating a hydrocarbon release
Silty sands
Sandy interval
Groundwater table
Dissipation test
High transmissivity zones
HPT Flow
Est. K

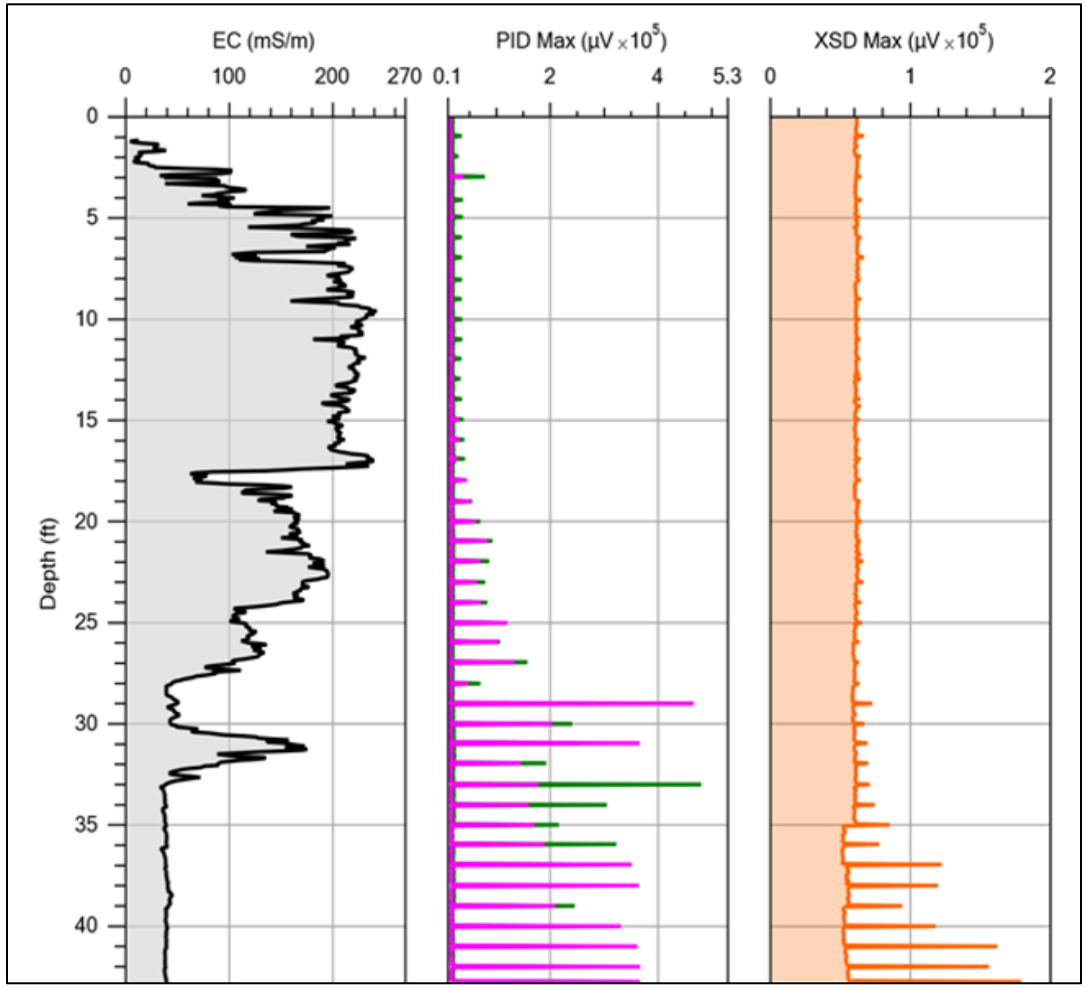
MIP Log Cross Sections



Low Level MiHPT

- ppb levels
- Slower detection rates

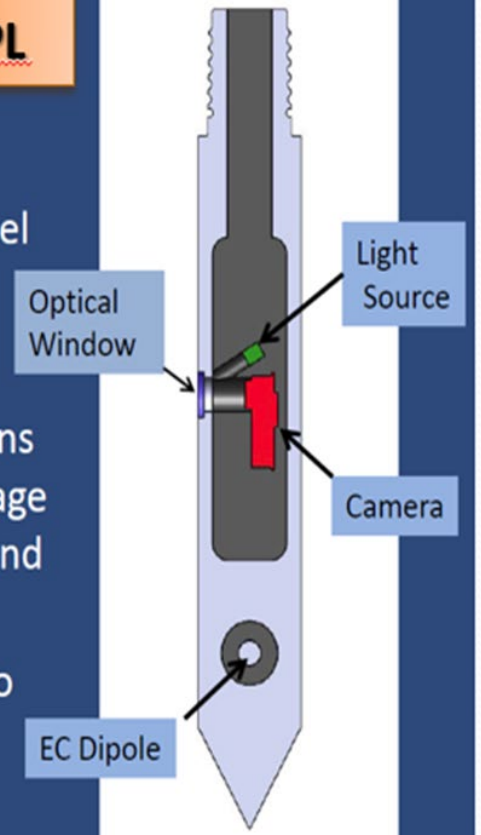




OIHPT – Optical Imaging Profiler

LED Fluorescence Technology for Subsurface Imaging of Petroleum NAPL

- **Purpose:** Detecting UV induced fluorescence of non aqueous phase fuel hydrocarbons in soil.
- **Method:** High intensity UV light directed at the soil causes hydrocarbons present in the soil to fluoresce. An Image of the soil is captured by the camera and analyzed for fluorescence.
- Visible light images of the soil may also be obtained.



OIHPT – Optical Imaging Probe

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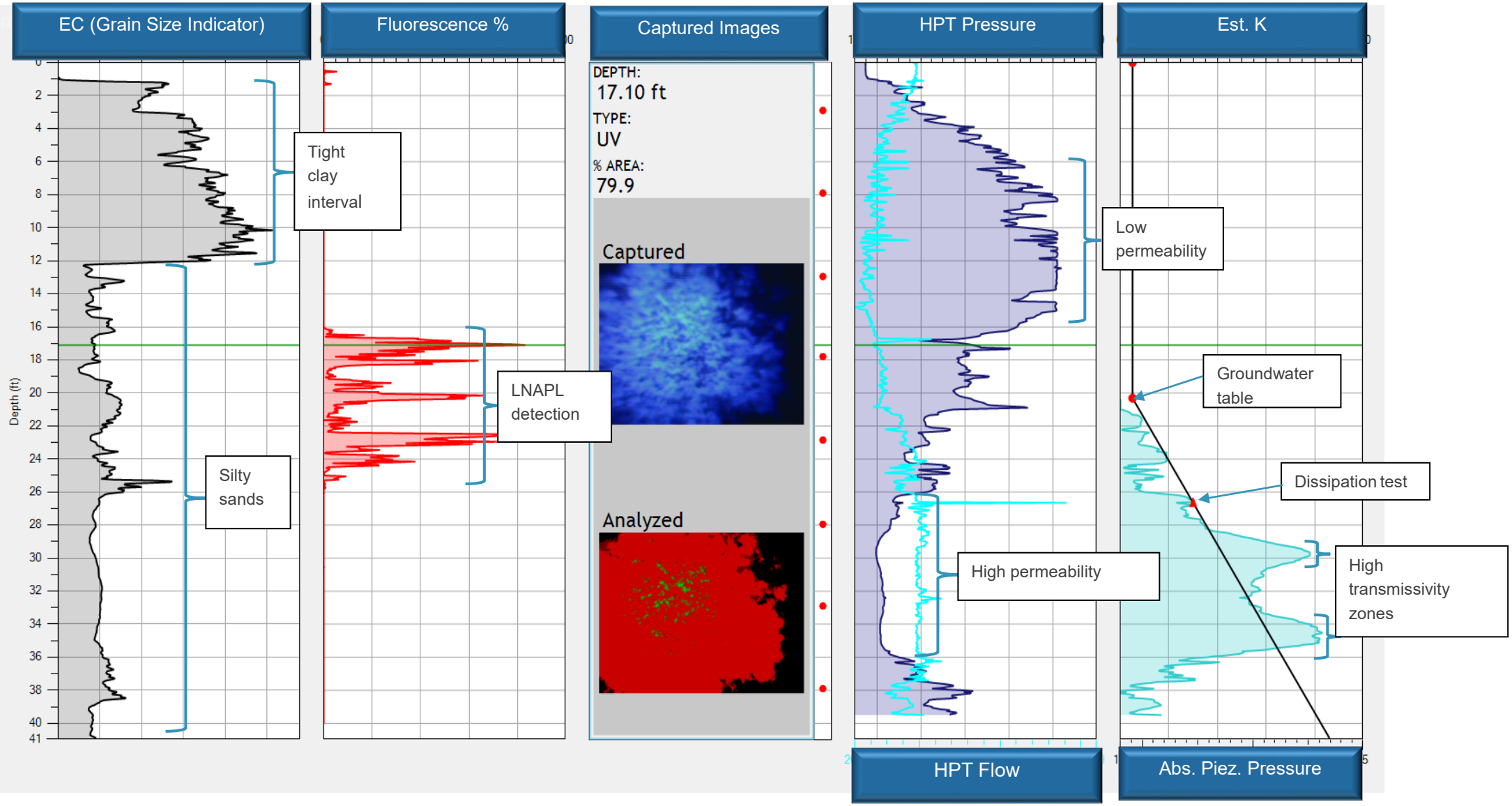
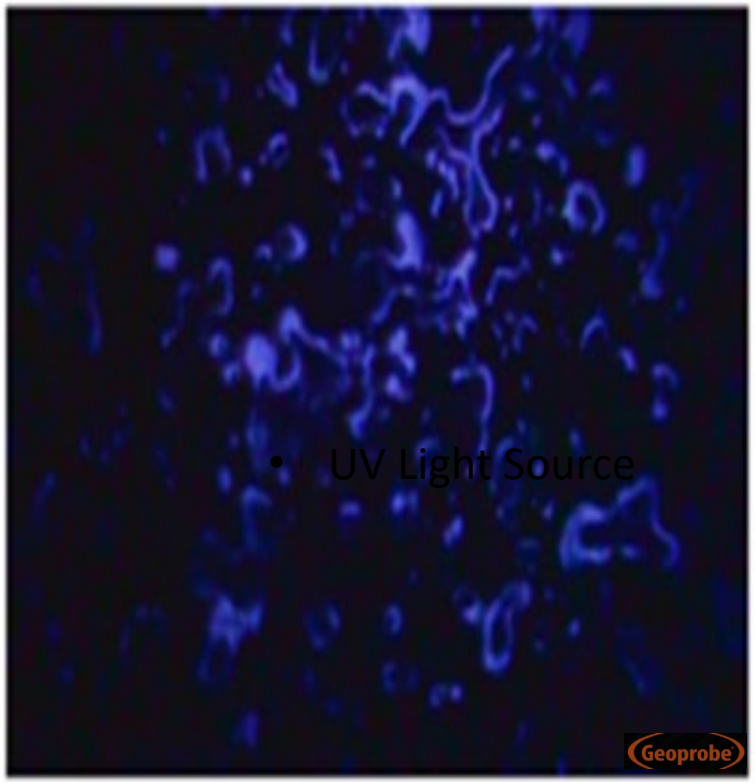
OIP Fluorescence Log



OIP/HPT - OIHPT – Two Light Sources



- UV Light Source

- UV Light Source
- Visible Light Source-
  - Forensics, Confirm Suspect Minerals, Etc

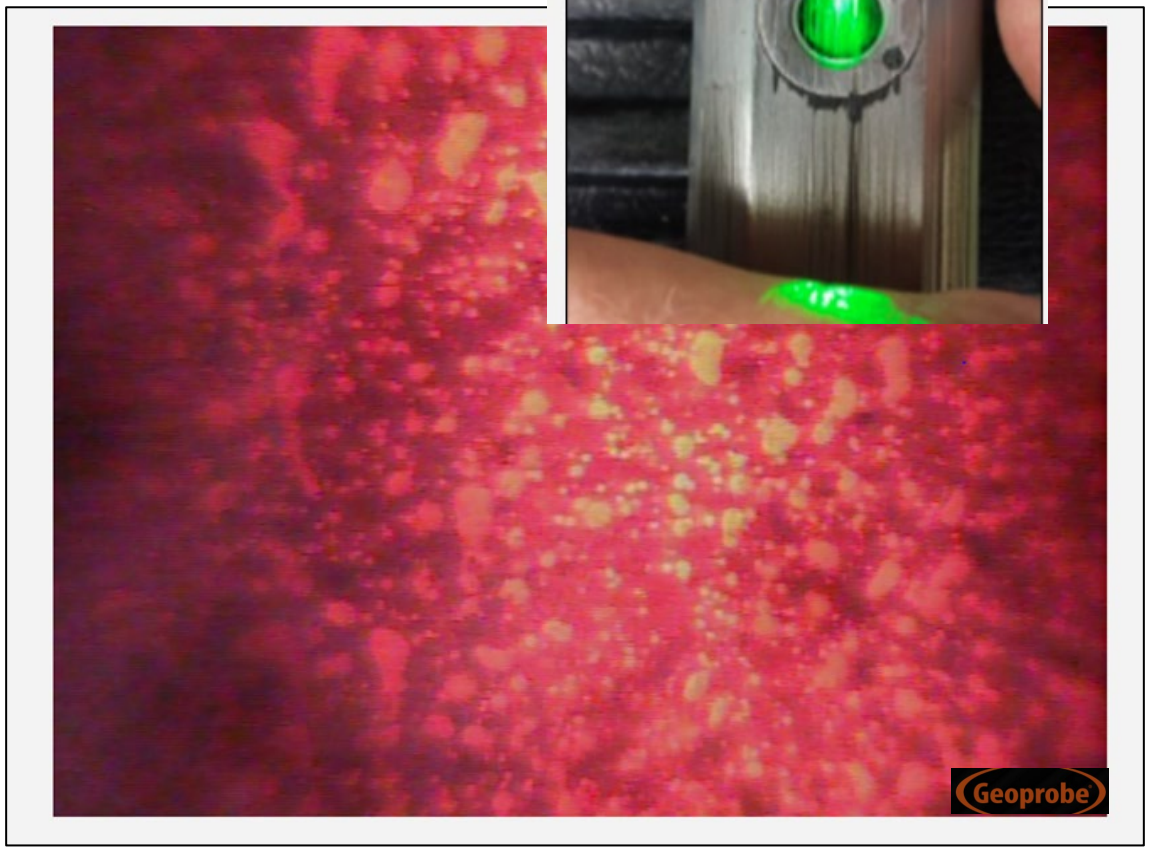
OIP - Green

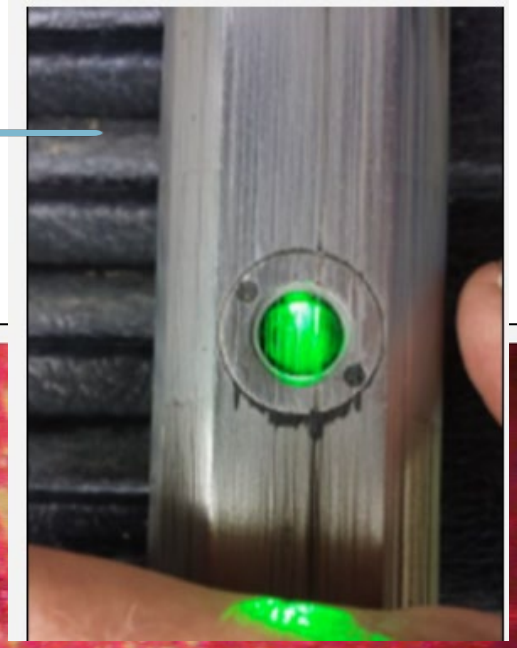
OIHPT -

- 520 nm Green laser Diode
- Larger PAH COCs
  - Heavy Crude Oils
  - Bunker Fuels
  - Creosote
  - Coal Tars

EC

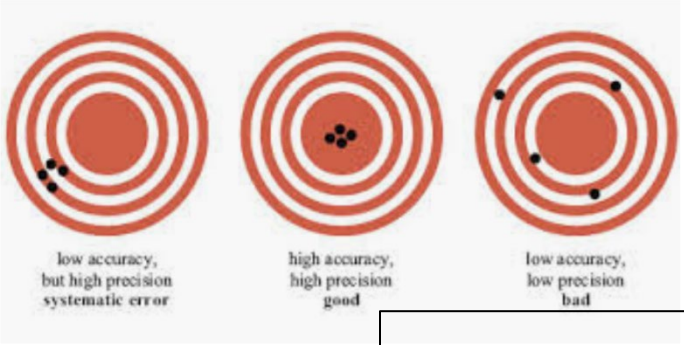
HPT



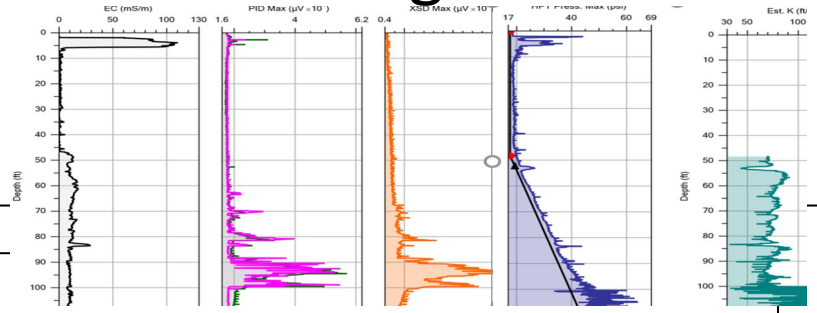


Strategic Optimization with HRSC – Critical for Success

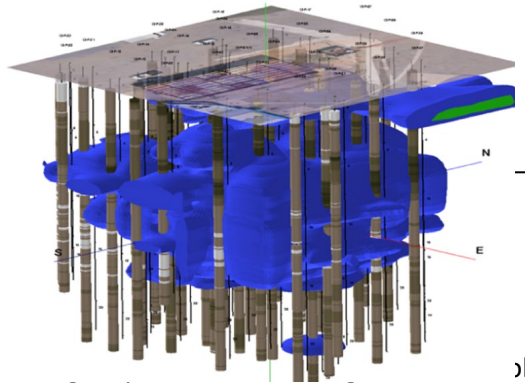
- #1 - ACCURATE DATA!



- #2 – REAL TIME DATA – Dynamic decision making

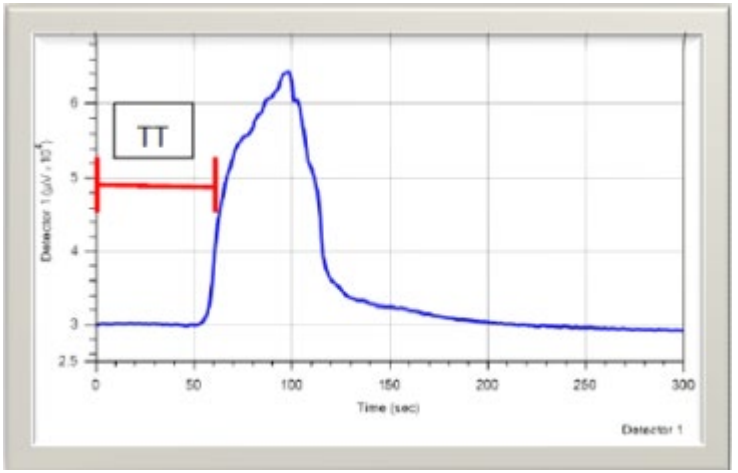


- #3 – Understand your data



Strategic Optimization with HRSC – Critical for Success- Ensure Accurate Data!

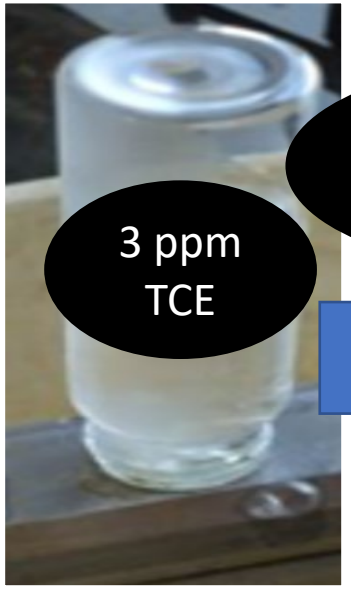
- QC Tests- before & after each boring:
- SOPs
- Reviews
- Trained Specialists Only!!



Log QA, Diesel Fuel

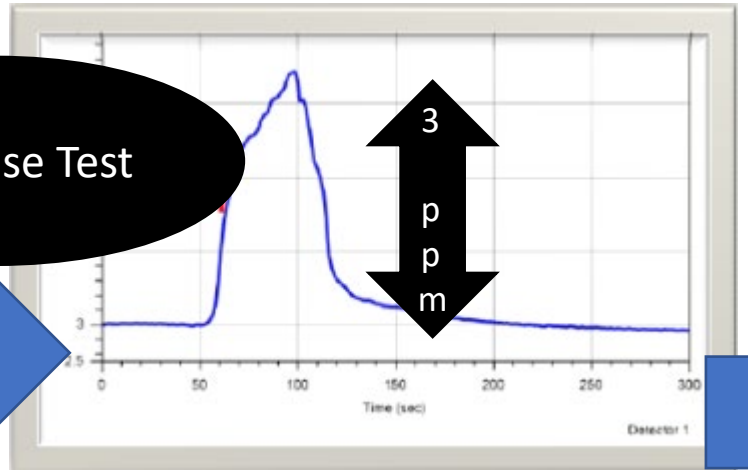
QA, Visible Target

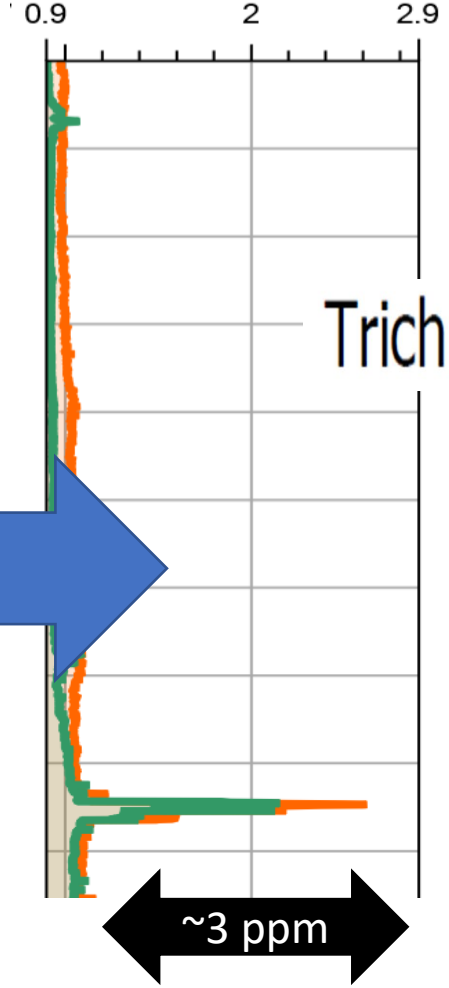
Semi-quantitative if utilized correctly:



3 ppm TCE

Response Test





Laboratory Results

Trichloroethene 3000 ug/L

Sample Accurately

Understand your HRSC Data

Yes, but only IF:

1. Strategic Accurate HRSC process
2. Correlate the data
   - Semi-quantitative ranges

Key to bridge the gap with just the right amount of analytical data

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Understand your HRSC Data

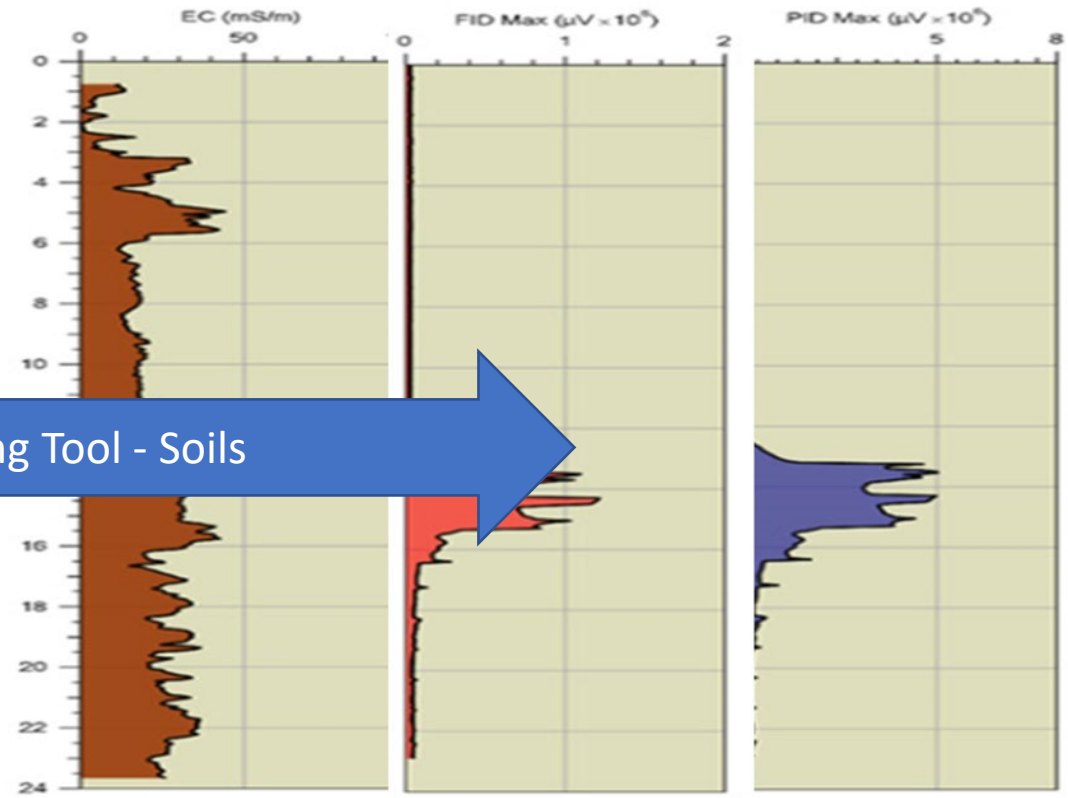
Correlation Sampling:

- ~10-20% of borings – for semi-quantitative data
  - MAP the discrete points to sample

Targeting Discrete HRSC Interval - with a high-resolution number of samples

Correlation Sampling – Soil & GW

Sampling Mapping Tool - Soils



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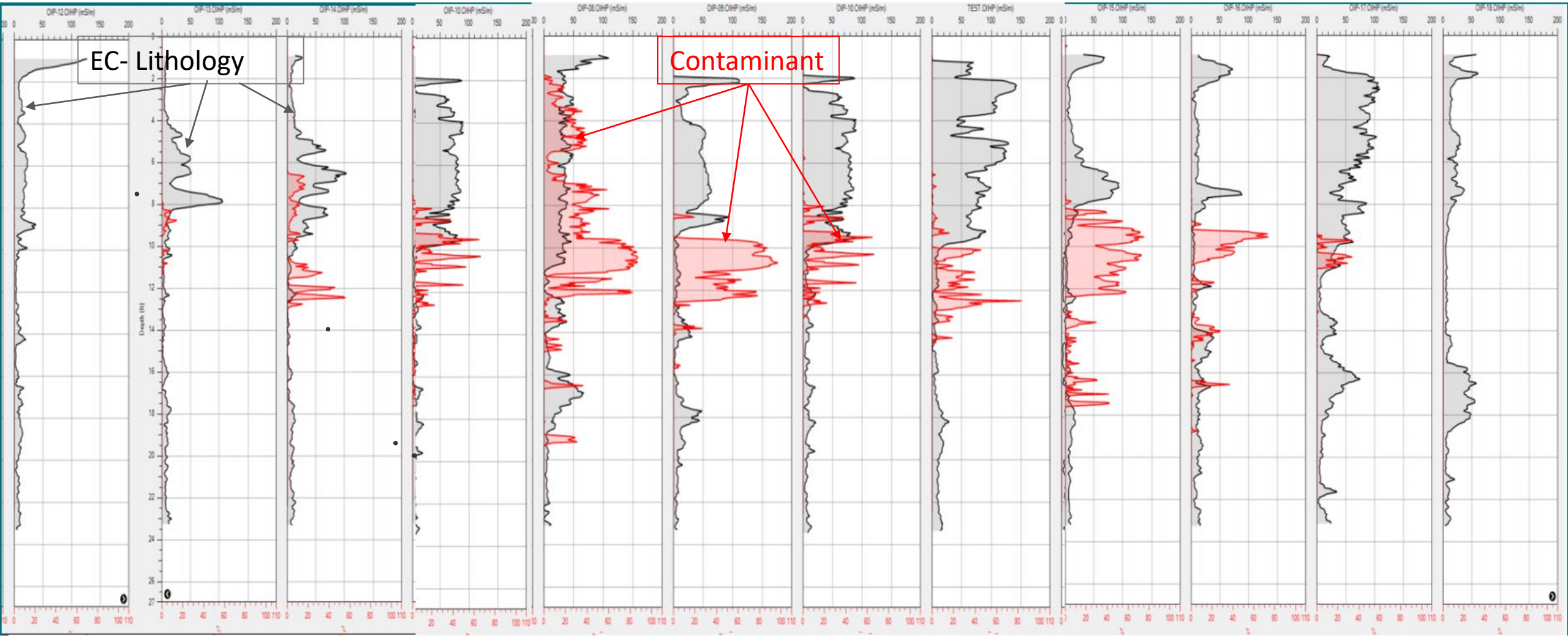
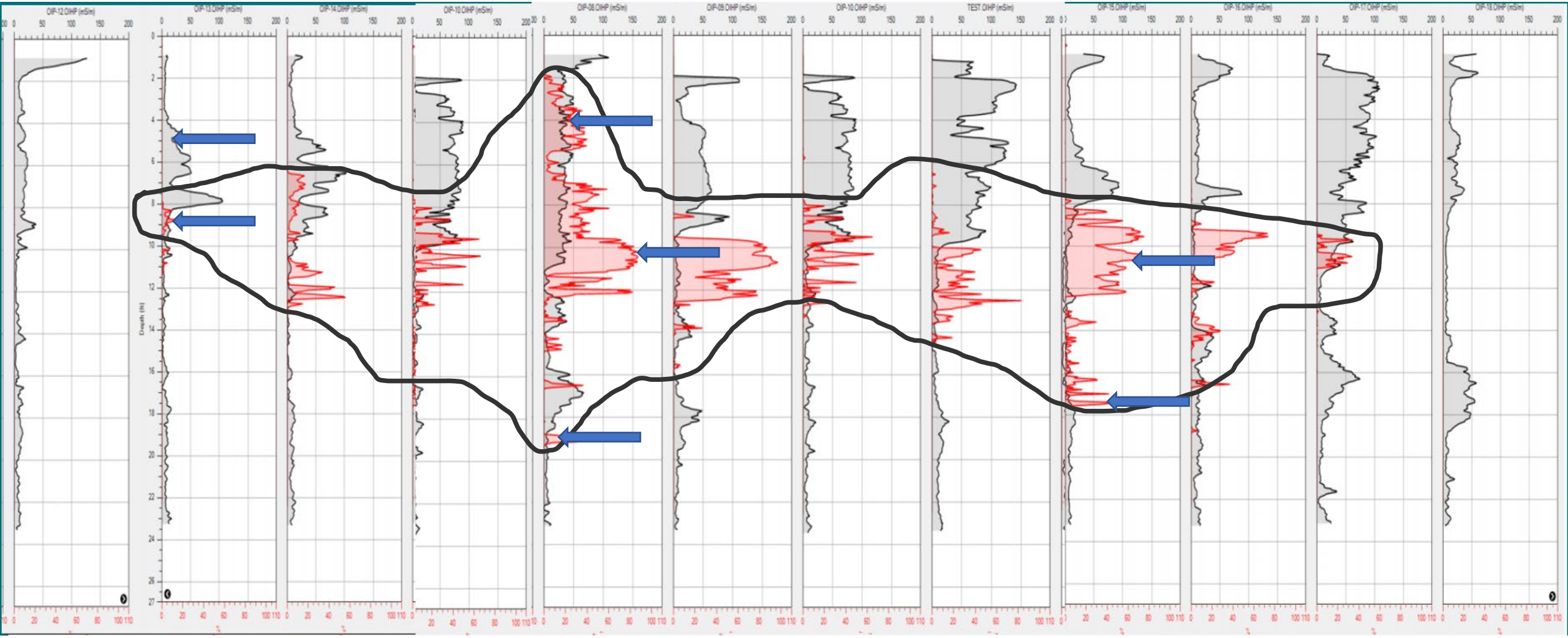
OIP Borings- Daily Cross Sections- 1 Day



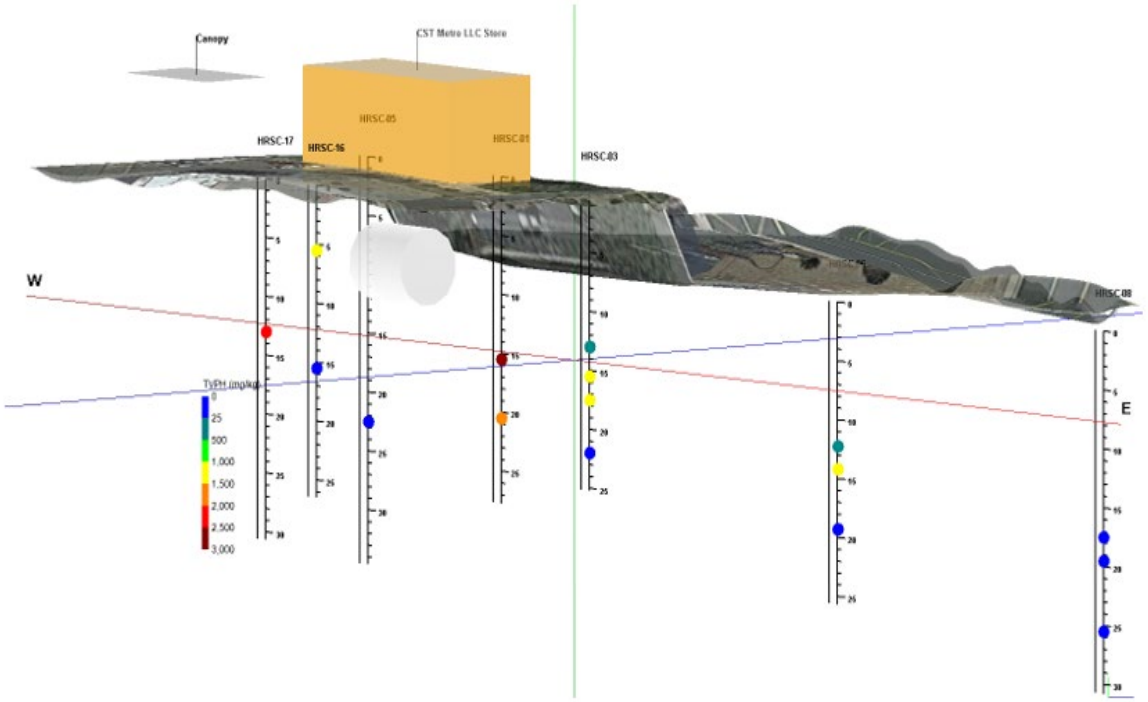
OIP Borings- Daily Cross Sections- 1 Day

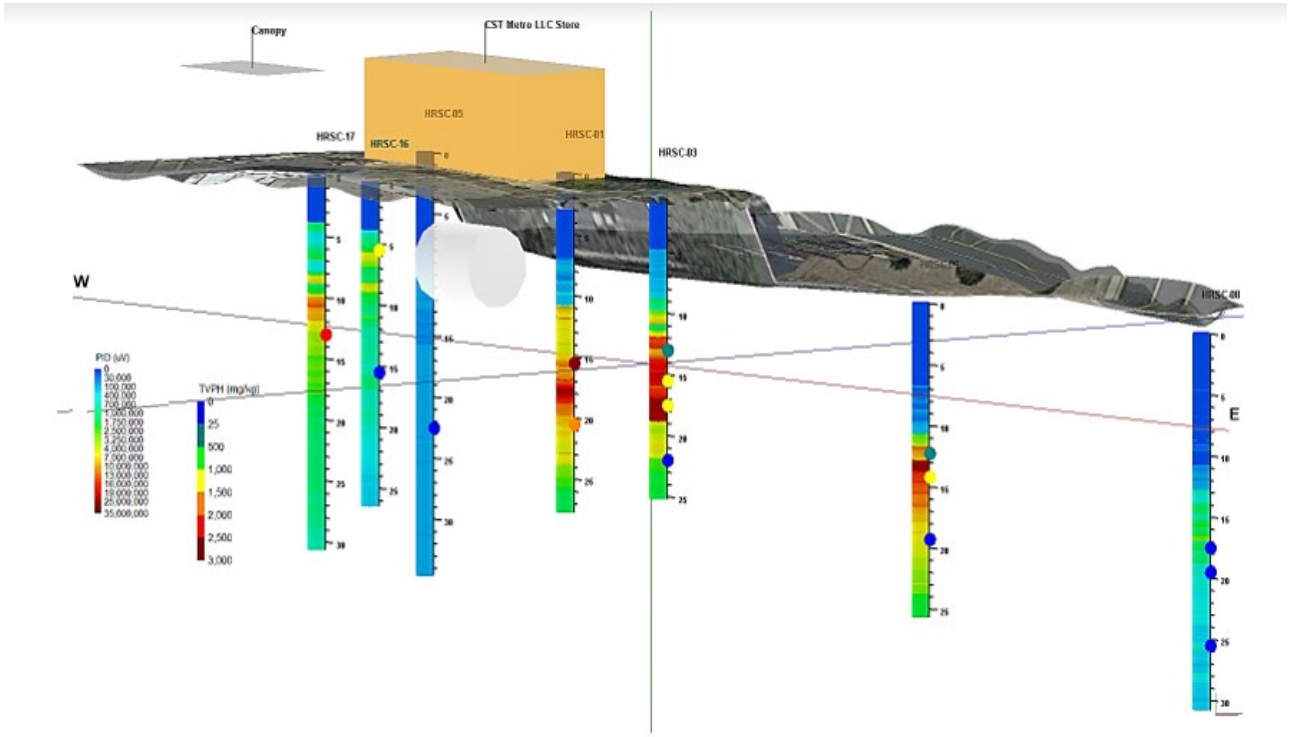


High Resolution Data for Targeted Remedial Design

Accurate CSM + Analytical Correlation Samples = Semi-quantitative data

Soil Confirmation Samples (TVPH)





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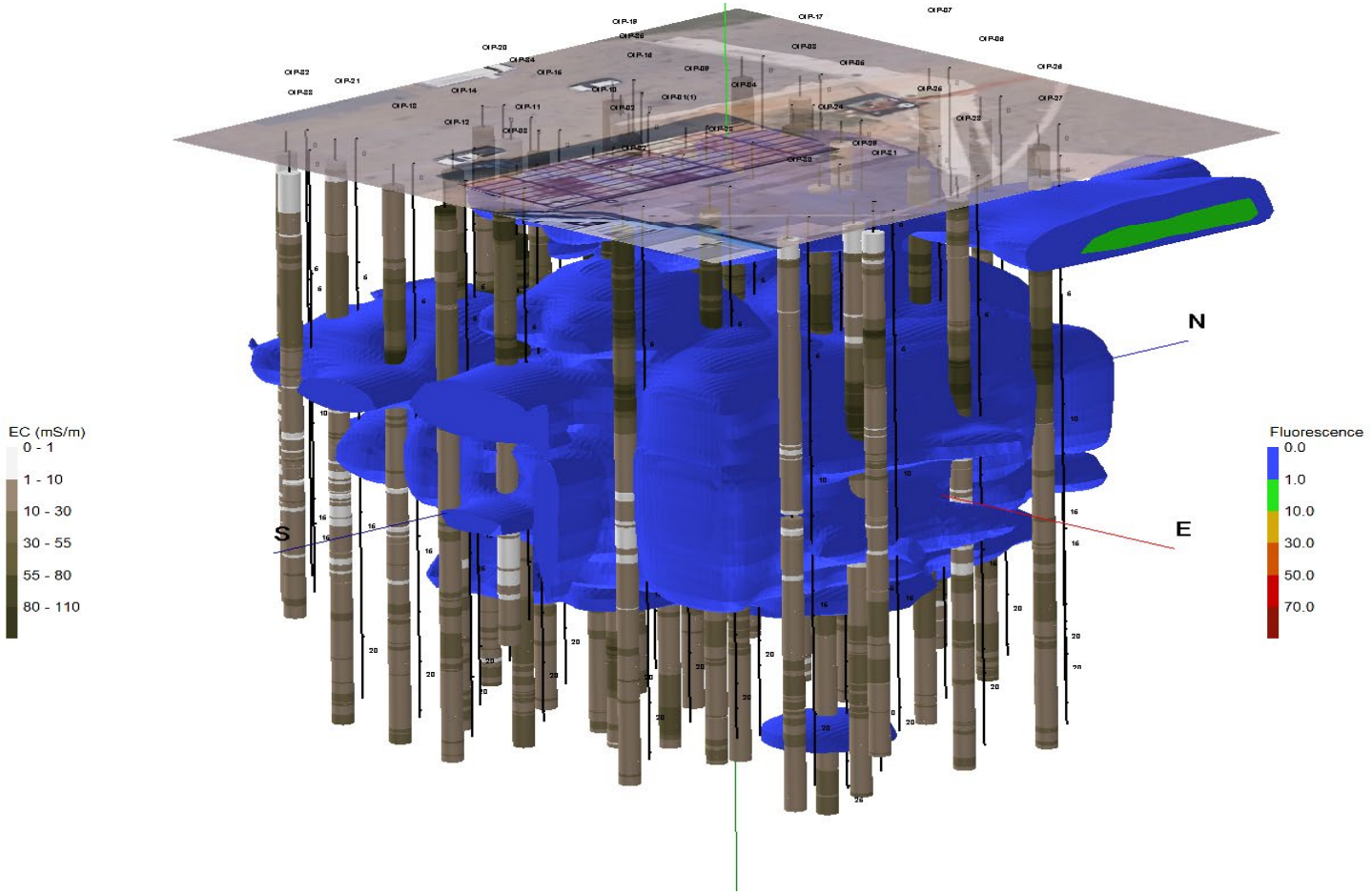
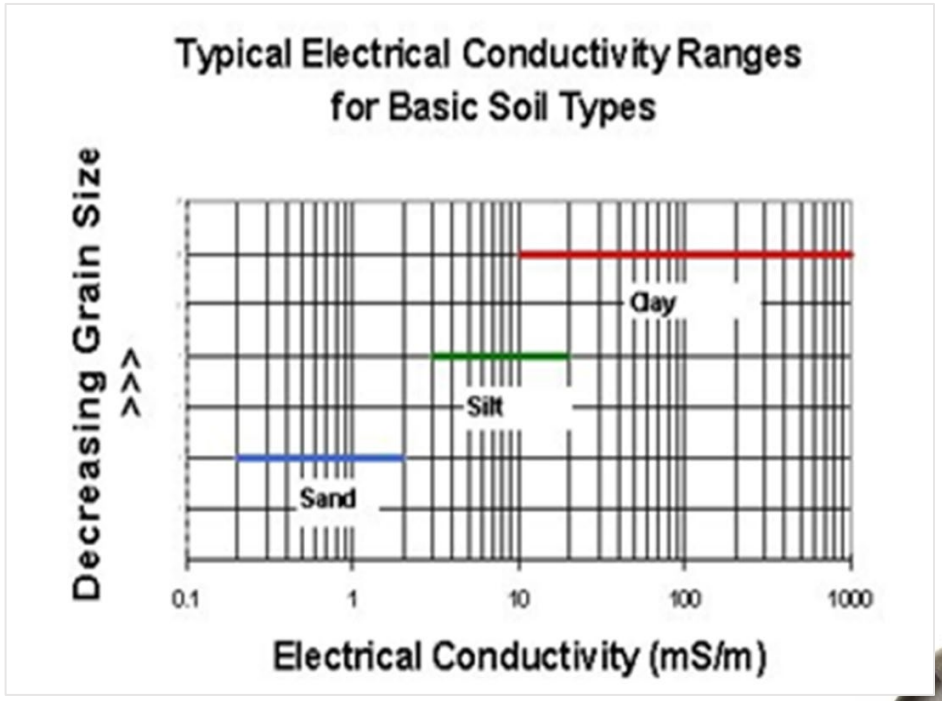
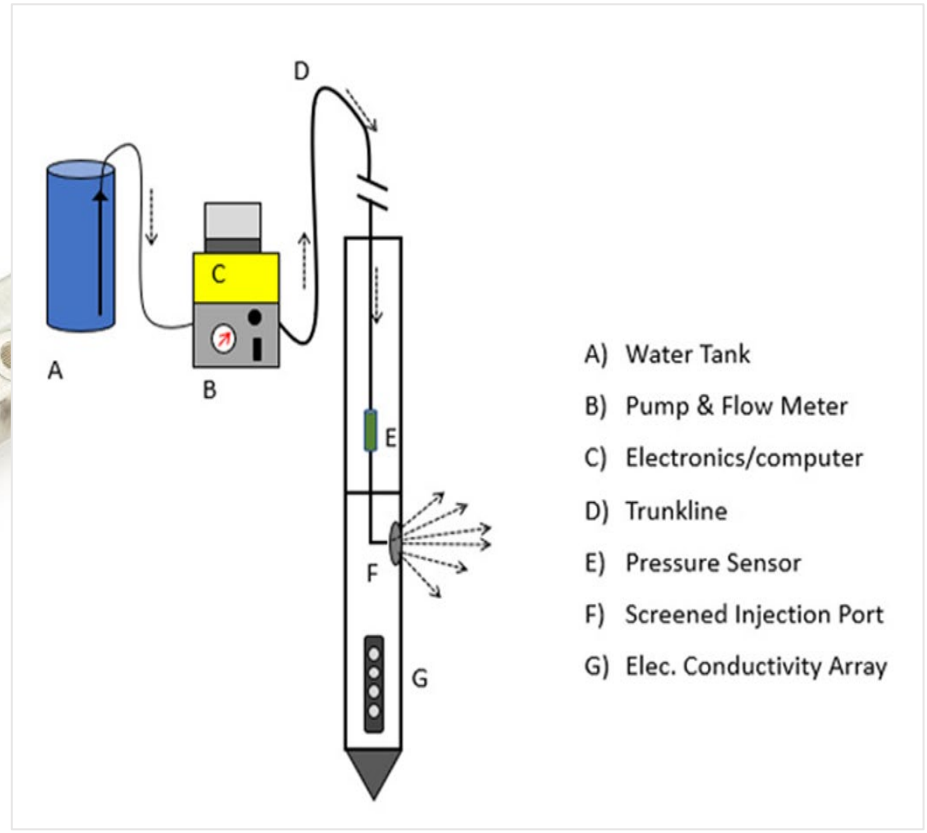
HRSC + soil & gw sample correlation = Semi-quantitative Data



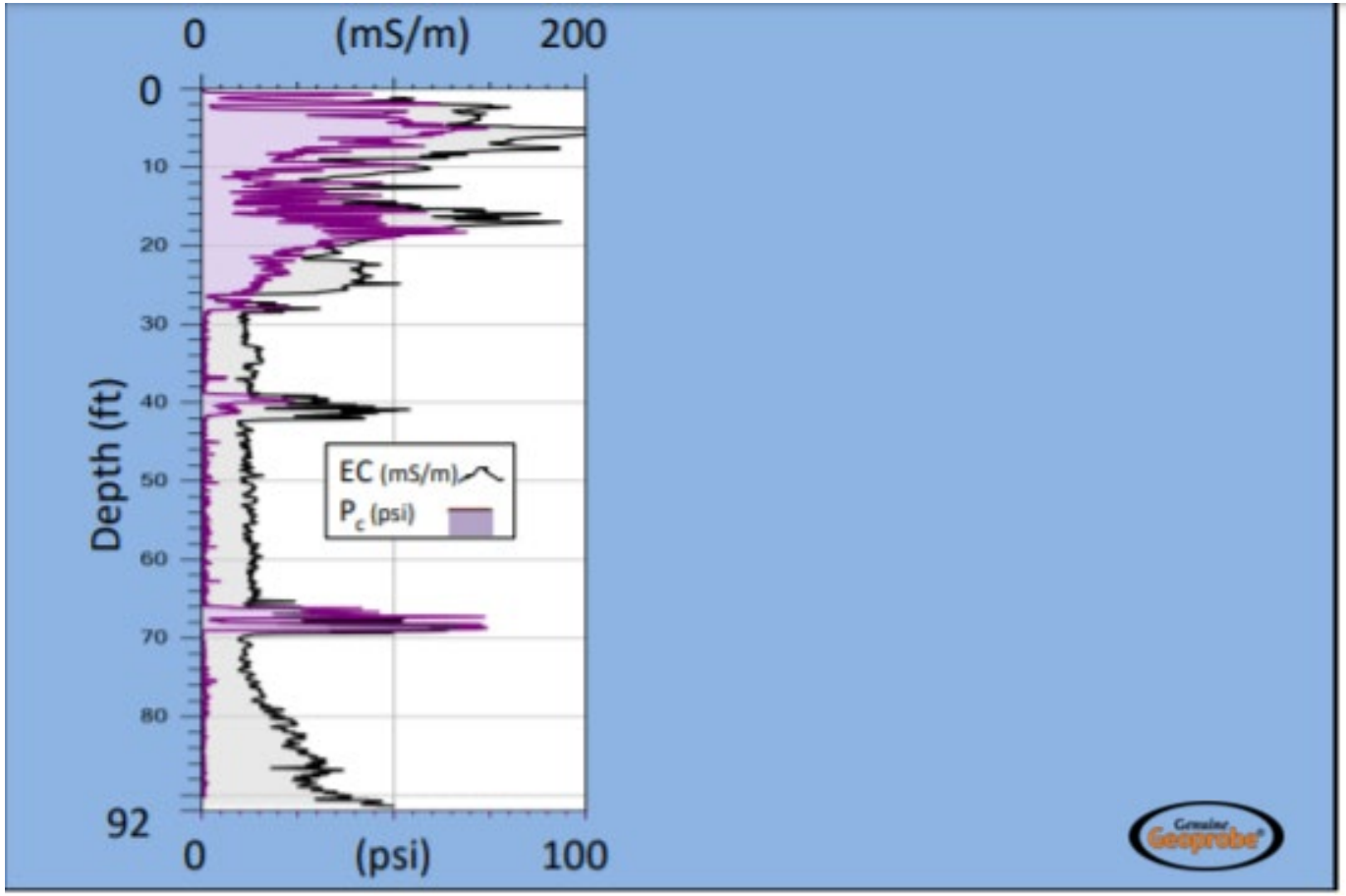
Discrete Water Samples

GW Profiler/Sampler





EC & HPT


0
(mS/m)
200
0
10
20
30
40
50
60
70
80
92
Depth (ft)
EC (mS/m)
P_c (psi)
0
(psi)
100

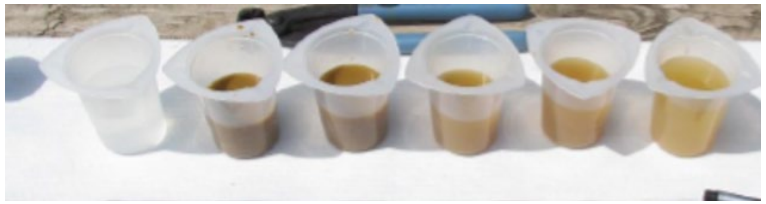
Utilizing HRSC for PFAs Site Investigations

Correlation Sampling- GroundWater Sampler Probe:

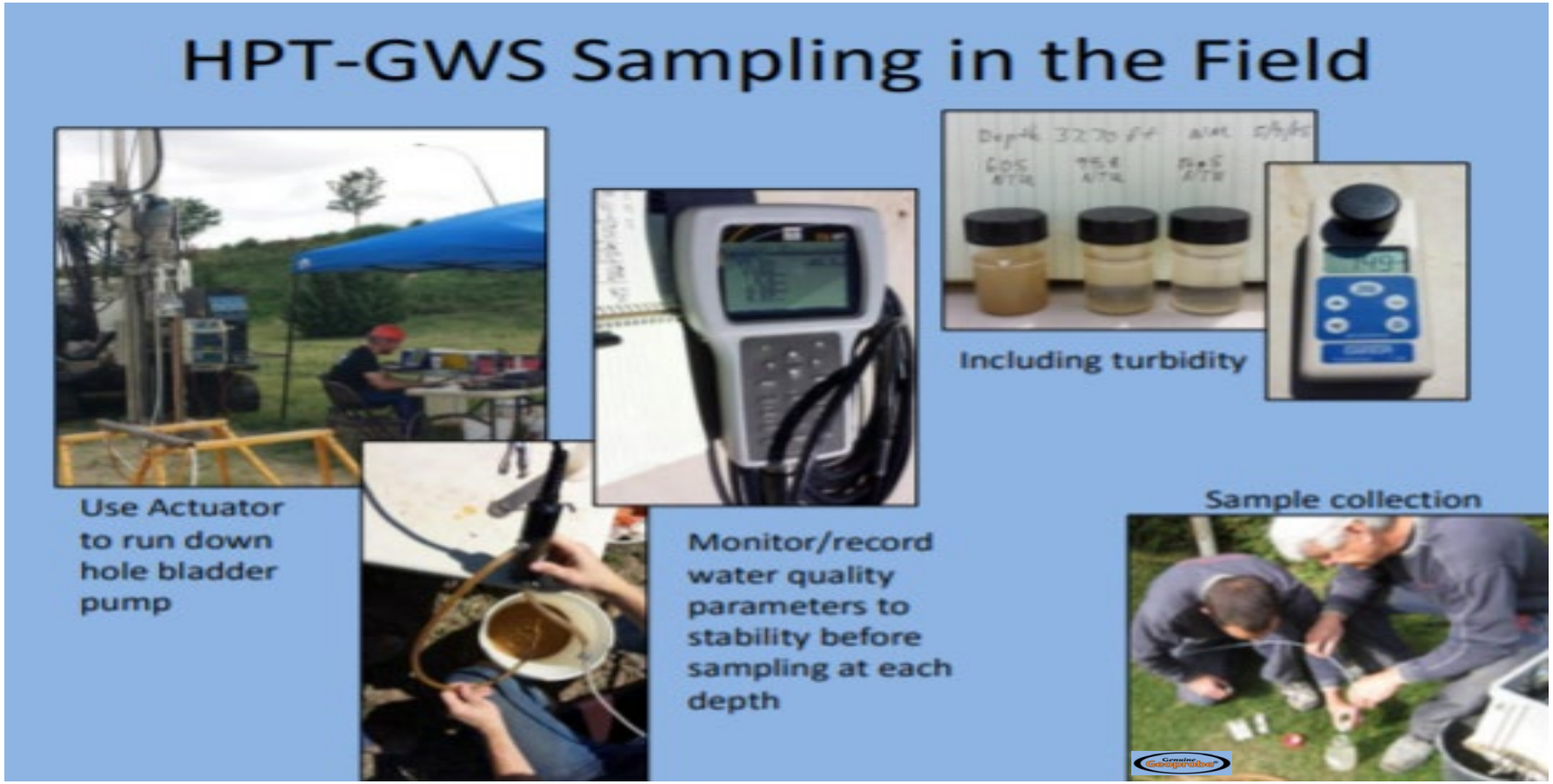
Discrete Water Samples

- Designed for use with Geoprobe 1.75 inch rods.
- Stainless Steel Construction.
- 20 Port HPT Screen Configuration.
- Uses downhole pump.
  - Teflon Bladder, or
  - Syringe piston
- 2 tube connections to surface:
  - Supply tube (HPT Flow) down.
  - Pump tube up.

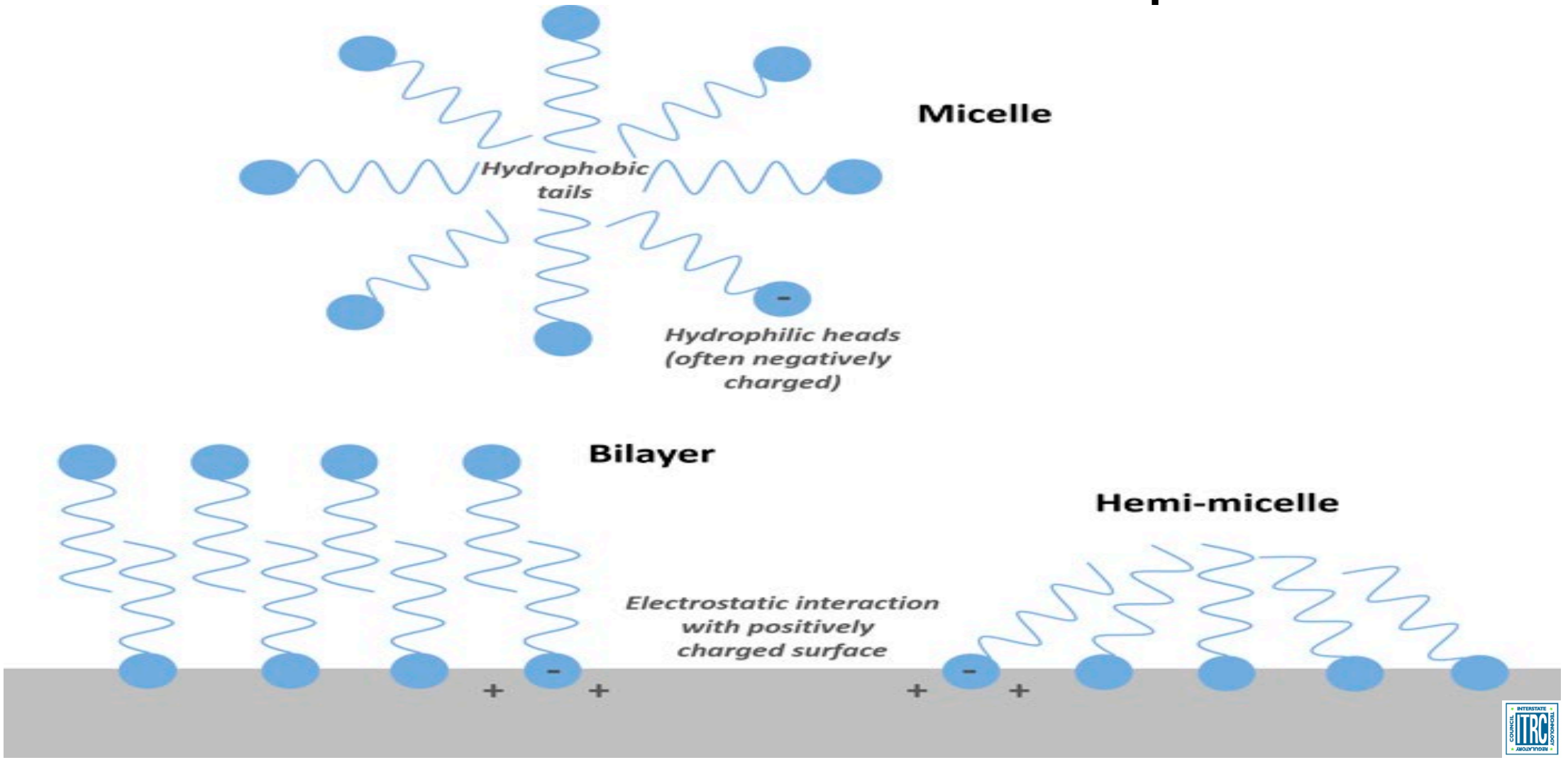
Geoprobe



•GW Sampler/Profiler

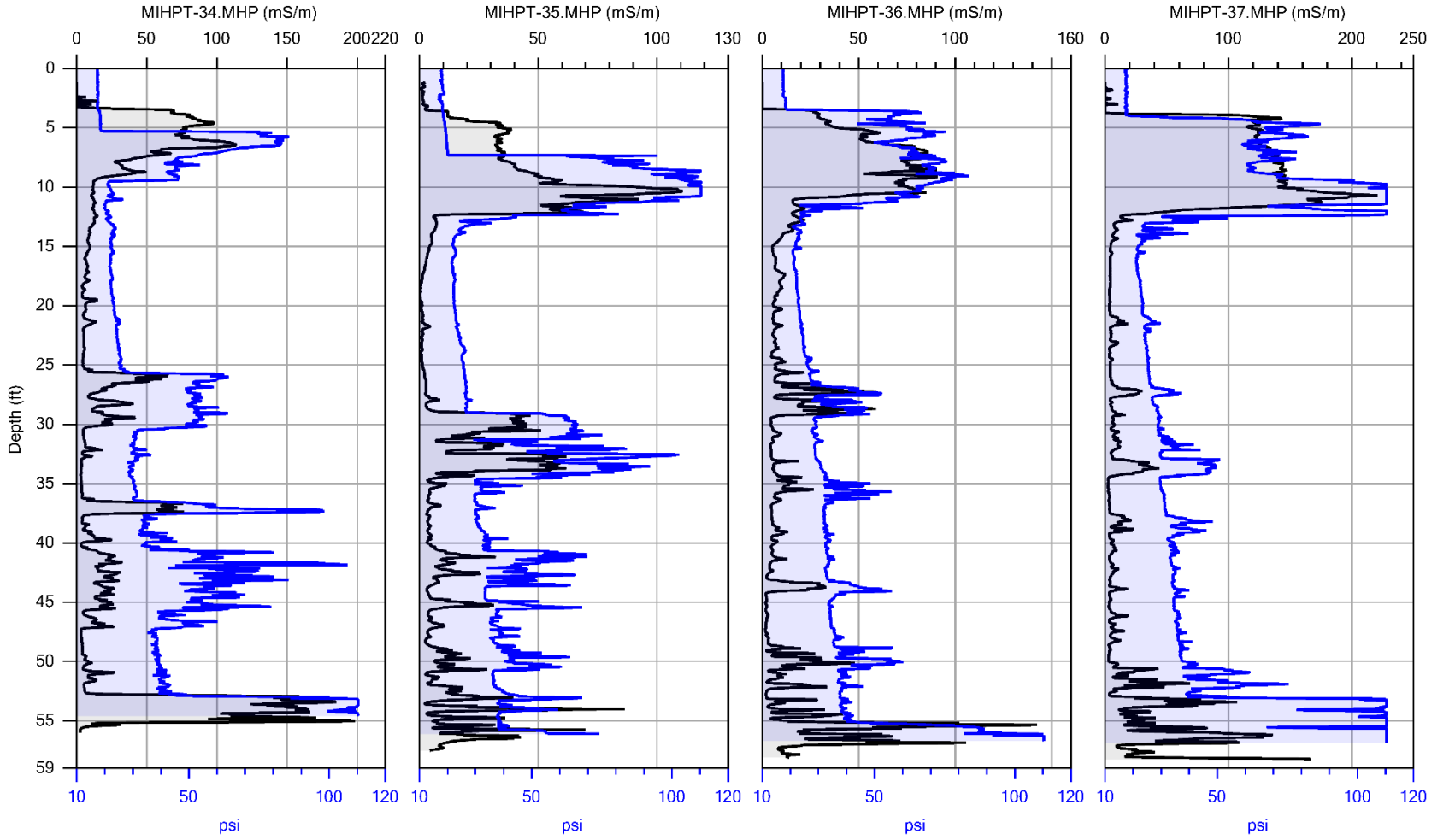


PFAS: Fate and Transport



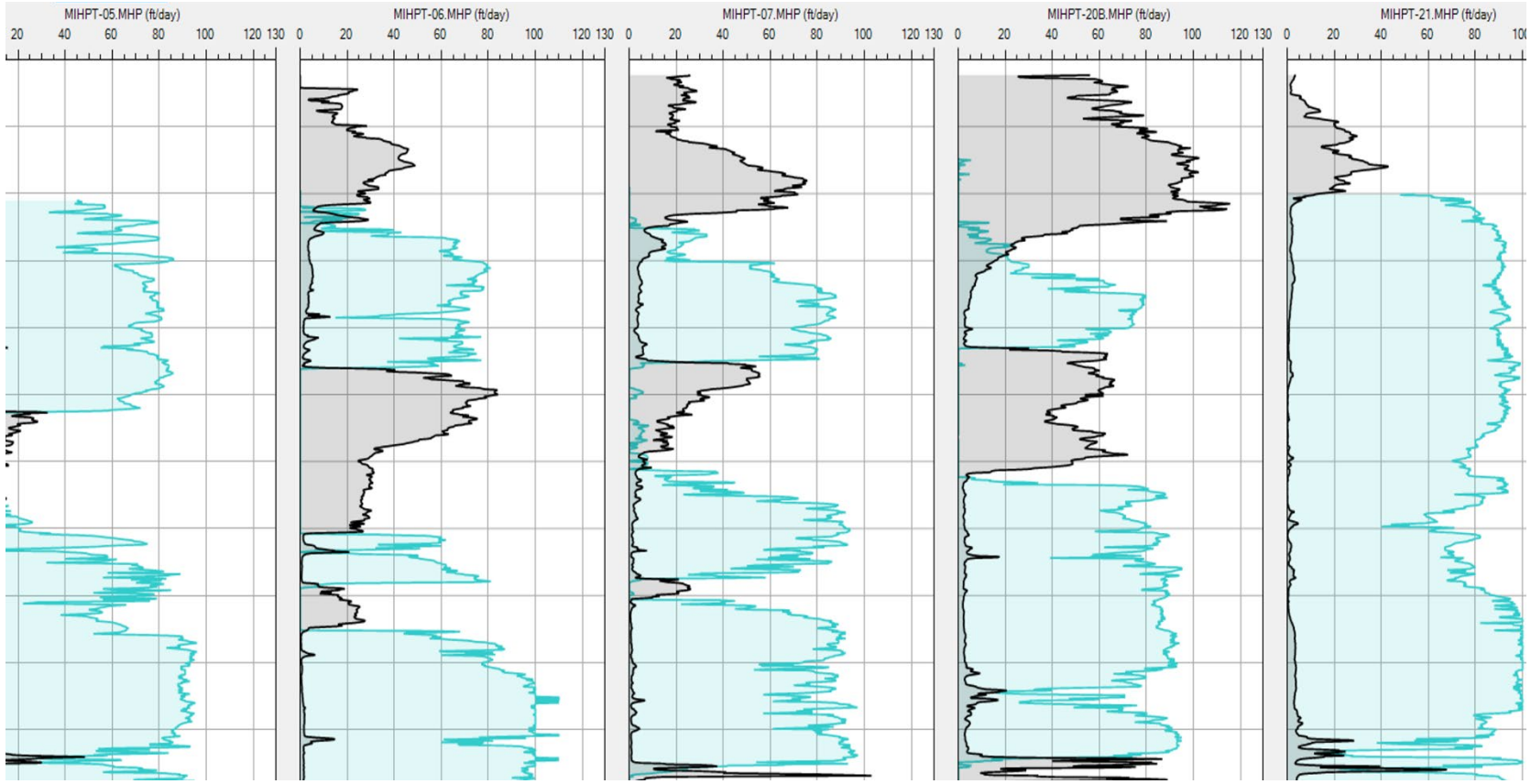
- *Table Source: ITRC PFAS Fact Sheets – Site Risk Assessment (updated April 2020)*

PFAS Site Investigation: Cross Sections



EC & Estimated K Values

Project Overview



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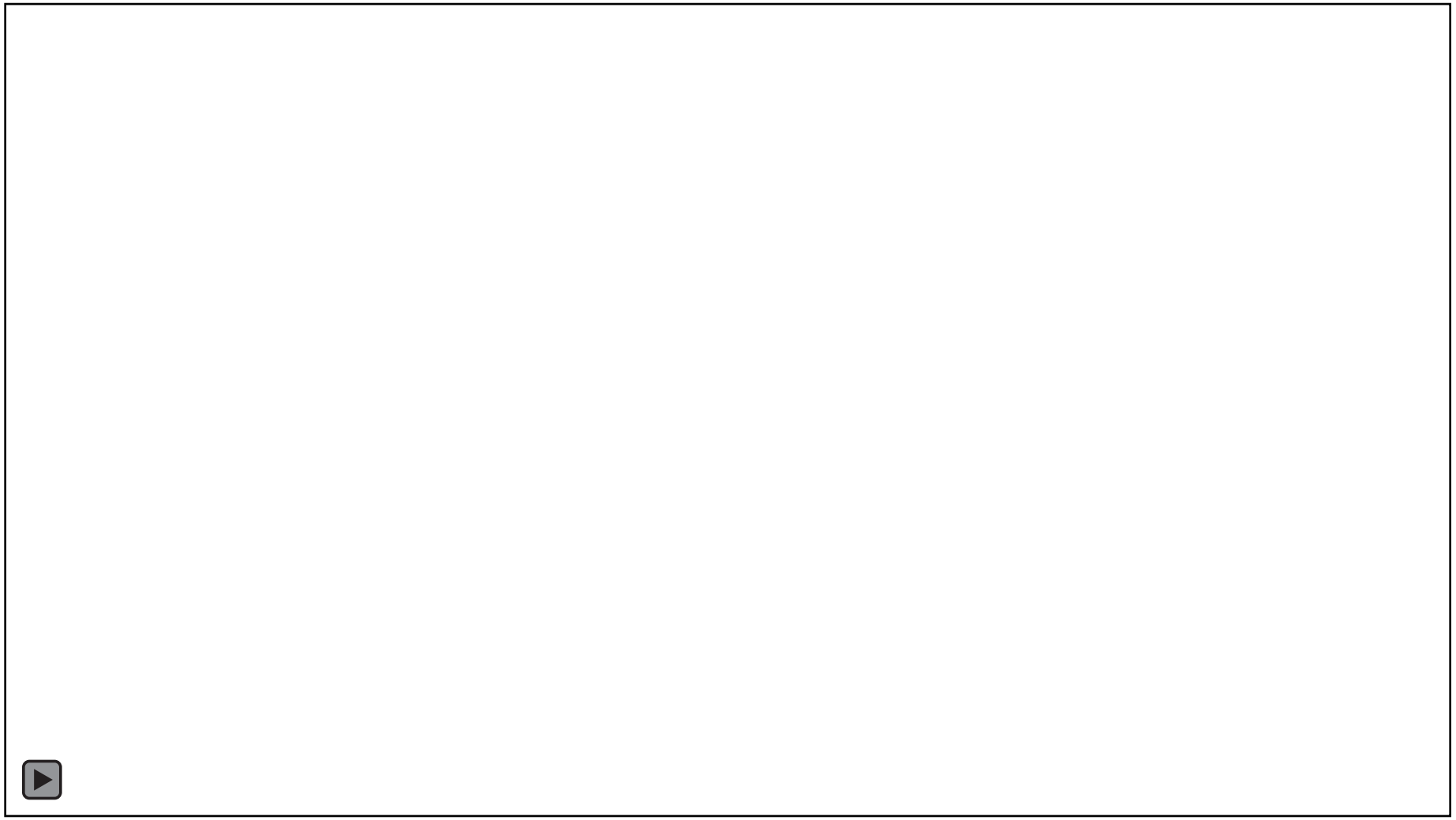
PFAS: Lithology & HPTModeling



UNDERSTANDING HRSC DATA WITH ADDITIONAL CORRELATIONS!

Key to bridge the "language/unit gap" with discrete correlating soil or water samples …which turns HRSC data into semi-quantitative data in ppb/ppm concentrations.

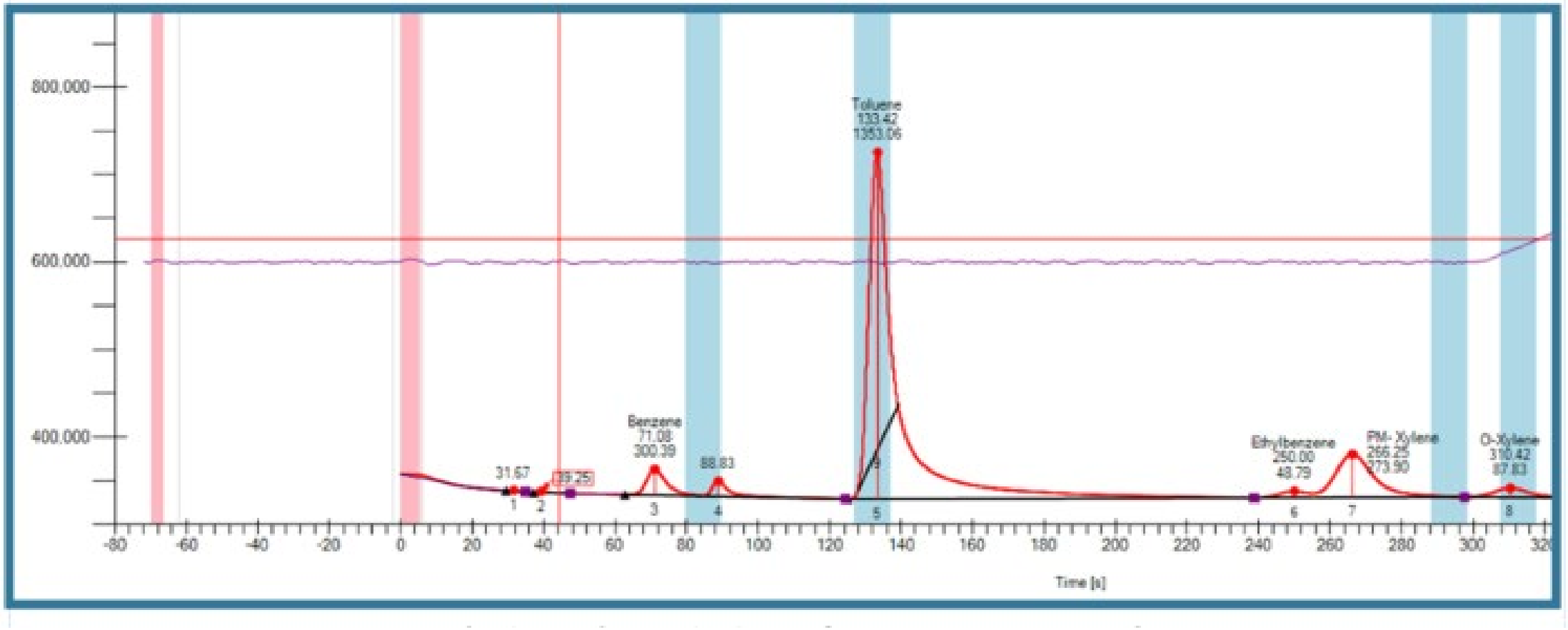
Bridging the "language gap" even further with lab grade speciation and approximate ppb/ppm concentrations in the field

Additional Optimizing Technology!

Lab Grade Portable GC

- Real Time
- On Site
- Samples in ~10 minutes in the Field!

Portable GC reading



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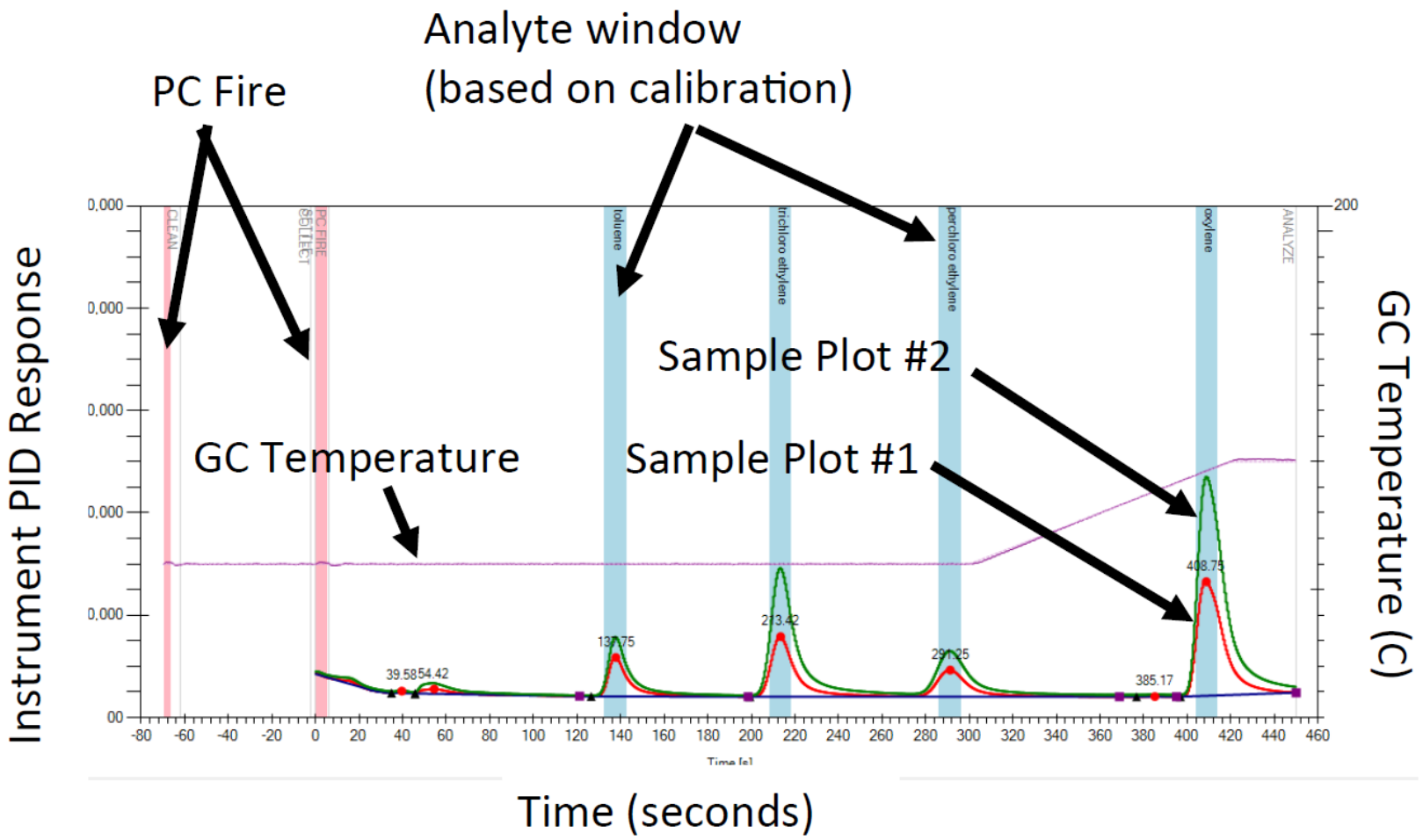
Portable GC reading



- Lab Grade - Calibrated
- Not lab certified

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Detectable Chemicals

1,1-Dichloroethene	75-35-4	10.0
1,2,4-Trichlorobenzene	120-82-1	9.0
1,2-Dibromoethane	106-93-4	10.4
1,2-Dichlorobenzene	95-50-1	9.1
1,3-Dichlorobenzene	541-73-1	9.1
1,4-Dichlorobenzene	106-46-7	9.0
1,4-Dioxane	123-91-1	9.2
1-Propanol	71-23-8	10.2
2-Butanone (MEK)	78-93-3	9.5
2-Chloroethanol	107-07-3	10.5
2-Hexanone	591-78-6	9.4
2-Pentanone	107-87-9	9.4
2-Picoline	109-06-8	9.4
2-Propanol	67-63-0	10.2
4-Methyl-2-pentanone	108-10-1	9.3
Acetone	67-64-1	9.7
Acrolein	107-02-8	10.1
Allyl alcohol	107-18-6	9.6
Allyl chloride	107-05-1	10.1
Benzene	71-43-2	9.2
Benzyl chloride	100-44-7	9.1
Bromoacetone	598-31-2	9.7
Bromodichloromethane	75-27-4	10.6
Bromoform	75-25-2	10.5
Bromomethane	74-83-9	10.5
Carbon disulfide	75-15-0	10.1
Chlorobenzene	108-90-7	9.1
Chlorodibromomethane	124-48-1	10.6
Chloroethane	75-00-3	10.0
Chloroprene	126-99-8	8.8
Crotonaldehyde	4170-30-3	9.7
Dibromomethane	74-95-3	10.5
Diethyl ether	60-29-7	9.5
Diisopropyl ether (DIPE)	108-20-3	9.2
Epichlorohydrin	106-89-8	10.6
Ethanol	64-17-5	10.6
Ethyl acetate	141-78-6	10.0
Ethyl tert butyl ether	637-92-3	9.4
Ethylbenzene	100-41-4	8.8
Ethylene oxide	75-21-8	10.6
Iodomethane	74-88-4	9.5
Isobutyl alcohol	78-83-1	10.1
Isopropylbenzene	98-82-8	8.8
Methacrylonitrile	126-98-7	10.3
Methyl methacrylate	80-62-6	9.7
Methyl tert-butyl ether	1634-04-4	9.2
m-Xylene	108-38-3	8.6
Naphthalene	91-20-3	8.1
n-Butanol	71-36-3	10.0
Nitrobenzene	98-95-3	9.9
n-Propylamine	107-10-8	8.8
o-Toluidine	95-53-4	7.4
o-Xylene	95-47-6	8.6
Propargyl alcohol	107-19-7	10.5
p-Xylene	106-42-3	8.5
Pyridine	110-86-1	9.3
Styrene	100-42-5	8.4
t-Butyl alcohol	75-65-0	10.3
Tetrachloroethene	127-18-4	9.3
Toluene	108-88-3	8.8
trans-1,2-Dichloroethene	156-60-5	9.7
Trichloroethene	79-01-6	9.5
Vinyl acetate	108-05-4	9.2
Vinyl chloride	75-01-4	10.0
β-Propiolactone	57-57-8	9.7

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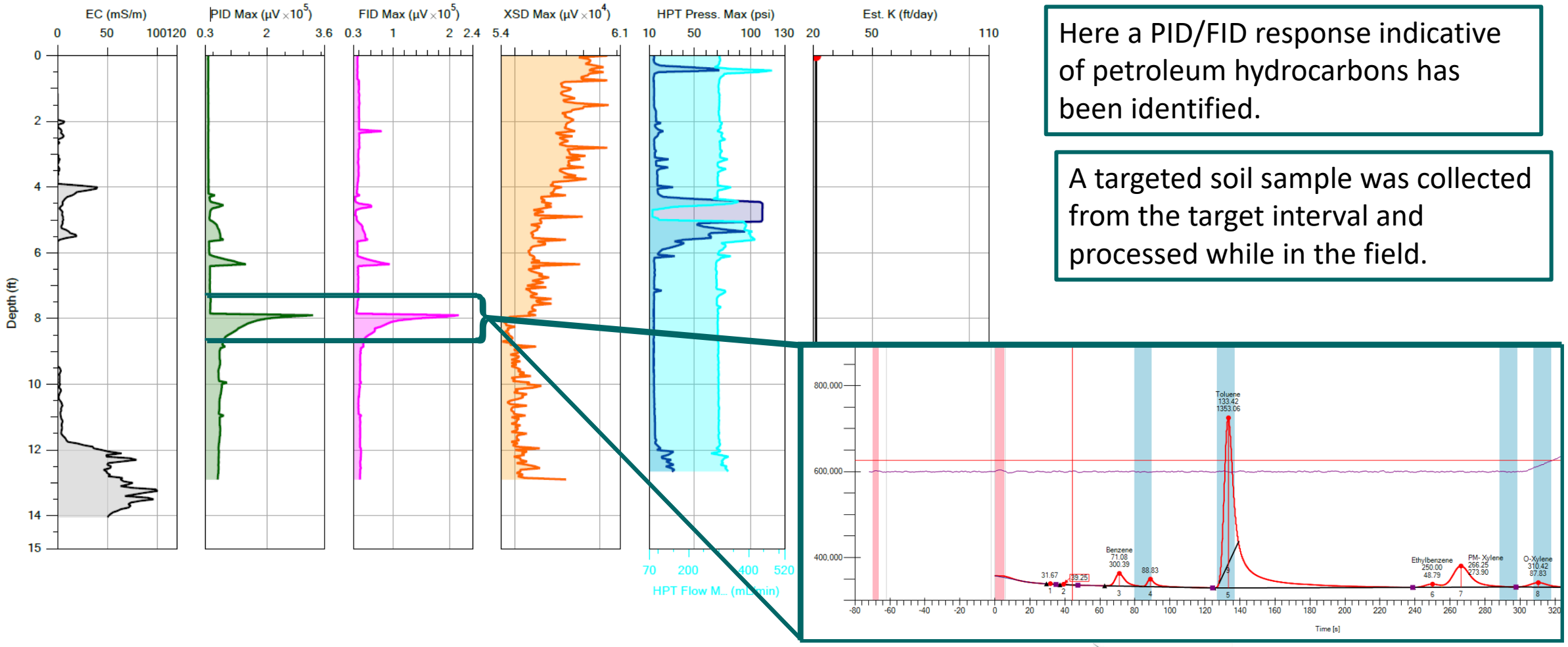
Portable GC data Correlated with HRSC Data



Here a PID/FID response indicative of petroleum hydrocarbons has been identified.

A targeted soil sample was collected from the target interval and processed while in the field.

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UNDERSTANDING HRSC DATA WITH ADDITIONAL Soil, GW, & Soil Gas CORRELATIONS

Key to bridge the "language/unit gap" with discrete correlating soil or water samples …which turns HRSC data into semi-quantitative data in ppb/ppm concentrations.

Bridging the "language gap" even further with lab grade speciation and approximate ppb/ppm concentrations in

Another thought – about "signature" data comparisons……!

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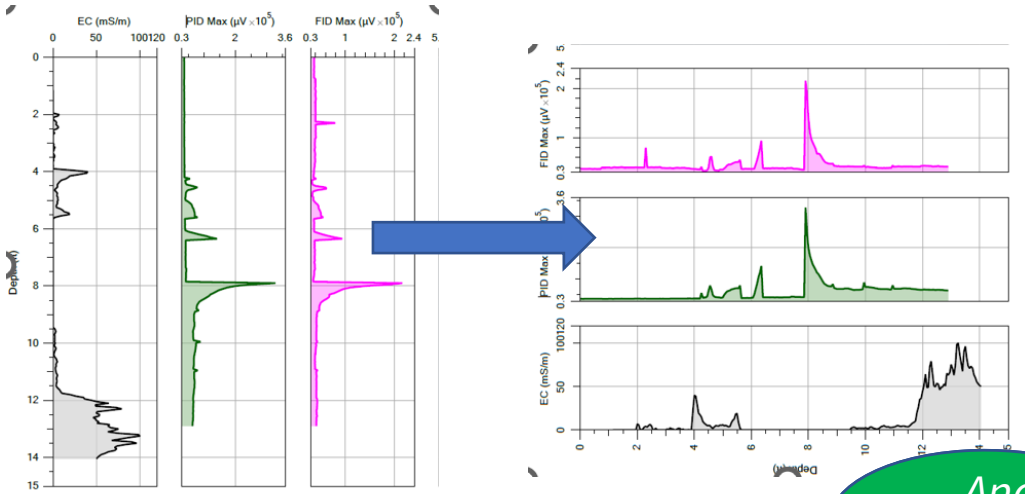
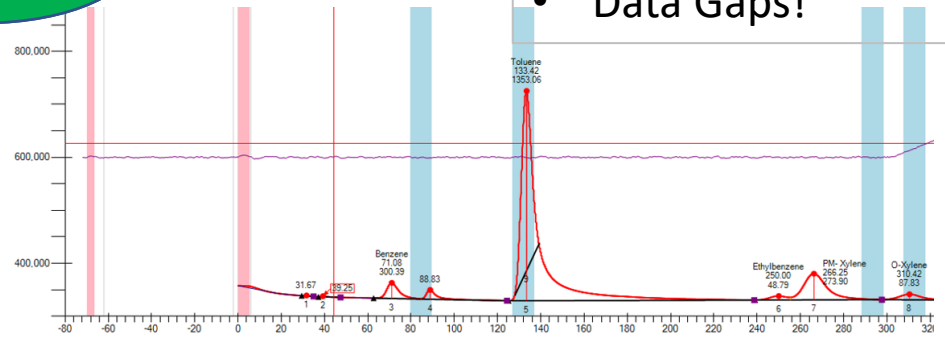
“Log Signatures/Deltas” –HRSC & Lab Samples



- Measuring the deltas of the peaks
- 1000s of points of data
- ~ no data gaps

Another thought – about “signature” data comparisons….!

- Measuring the deltas of the peaks
- A relative small number of data samples
- Speciation
- Data Gaps!



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1000s of Samples vs Diluted &/or small samples for Investigation…

AND MORE THOUGHTS….
1000s of samples in days….versus years or decades

….and more accurate with less data gaps…more successful remediation

….more targeted sampling for the lab…so less "wasted" samples

….and very little waste in the field …MORE SUSTAINABLE FOR THE ENVIRONMENT!

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Eagle Synergistic
Optimizing Technologies, LLC

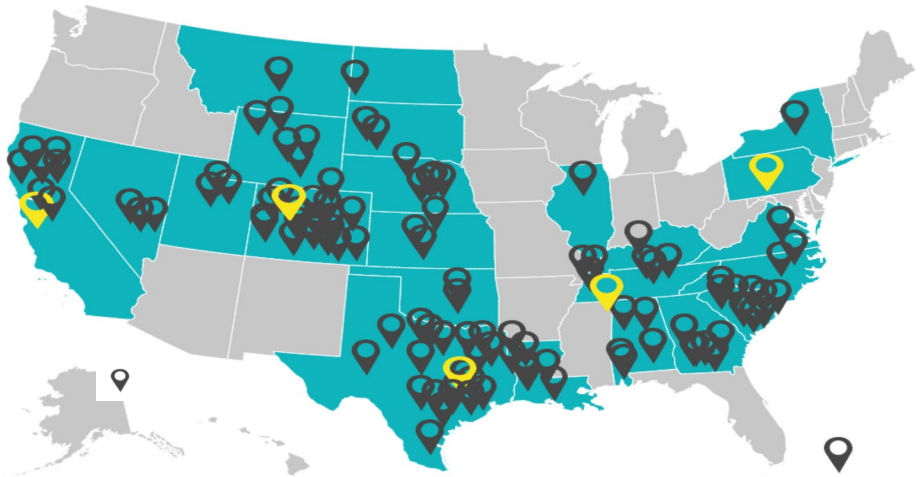
Janet L Castle
President, PG

WOSB
8A Pending

Locations Nationwide:
CA, CO, TX, GA, PA, IL

C:720-475-0022

Eagle Synergistic's Locations & Project Experience



Eagle Synergistic
Optimizing Technologies, LLC

HRSC
3D Models
&
Case Studies

Janet L Castle, PG
President
jcastle@eaglesynergistic.com
WOSB

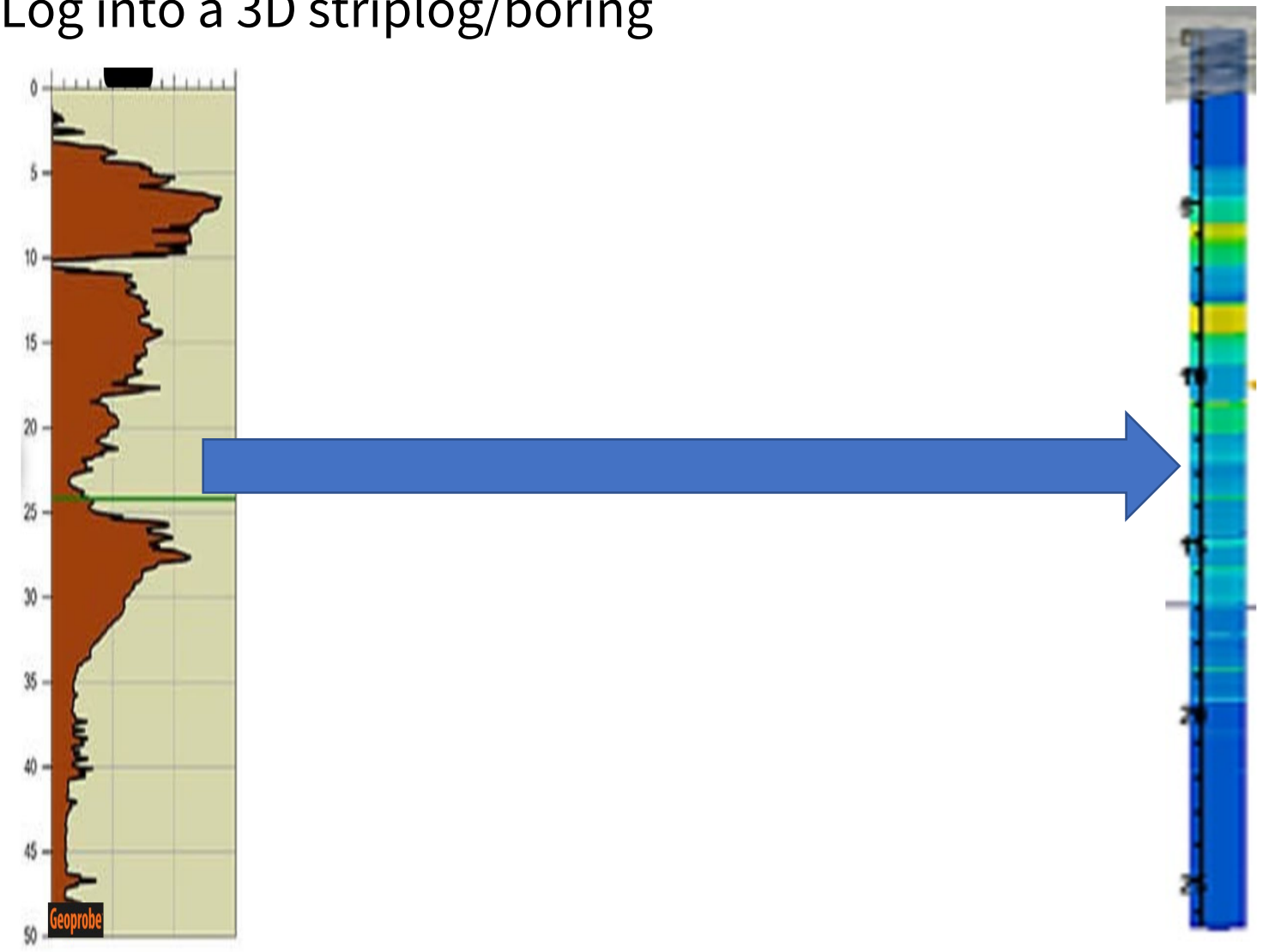
Locations Nationwide:
CO, TX, GA, CA, PA, IL

HRSC Investigation

3D Visualizations to Meet your Goals!

- Assist with Your Client's Visualization
- Regulator's Understanding & Reimbursement Qualifications
- Consultant and Remediation Vendor's objectives- More Accurate & Targeted Remediation Plan
- Clearer and More Accurate CSM – with Visualizations & Videos!

HRSC Log into a 3D striplog/boring



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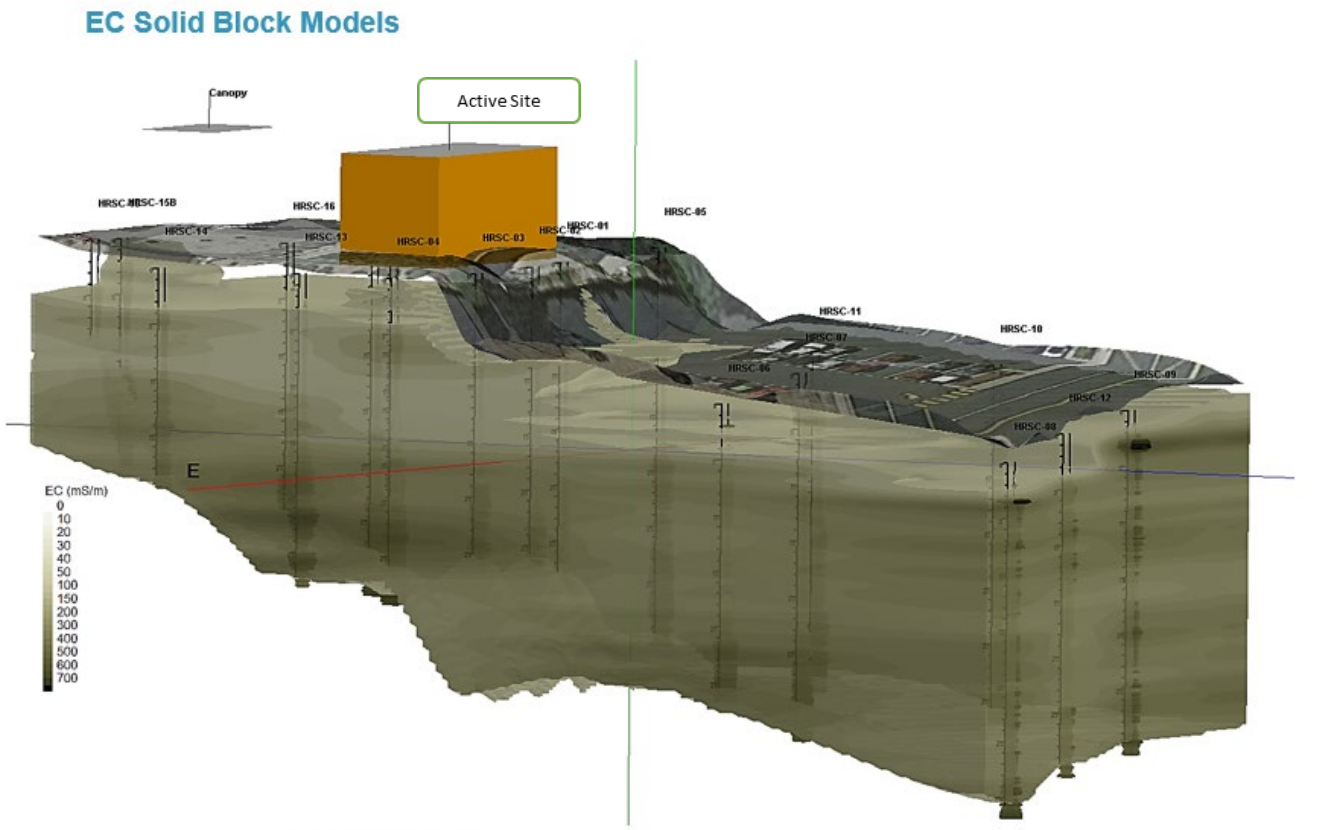
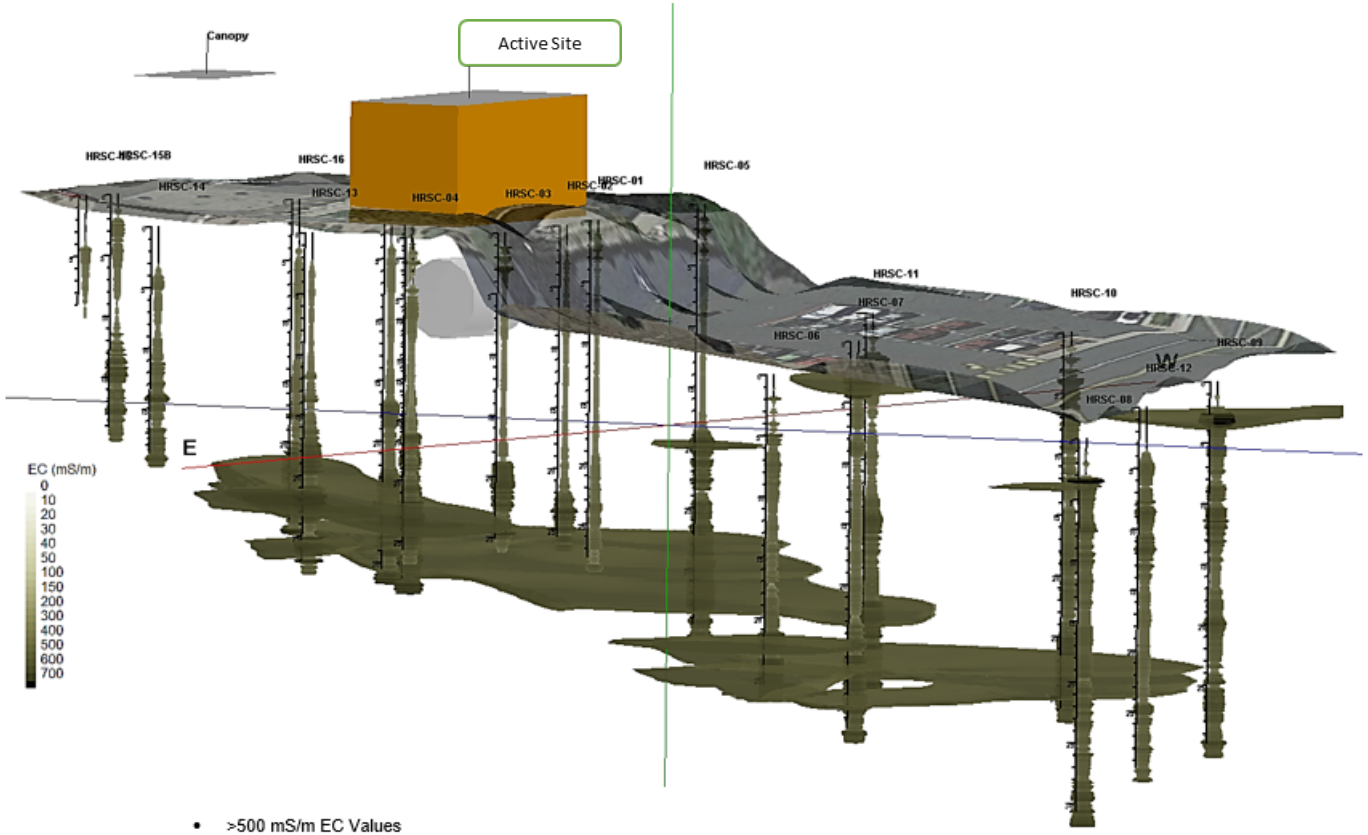
HRSC Investigation – Lithology



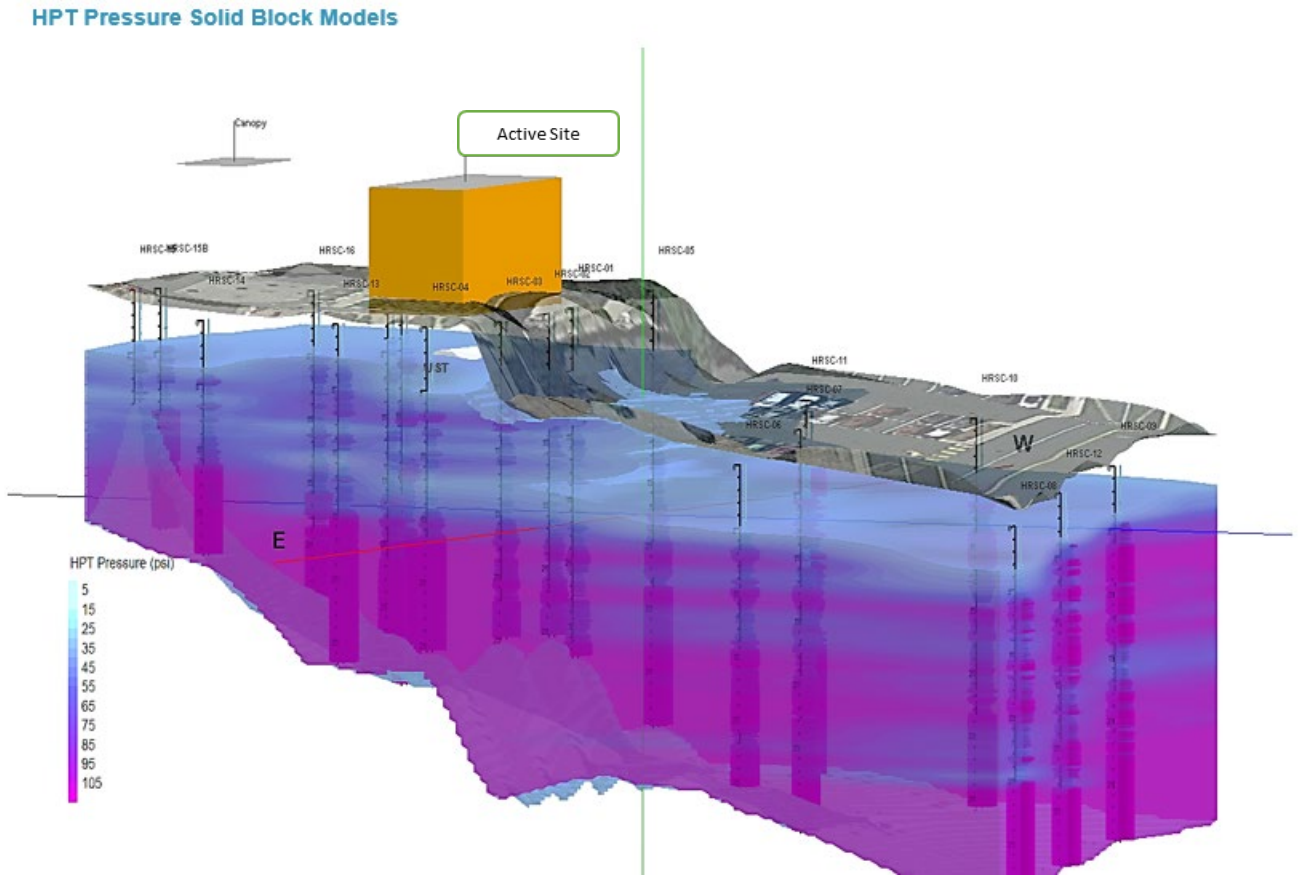
- >100 mS/m EC Values
- Lighter colors are lower EC values generally indicating coarser, more permeable lithology

HRSC Investigation – Lithology

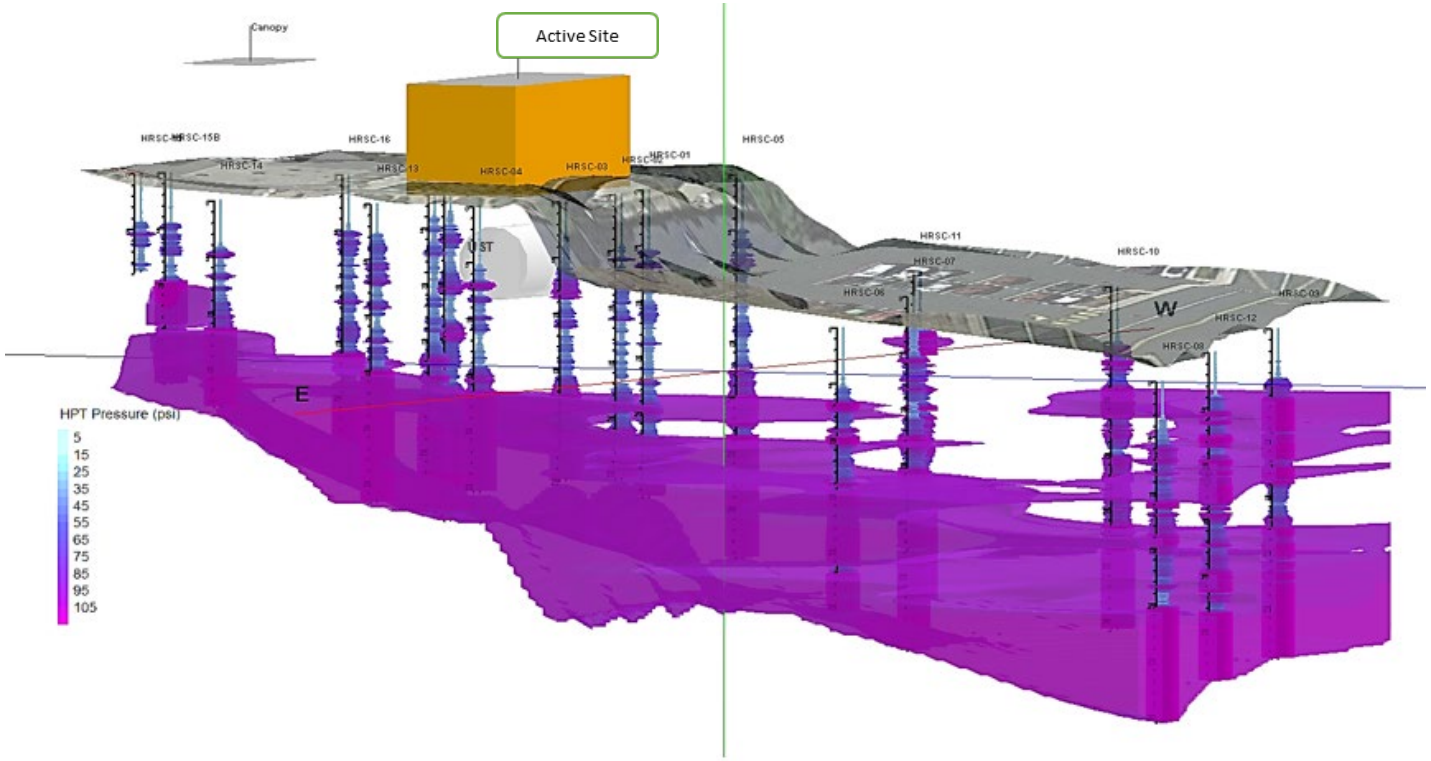


- >500 mS/m EC Values
- Lighter colors are lower EC values generally indicating coarser, more permeable lithology

HRSC Investigation – Hydrogeological



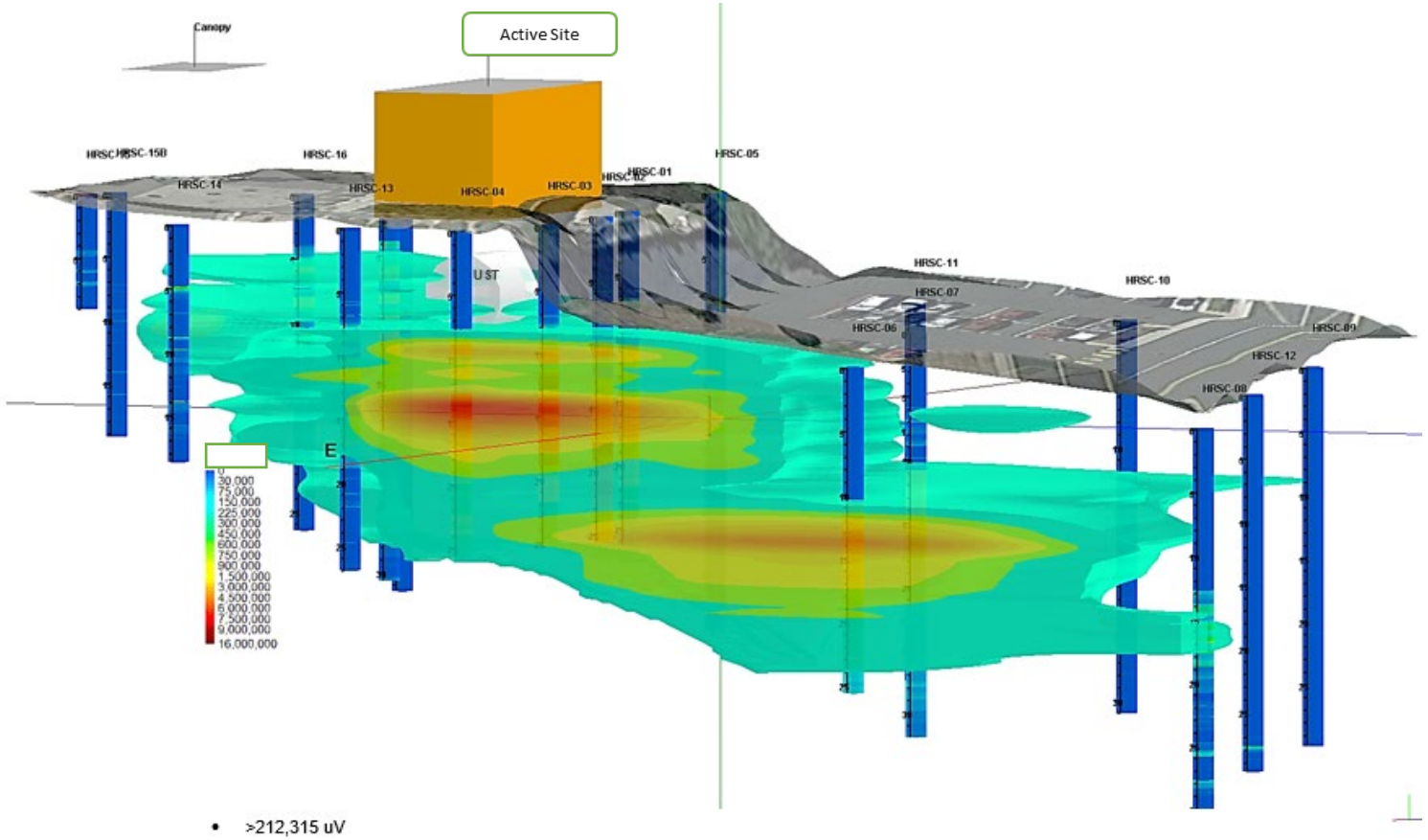
HRSC Investigation – Hydrogeological



- >100 psi HPT values

HRSC Investigation – Contaminant Plume

5 days



- >212,315 uV

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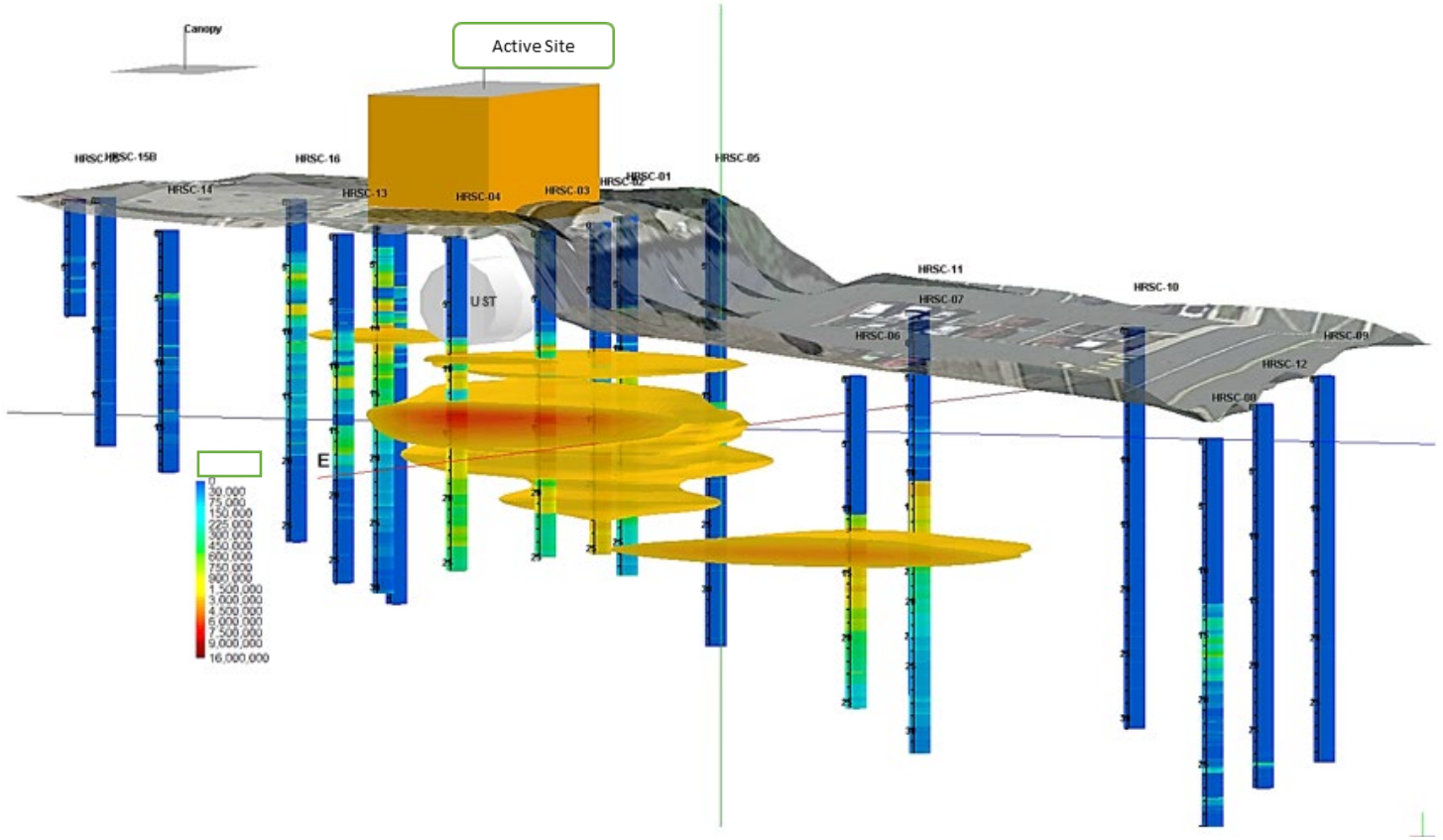
HRSC Investigation – Contaminant Plume

5 days



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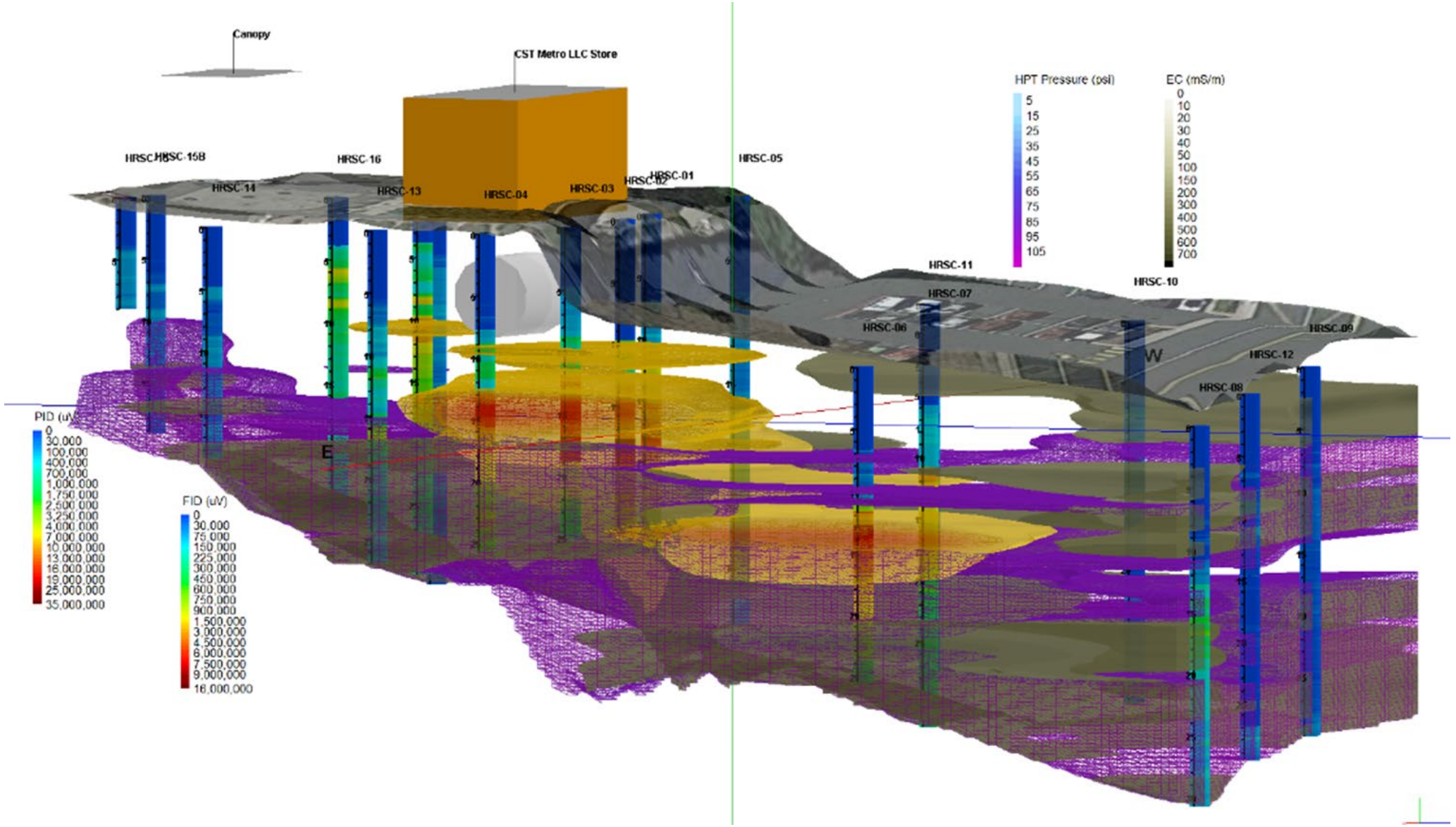
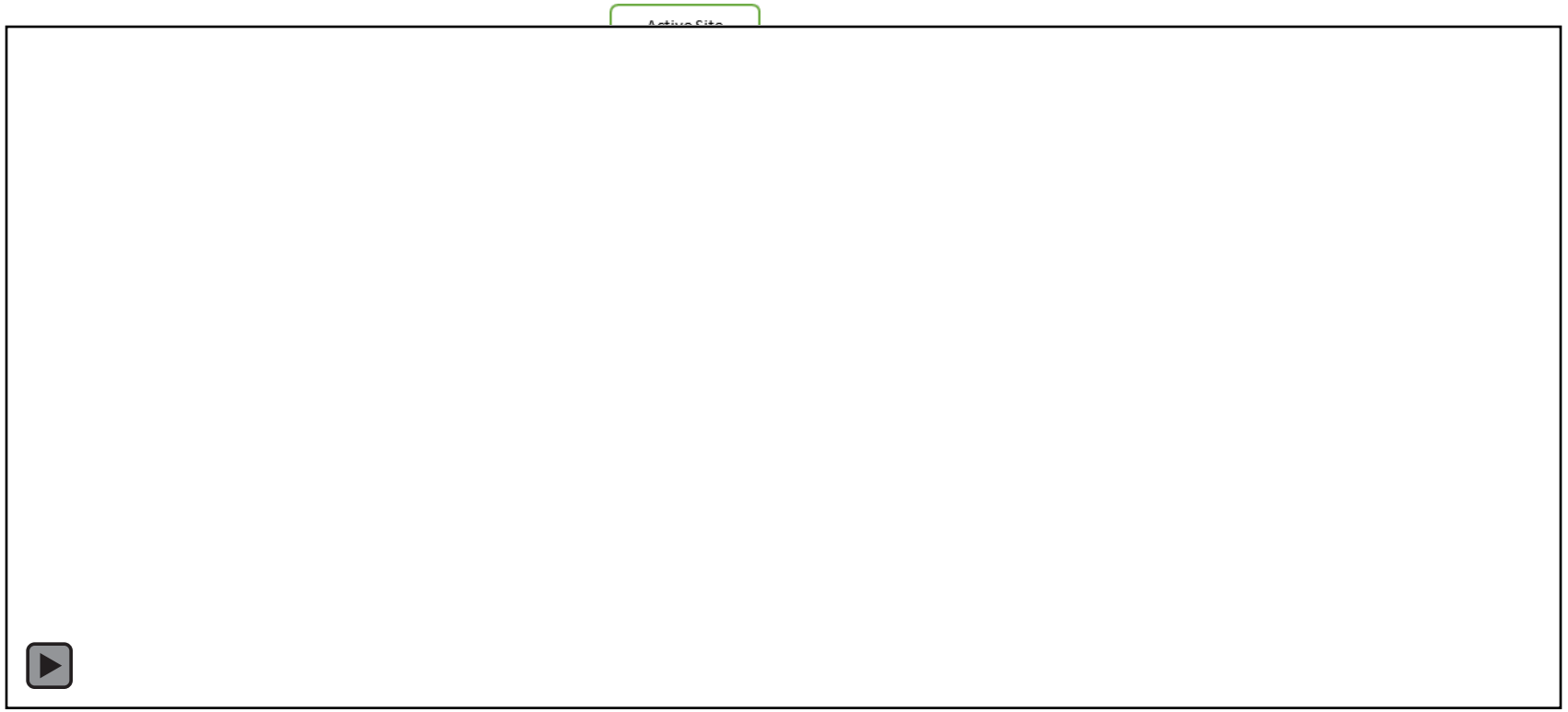
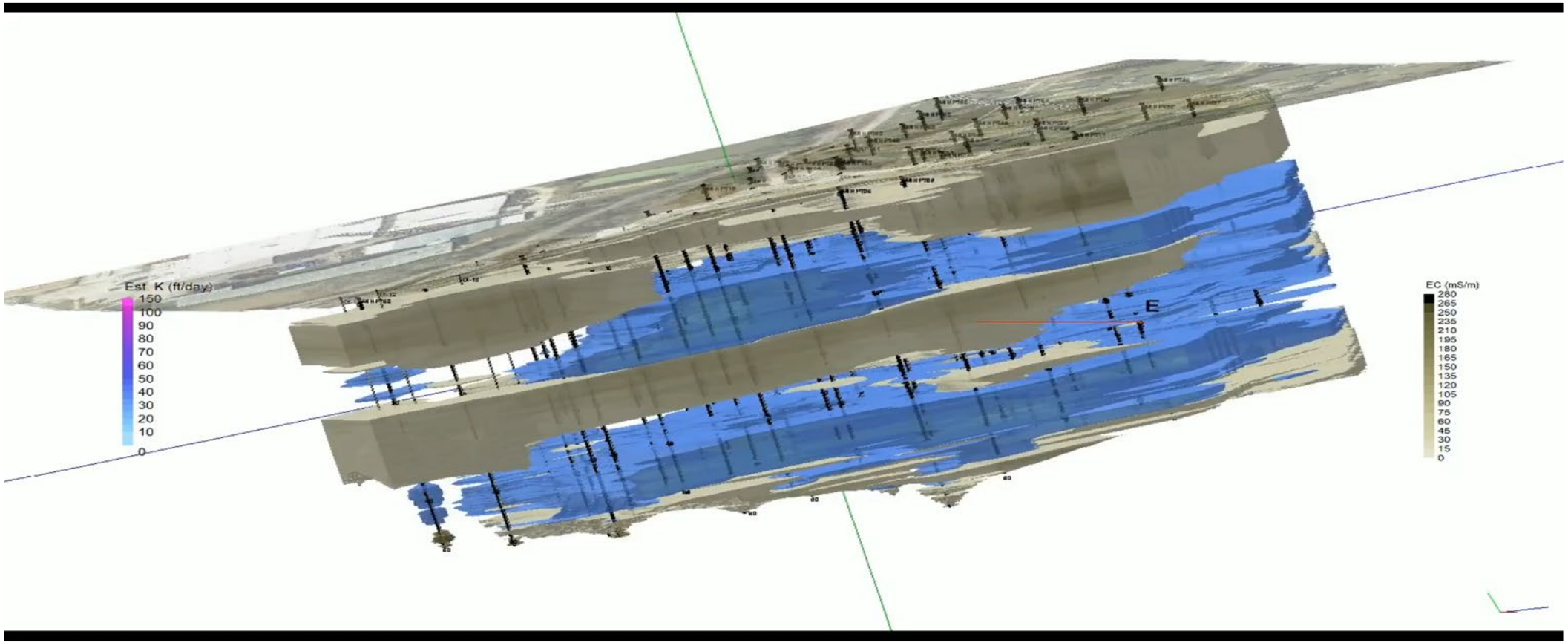
Contaminate Plume at risk level, confining layers, transmissivity zones – allows for surgical & targeted treatment



Strategic Optimization with HRSC



HRSC 3D Model- PFAS Site



EC=Gray - Confining layers

HPT=Blue - High Transmissivity Zones

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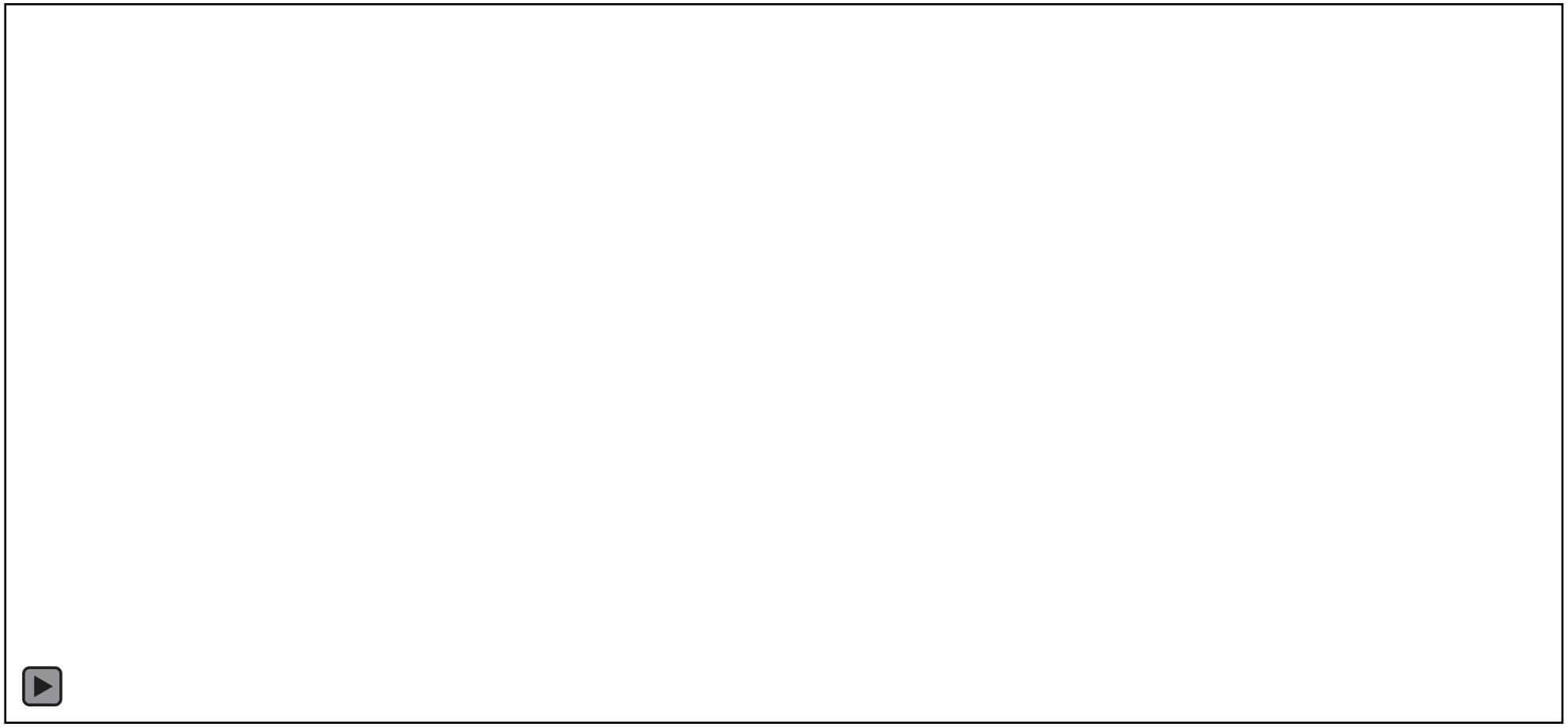
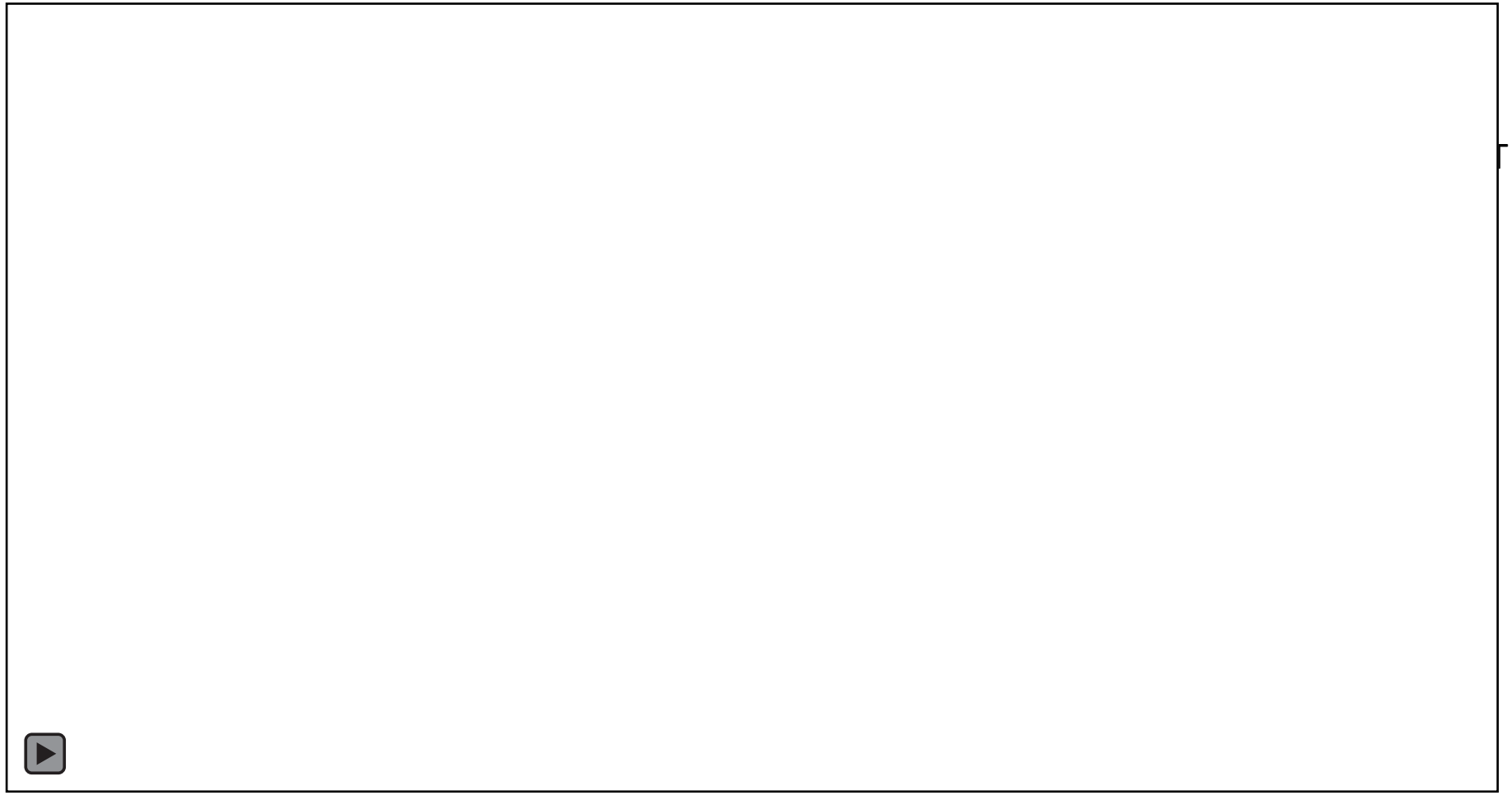
HRSC 3D Model- PFAS Site

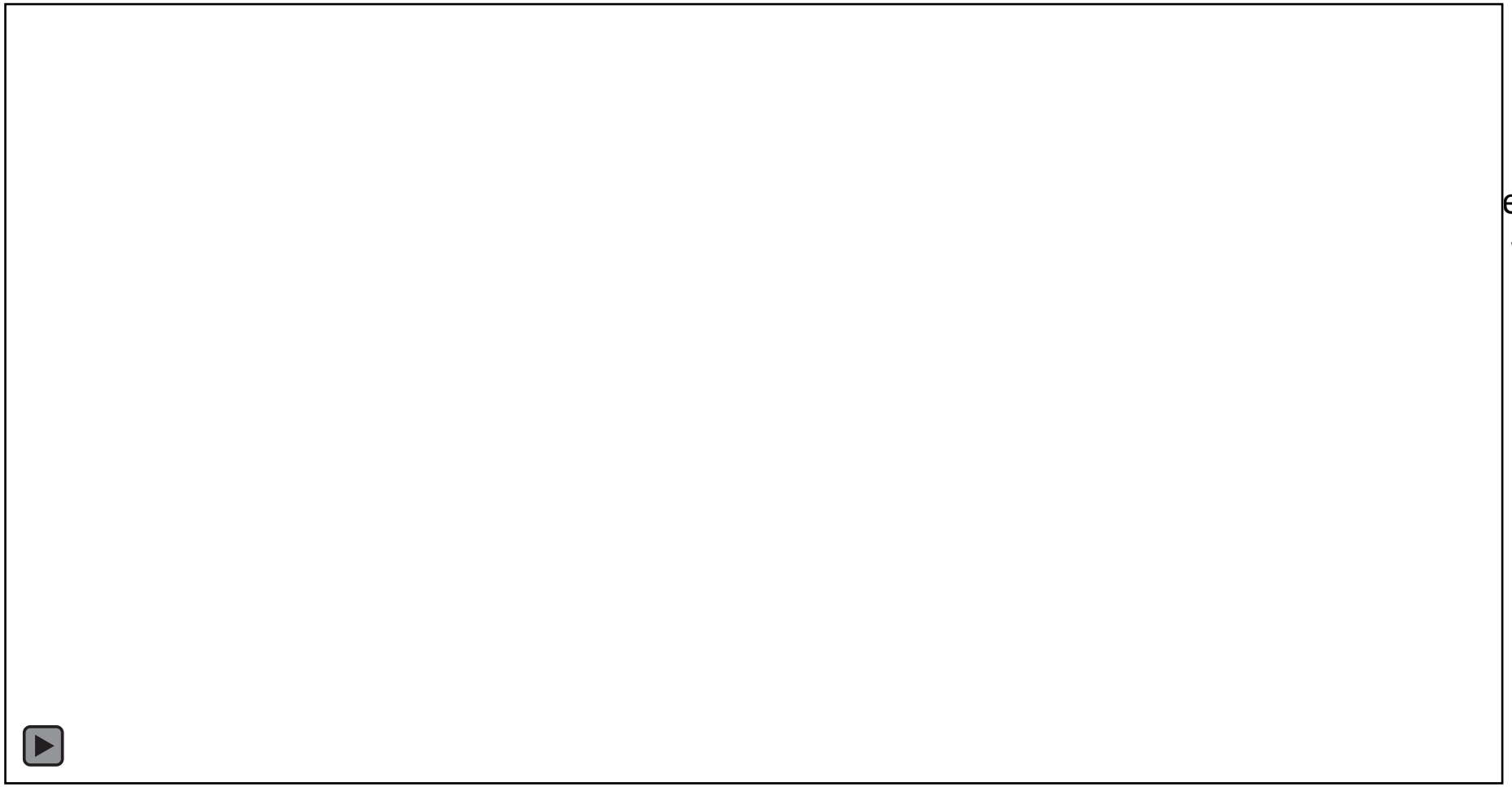


3D Visualization



T Investigation

3D Visualization



estigation
water table in blue)

Case Study 1:

- Known Release
- UST was excavated years ago

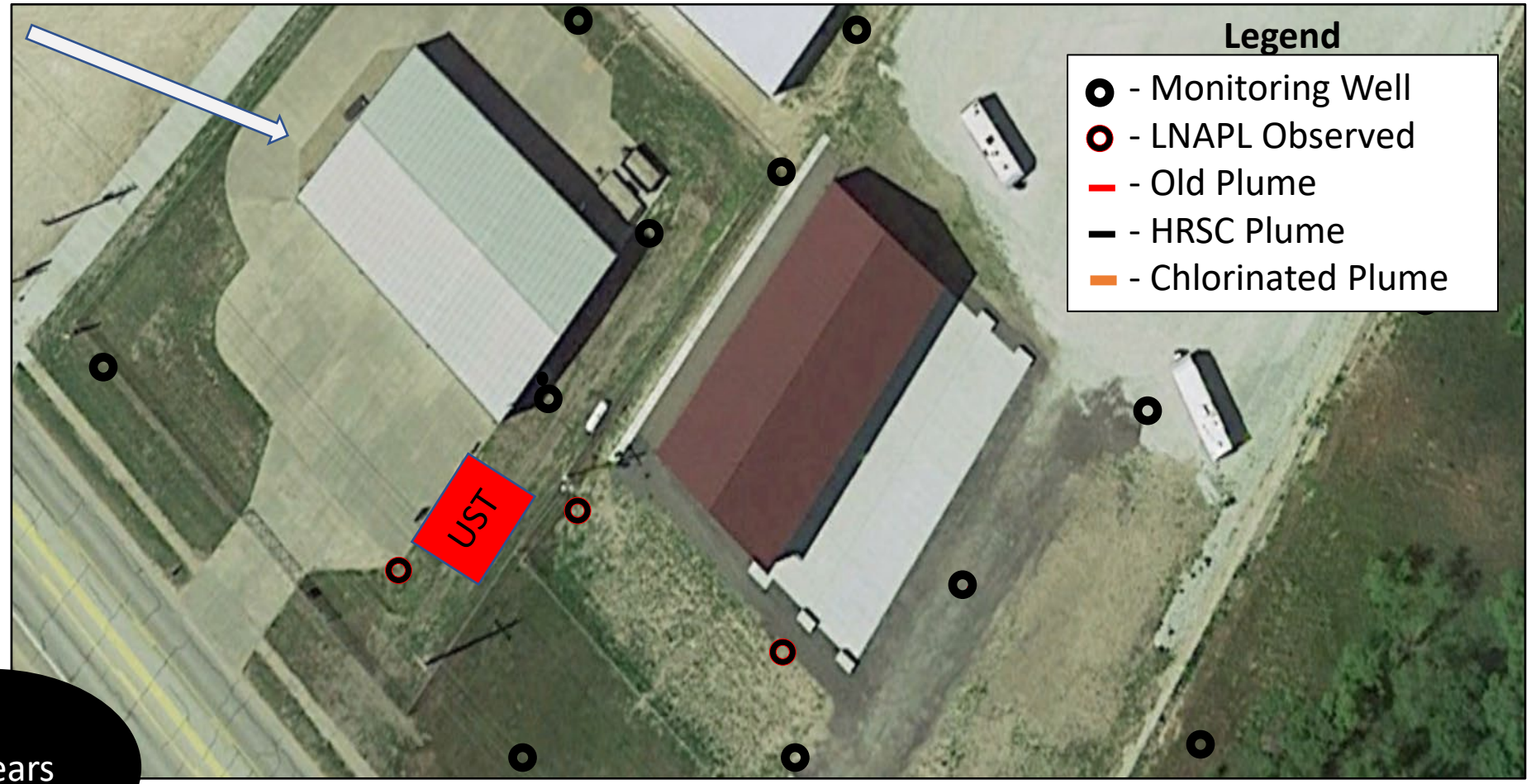
Case Study 1:

- Known Release
- UST was excavated years ago
- Over 4 years:
  - Soil sampling
  - Monitoring Wells

1-4 years

Case Study 1:

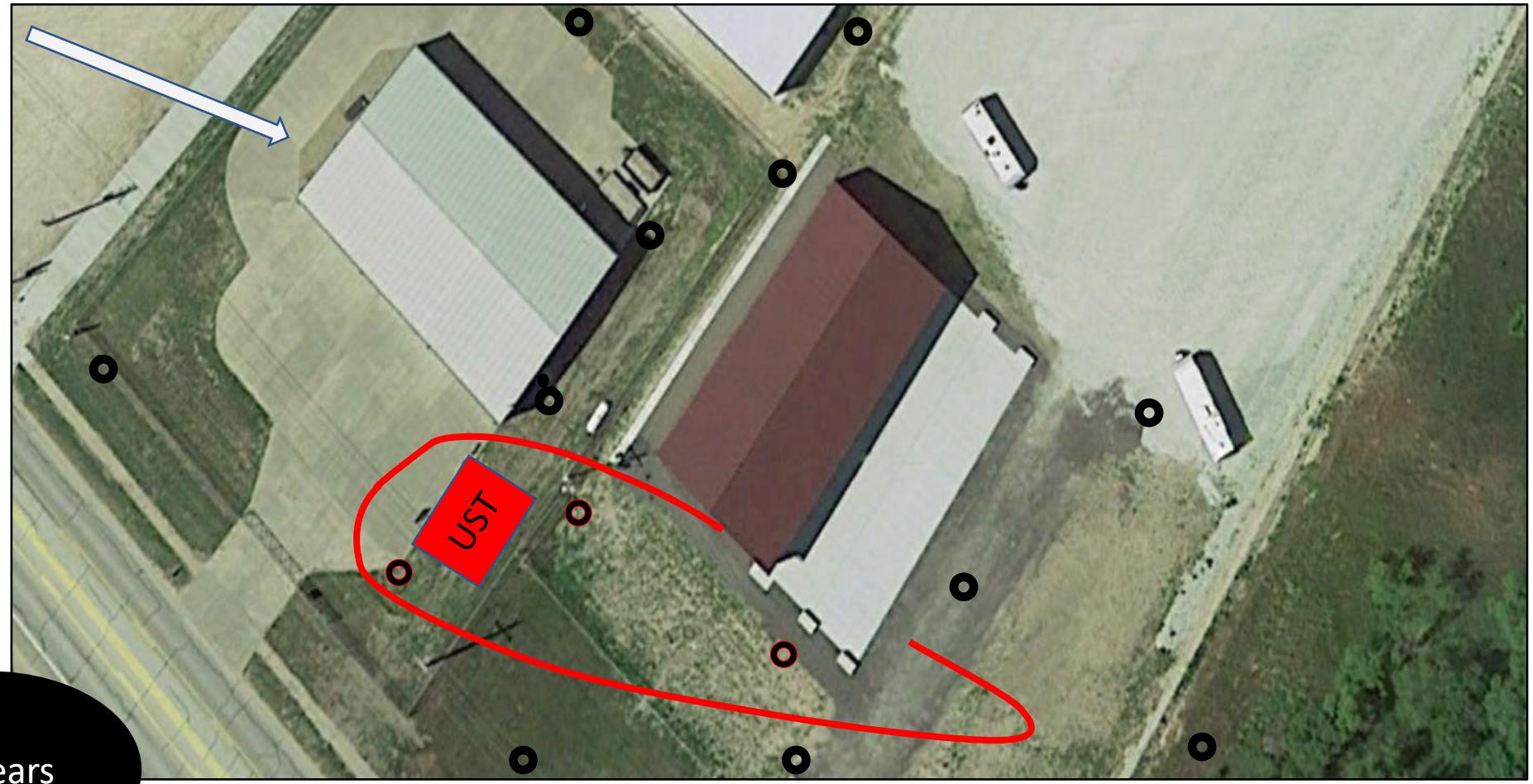
- Three Monitoring Wells contained LNAPL for years
- Majority of MW were ~clean
- 3 Monitoring Wells with measurable LNAPL that continued to vary in thickness



~5 years

Case Study 1:

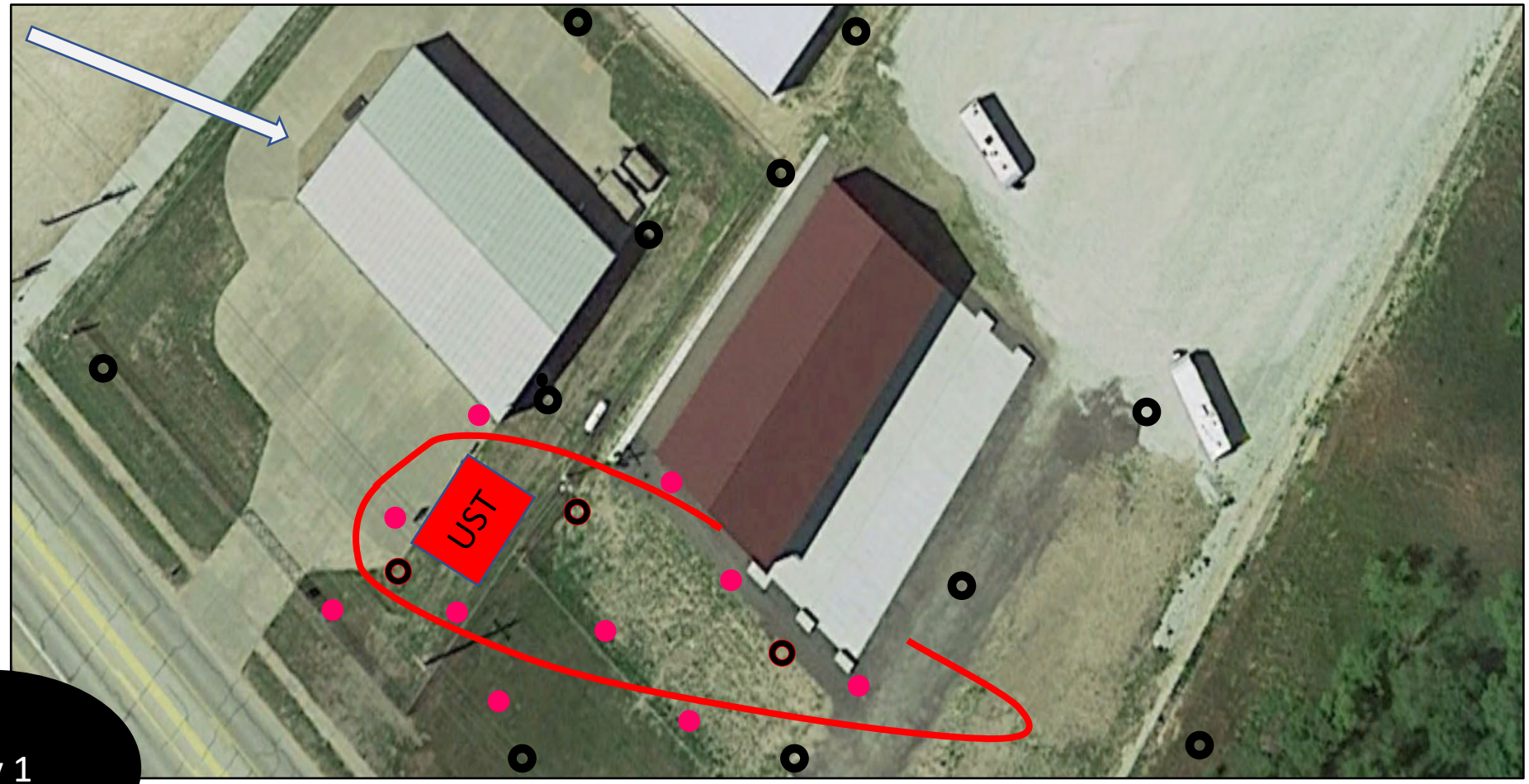
- Planned Remediation Phase
- Injections planned from 5’-30’bgs
- Consultant advised client to utilize HRSC first



~6 years

Case Study 1:

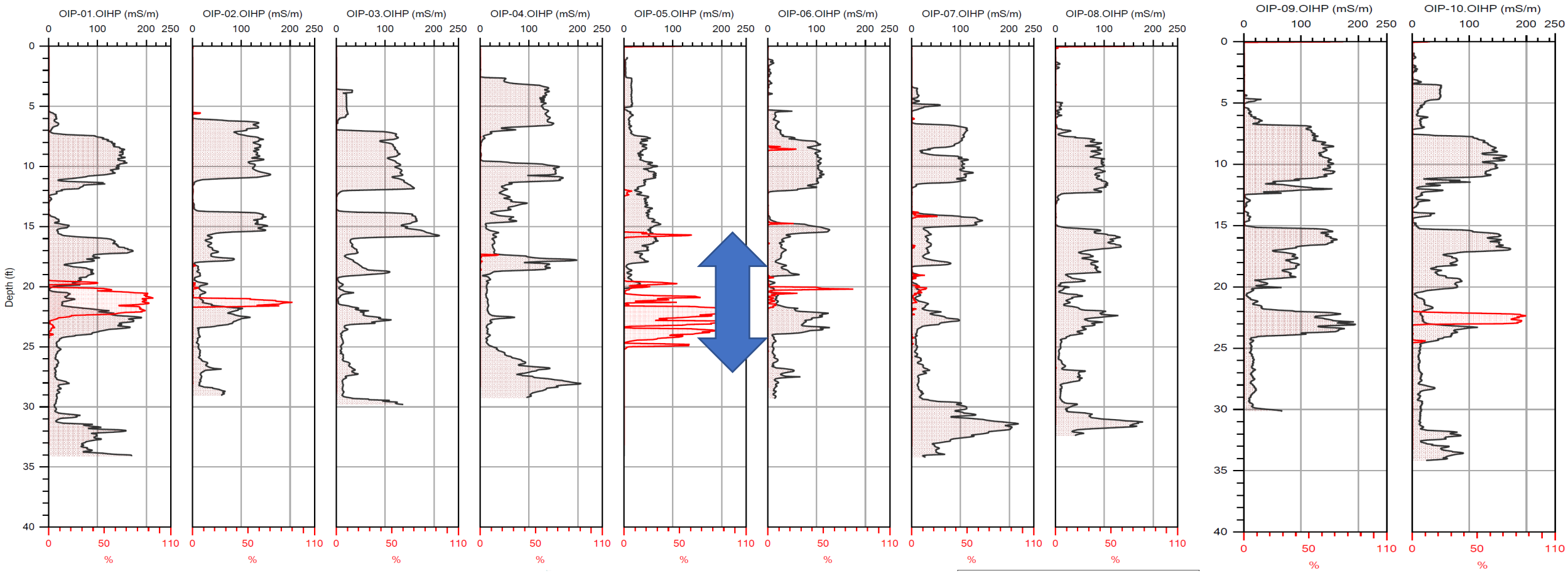
- Consultant Revised Plan and Halted Injections from 5’-35’bgs
- Dynamic Decisions for HRSC placement to better characterize site
- OiHPT- lnapl – 10pts
- Confirmed



Case Study 1:

- Dynamic Decisions for HRSC placement to better characterize site
- OiHPT- lnapl – 9 additional pts for a total of 19 HRSC pts:
- Dynamically characterizing the lateral length

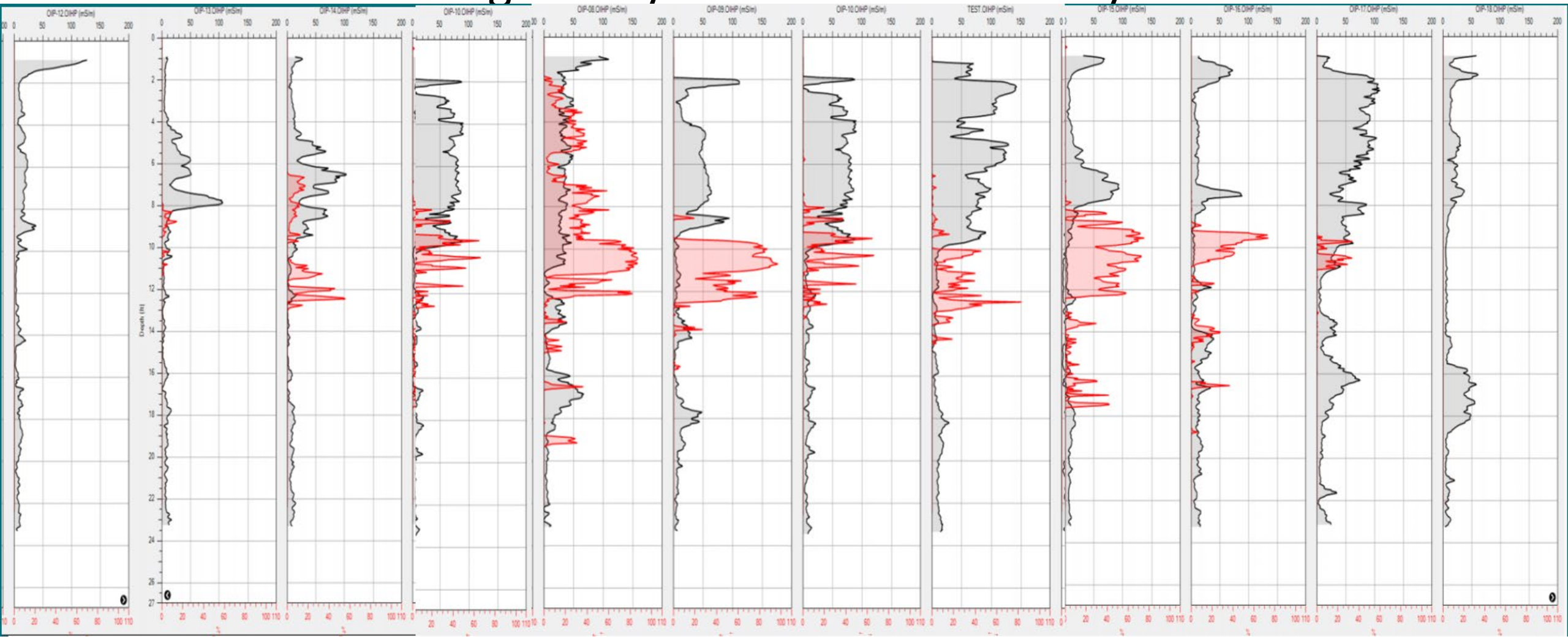
Lithogical


OIP-01.OIHP (mS/m)
OIP-02.OIHP (mS/m)
OIP-03.OIHP (mS/m)
OIP-04.OIHP (mS/m)
OIP-05.OIHP (mS/m)
OIP-06.OIHP (mS/m)
OIP-07.OIHP (mS/m)
OIP-08.OIHP (mS/m)
OIP-09.OIHP (mS/m)
OIP-10.OIHP (mS/m)
0 100 200 250
Depth (ft)
0 5 10 15 20 25 30 35 40
0 50 110
%

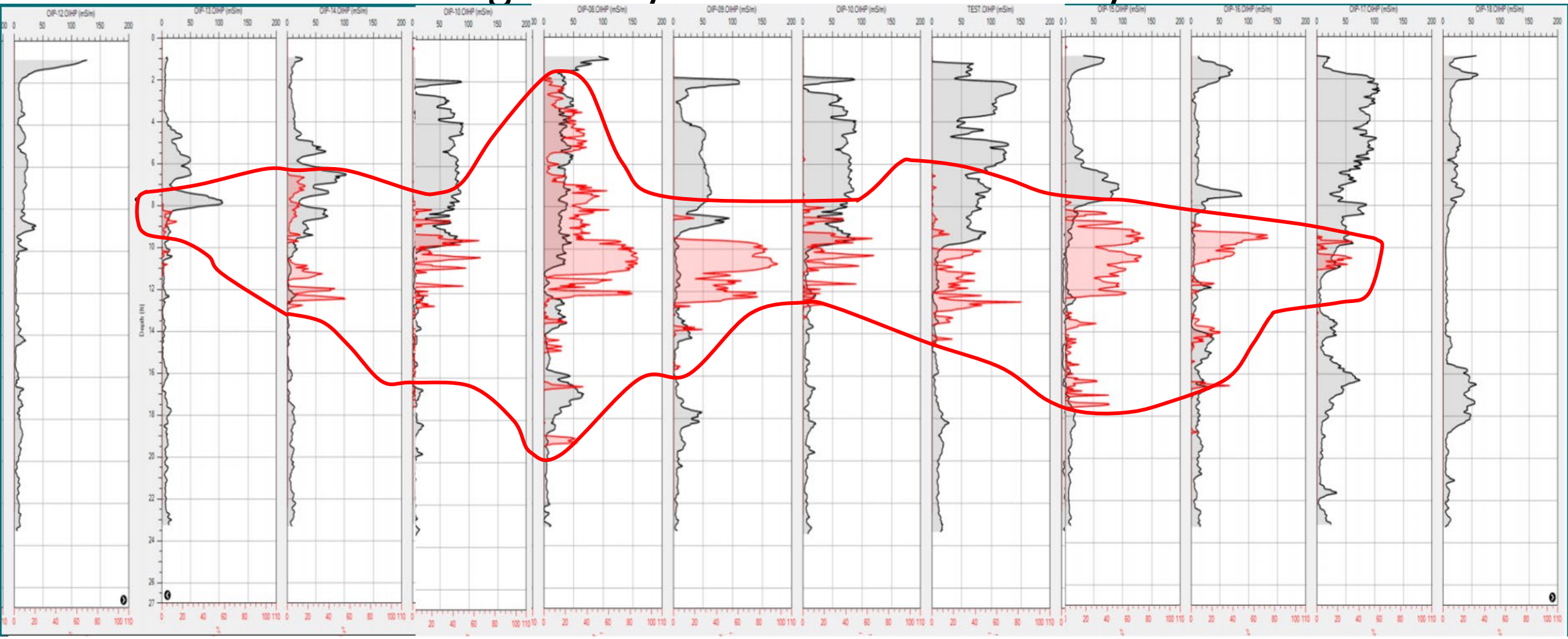
Case Study 1:

- Continued Dynamic Decisions for HRSC placement to better characterize site
- OiHPT- lnapl – 9 additional pts for a total of 28 HRSC pts:

OIP Borings- Daily Cross Sections- 1 Day



OIP Borings- Daily Cross Sections- 1 Day

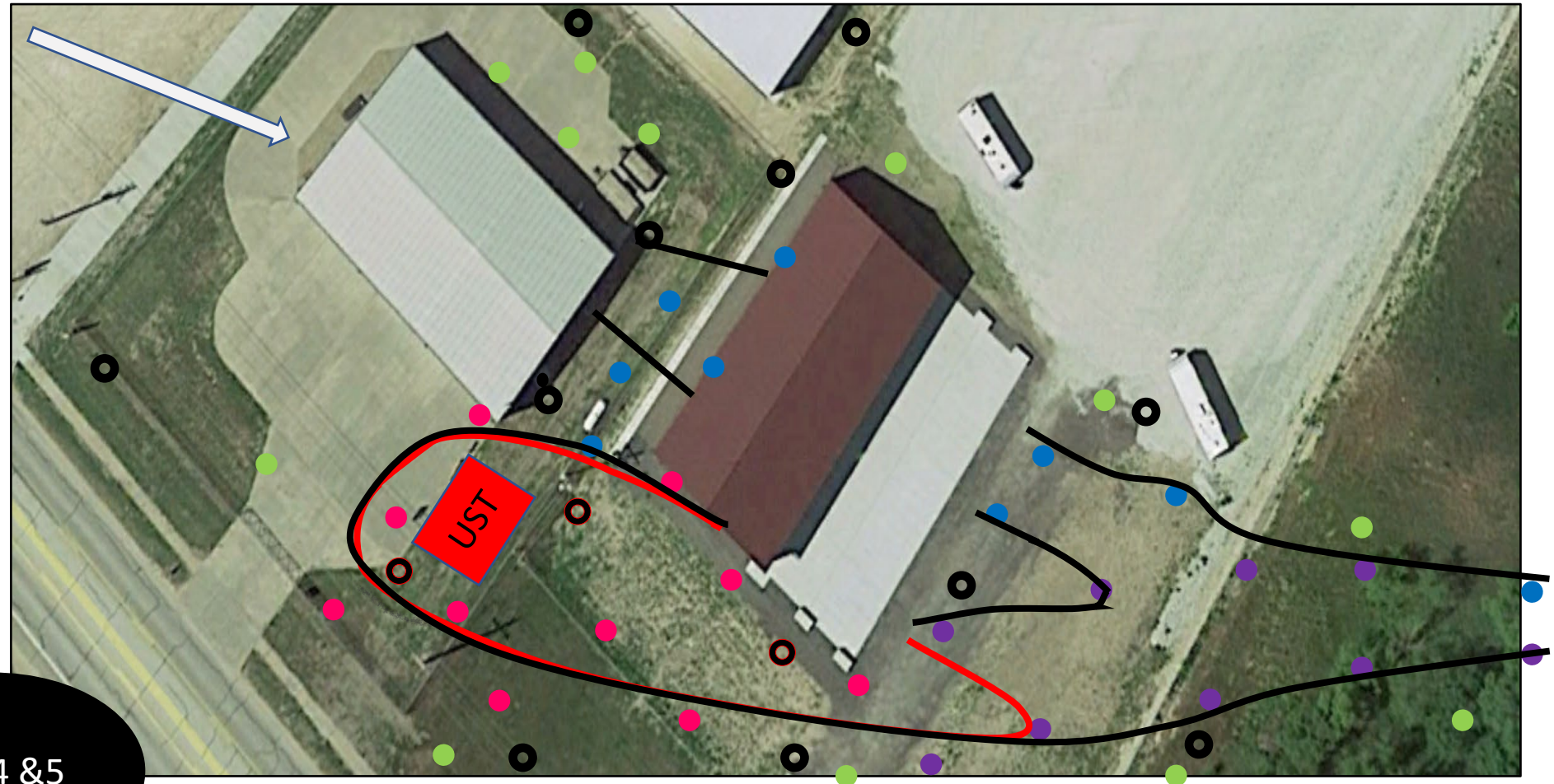


Case Study 1:

- Continued Dynamic Decisions for HRSC placement to better characterize site
- OiHPT- lnapl – 9 additional pts for a total of 28 HRSC pts:
- Dynamically characterizing the lateral length of LNAPL

Case Study 1:

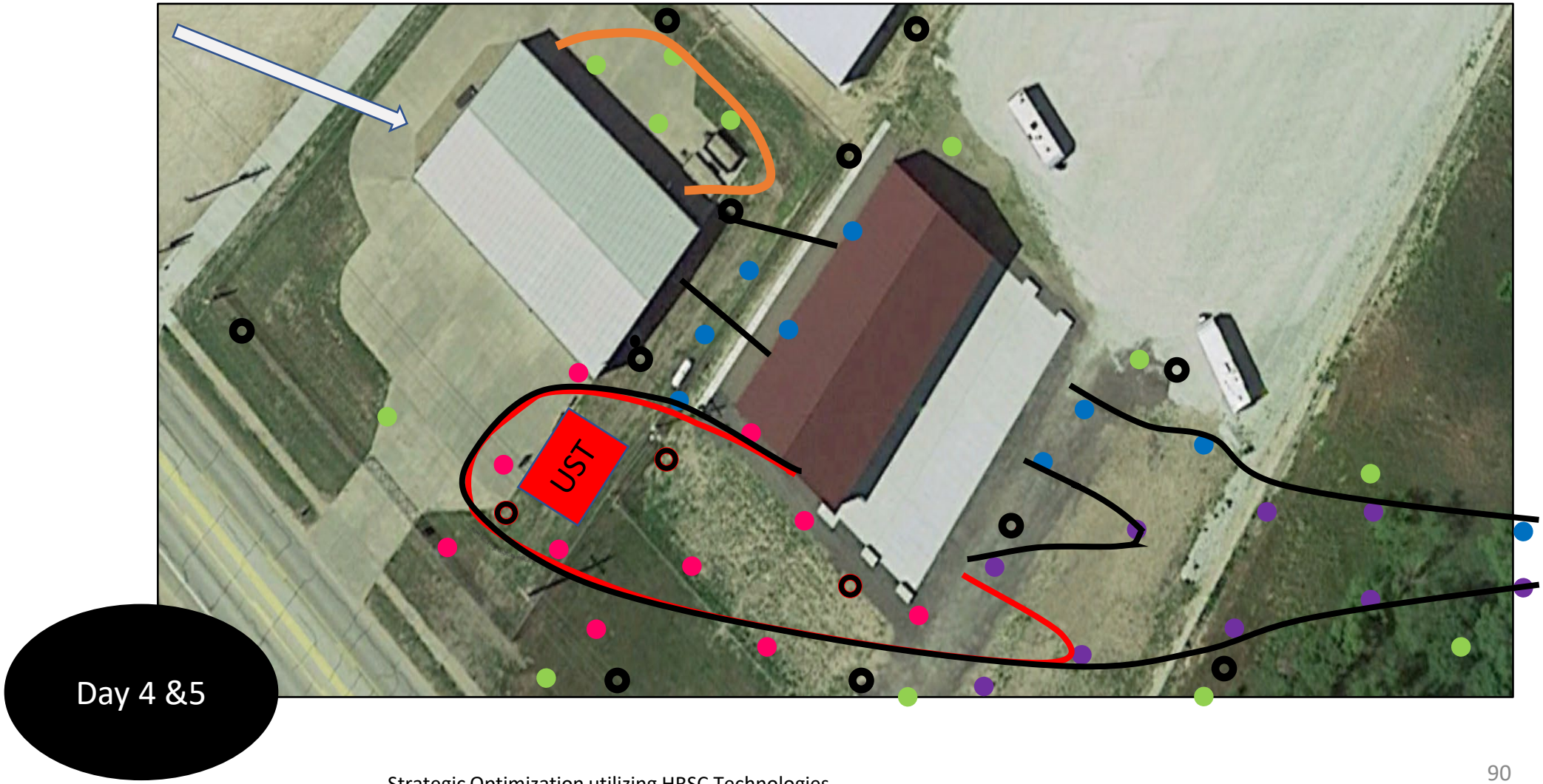
- OiHPT- Lnapl -28 HRSC pts
- MiHPT-Vocs- 12 pts
- Total of 42 HRSC pts/5 days
- Soil Confirmation Cores- 5



Day 4 &5

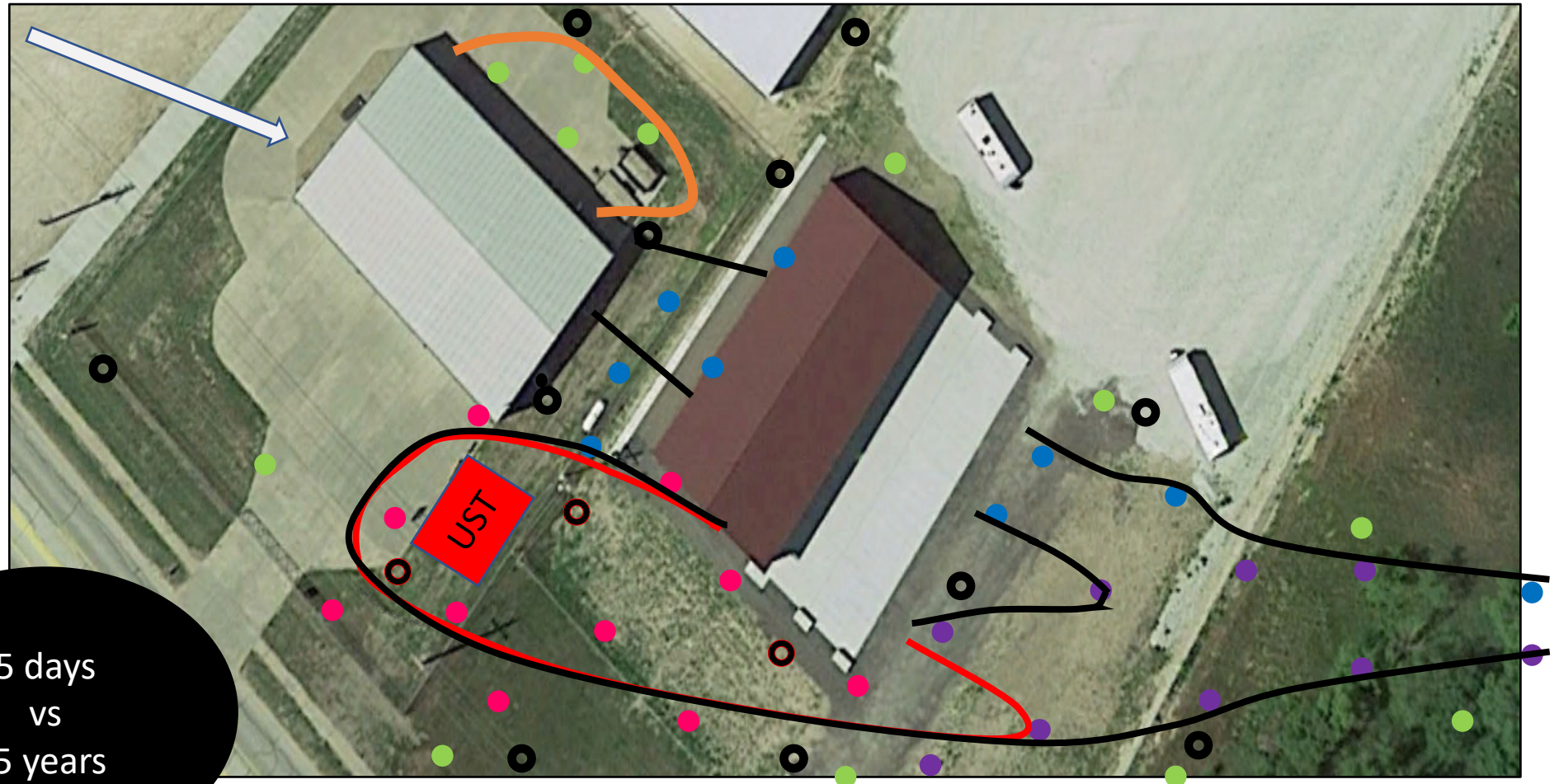
Case Study 1:

- OiHPT- Lnapl -28 HRSC pts
- MiHPT-Vocs- 12 pts
- Total of 42 HRSC pts/5 days
- Soil Confirmation Cores- 5



Case Study 1:

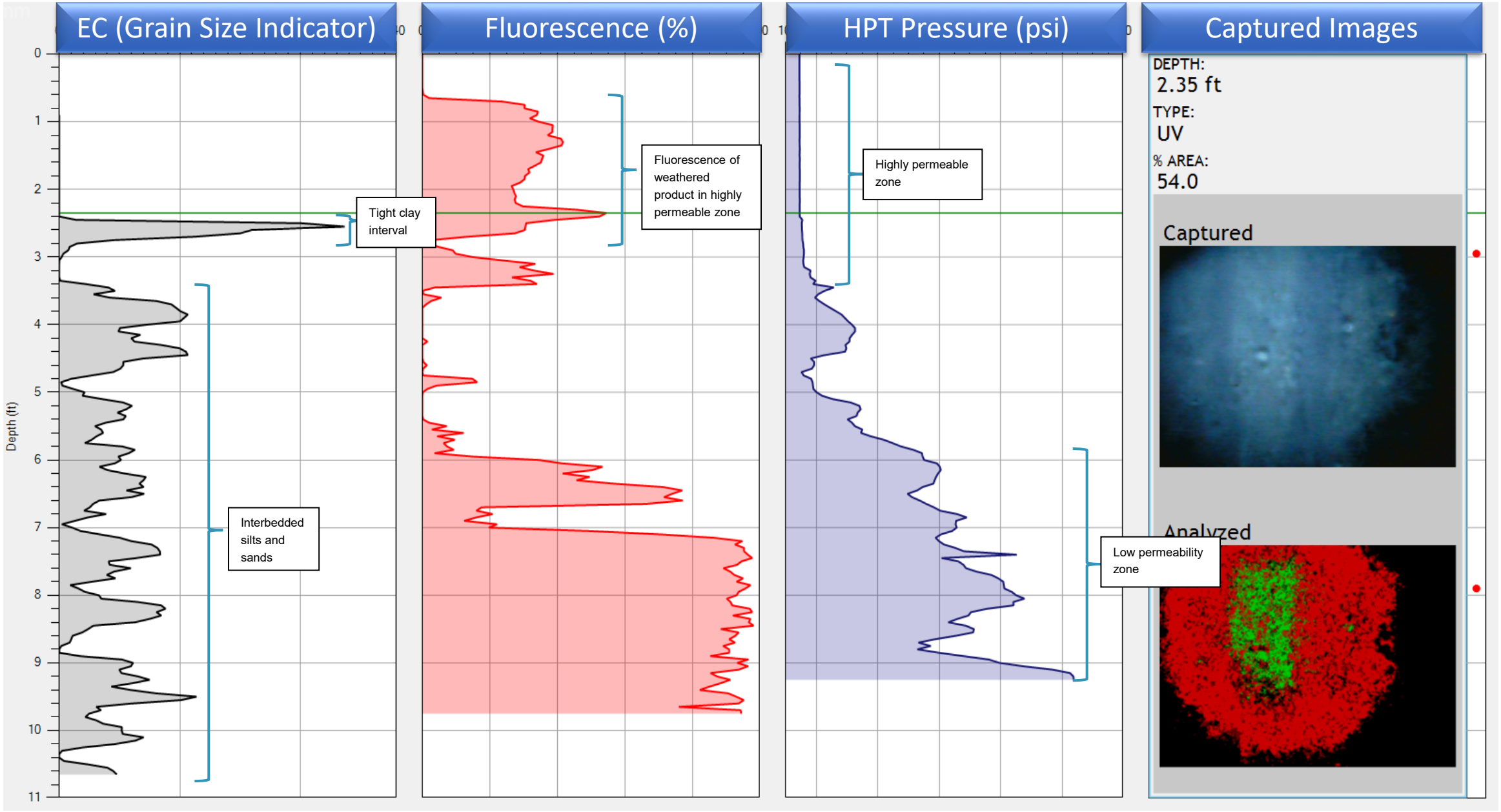
- Accurate Delineation of Plume(s)
- Lateral and Vertical Characterization
- Lithology and Hydrological Properties
- Soil and GW Samples to Confirm



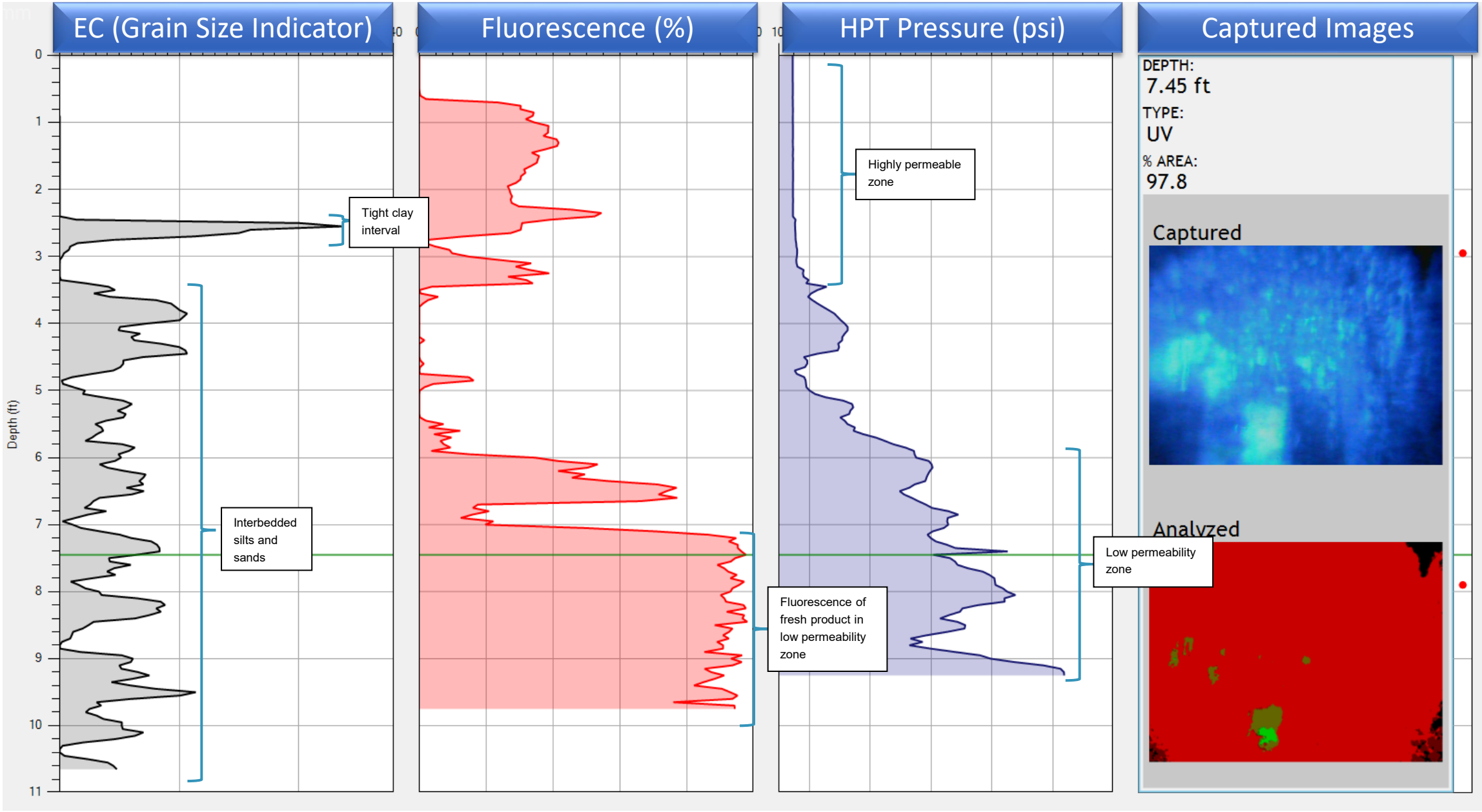
5 days
vs
5 years

2nd Case Study: Two Separate Hydrocarbon Releases on Same Site

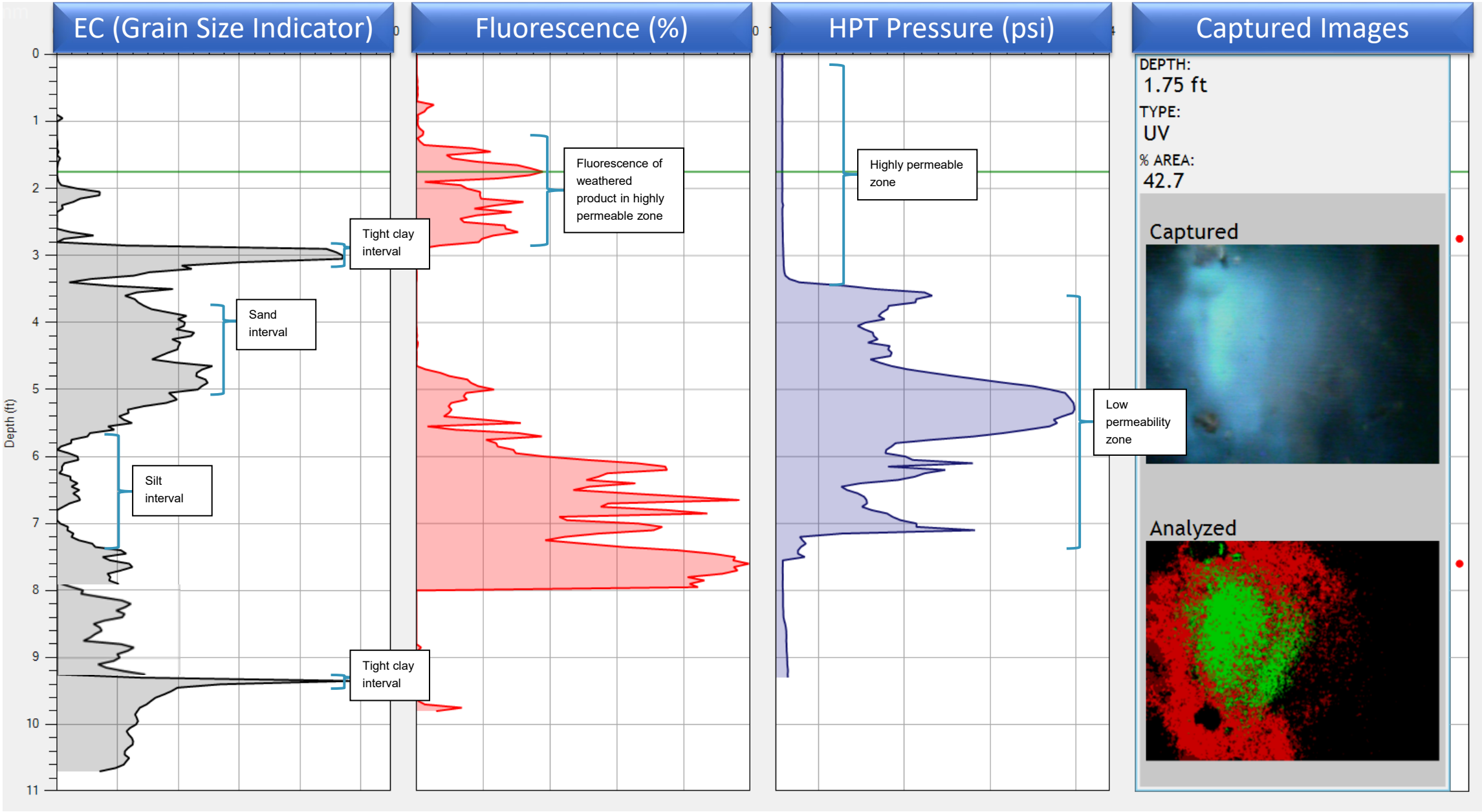
OIP-01 Shallow Release



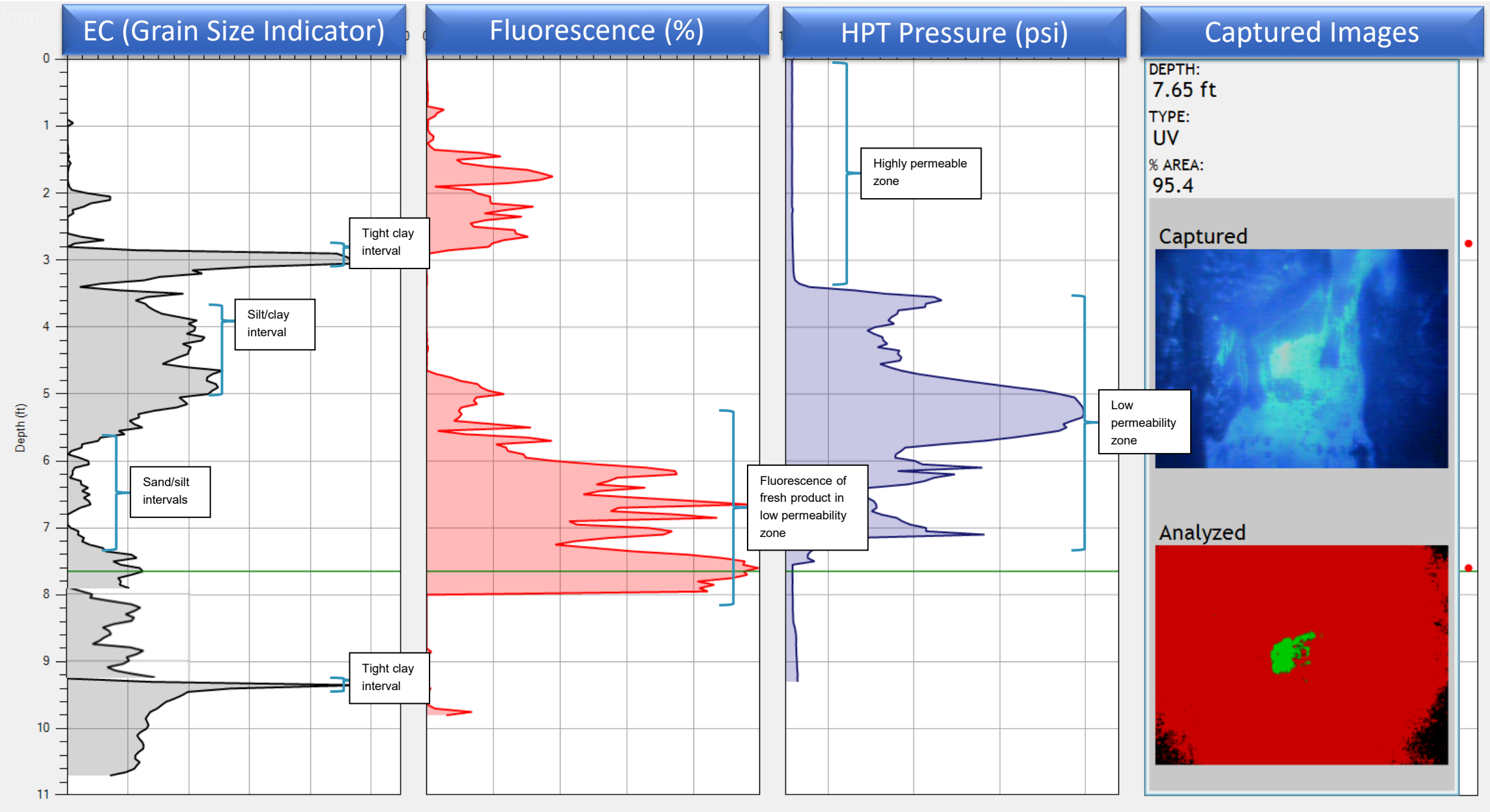
OIP-01 Deep Release



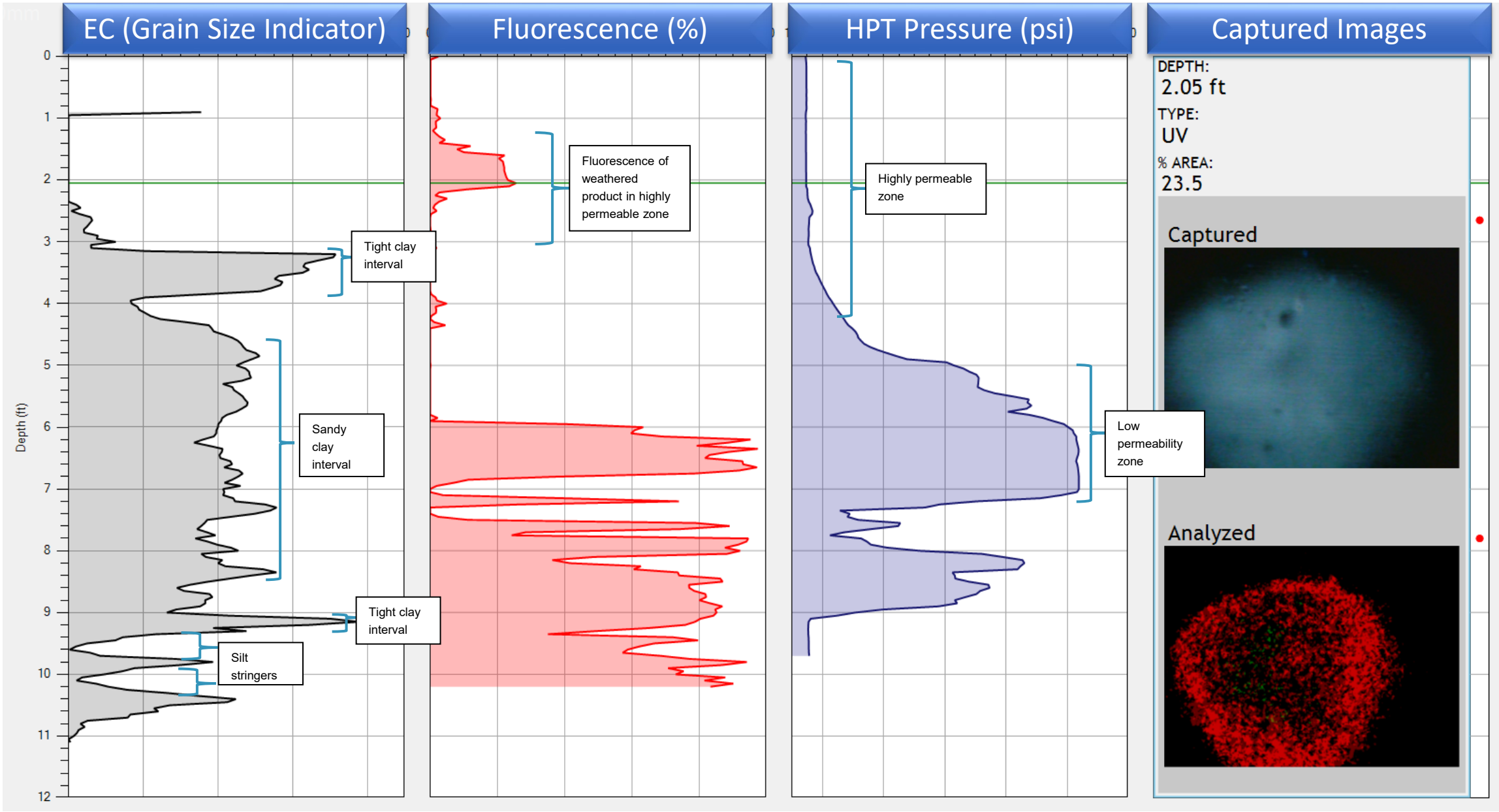
OIP-02 Shallow Release



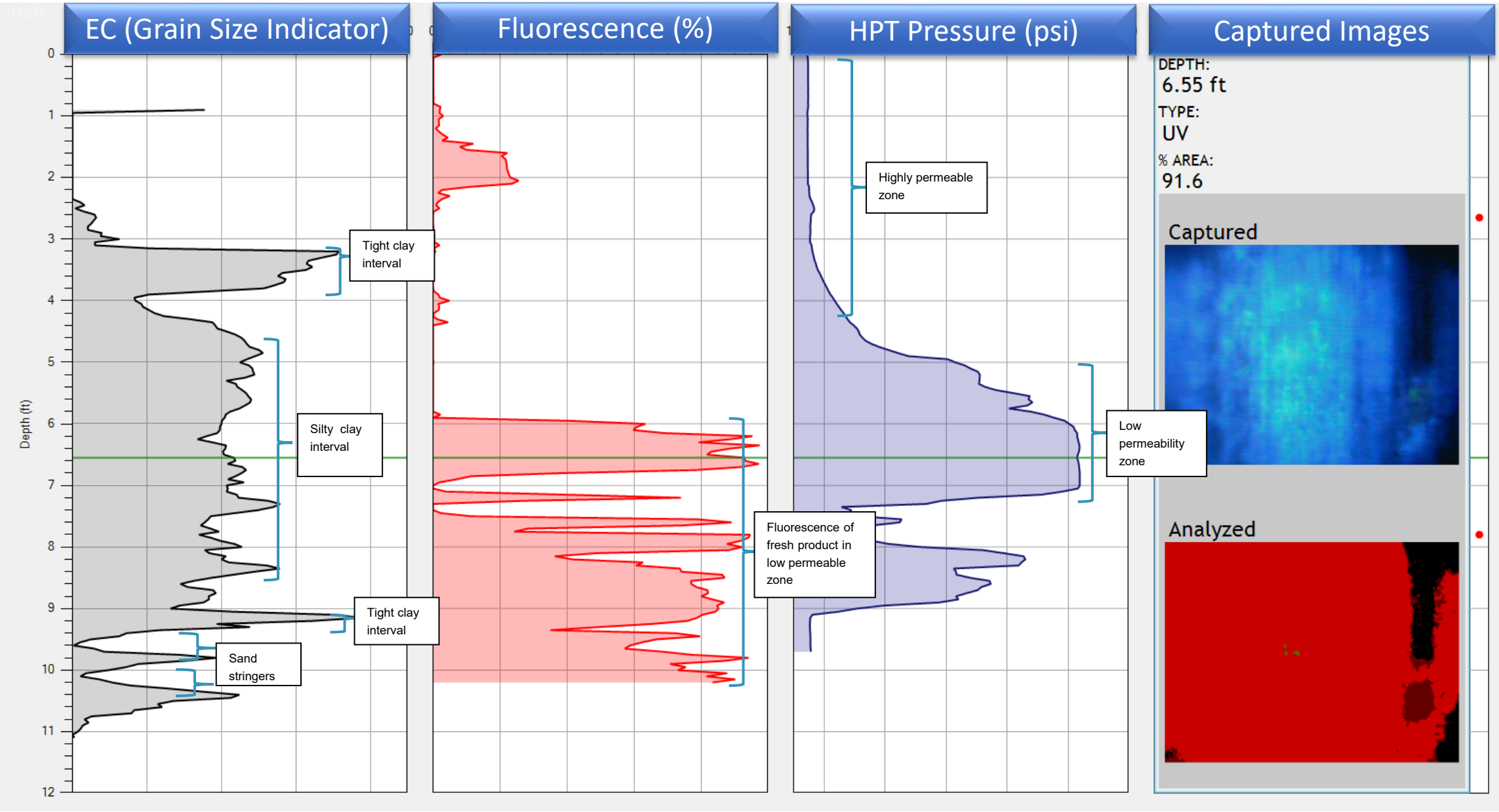
OIP-02 Deep Release



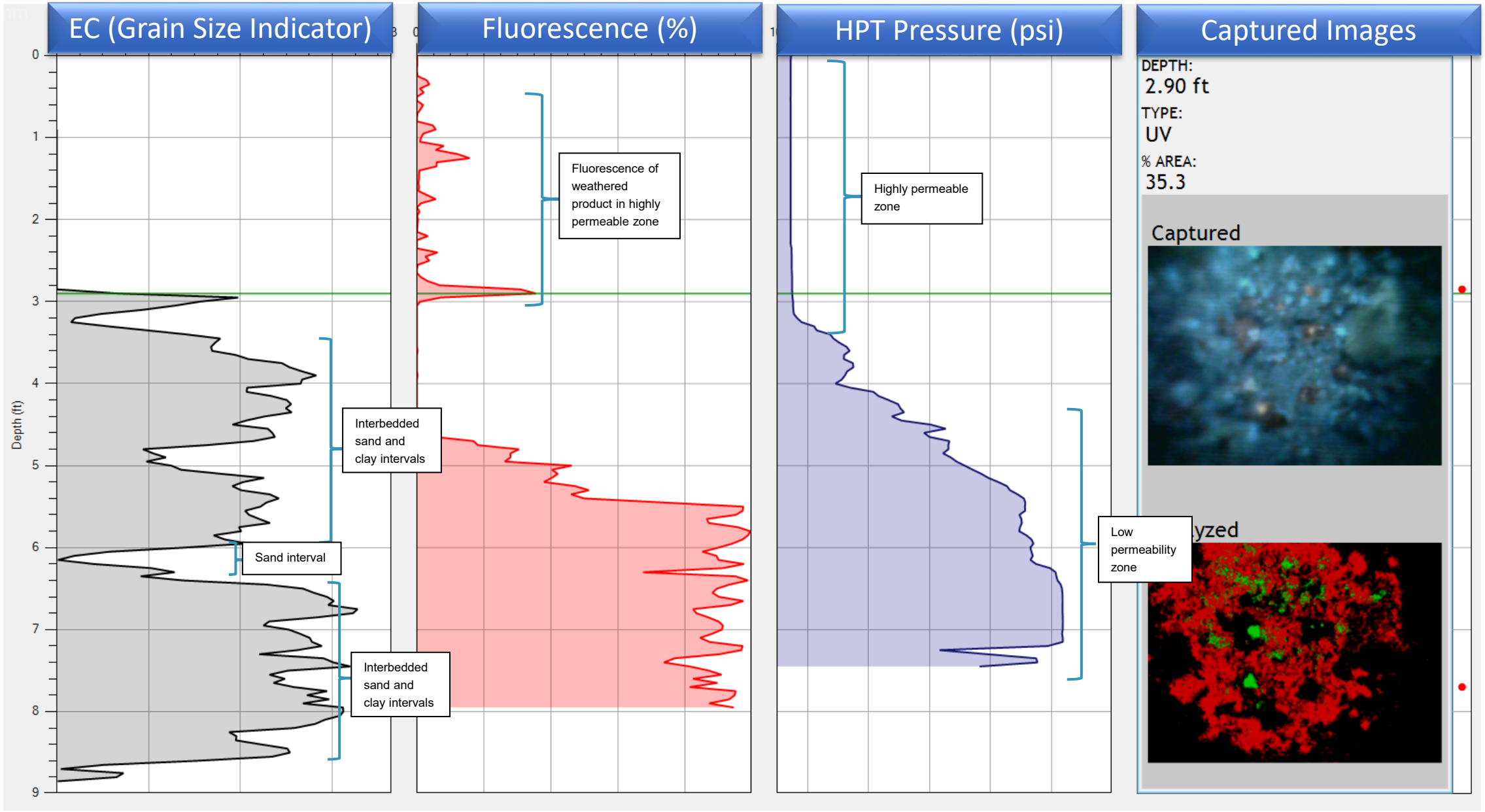
OIP-03 Shallow Release



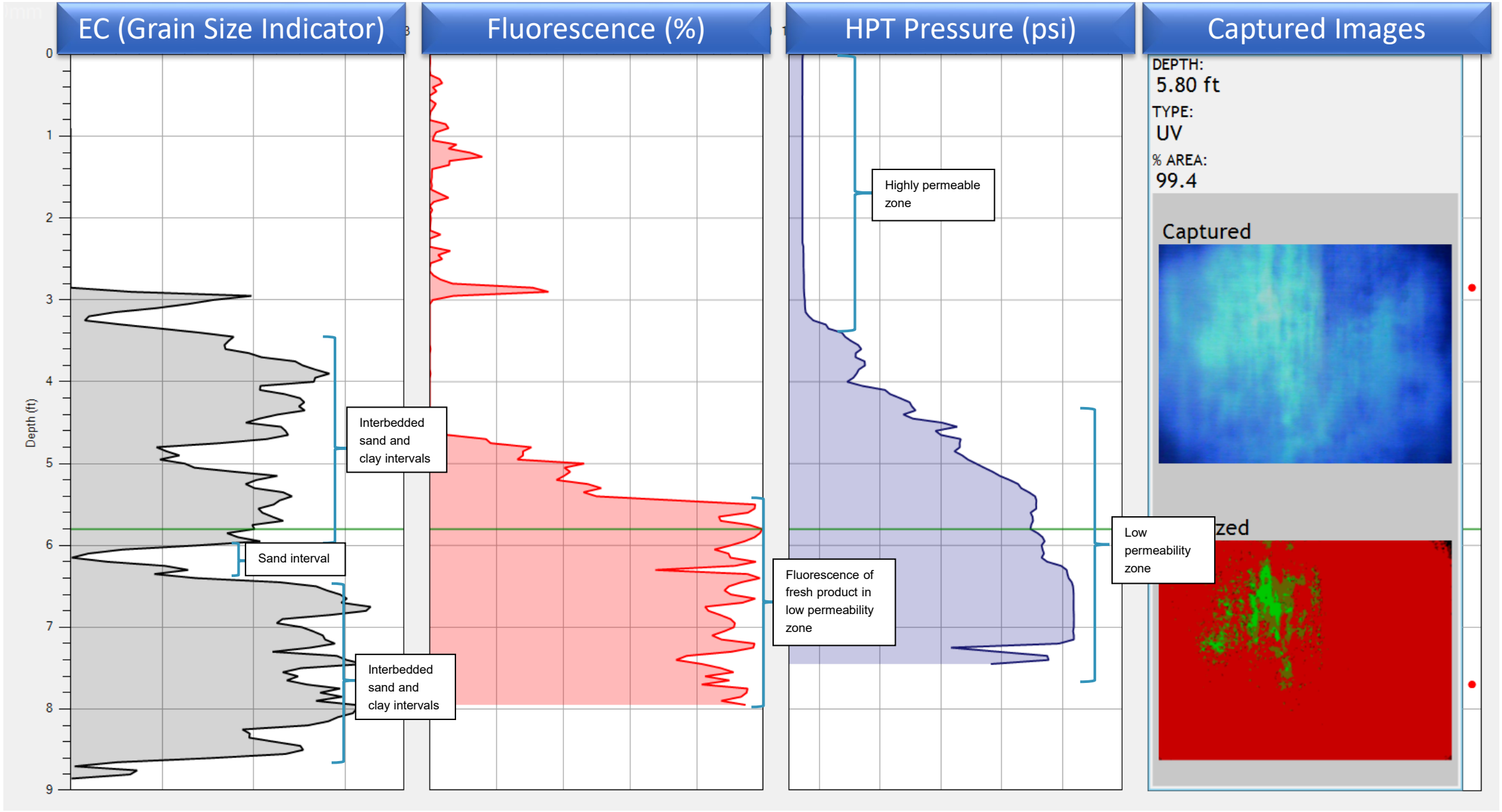
OIP-03 Deep Release



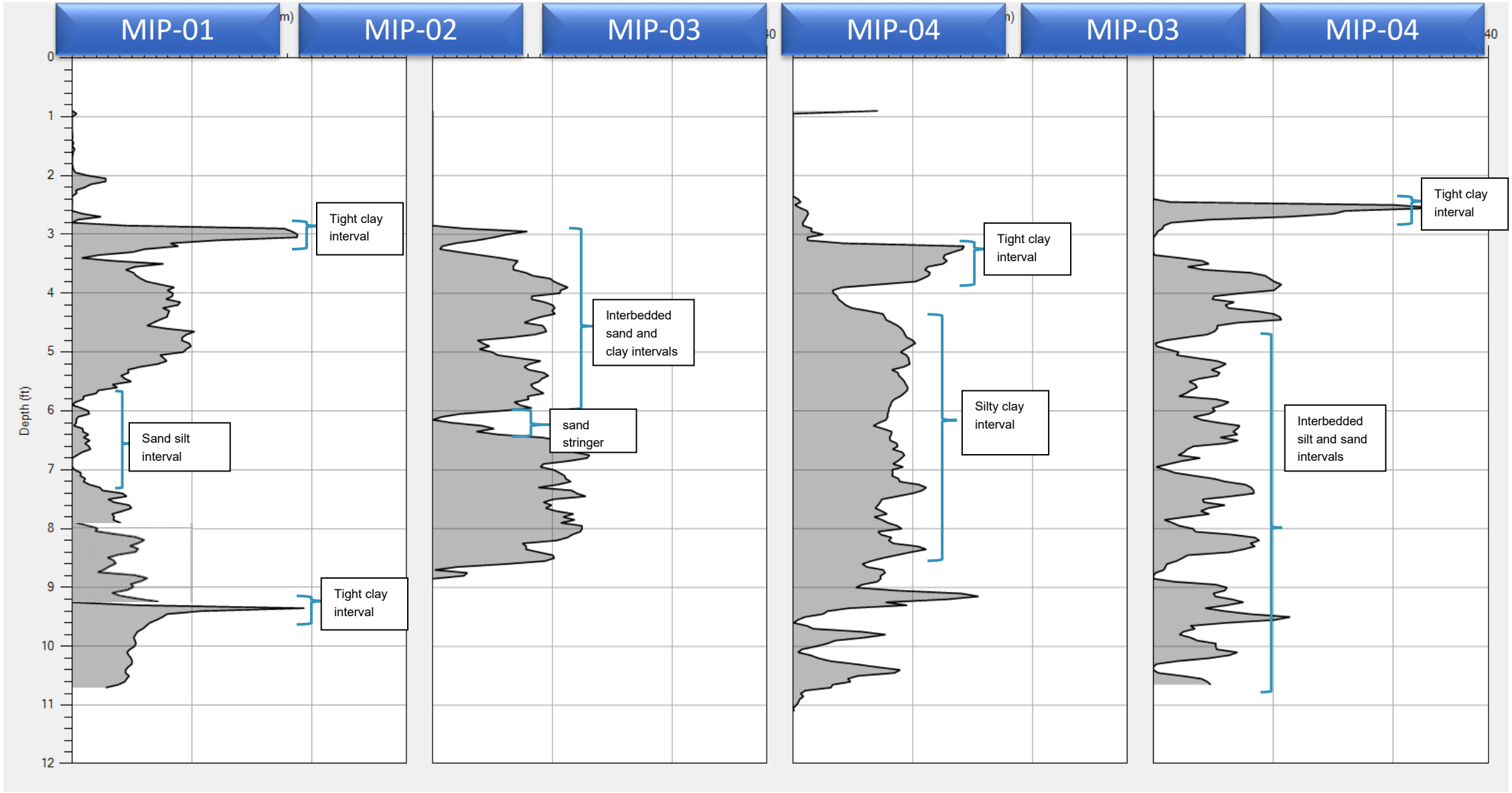
OIP-04 Shallow Release



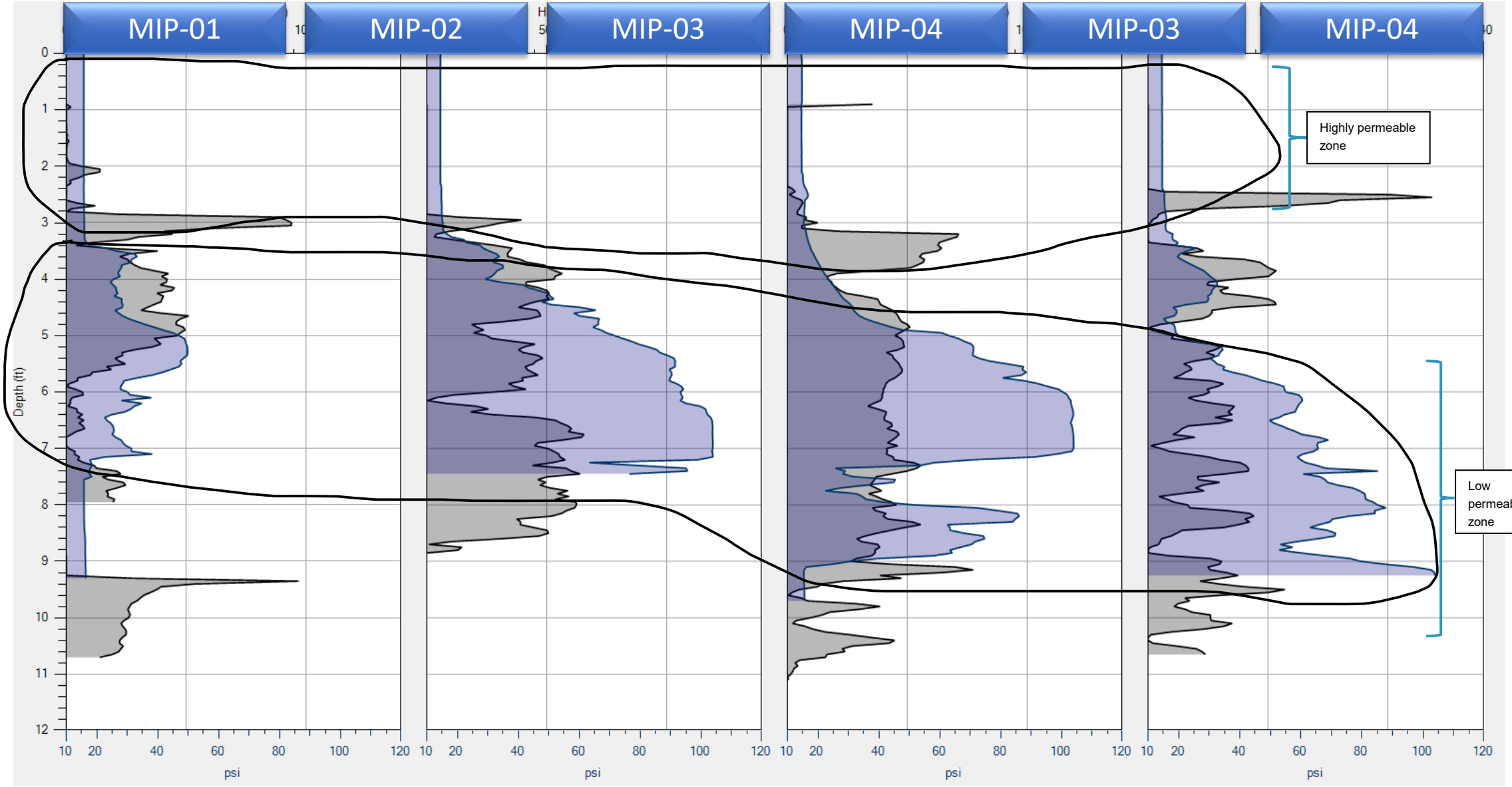
OIP-04 Deep Release



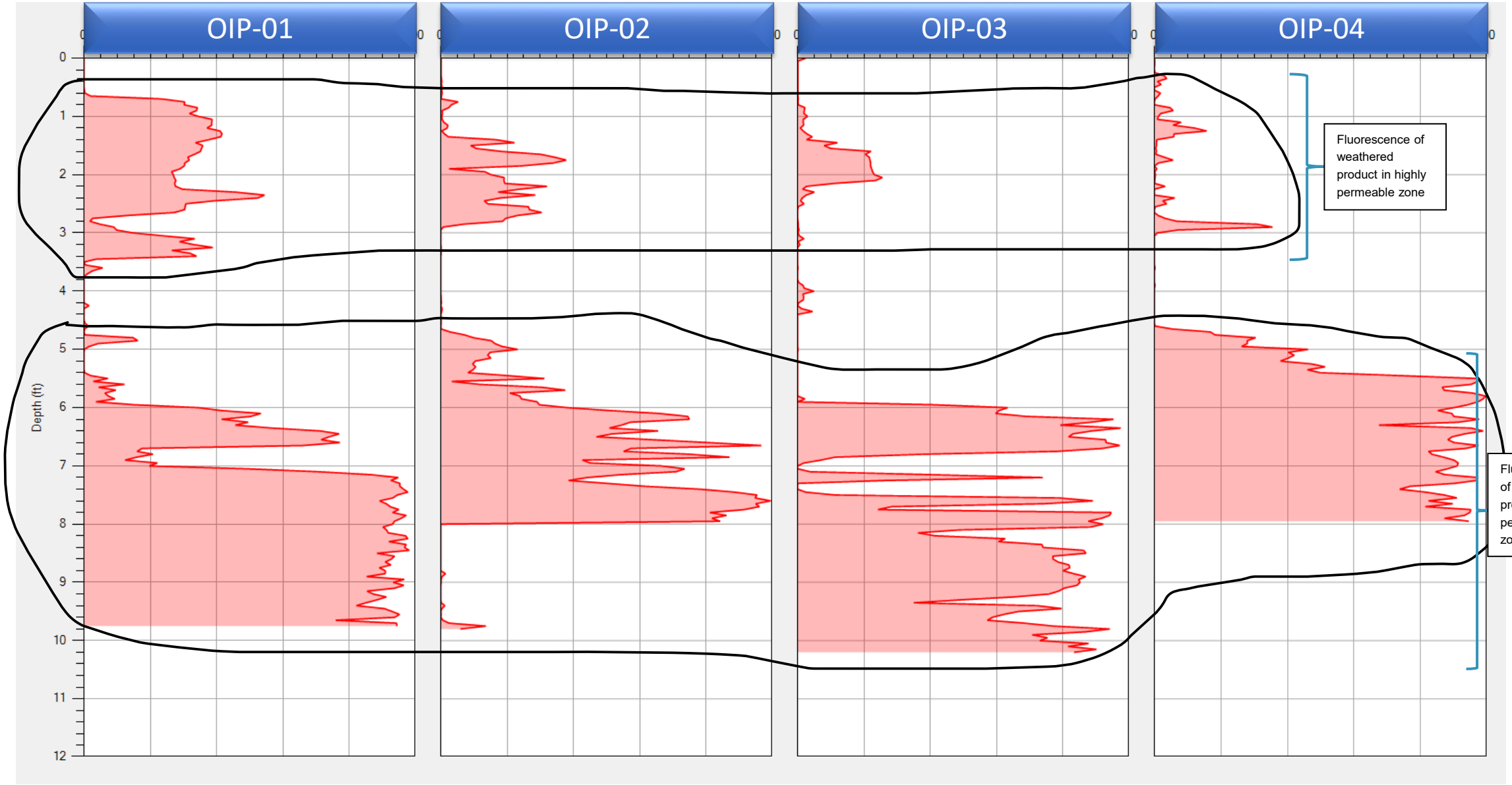
Electrical Conductivity (EC) Lithology Indicator



Lithology Indicators: Hydraulic Pressure Tool (HPT) & EC



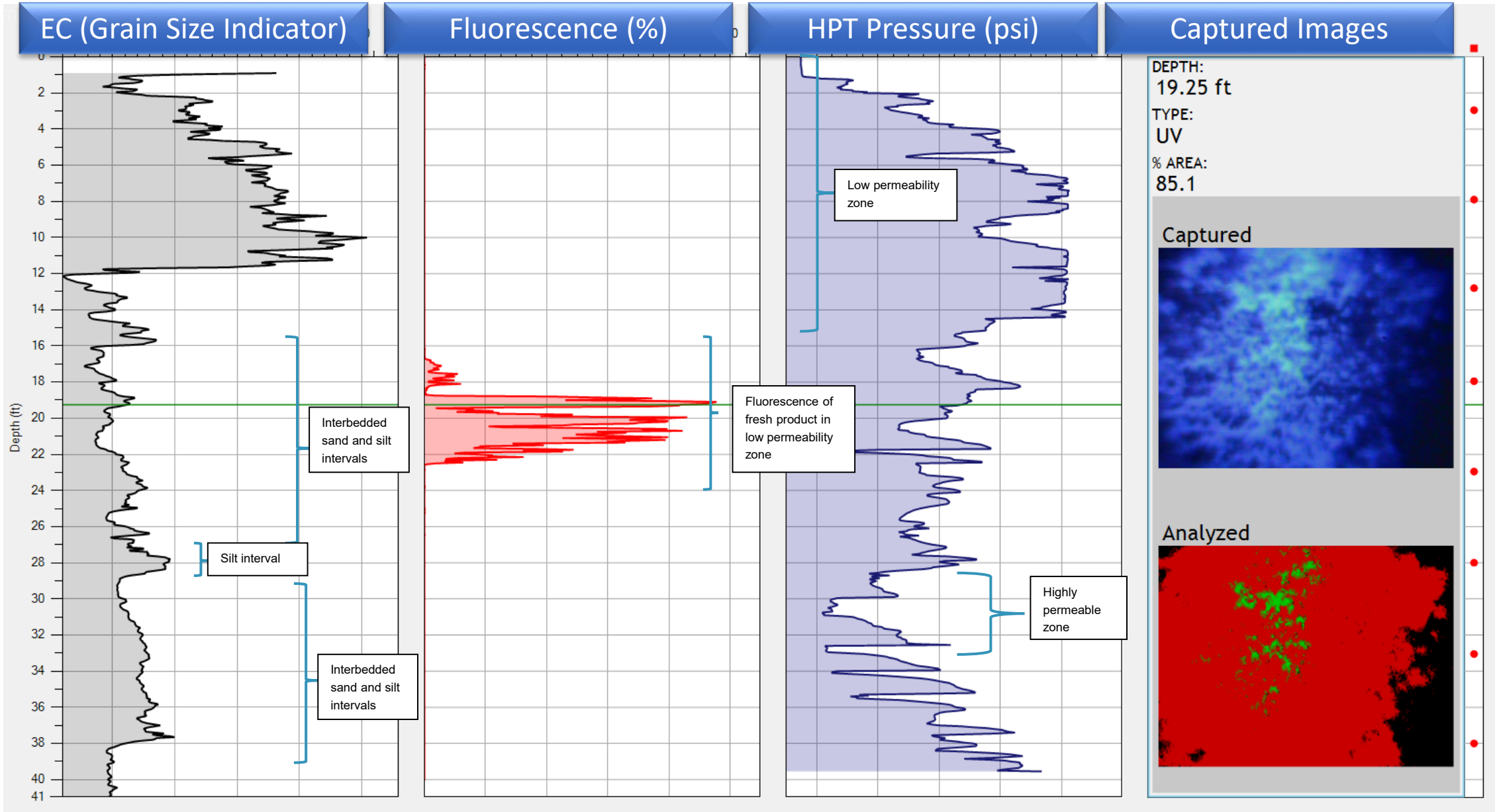
Fluorescence Detection Cross Section



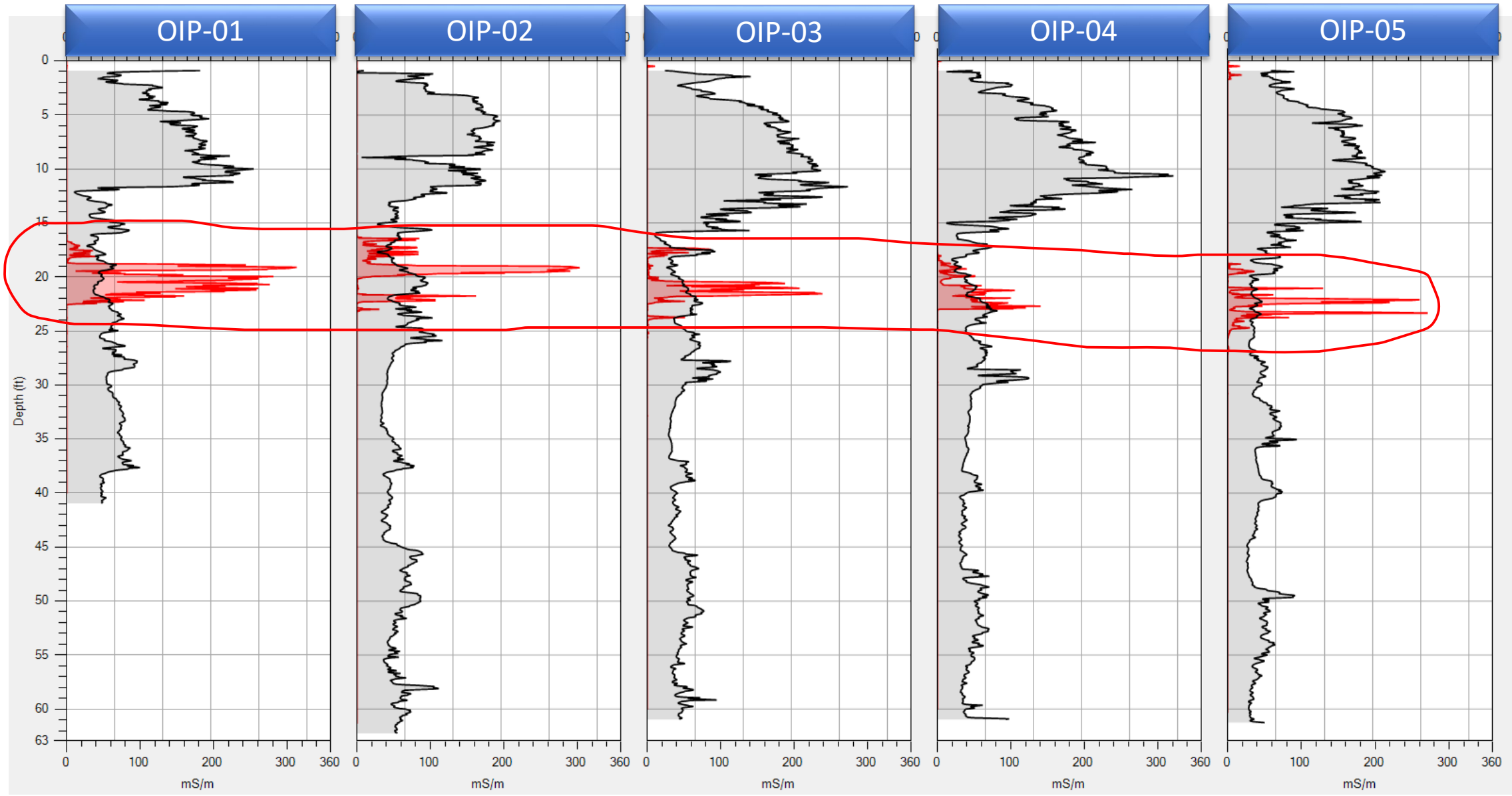
3rd Case Study: Saturated Waste at a Historic Land Fill

4th Case Study: Multiple Plumes on Same Site

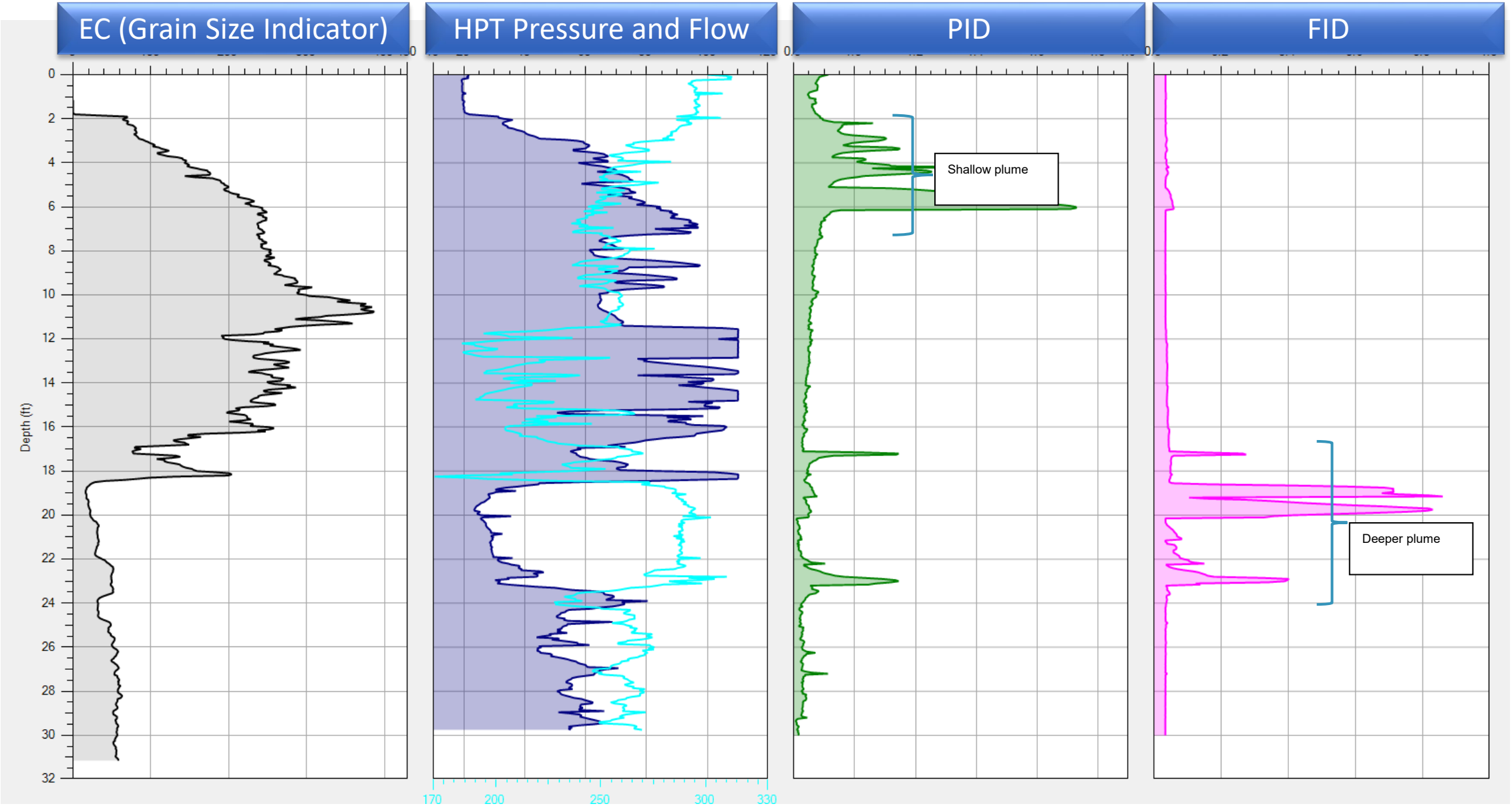
OIP showing free phase LNAPL



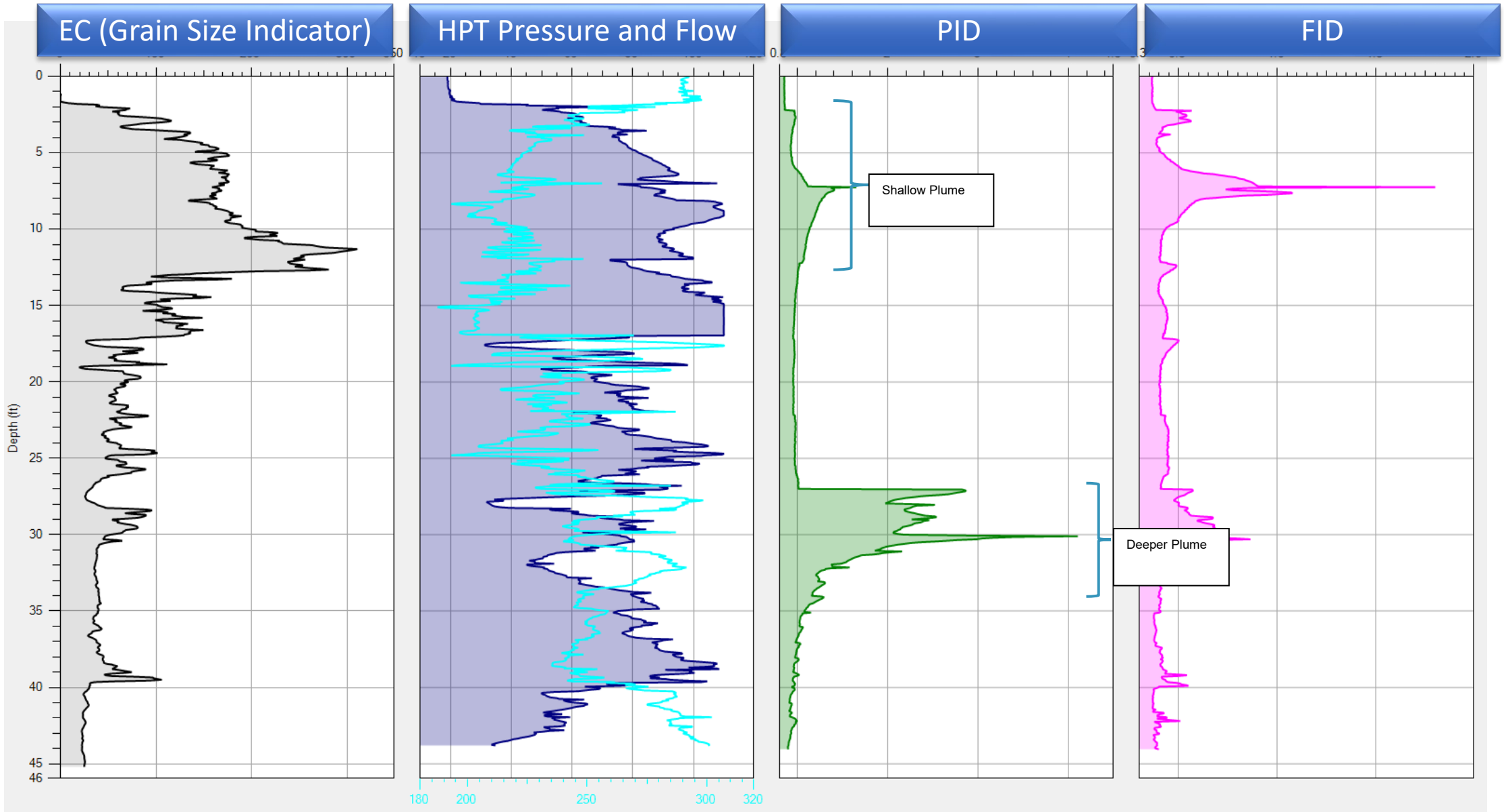
Fluorescence Detection Cross Section



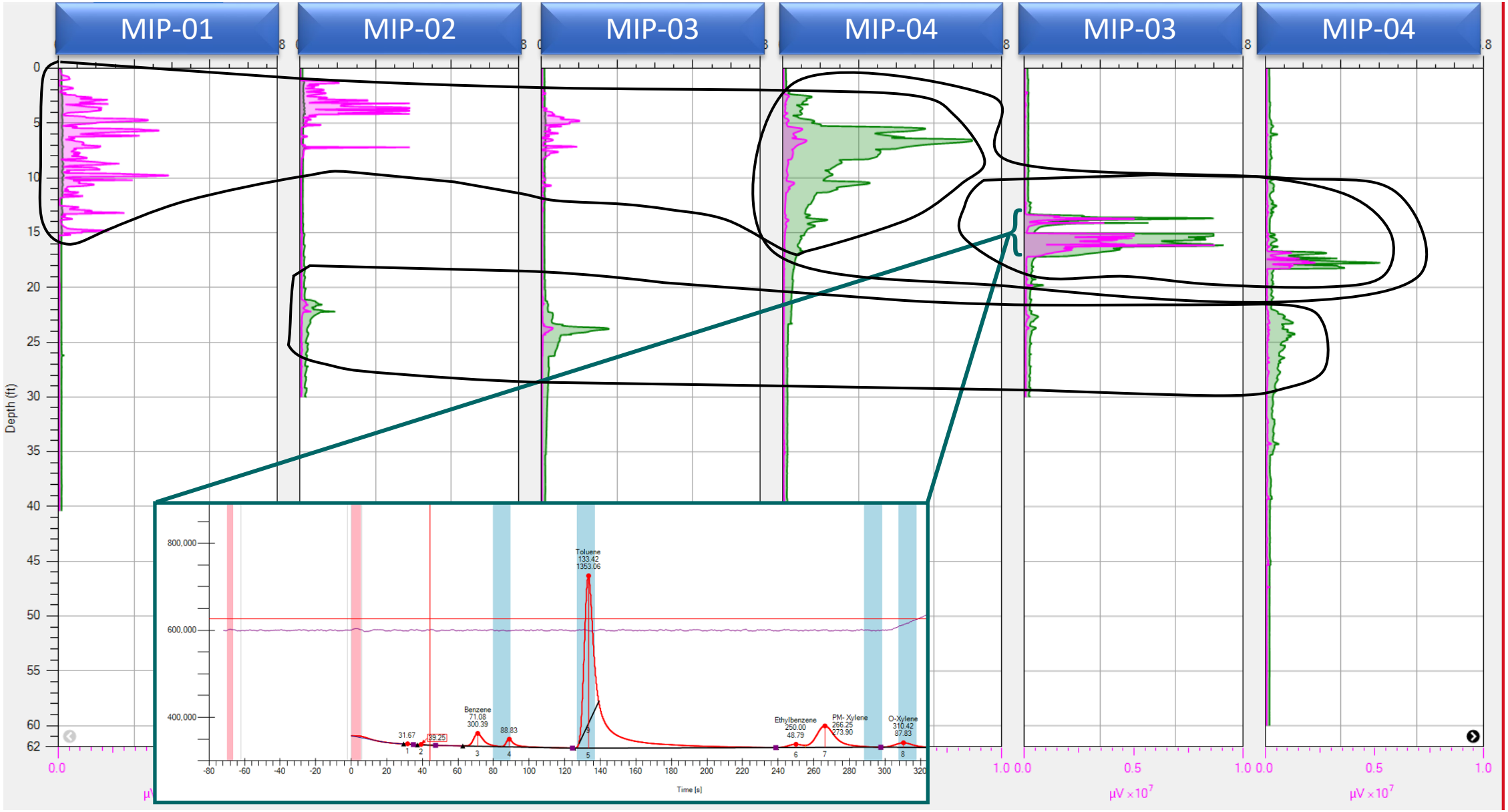
MIP Showing 2 separate plumes



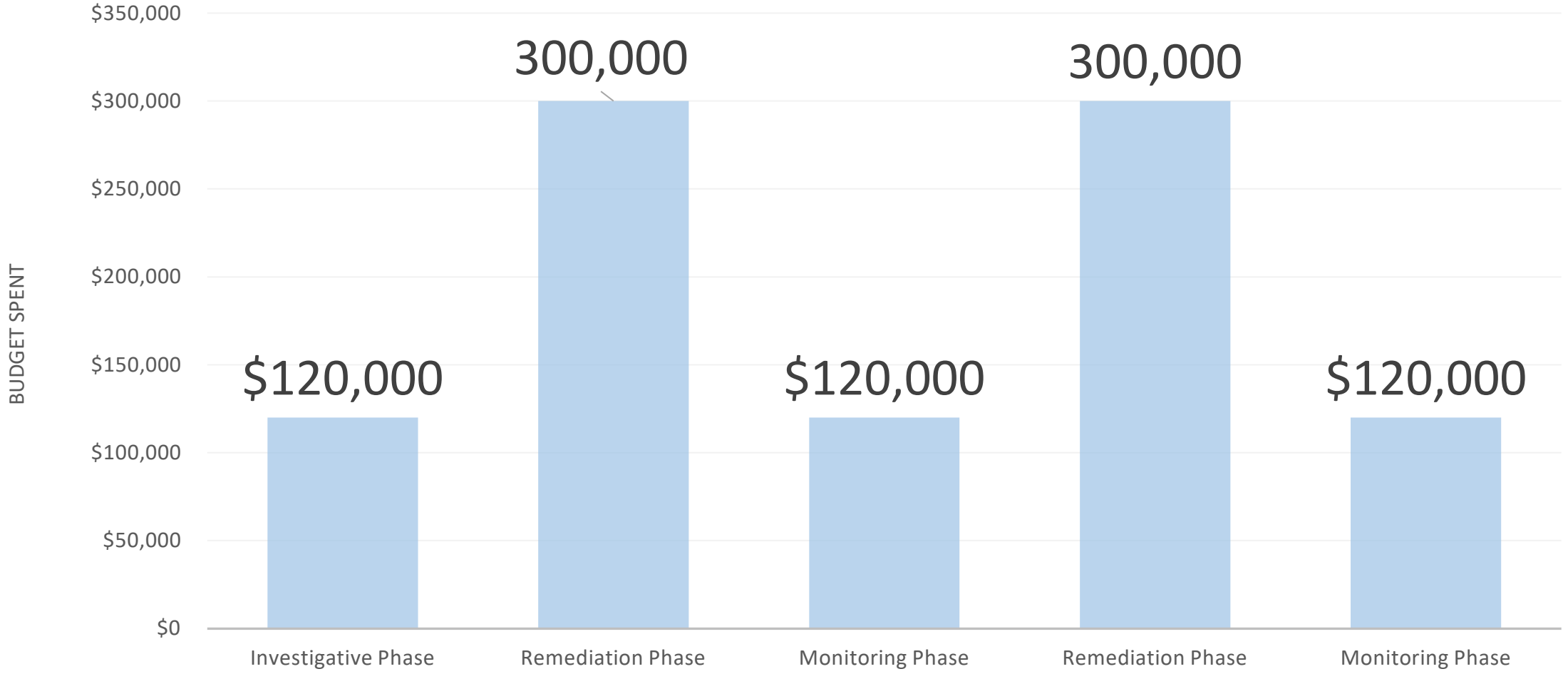
MIP Showing 2 separate hydrocarbon plumes



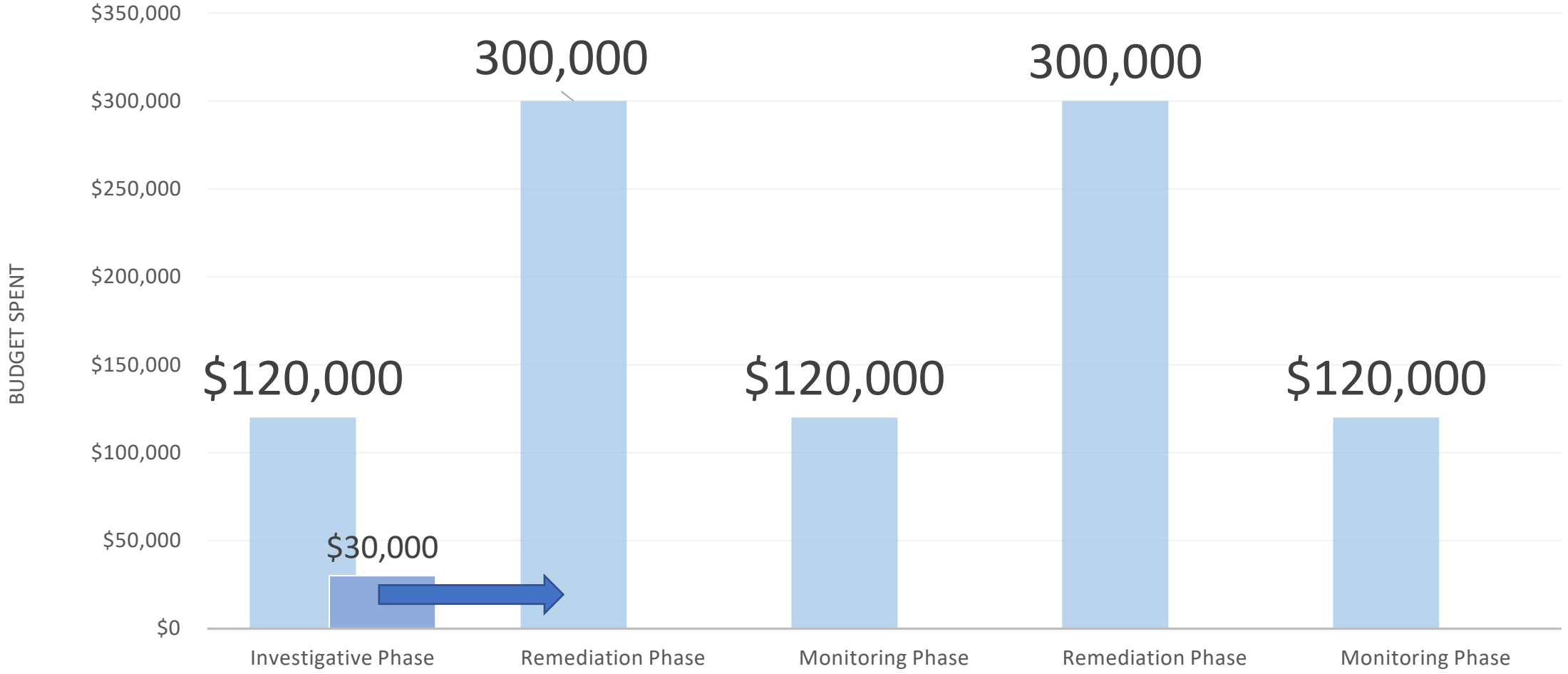
Case Study: Comingled Plume



Cost Benefit Analysis for HRSC – small site

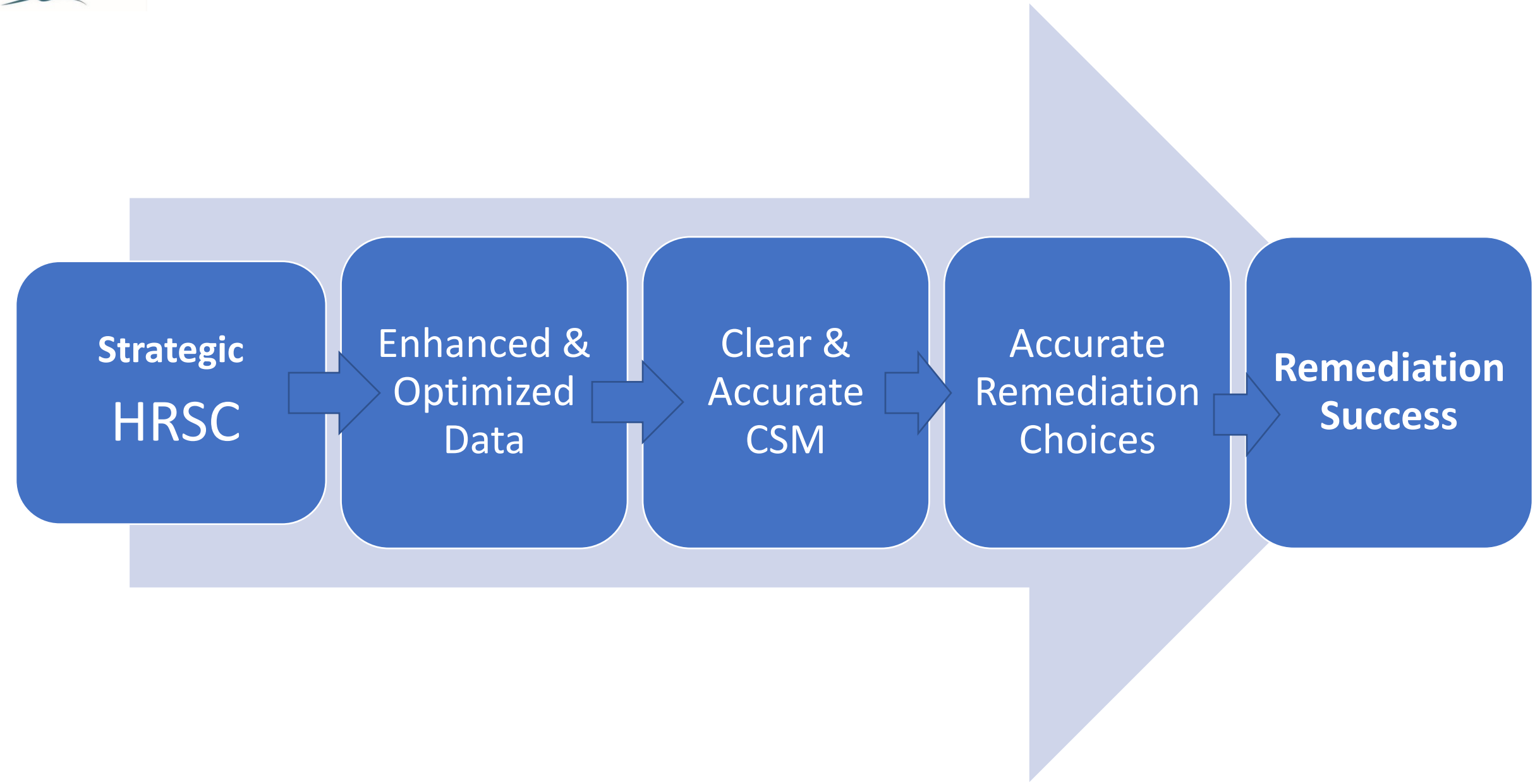


Cost Benefit Analysis for HRSC



Cost Benefit Analysis for HRSC

Cost Savings & Time Savings!



Strategic Optimization utilizing HRSC Technologies

Eagle Synergistic
Optimizing Technologies, LLC

Janet L Castle
President, PG

WOSB
8A Pending

Locations Nationwide:
CA, CO, TX, GA, PA, IL

C:720-475-0022

Eagle Synergistic's Locations & Project Experience