MiHpt

Membrane Interface Probe
+
Hydraulic Profiling Tool

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Genuine Geoprobe

MiHpt

Membrane Interface Probe
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Hydraulic Profiling Tool

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- RemTech Remediation Technology Symposium
  Banff Alberta, Canada October 2013

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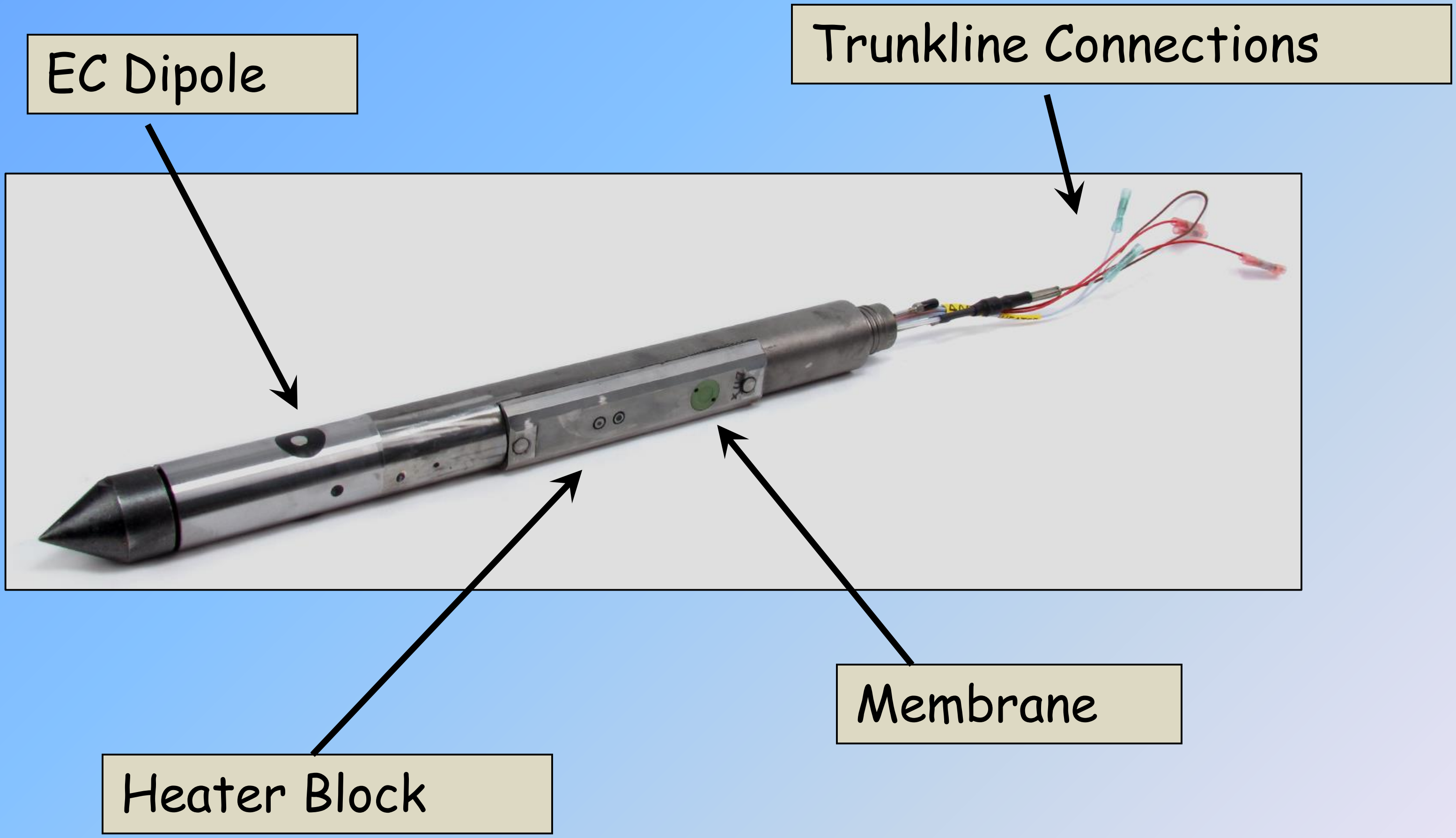
Outline

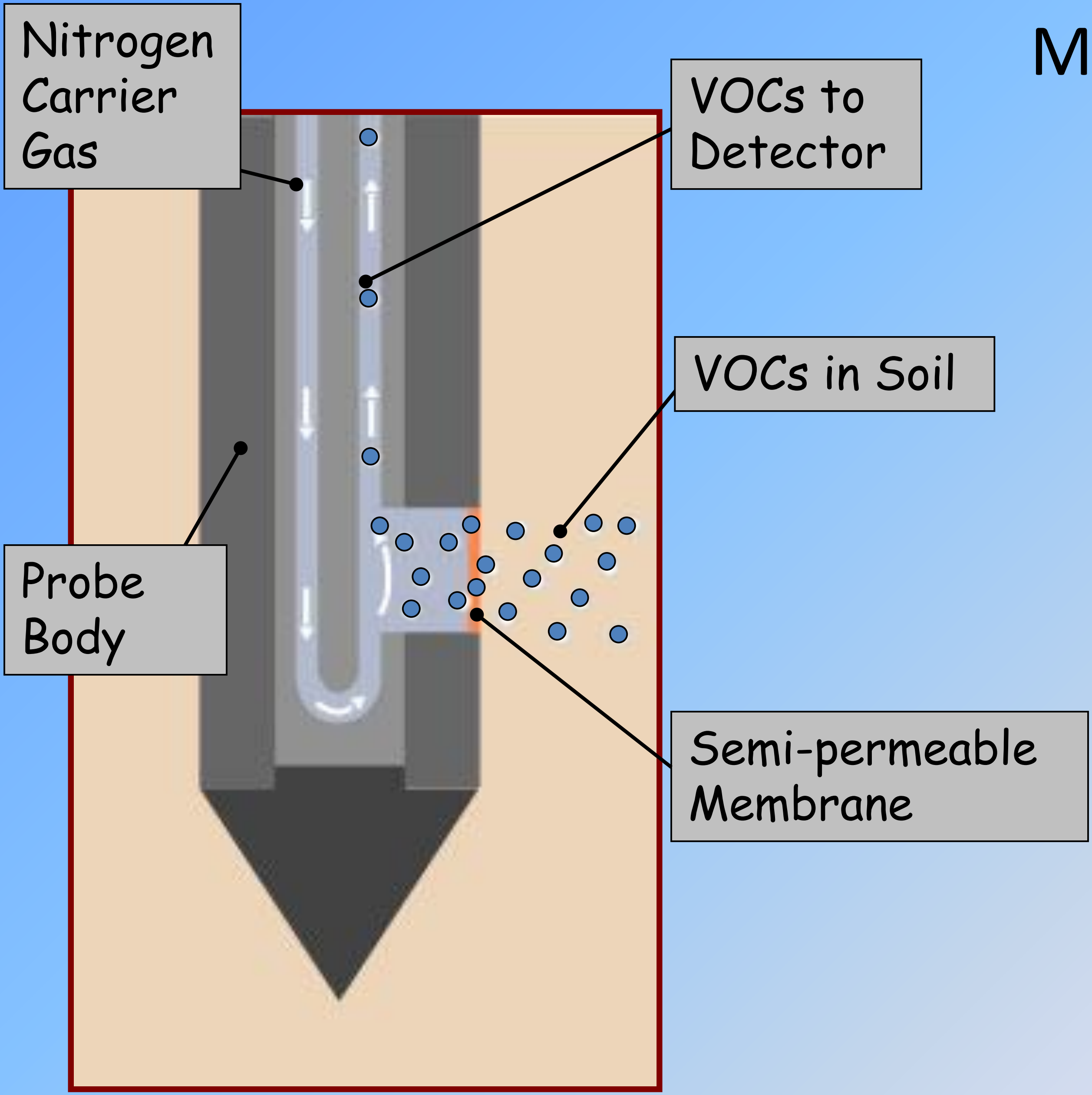
- How Does MIP Work ?   MIP Log
- How Does HPT Work?   HPT Log
- The Combined MiHpt Probe & Log
- Cross Sections with MiHpt logs
- Developing a Conceptual Site Model

MIP Probe



The heater block heats up to 120C to help “extract” volatiles from the formation. The thermocouple is used to monitor & control the temperature. Supply and return gas lines in the trunkline connect to the fittings at the probe.

MIP Principles of Operation:

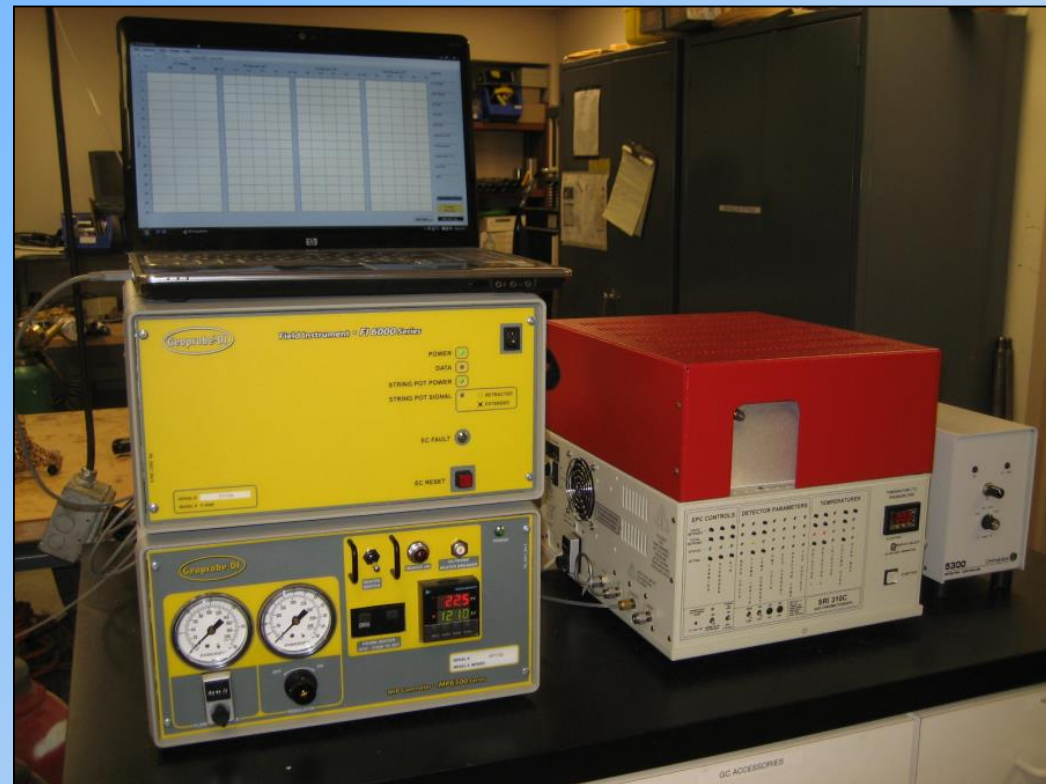


VOCs diffuse across the semi-permeable membrane under a concentration gradient.

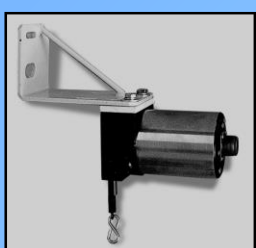
Carrier gas delivers the VOCs to gas phase detectors at the surface.

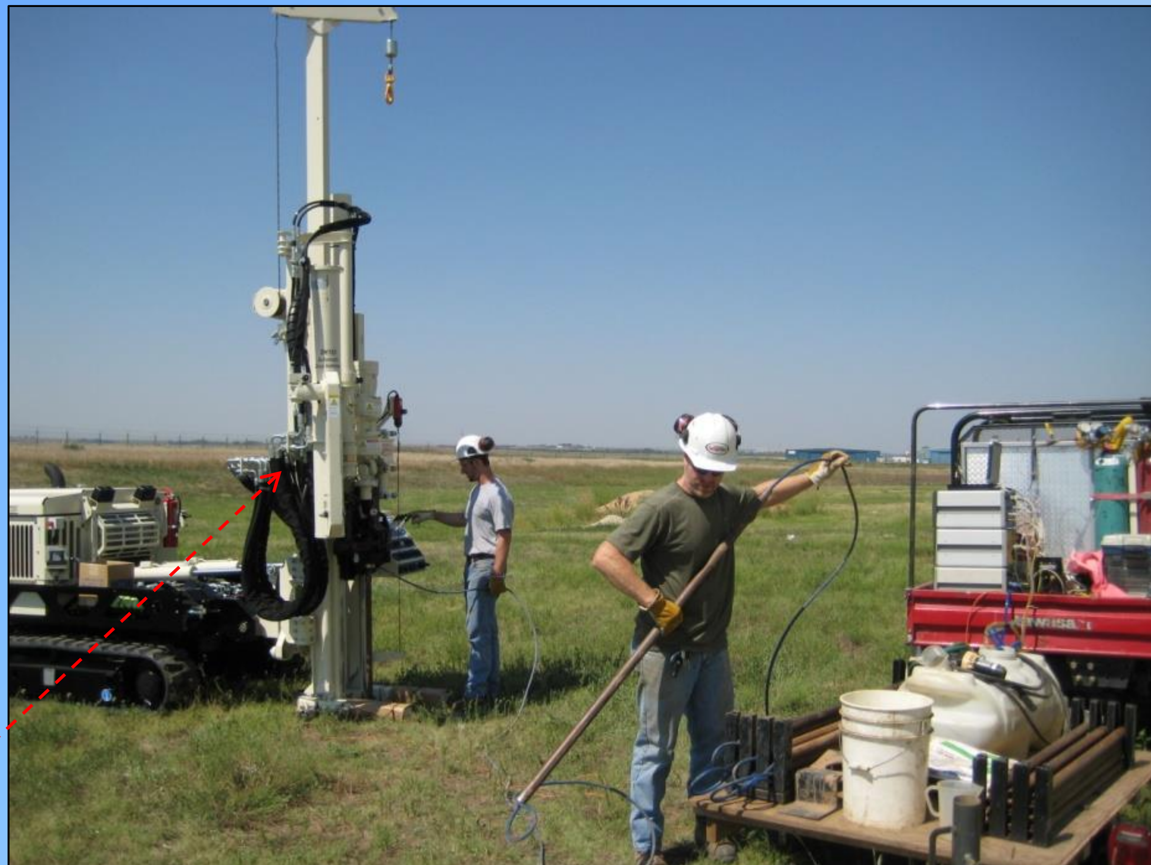
MIP Instrumentation

- Portable Computer
- FI6000 Field Instrument
- MIP Controller
- Gas Chromatograph with three detectors:
    - PID
    - FID
    - XSD (or ECD)



MIP Field Operation





A probe machine advances the tool string into the subsurface incrementally while a stringpot tracks the depth of the probe. Rod and trunkline management provide your daily workout routine.

MIP QA/QC
Field VOC Response Testing

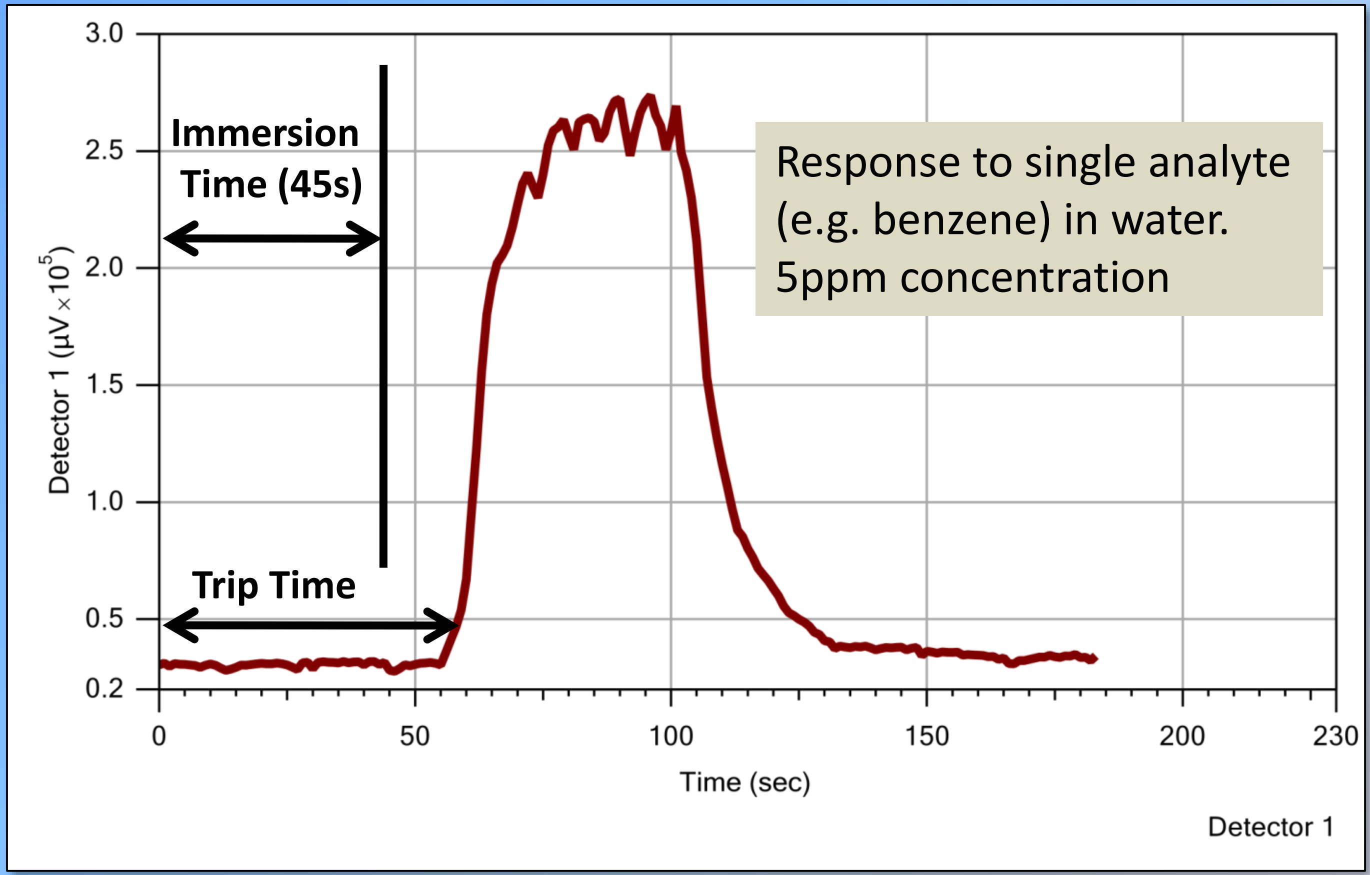
Field standard
(e.g. Benzene,
TCE, PCE, etc.)

Field standard is injected
into 500ml of clean water

The heated MIP probe is
inserted into the working
standard for 45 seconds

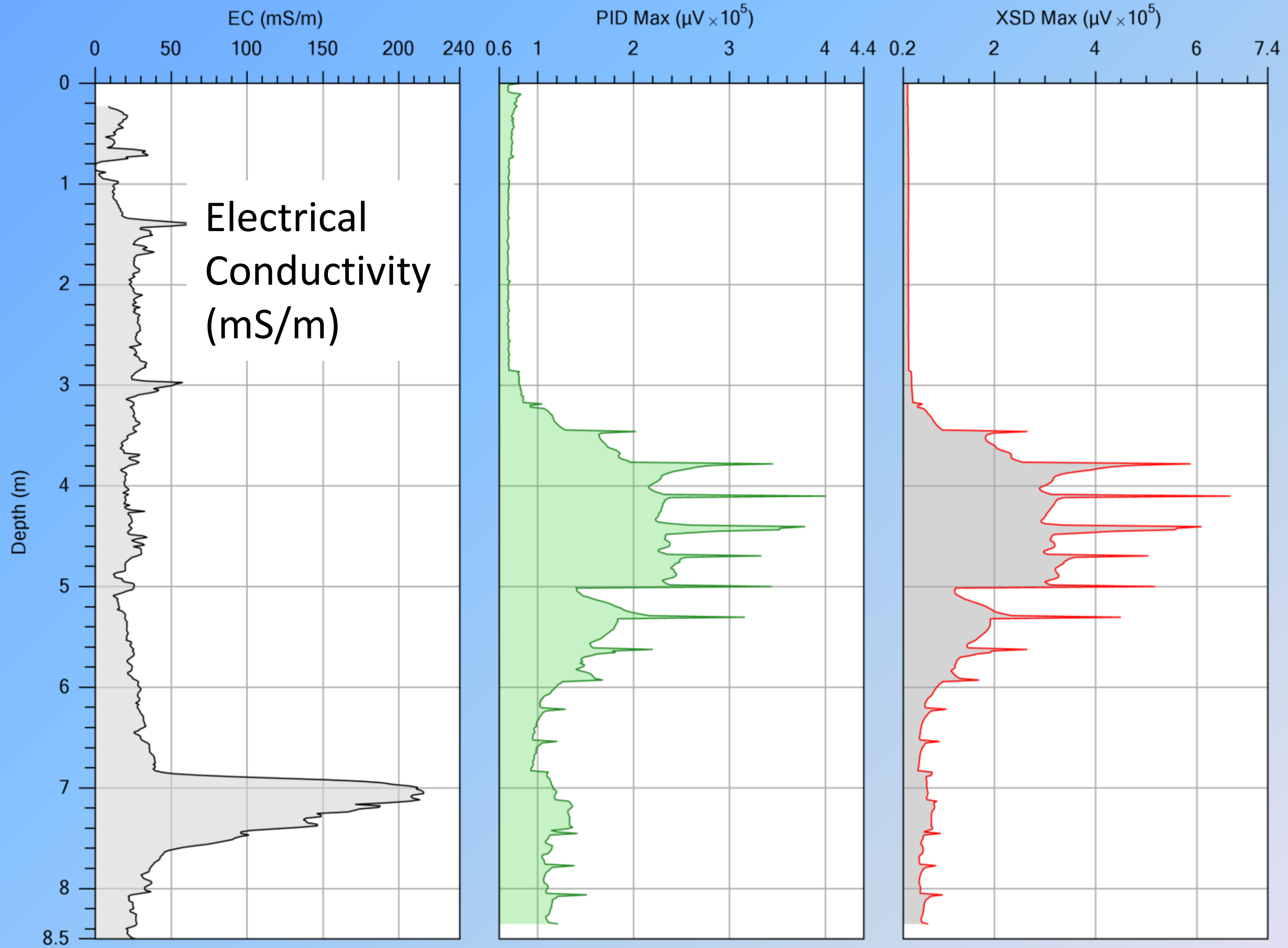
NOT A CALIBRATION

Typical Chemical Response Test



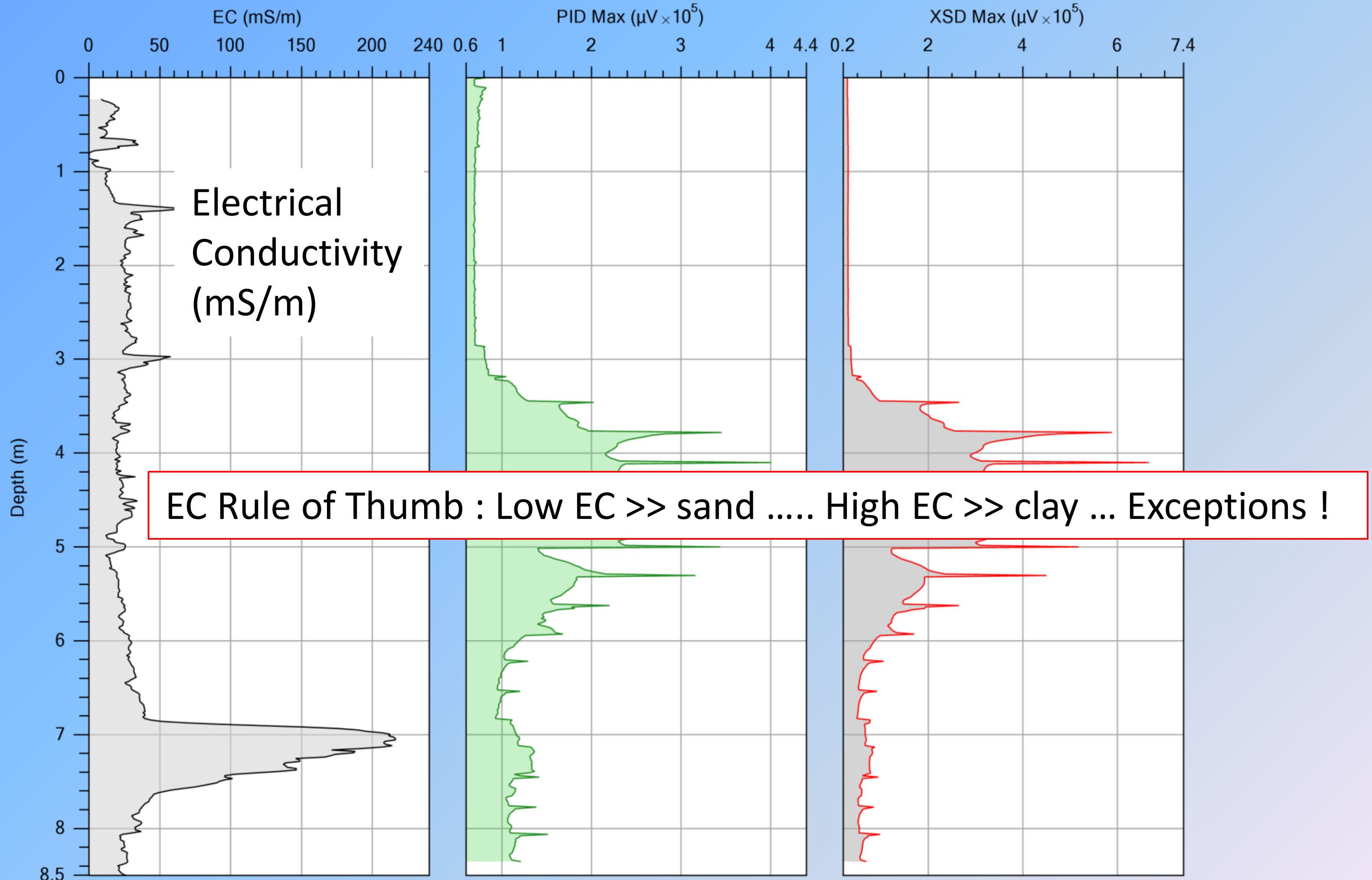
Trip time is the time required for analyte to travel across the membrane and through the trunkline to its first observation at the detector. The trip time is entered into the software to allow for accurate tracking of contaminants in the log.

Example MIP Log: Skuldelev SK05



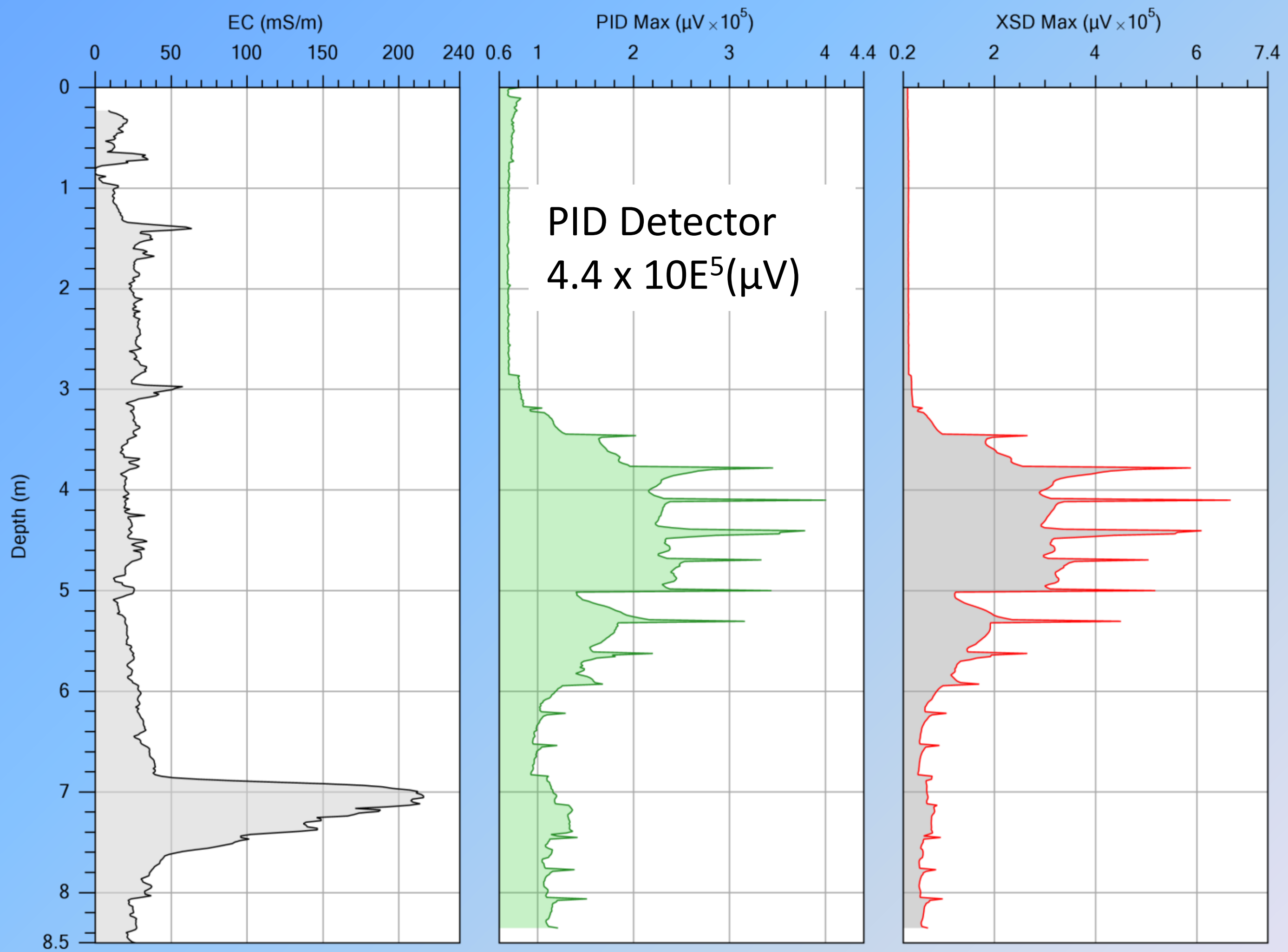
Here is a fairly typical MIP log. EC graph on the left, units are millisiemens per meter.

Example MIP Log: Skuldelev SK05

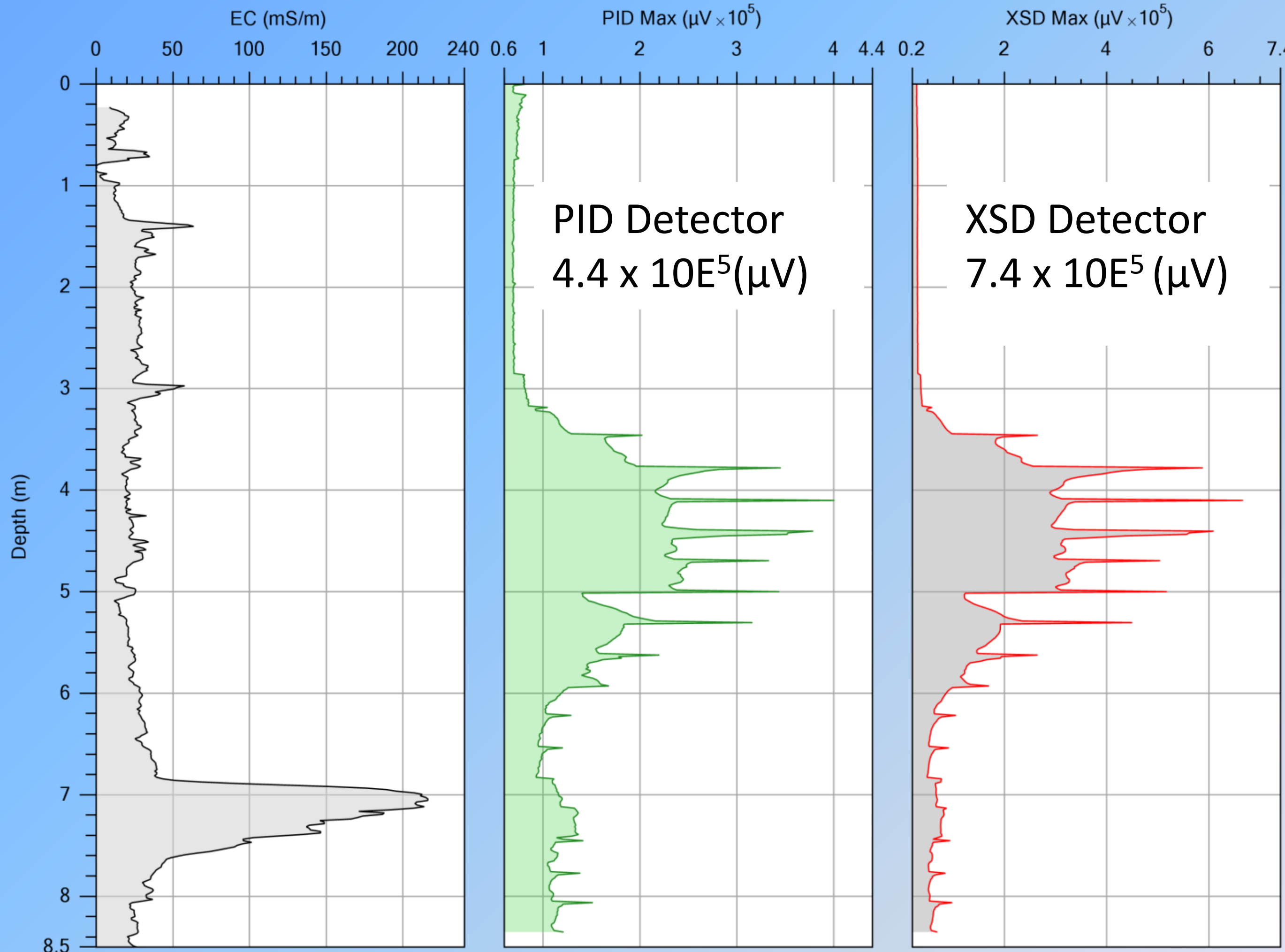


The EC rule of thumb is for fresh water formations. There are exceptions to the EC rule … ionic contaminants can cause hi EC even in a clean sand

Example MIP Log: Skuldelev SK05

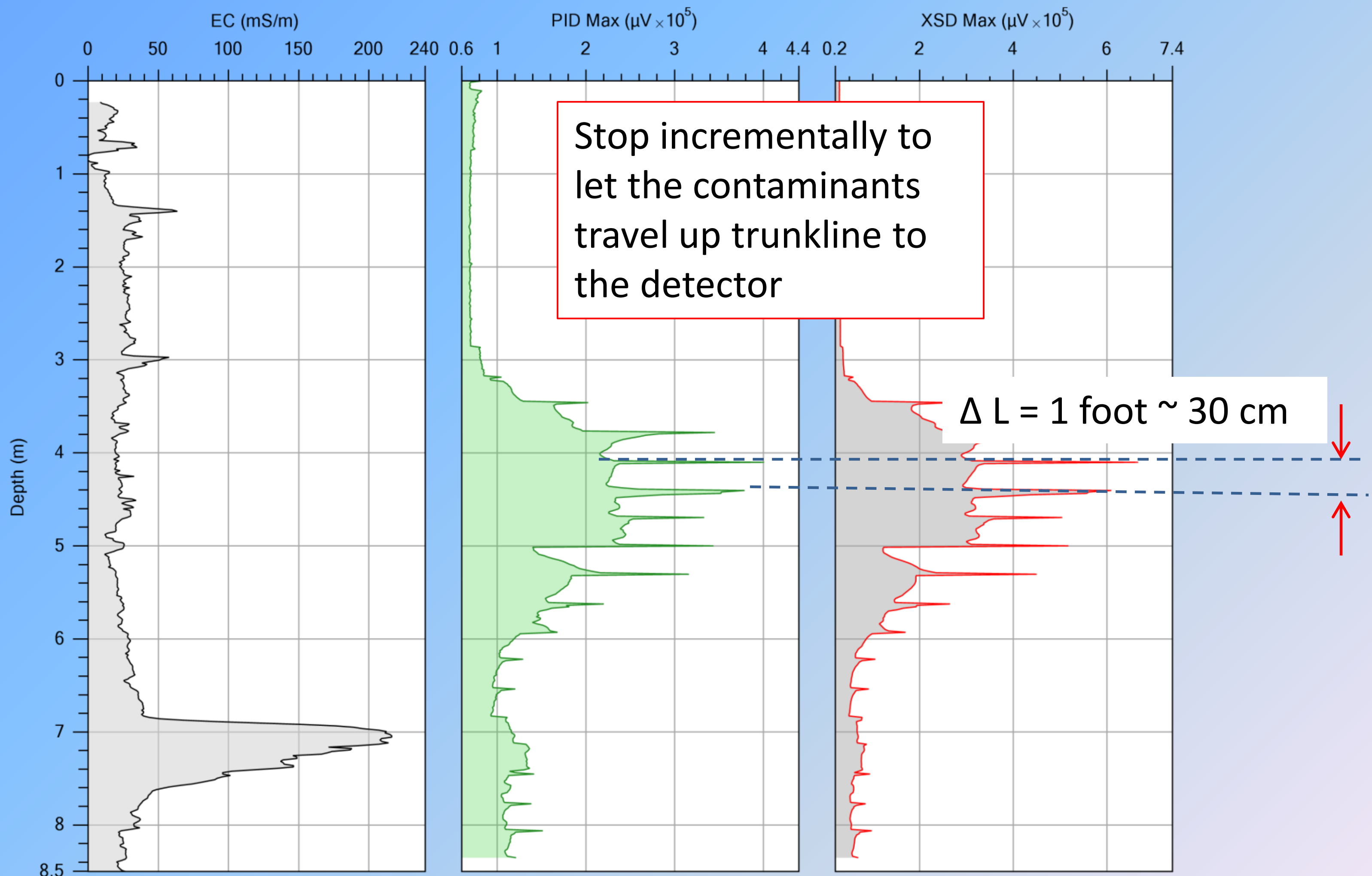


Example MIP Log: Skuldelev SK05



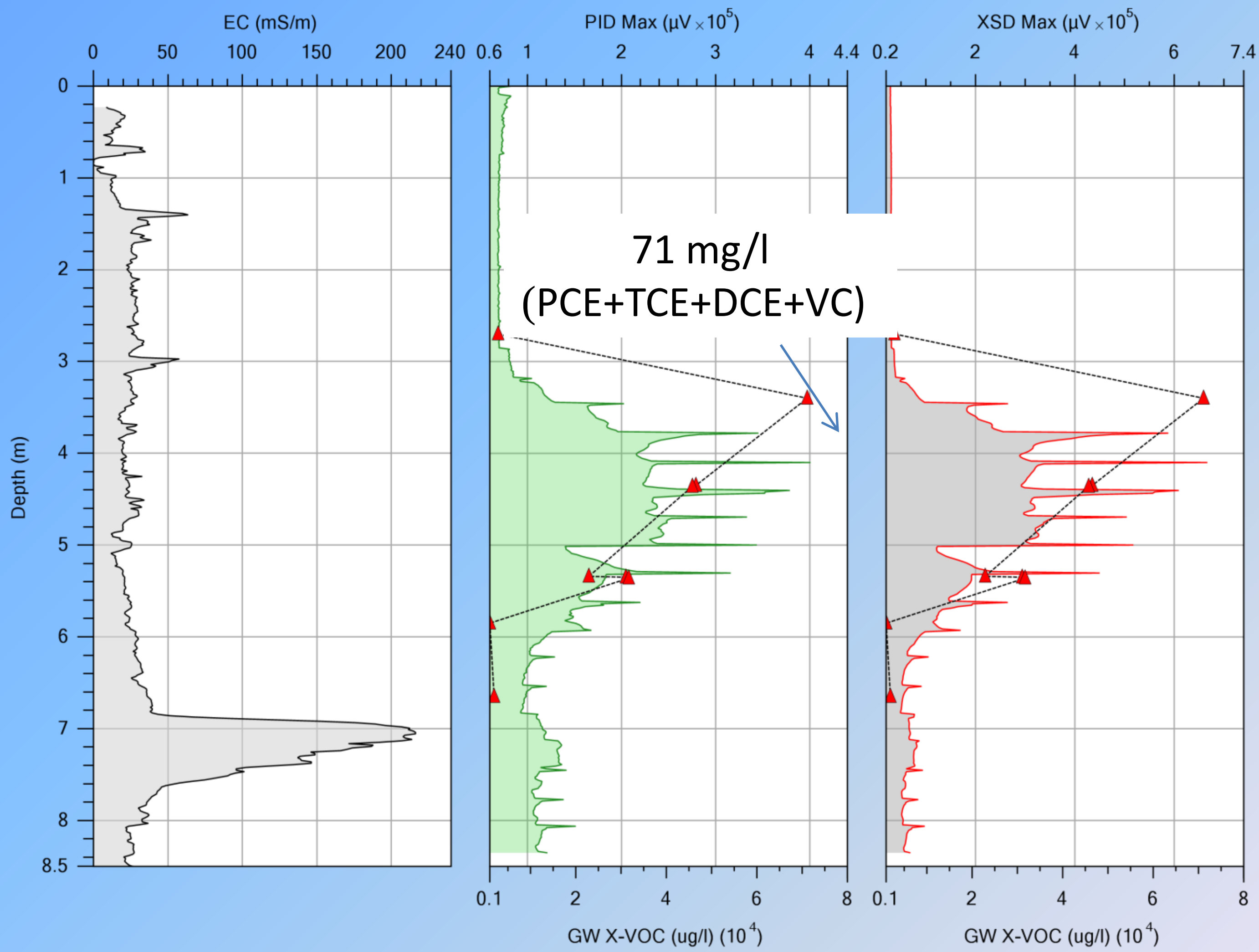
Scale is Important !

Incremental Probing & Trip Time



The peaks or "spikes" in the detector logs are caused by the incremental probing. Stopping at each depth interval for about 45 seconds to allow time for the probe to reach temperature and diffuse contaminants across the membrane.

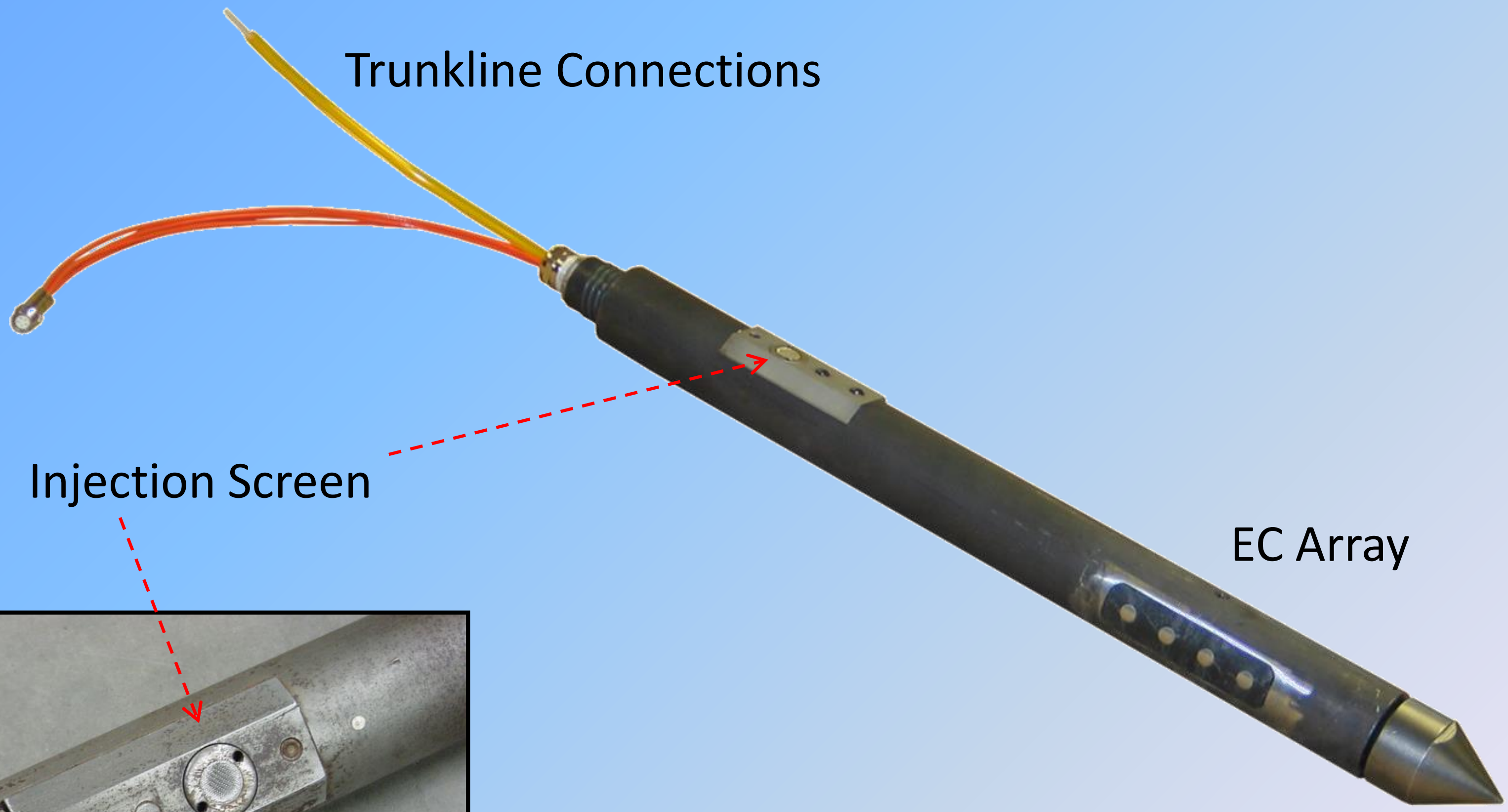
Correlating MIP Detector to Groundwater Samples



How does the MIP detector response correlate with groundwater sample results? At the Skuldelev site the results correlate pretty well. We used a direct push piezometer with a 1-foot screen interval to collect discrete samples for this comparison.

The HPT Probe System

Trunkline Connections

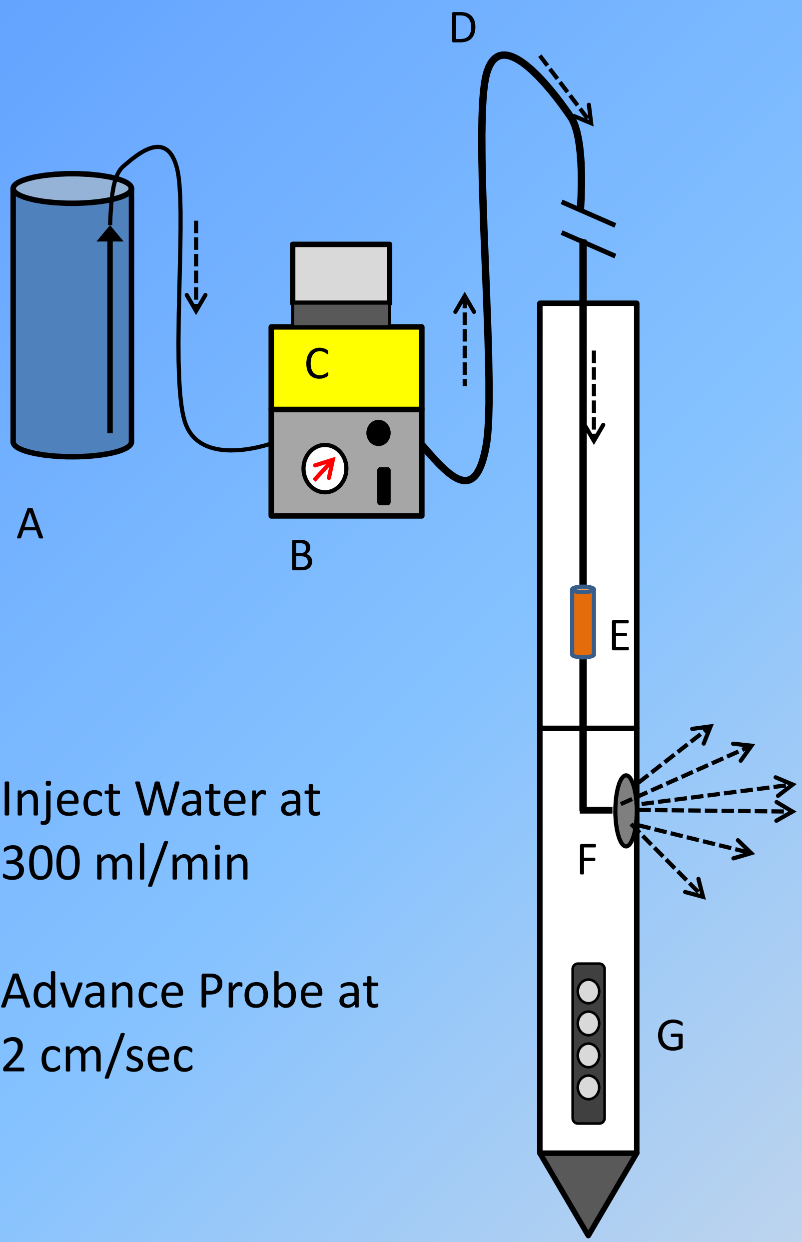


Injection Screen

EC Array

Replaceable
Screens

HPT Principles of Operation

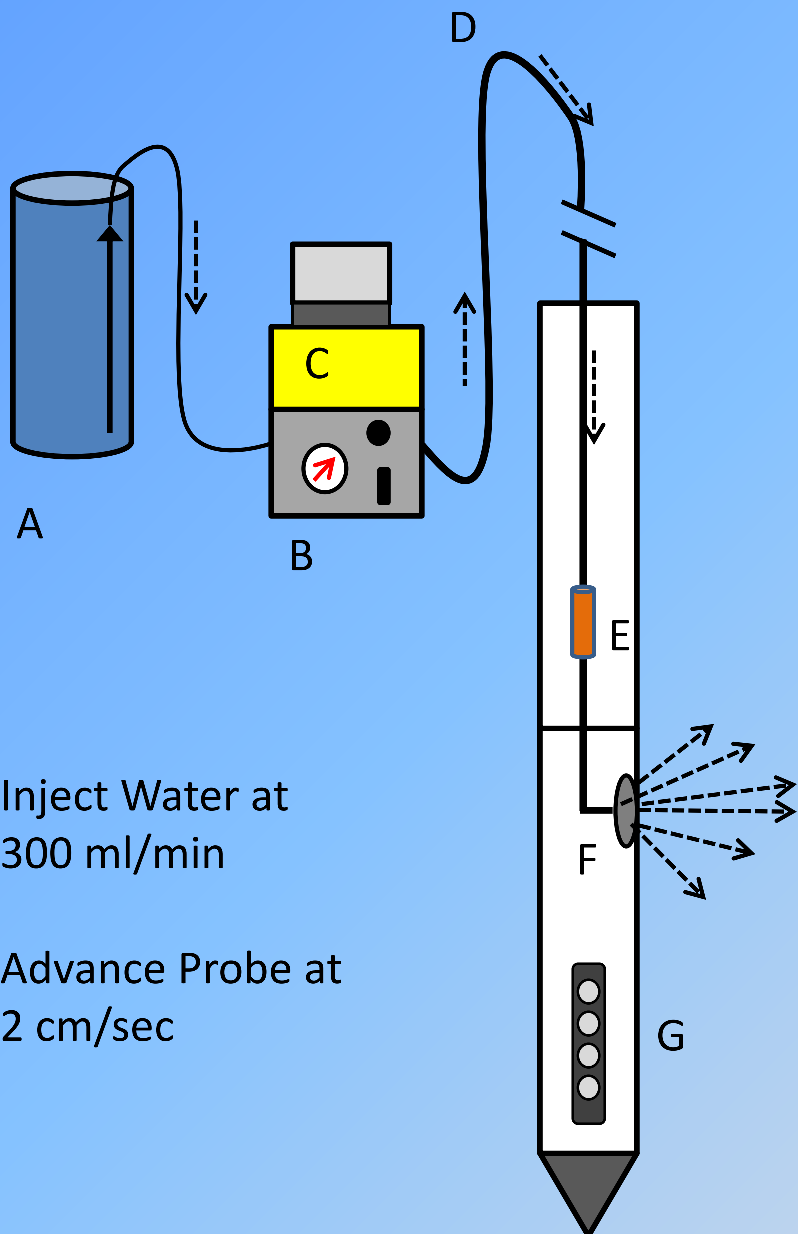


Inject Water at 300 ml/min

Advance Probe at 2 cm/sec

A) Water Tank
B) Pump & Flow Meter
C) Electronics/computer
D) Trunkline
E) Pressure Sensor
F) Screened Injection Port
G) Elec. Conductivity Array

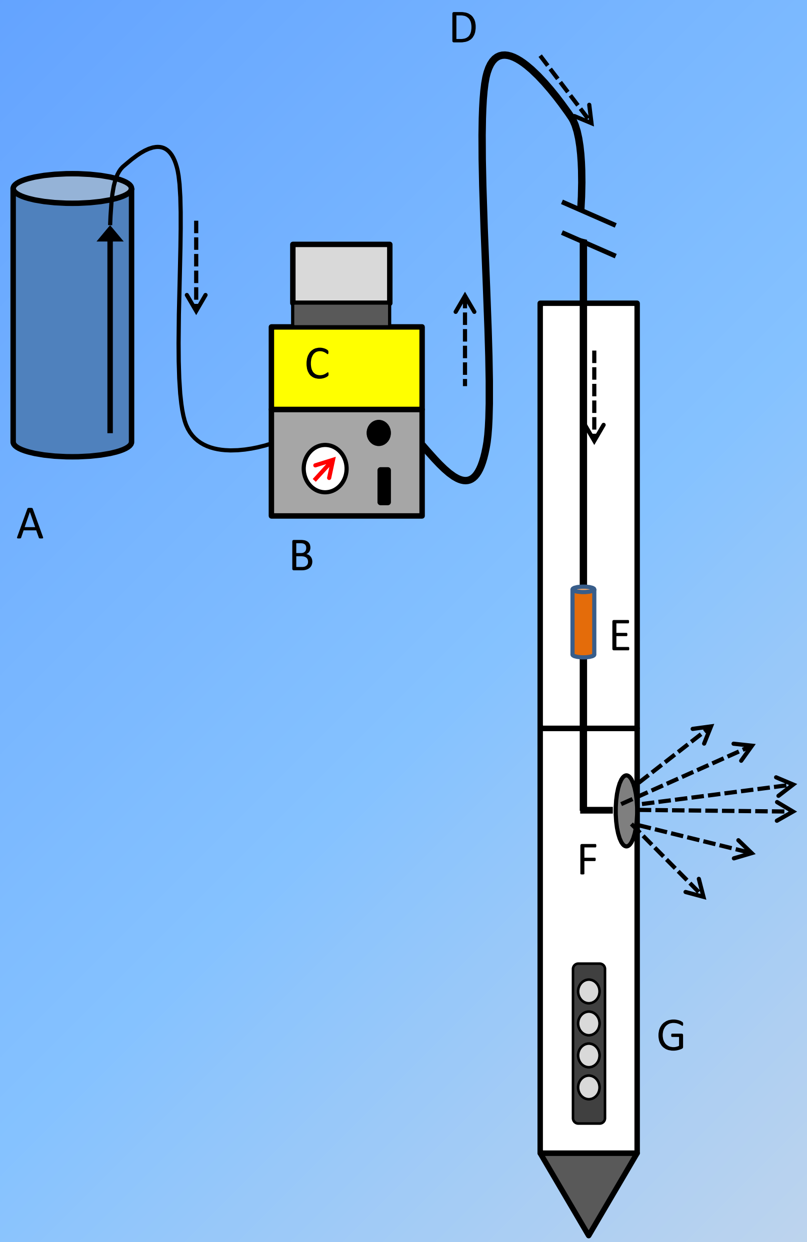
HPT Principles of Operation



Inject Water at
300 ml/min

Advance Probe at
2 cm/sec

The pump in the HPT flow module (B) draws water from the supply tank and pumps water down the trunkline at a constant flow rate. An inline flow meter measures the flow rate. The downhole pressure sensor (E) monitors the pressure generated by injecting water into the formation matrix. The HPT probe includes an electrical conductivity (EC) Wenner array. The EC, pressure and flow rate are logged every 0.05 ft (15 mm) and displayed onscreen as the probe is advanced.



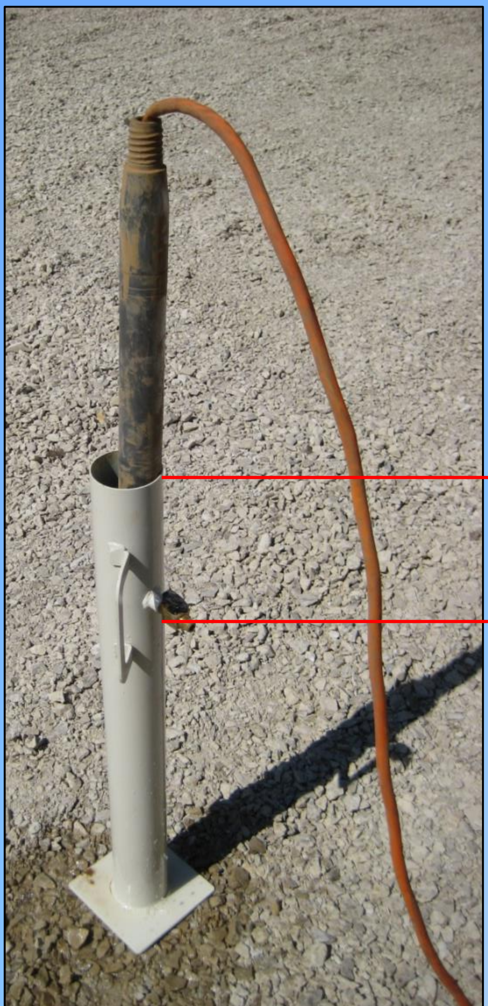
HPT Interpretation

HPT Pressure Rule of Thumb:

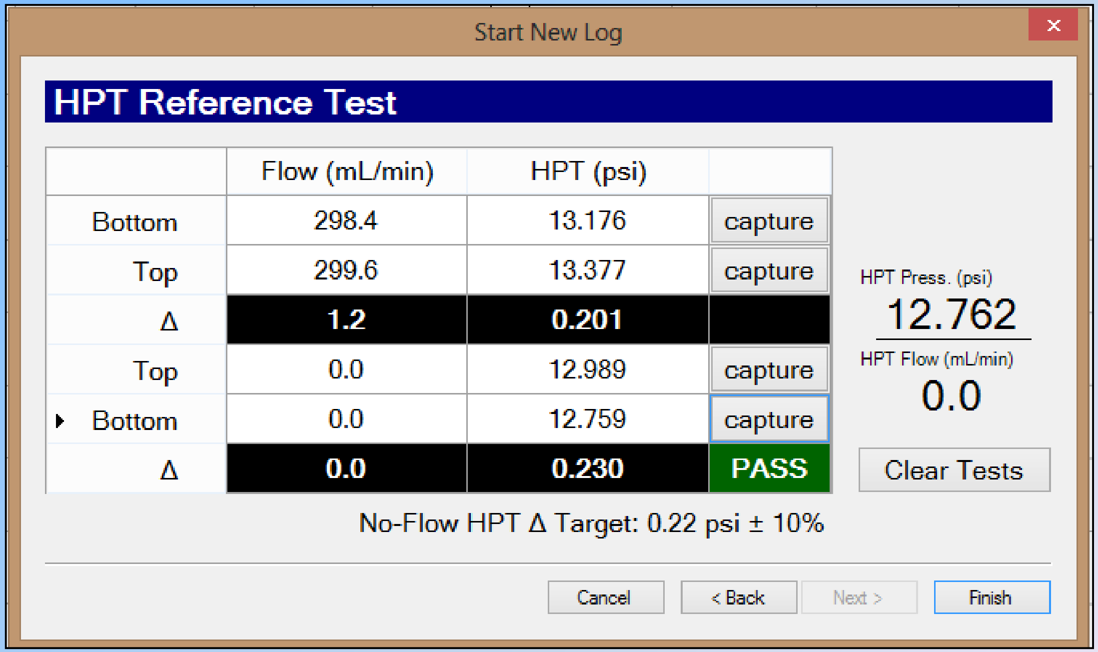
Hi Pressure >> Lo Permeability

Low Pressure >> Hi Permeability

HPT QA/QC

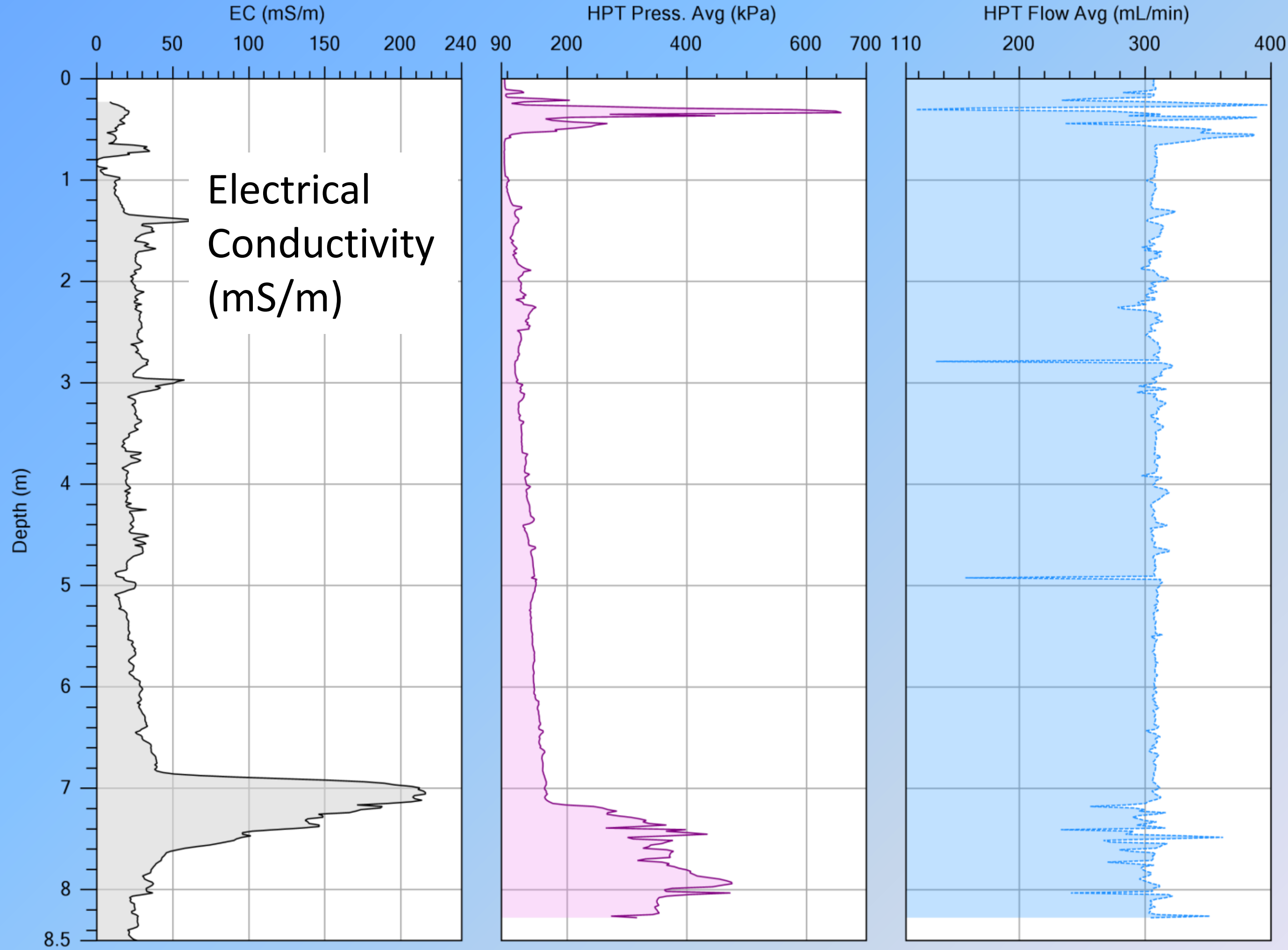


HPT Probe in Reference Tube to Verify
Δ6” Water Pressure = 0.22 psi (1.52kPa)

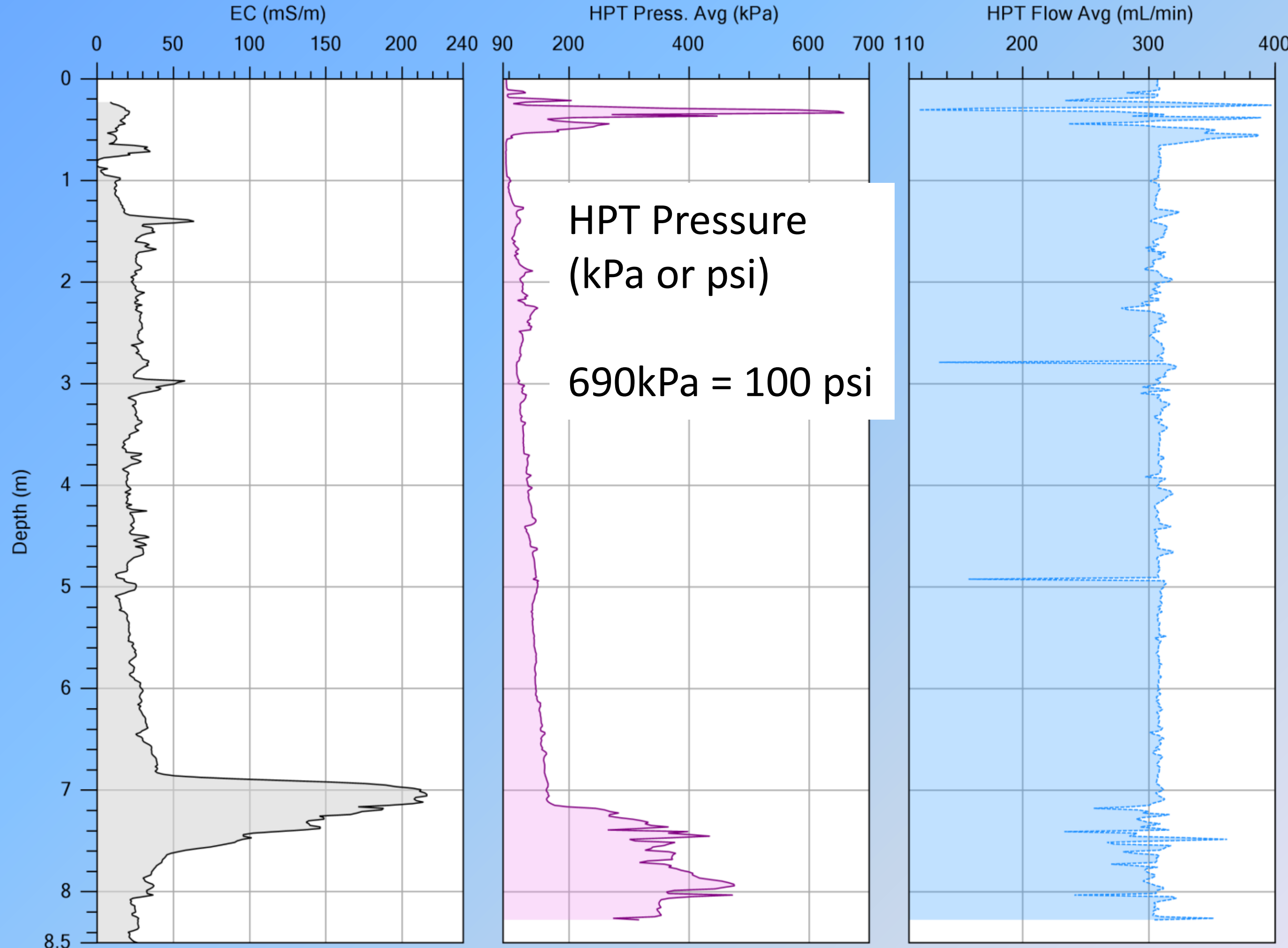


HPT Pressure Transducer Onscreen QA Report
(data saved to log file)

Example HPT Log: Skuldelev SK05



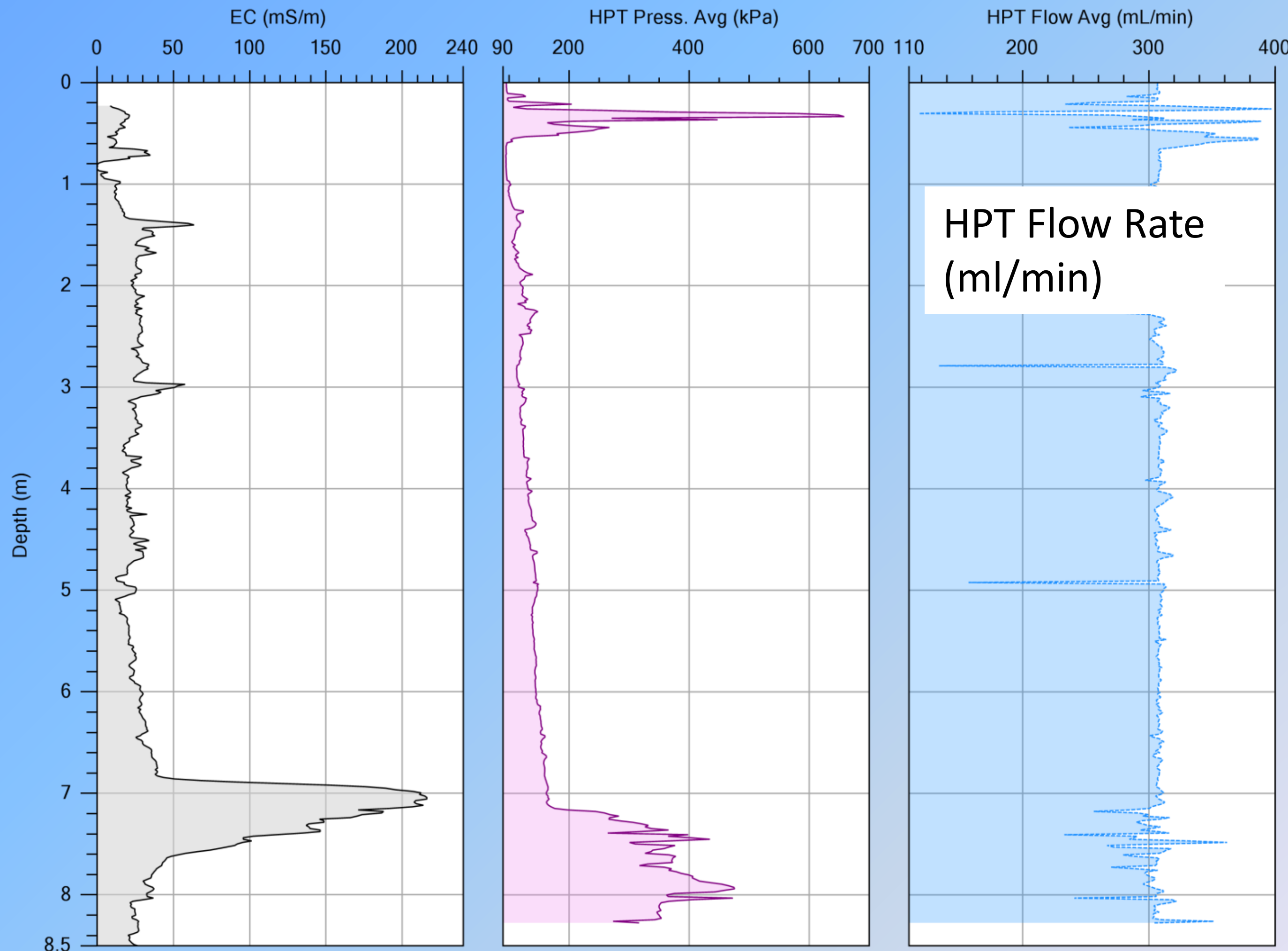
Example HPT Log: Skuldelev SK05



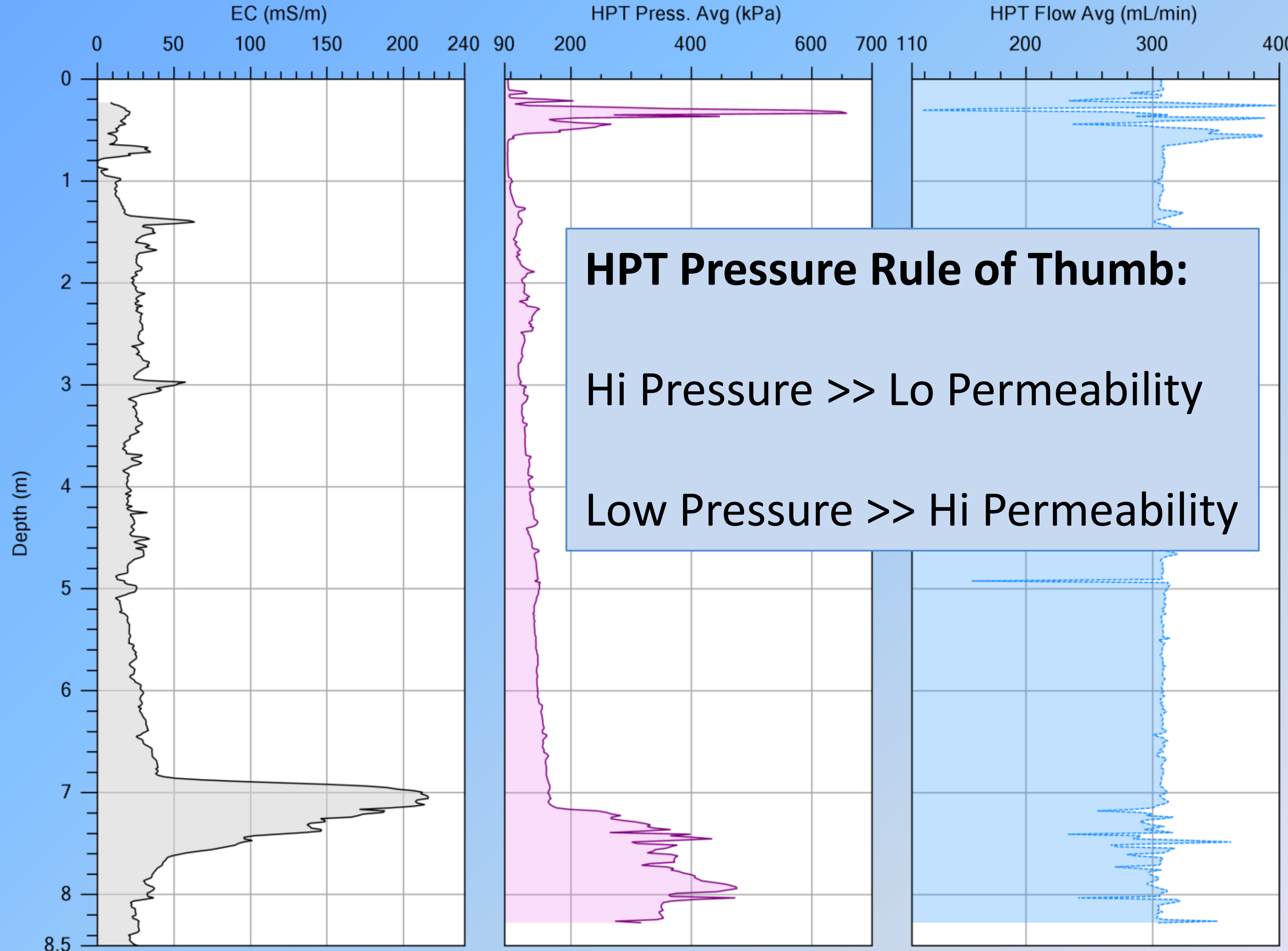
HPT Pressure
(kPa or psi)

690kPa = 100 psi

Example HPT Log: Skuldelev SK05



Example HPT Log: Skuldelev SK05

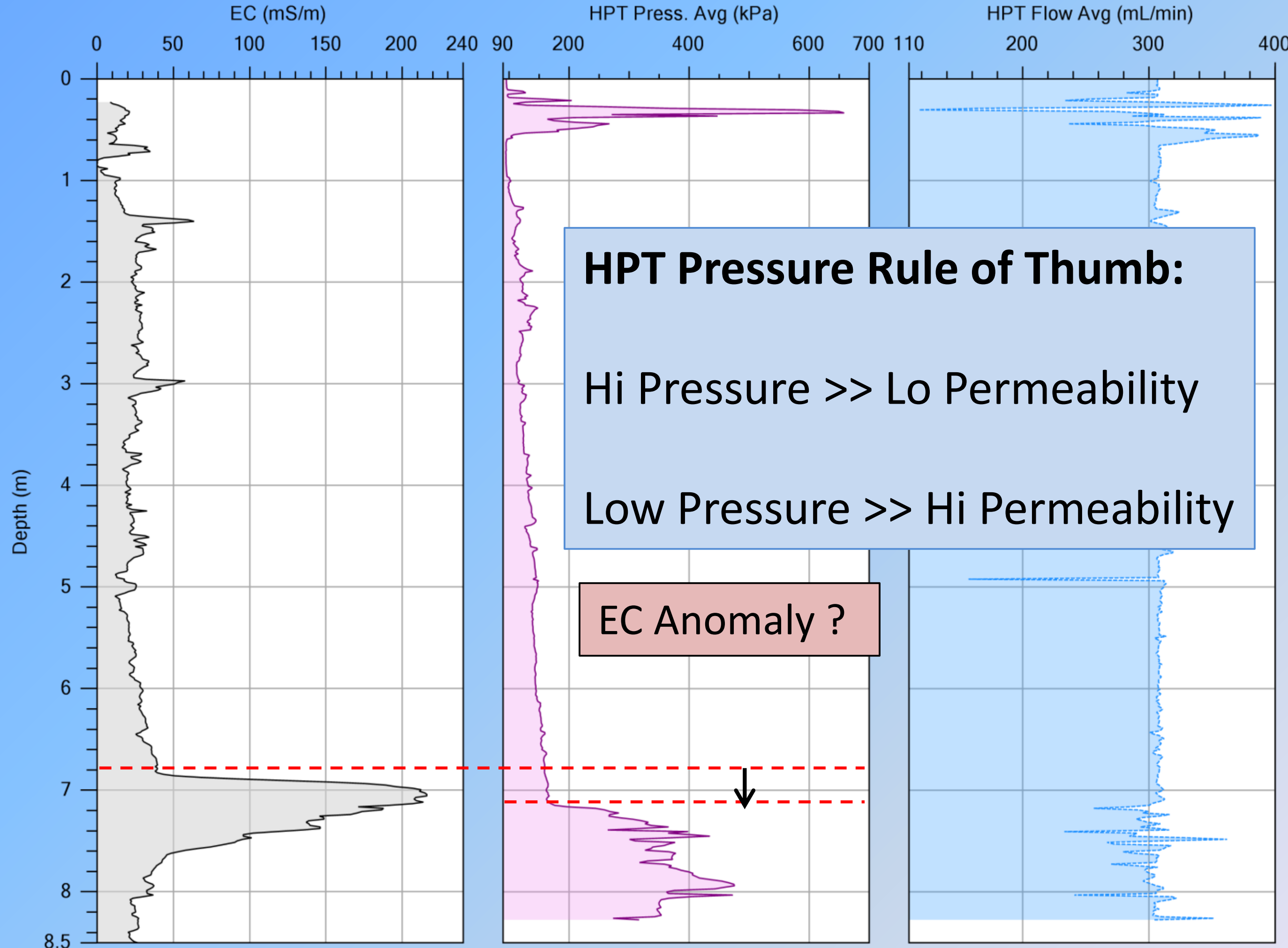


HPT Pressure Rule of Thumb:

Hi Pressure >> Lo Permeability

Low Pressure >> Hi Permeability

Example HPT Log: Skuldelev SK05

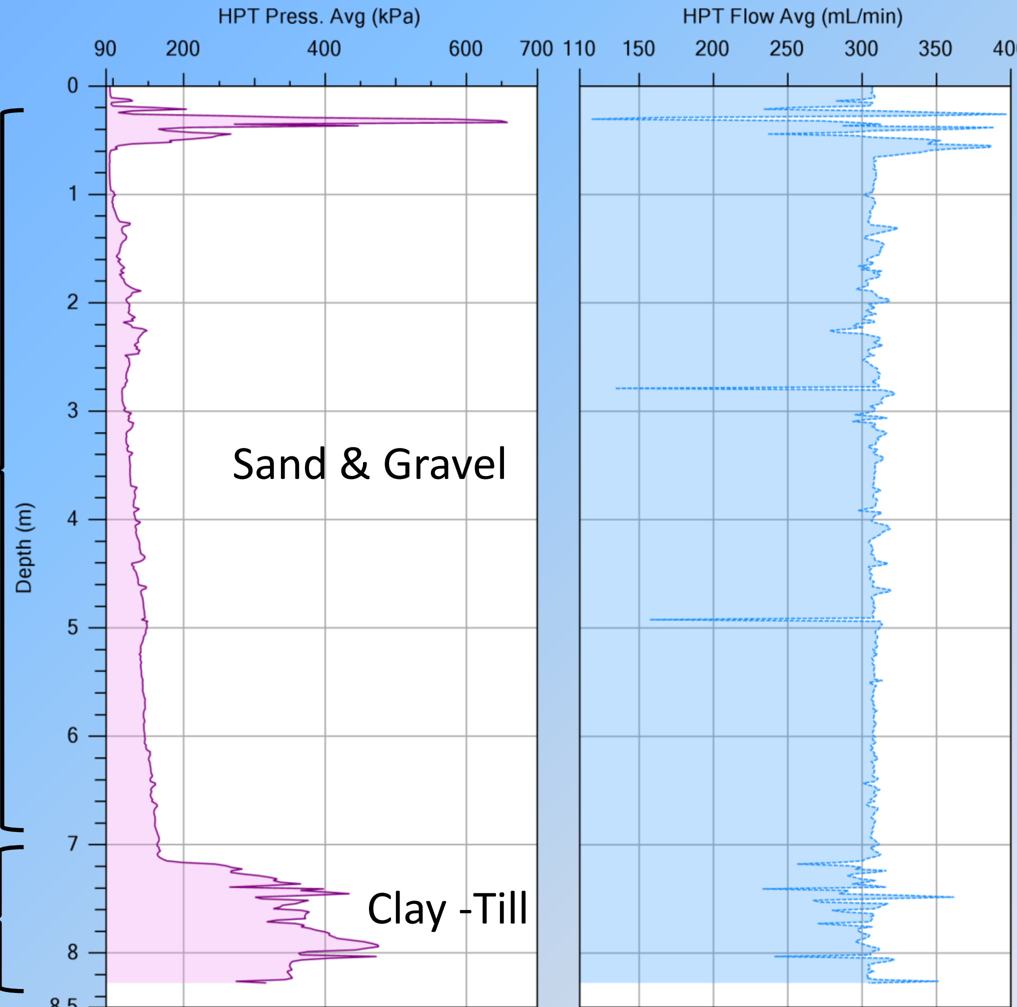


HPT Pressure Rule of Thumb:

Hi Pressure >> Lo Permeability

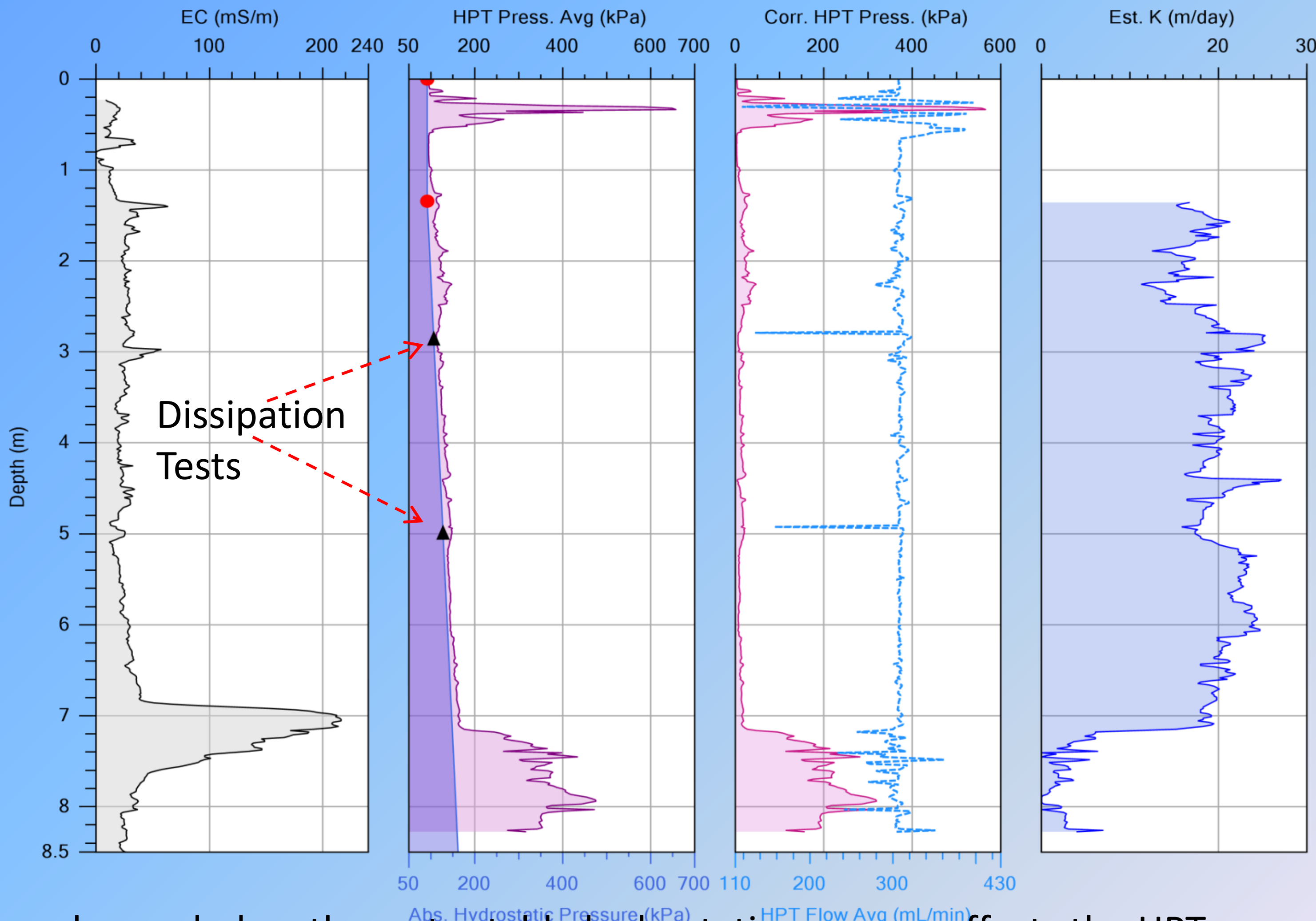
Low Pressure >> Hi Permeability

Correlating HPT Pressure to Soil Cores



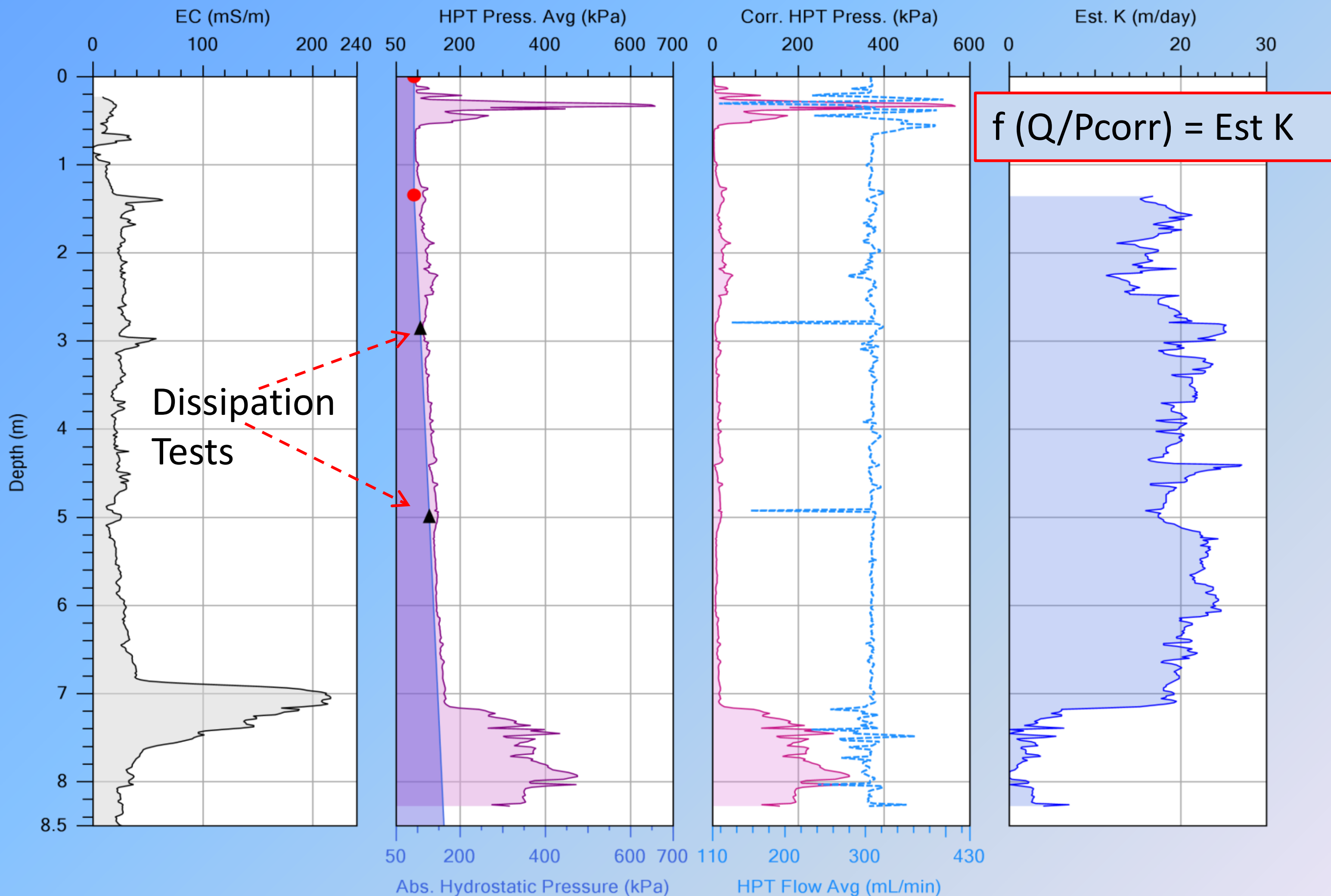
How well does HPT pressure respond to lithologic changes? Here we can see the sand +/- gravel gives low HPT pressure while higher HPT pressure corresponds to the lower permeability clay-till.

HPT and Hydrostatic > Corrected Pressure > Est K



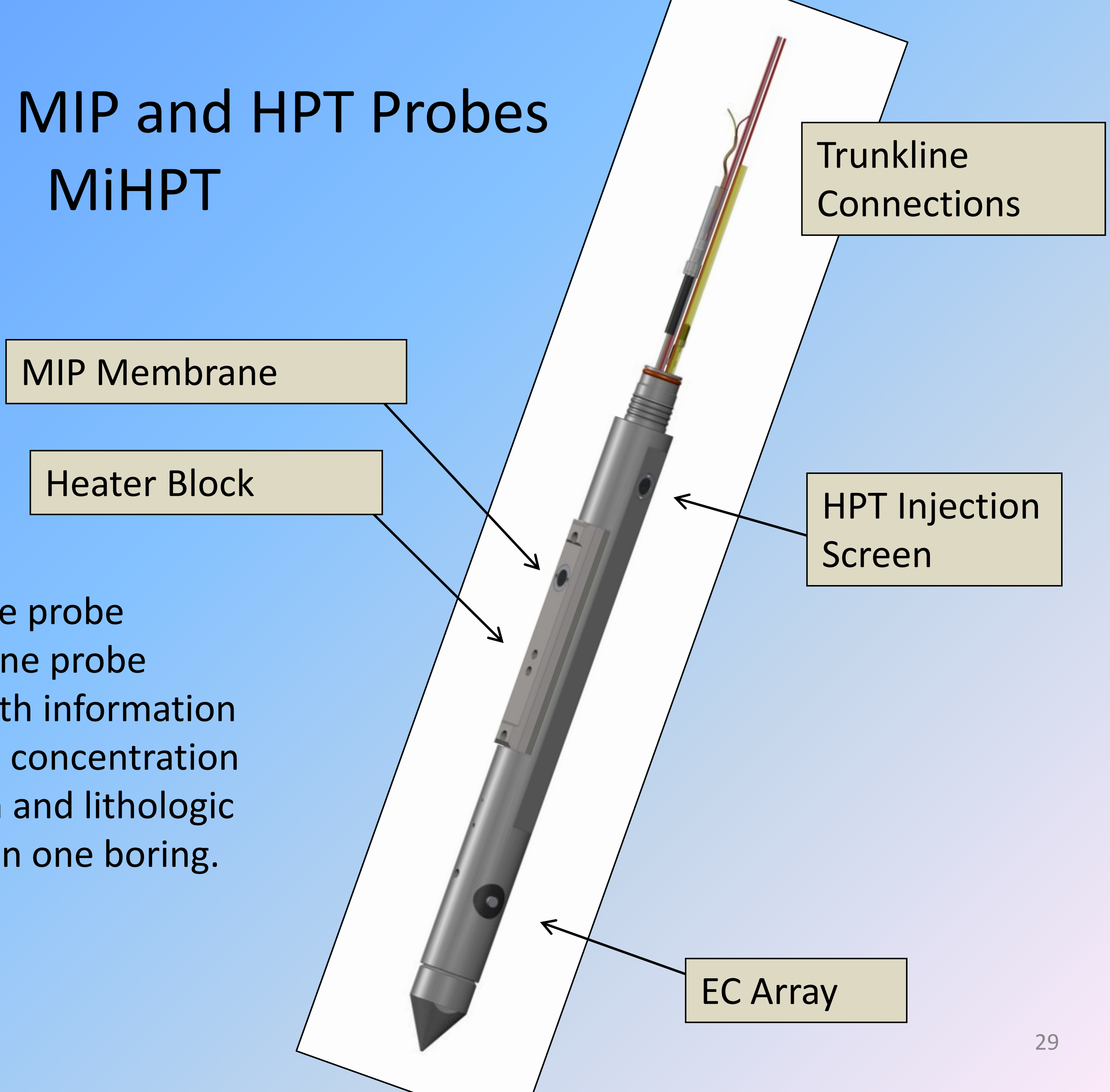
As you advance below the water table hydrostatic pressure effects the HPT pressure measured. Dissipation tests are used at selected depths to determine the piezometric pressure. Once we have the potentiometric profile that pressure can be subtracted from the total HPT pressure to determine the corrected HPT pressure.

HPT and Hydrostatic P > Corrected P > Est K



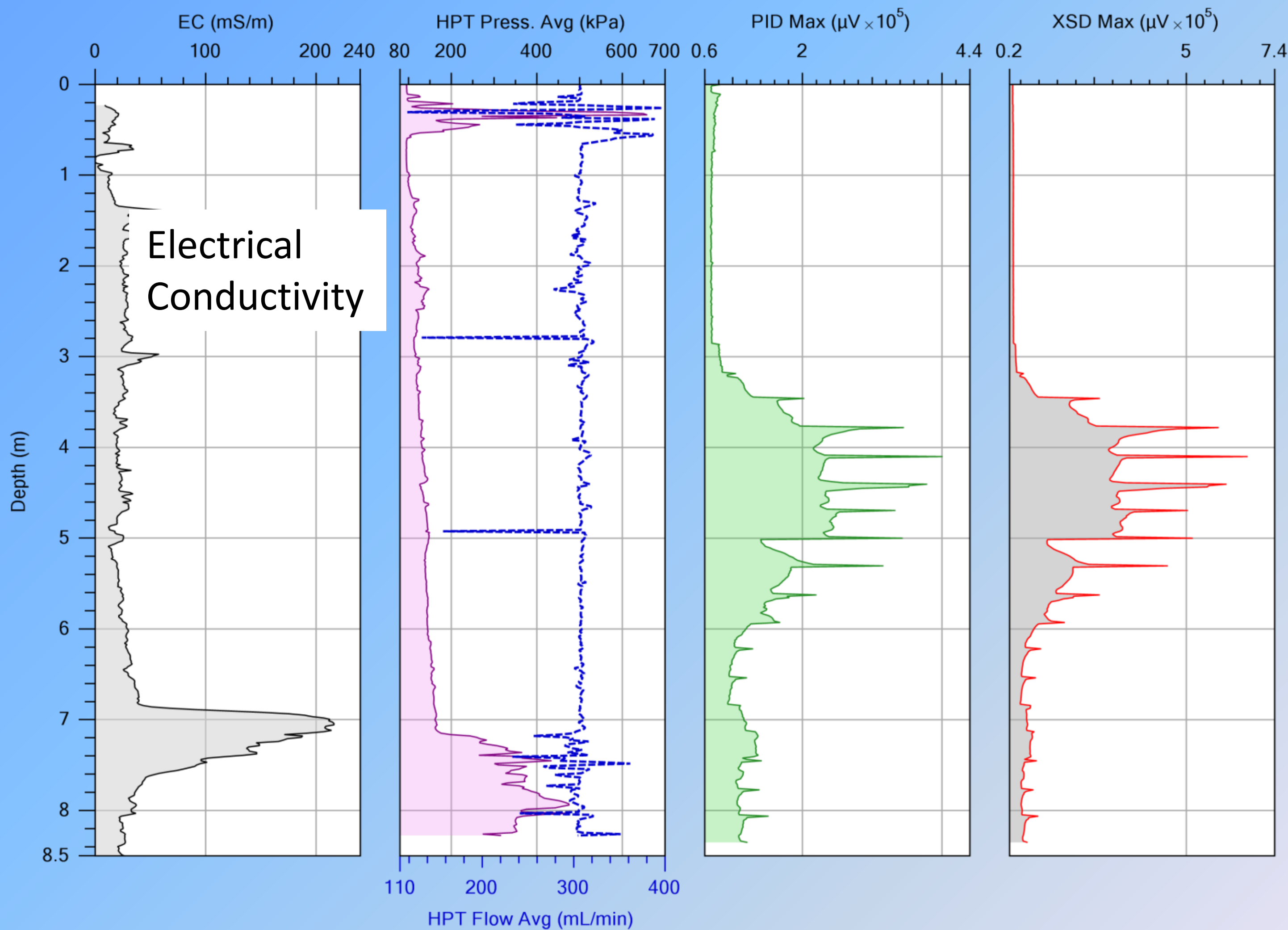
The corrected HPT pressure is the pressure required to inject water into the formation. The corrected pressure and flow are then used in an empirical model to calculate the estimated hydraulic conductivity of the formation at the inch-scale.

Combining MIP and HPT Probes MiHPT



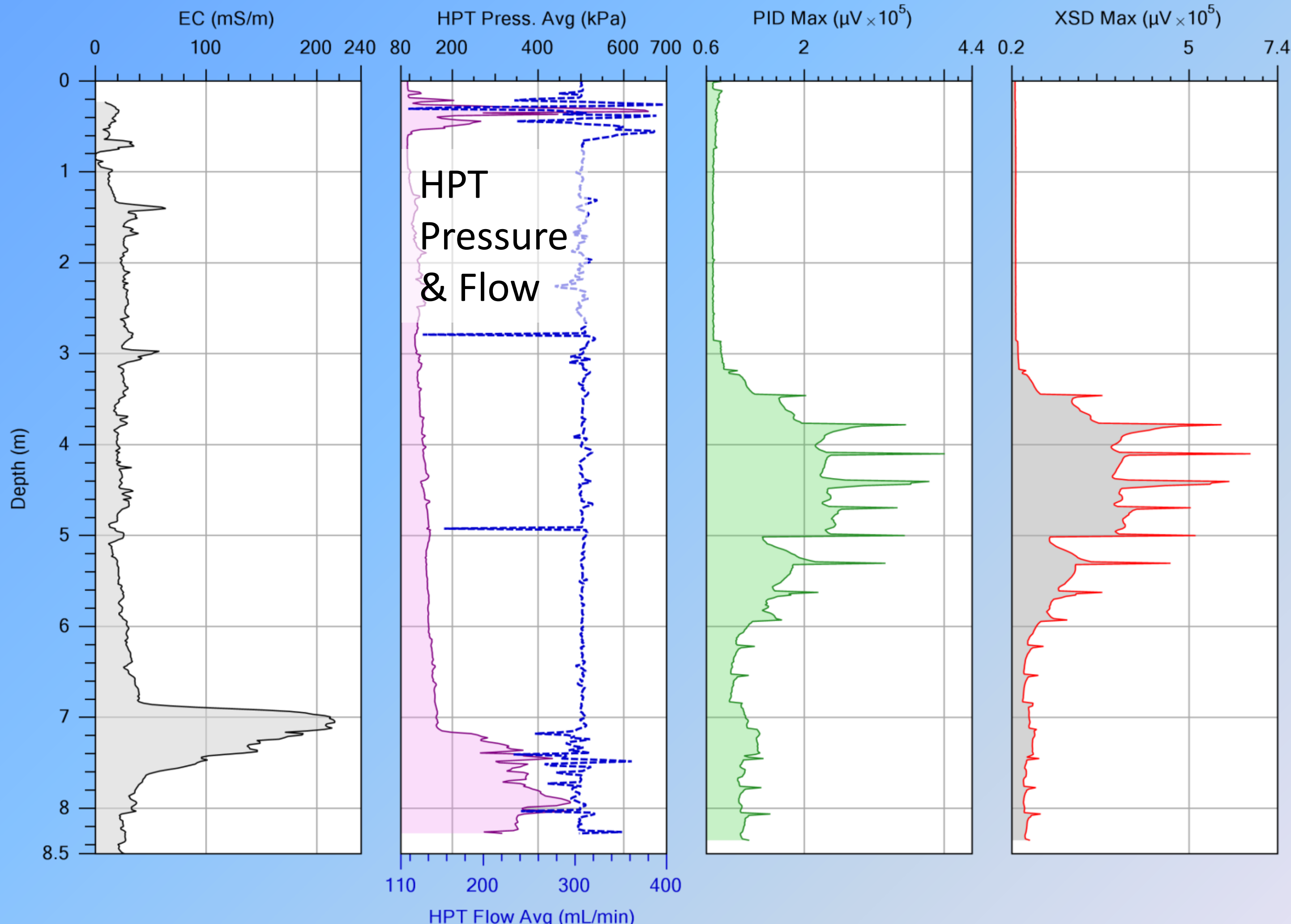
Combining these probe functions into one probe provides you with information on contaminant concentration and distribution and lithologic information all in one boring.

The MiHpt Log: SK05 at Skuldelev



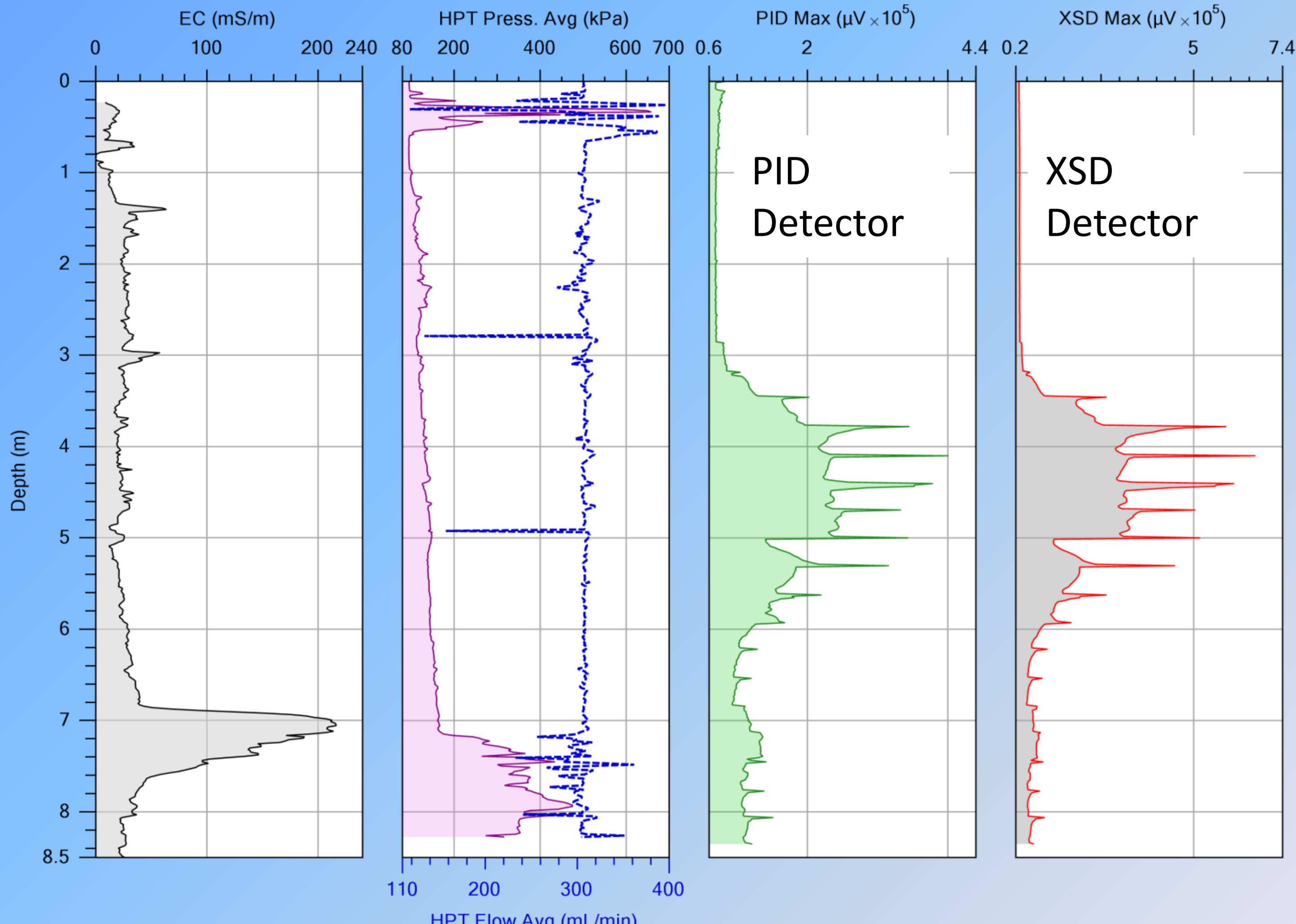
These logs give us the EC graph …

The MiHpt Log: SK05 at Skuldelev



HPT pressure and flow rate data …

The MiHpt Log: SK05 at Skuldelev



As well as the detector logs for contaminant level and distribution. Here we see the chlorinated VOC contaminants are located within the sandy aquifer material at this location. Now … Where did we run this log ?

Location of Skuldelev, Denmark

Here the insert map shows that Skuldelev is located about one hour west of Copenhagen in Denmark. A small community in the pastoral countryside.

Skuldelev Geology

Glaciated Region

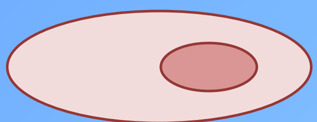
Site underlain by glacial till and related unconsolidated deposits

Skuldelev Site Map

MiHpt Log X - - - -

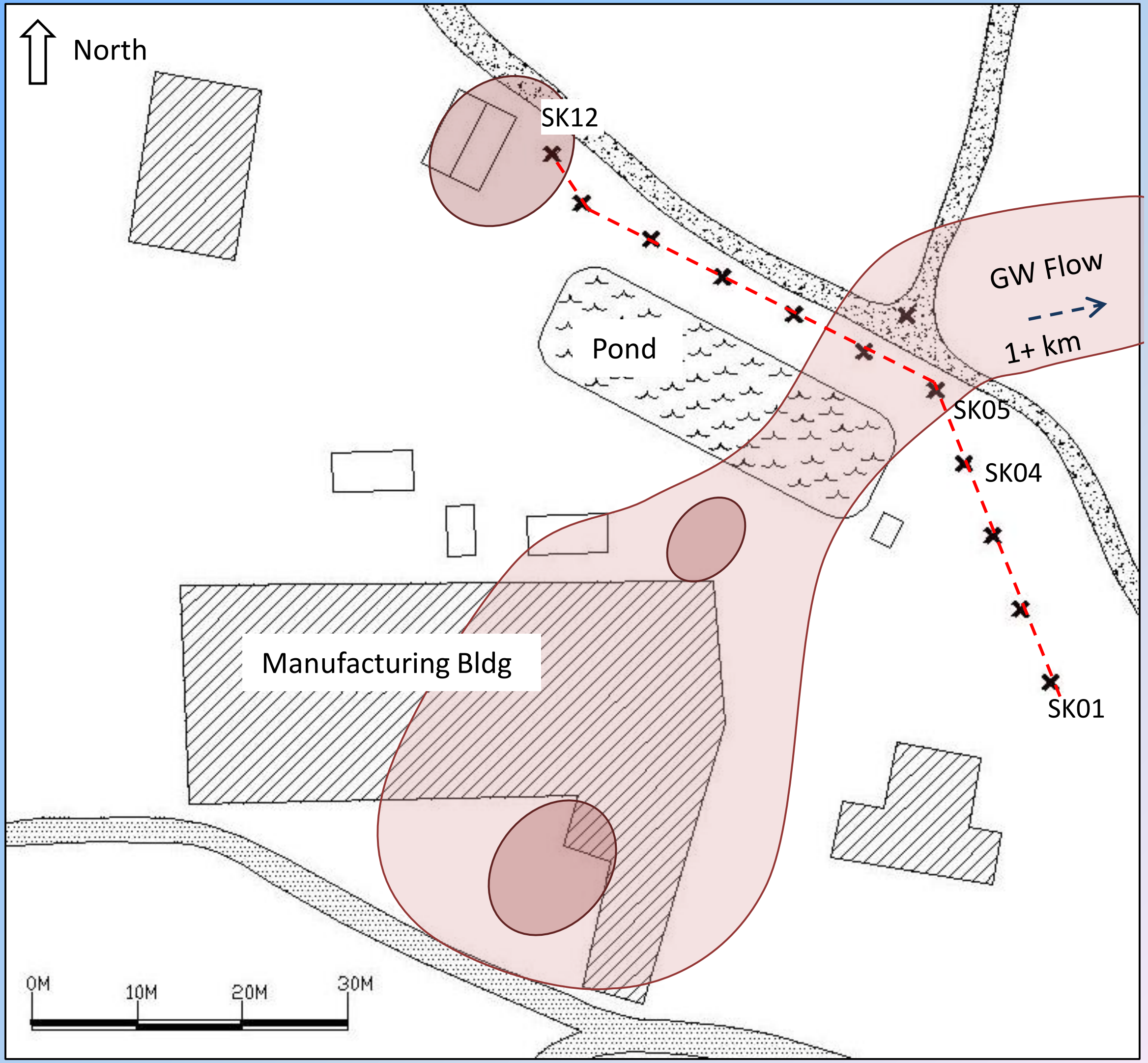
Cross section Line

GW Plume & Hot Spot



PCE, TCE, DCE & VC

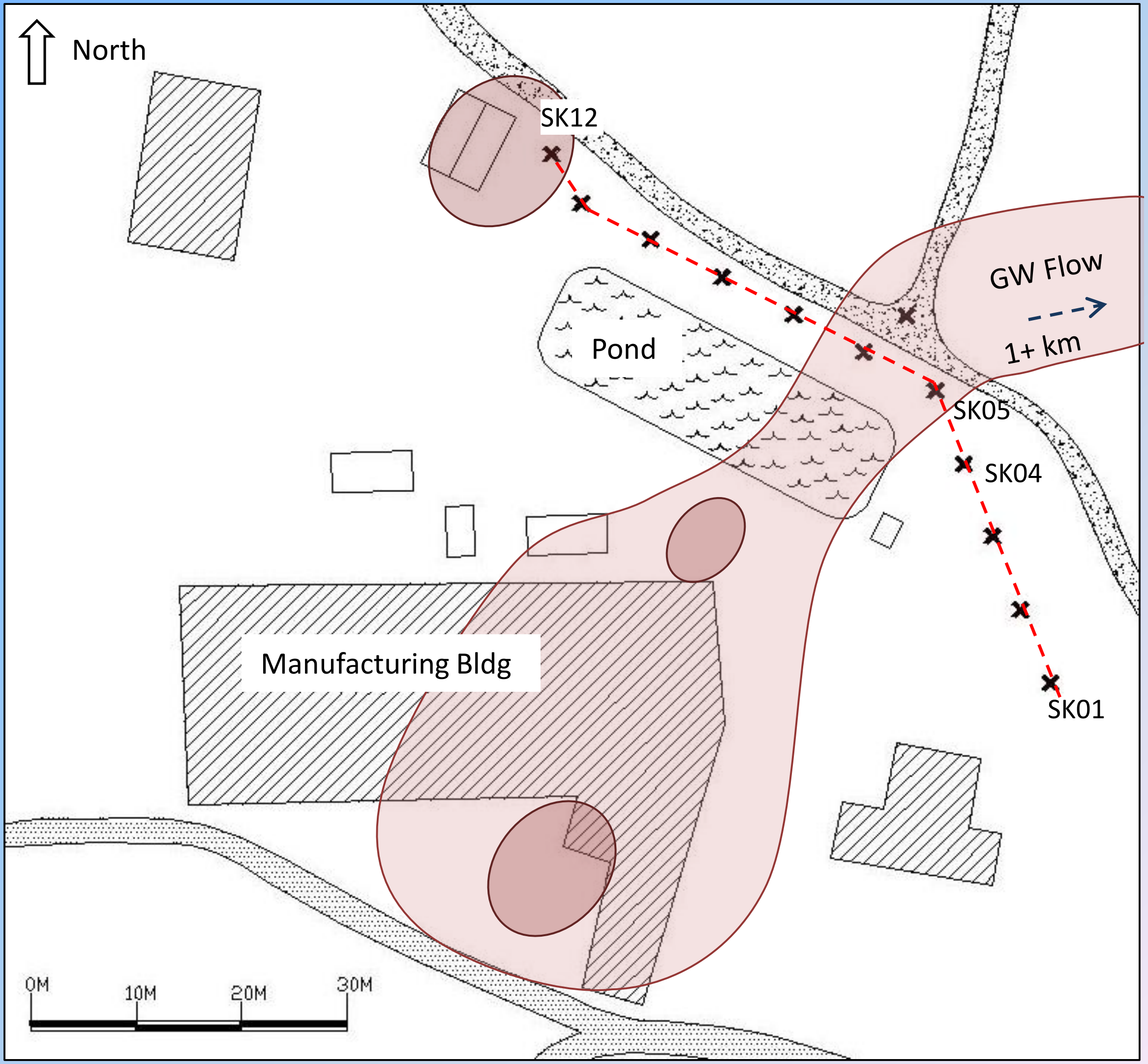
Previous work with the MIP system and Electrical conductivity logs was not able to distinguish between the coarse grained materials and fine grained materials in the subsurface as observed with targeted soil cores.



Logs are spaced 8 m (~25ft) apart.

Skuldelev Site Map

So we ran some MiHpt logs to see if the HPT pressure logs could help understand the local hydrostratigraphy. To date it was unclear why the groundwater plume was migrating in the direction it was following. Logs in the transect were placed about 8 meters (25ft) apart.



Logs are spaced 8 m (~25ft) apart.

Skuldelev Site Map

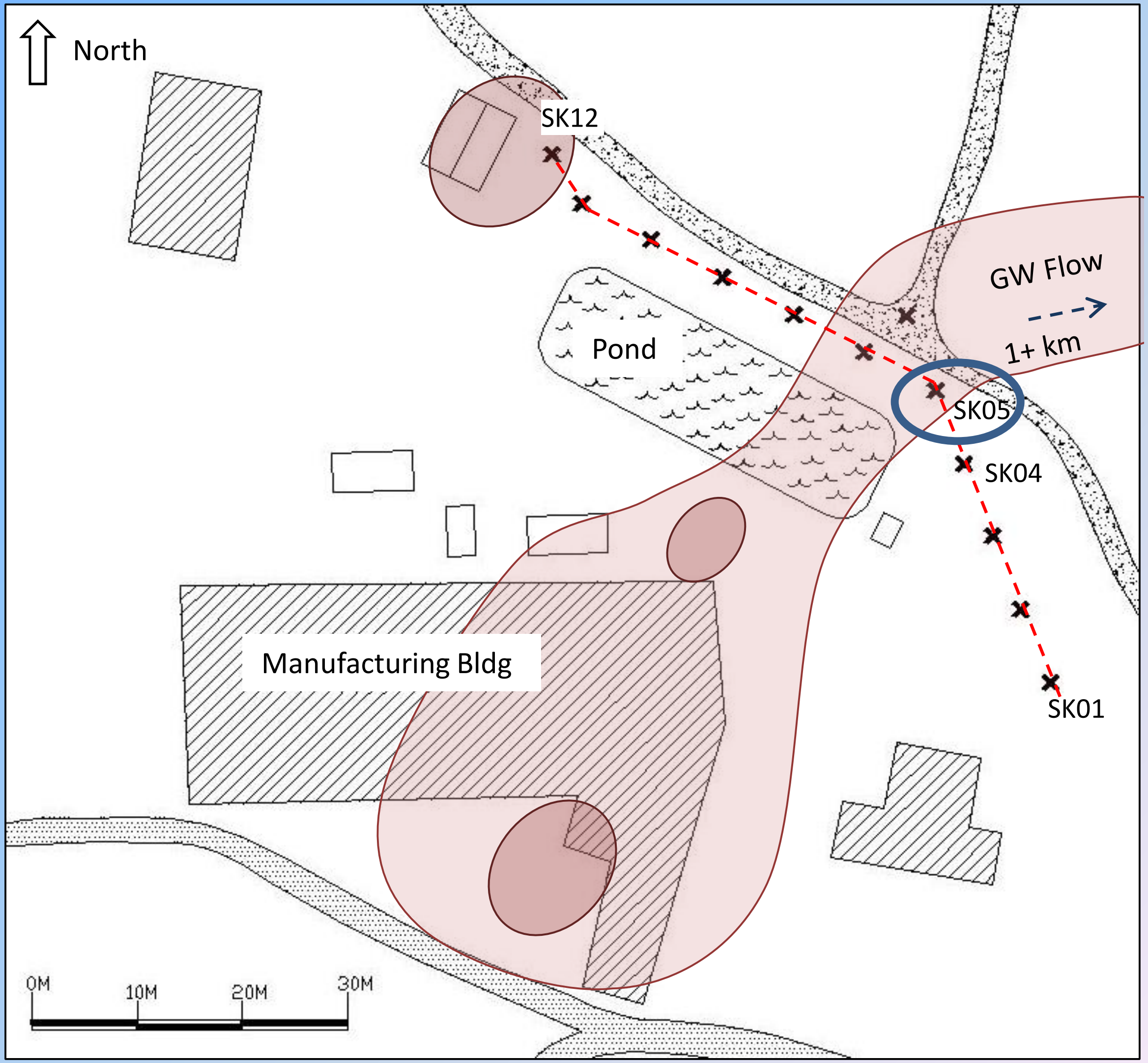
MiHpt Log X - - - - -

Cross section Line

GW Plume & Hot Spot

PCE, TCE, DCE & VC

We have been looking at data from the SK05 log at Skuldelev …



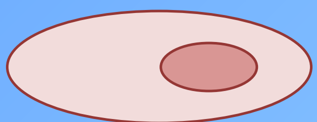
Logs are spaced 8 m (~25ft) apart.

Skuldelev Site Map

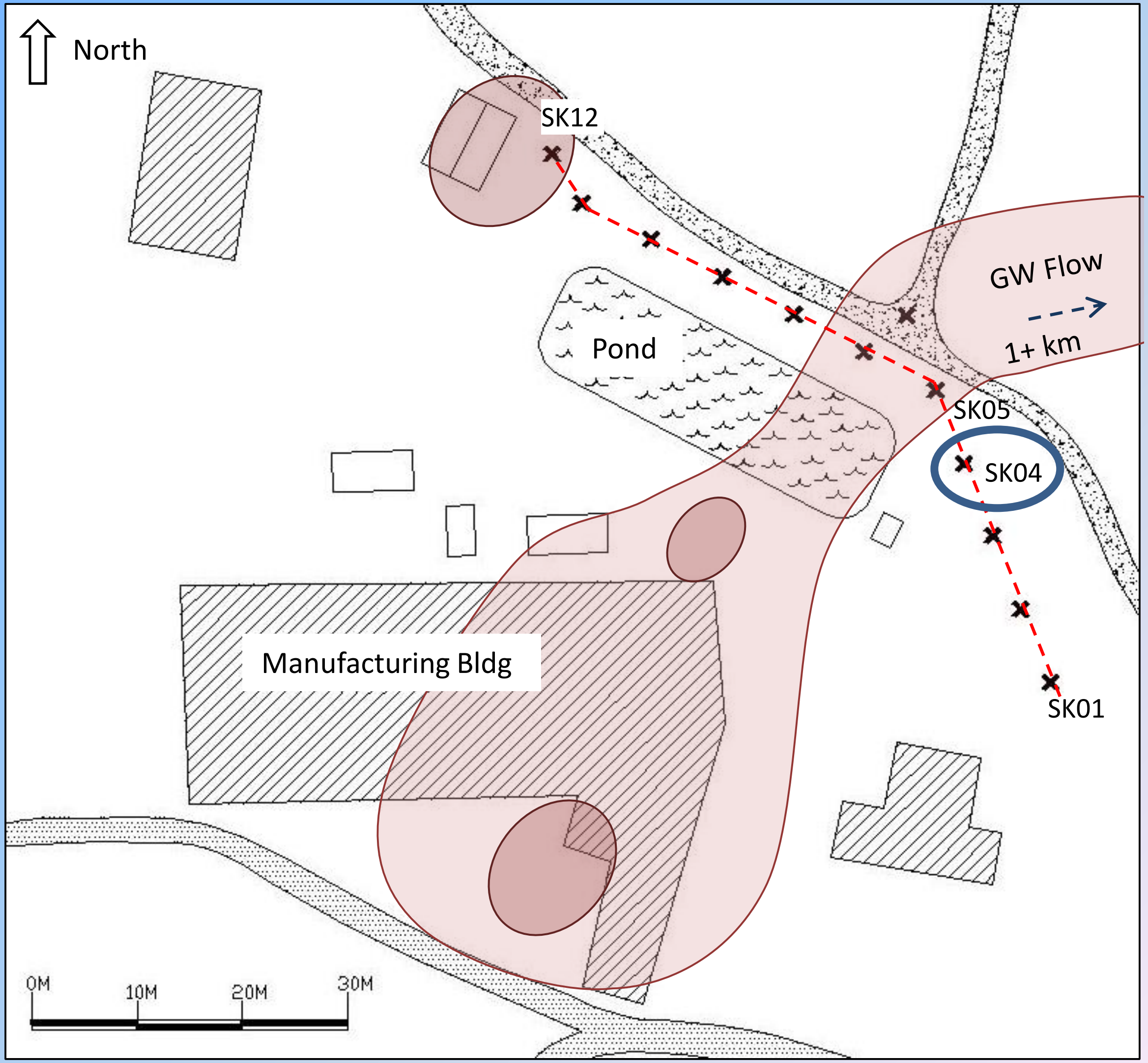
MiHpt Log X - - - - -

Cross section Line

GW Plume & Hot Spot



Now let's look at results for the SK04 log, just outside of the main groundwater plume body.

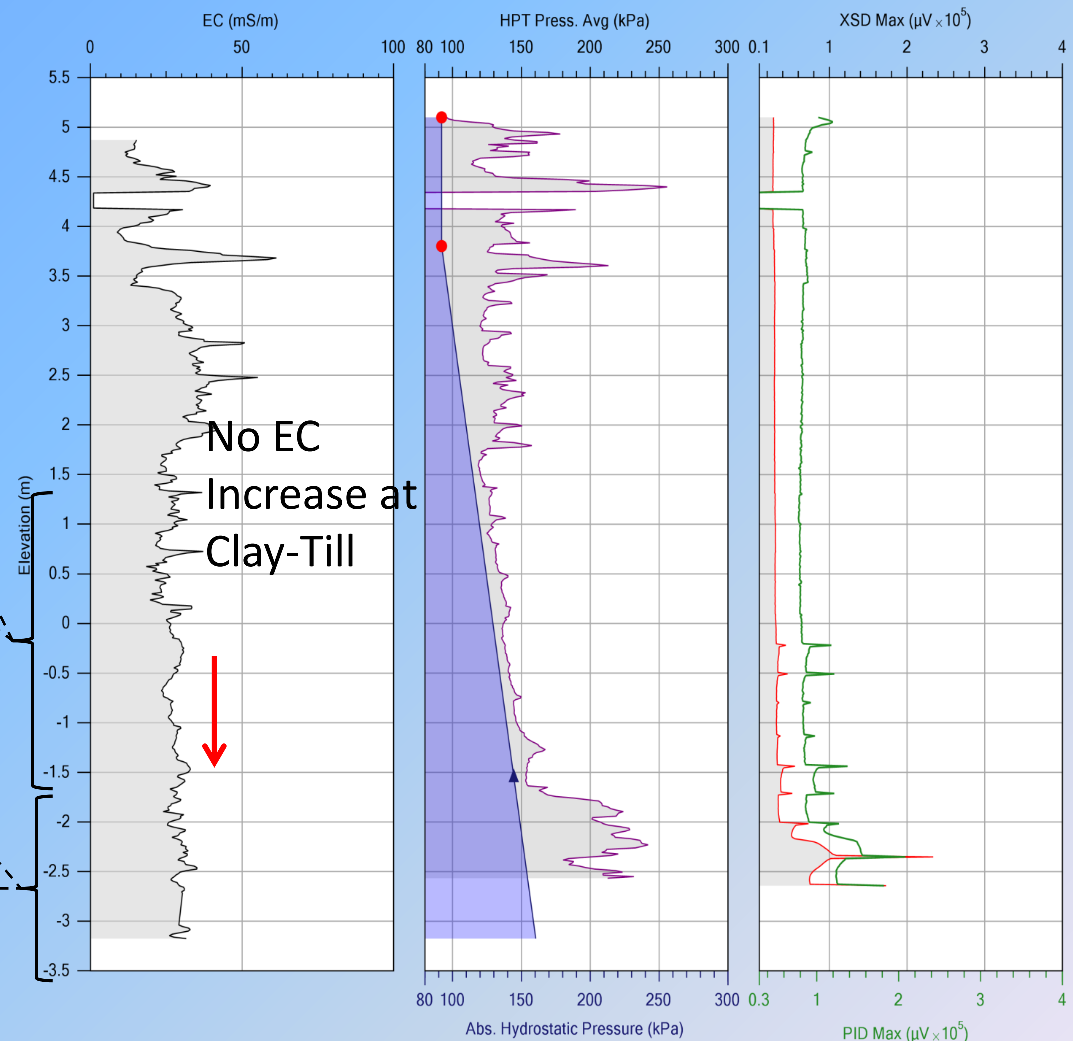


Logs are spaced 8 m (~25ft) apart.

Skuldelev SK04 Location Log

Sand & Gravel

Clay-Till

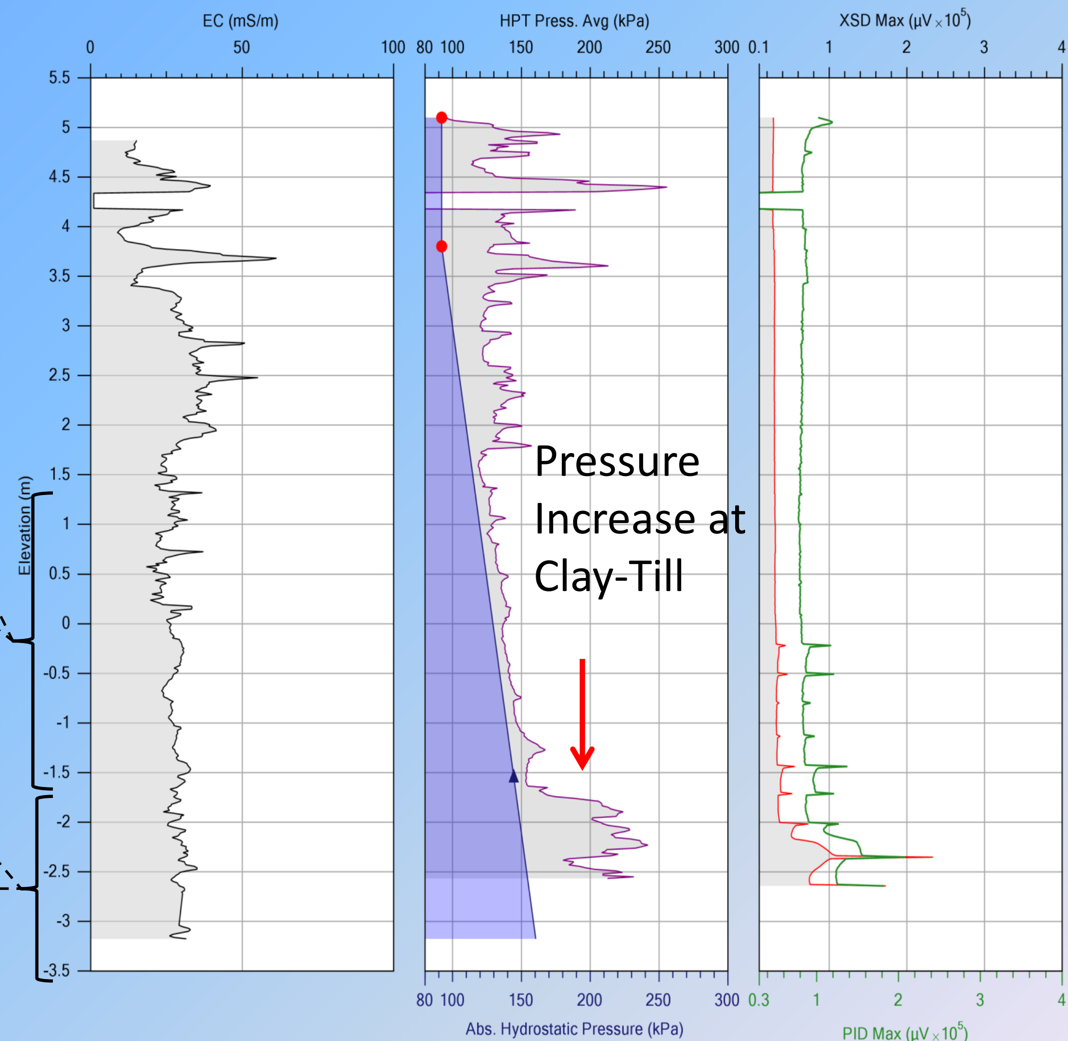


At Skuldelev the EC of the clay-till was essentially the same as the EC of sands and gravels. So maybe that EC peak at the SK05 log was an anomaly?

Skuldelev SK04 Location Log

Sand & Gravel

Clay-Till

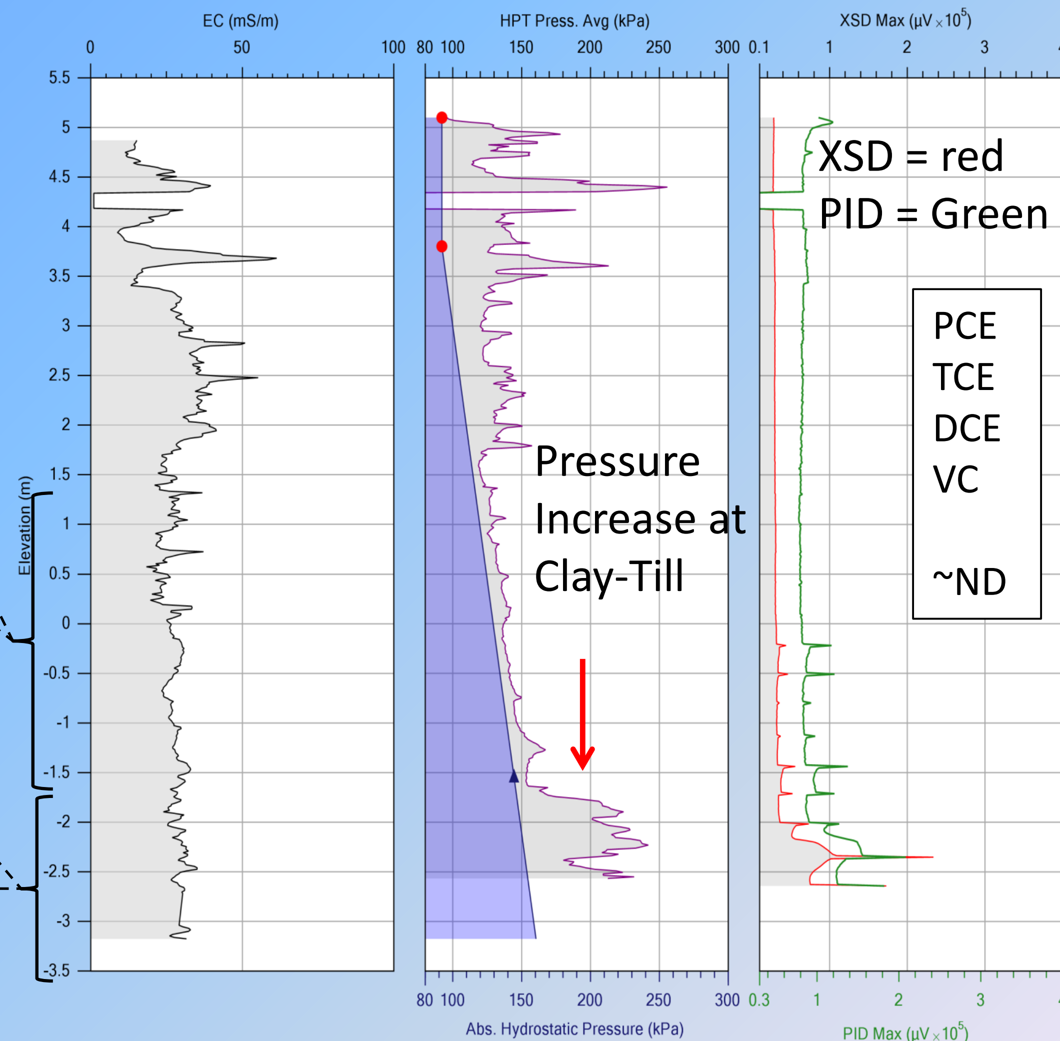


However, the HPT pressure increased significantly in the clay-till.

Skuldelev SK04 Location Log

Sand & Gravel

Clay-Till



At this location outside of the main groundwater plume the halogen specific detector (XSD) found only minor detects of contamination.

Skuldelev Site Map

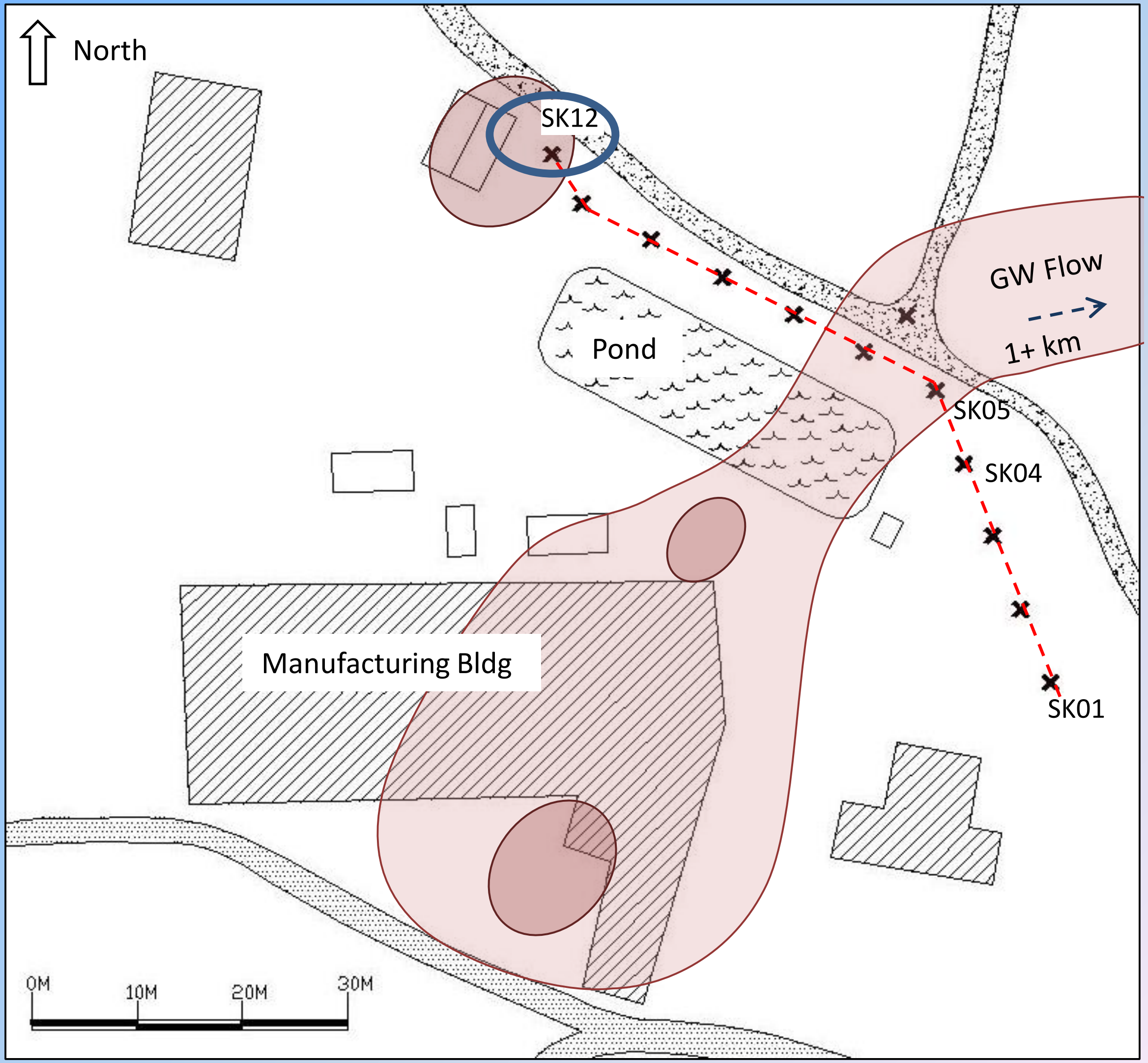
MiHpt Log X

Cross section Line

GW Plume & Hot Spot

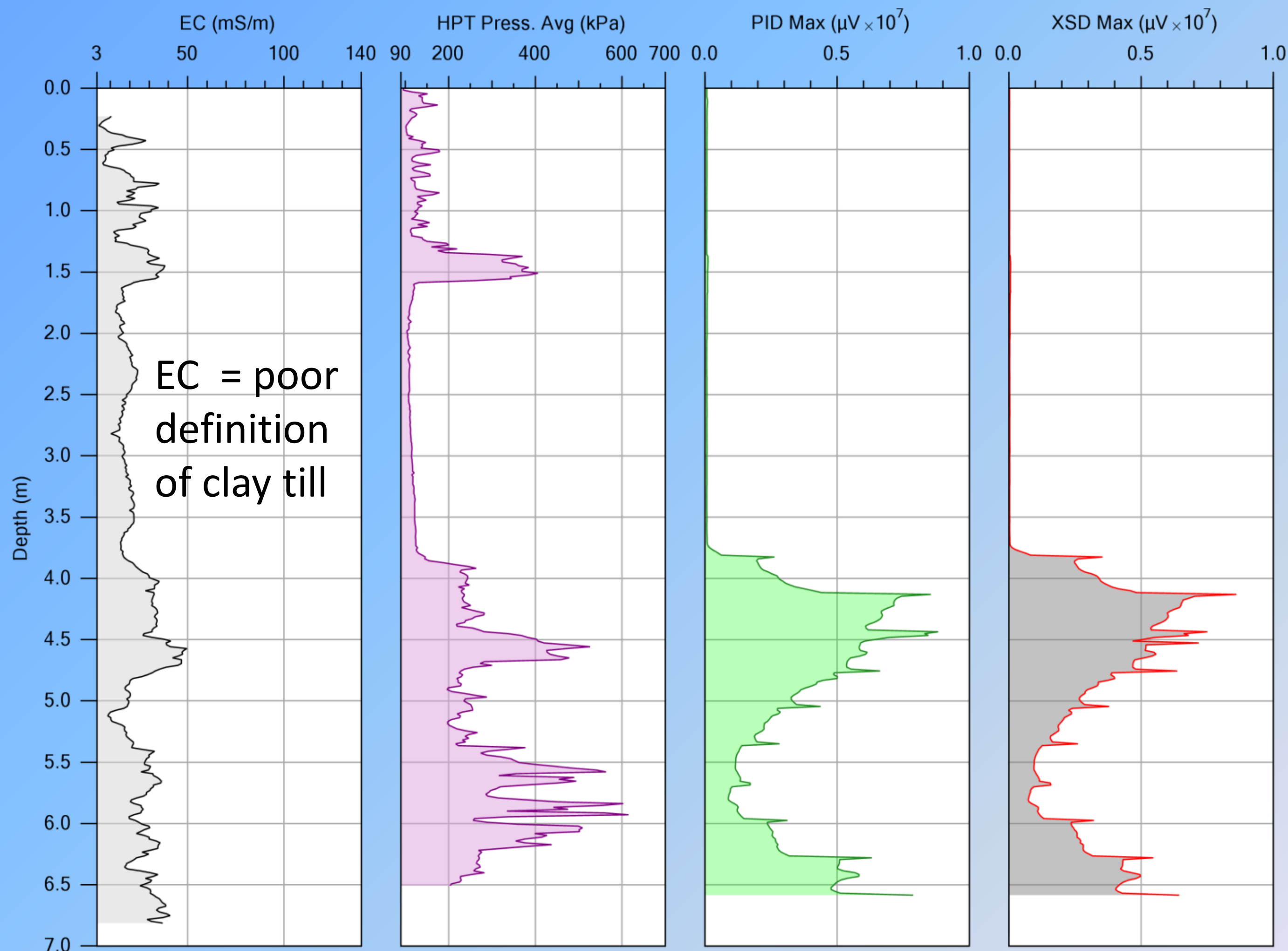
PCE, TCE, DCE & VC

Now let's look at the SK12 location log …

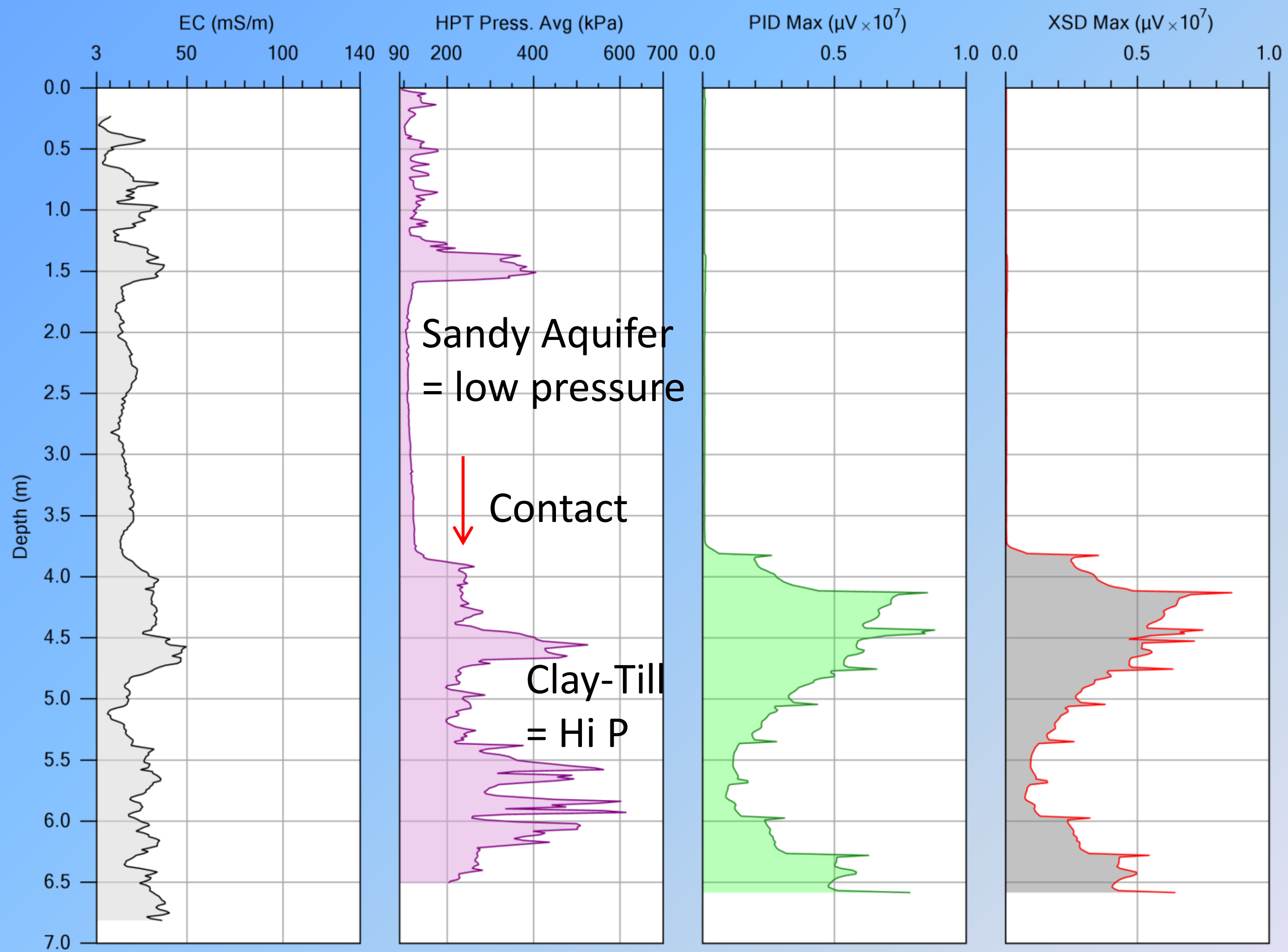


Logs are spaced 8 m (~25ft) apart.

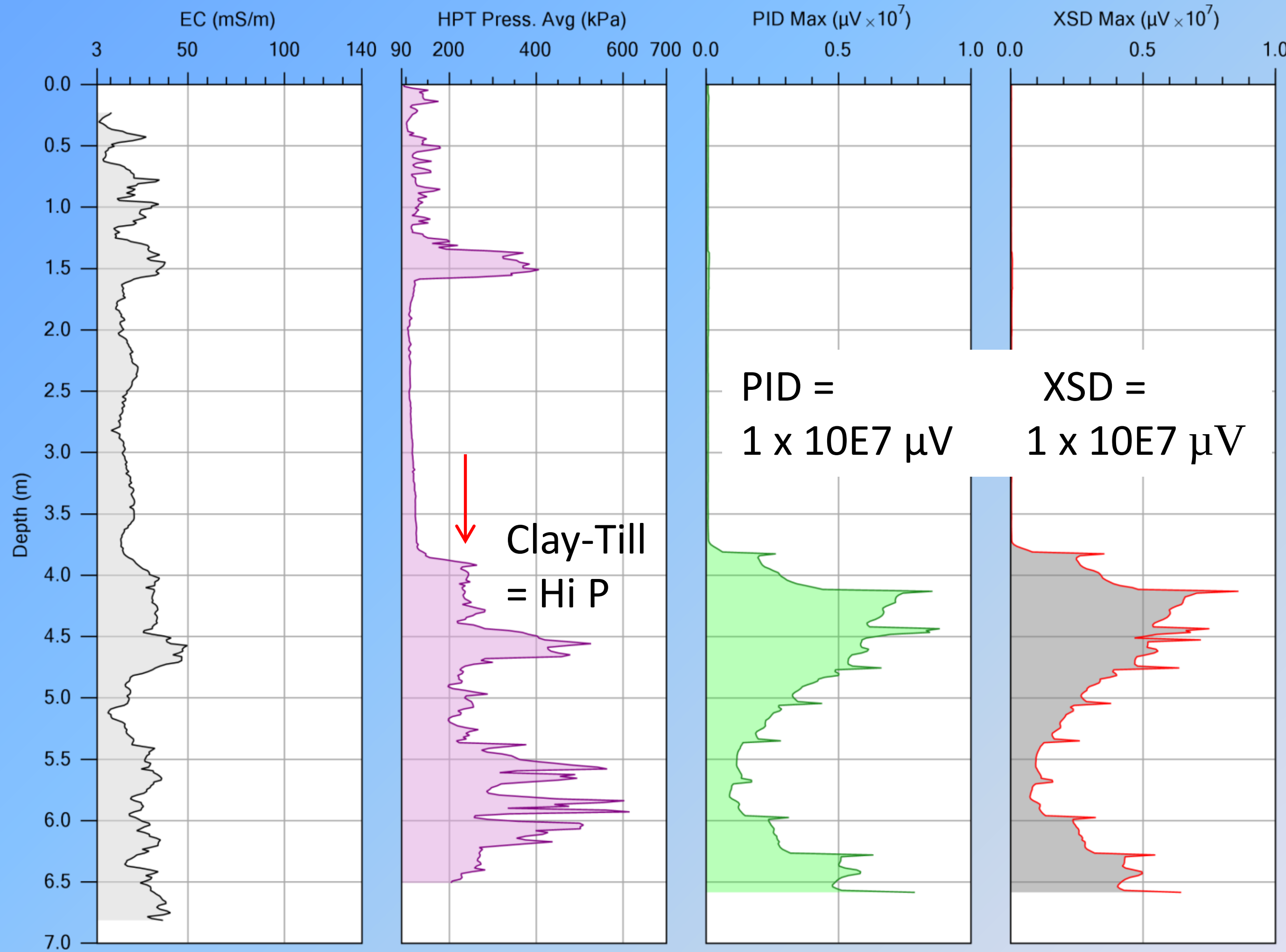
Skudelev SK12 MiHpt Log



Skudelev SK12 MiHpt Log



Skudelev SK12 MiHpt Log



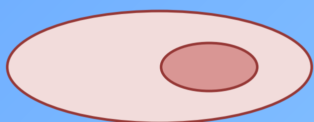
Notice that the detector responses are almost exclusively in the clay-till at this location. The detector responses are high, almost at the maximum of the detector range for both detectors.

Skuldelev Cross Section Map

MiHpt Log **X** - - - - -

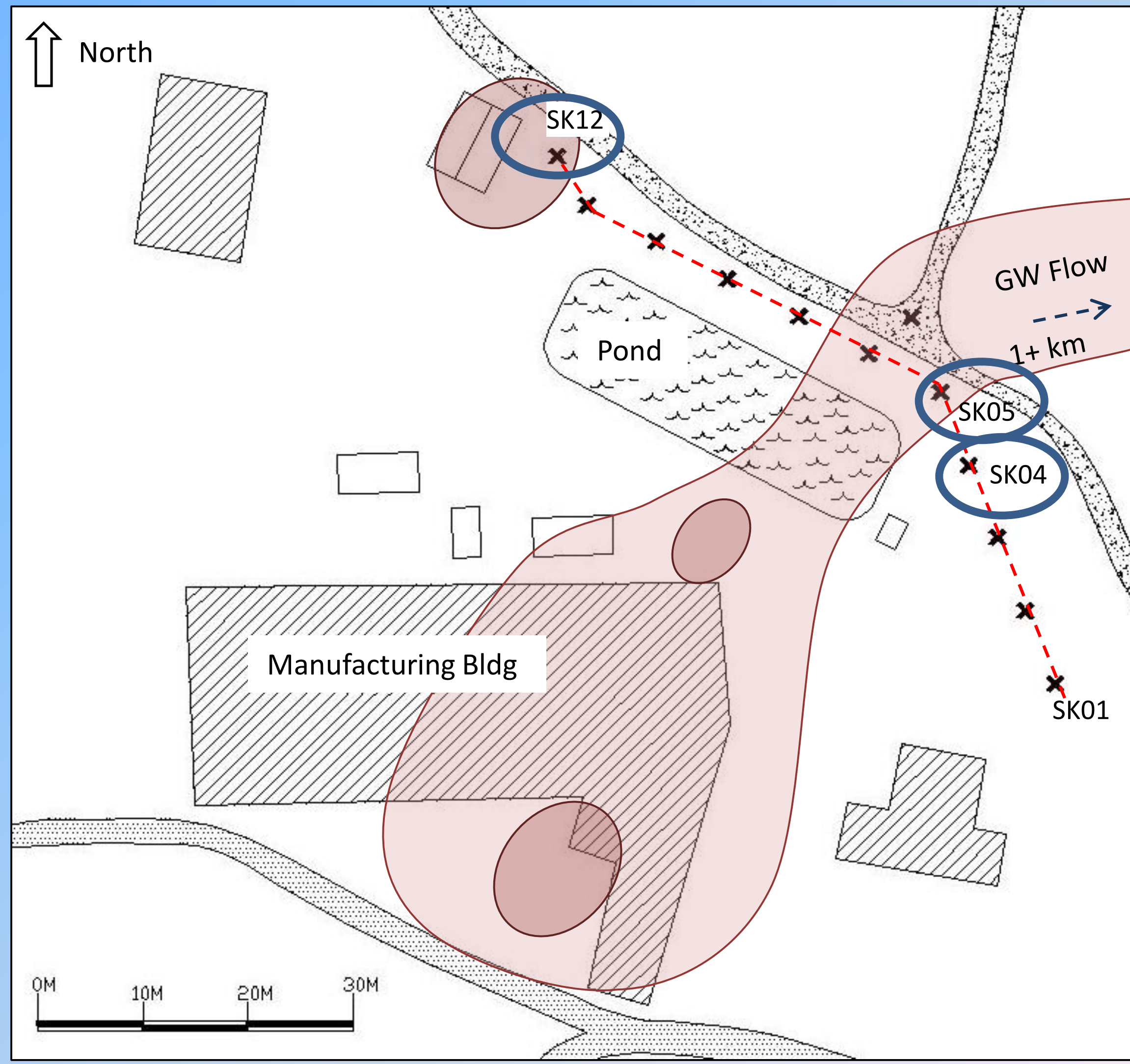
Cross section Line

GW Plume & Hot Spot



PCE, TCE,
DCE & VC

Back at the site map, we have looked at the SK12, SK05 and SK04 logs …



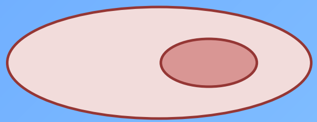
Logs are spaced 8 m (~25ft) apart.

Skuldelev Cross Section Map

MiHpt Log X - - - - -

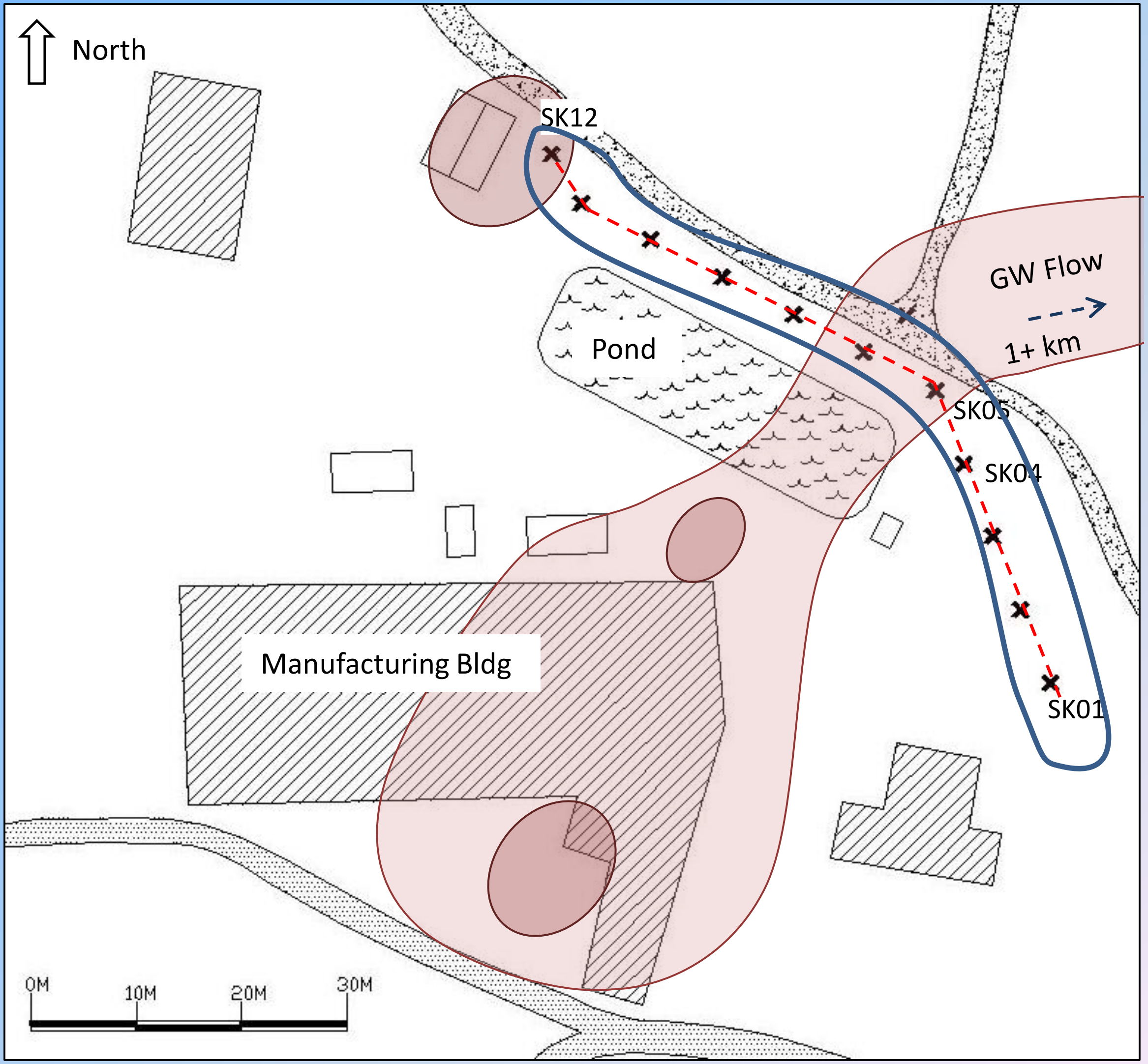
Cross section Line

GW Plume & Hot Spot



PCE, TCE, DCE & VC

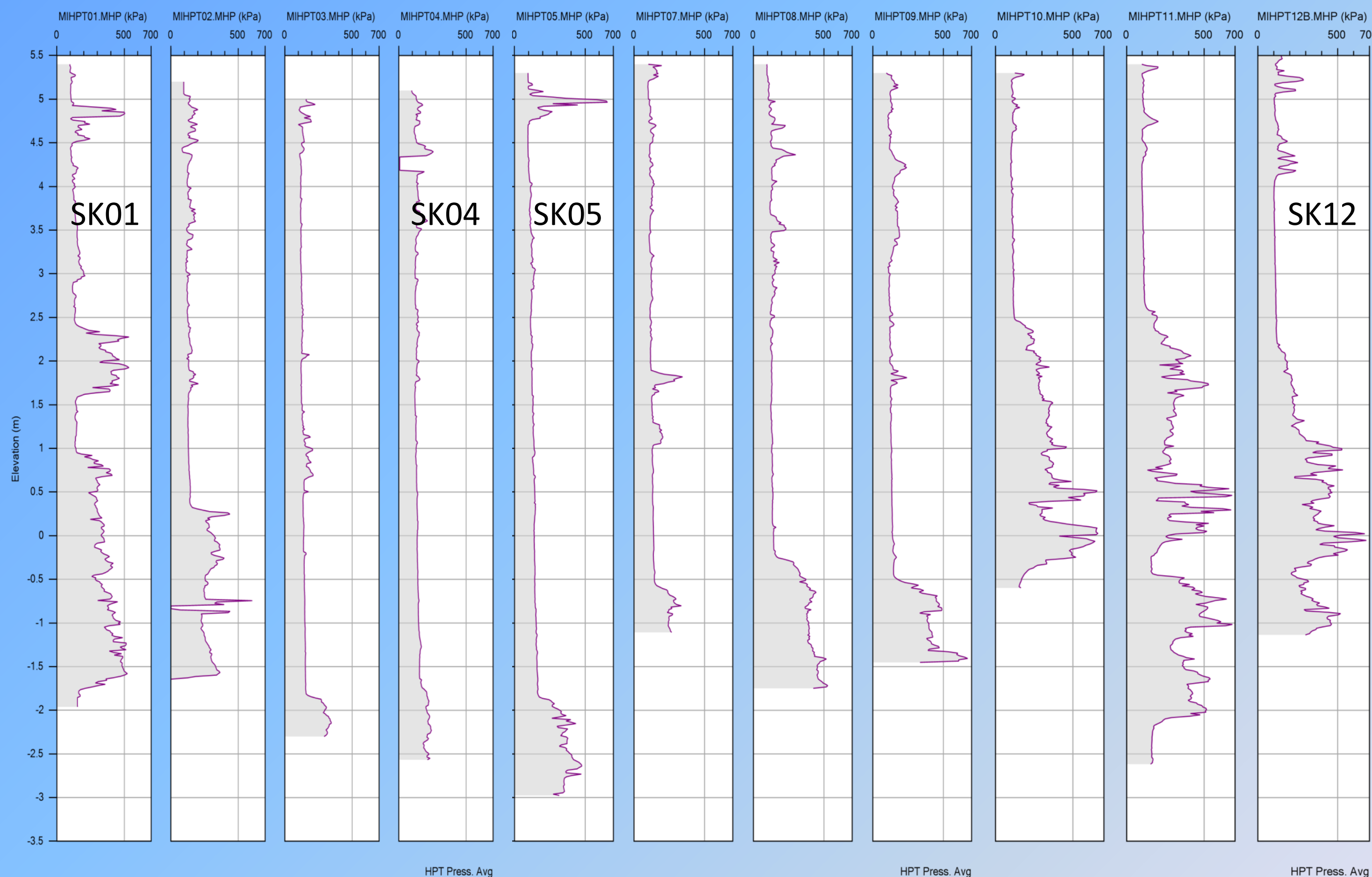
Now, let's look at a cross section of HPT pressure, looking from the northeast to the south west.



Logs are spaced 8 m (~25ft) apart.

Skuldelev HPT Pressure X-Section

East (Elevation Corrected) West

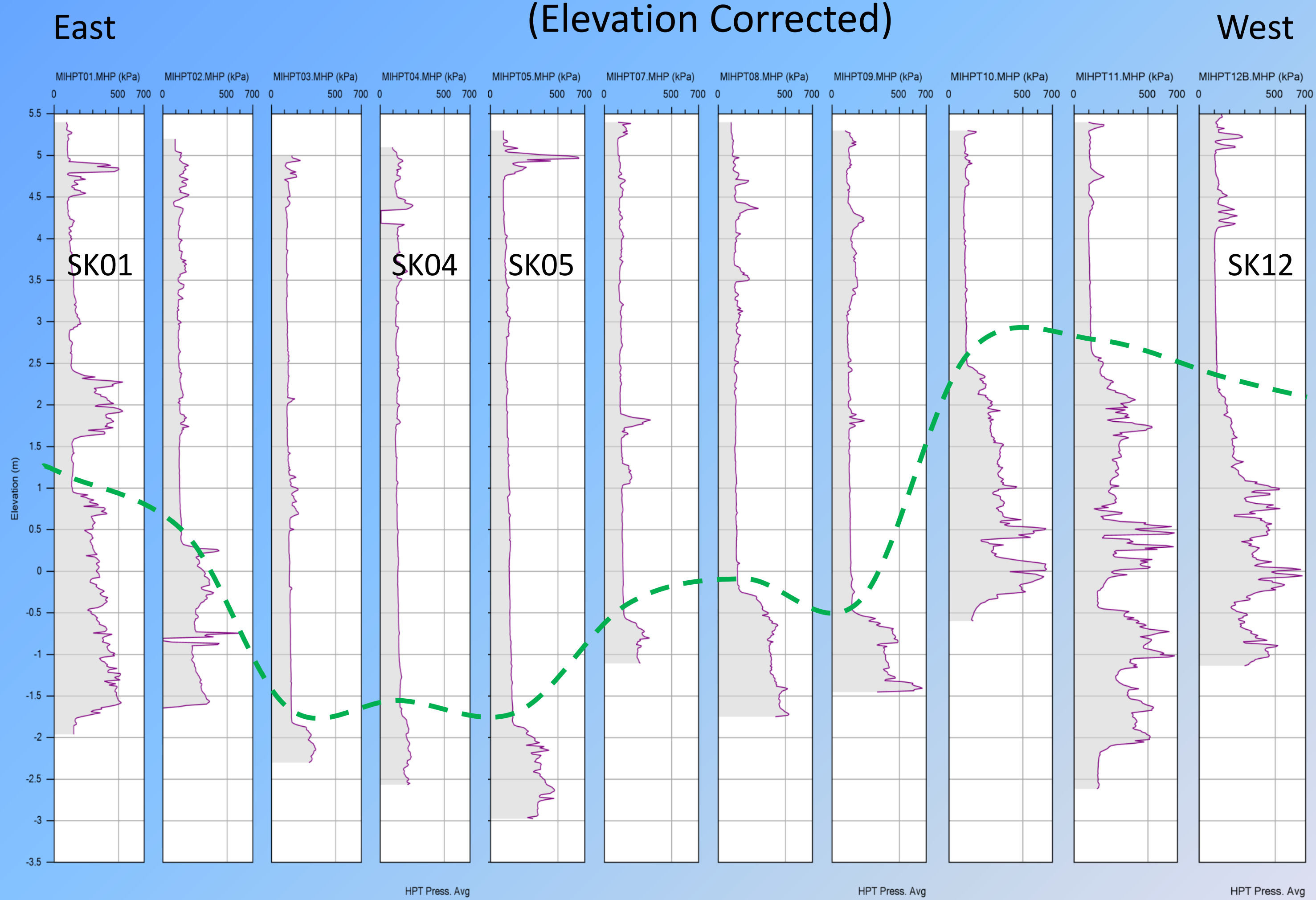


(Facing ~ Southwest)

We can see the top of the clay-till in the subsurface across the site where the HPT pressure increases in each log.

Skuldelev HPT Pressure X-Section

(Elevation Corrected)

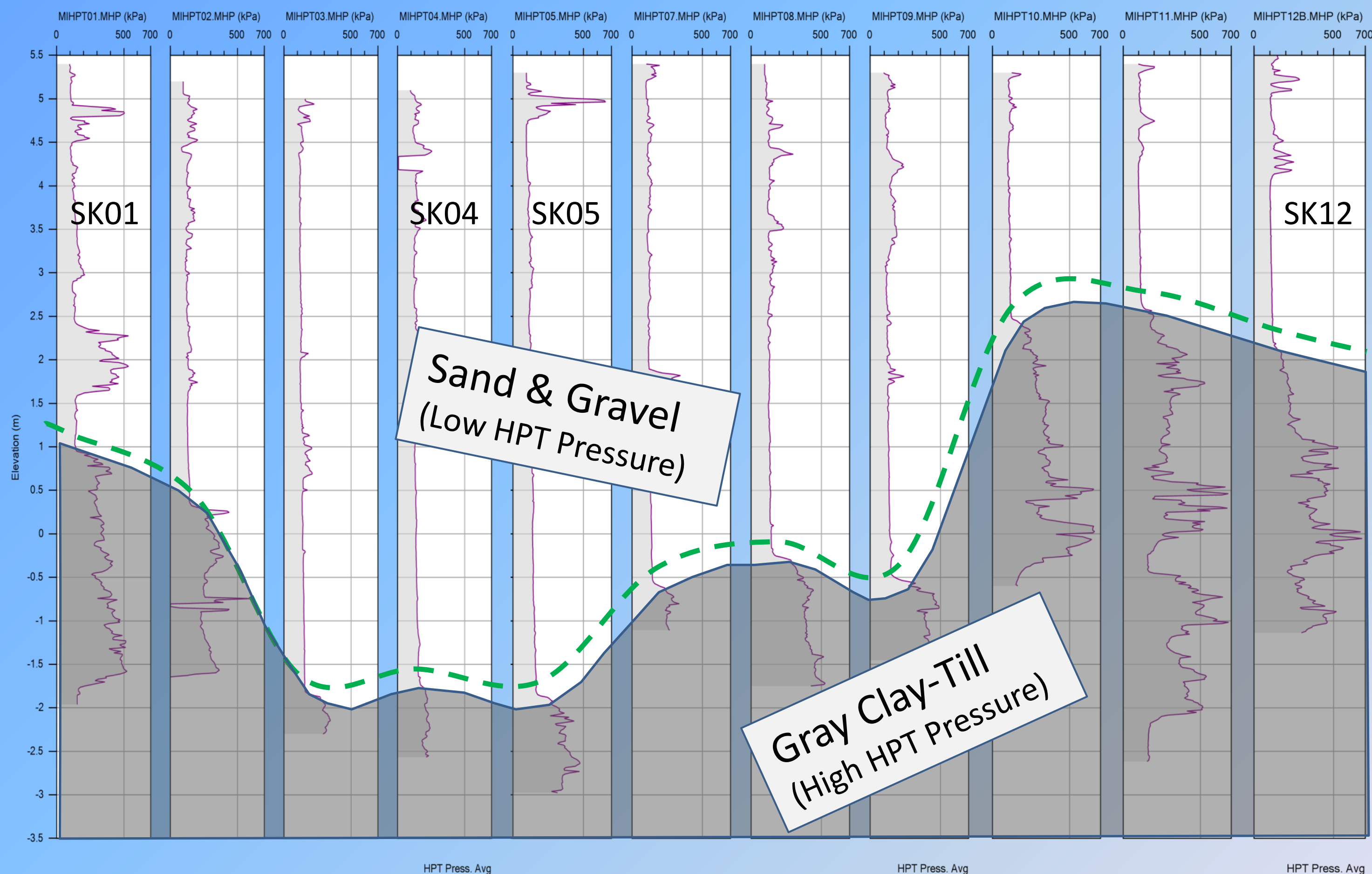


(Facing ~ Southwest)

If we draw a line between each log connecting the elevation where the HPT pressure increases we define a surface of contact …

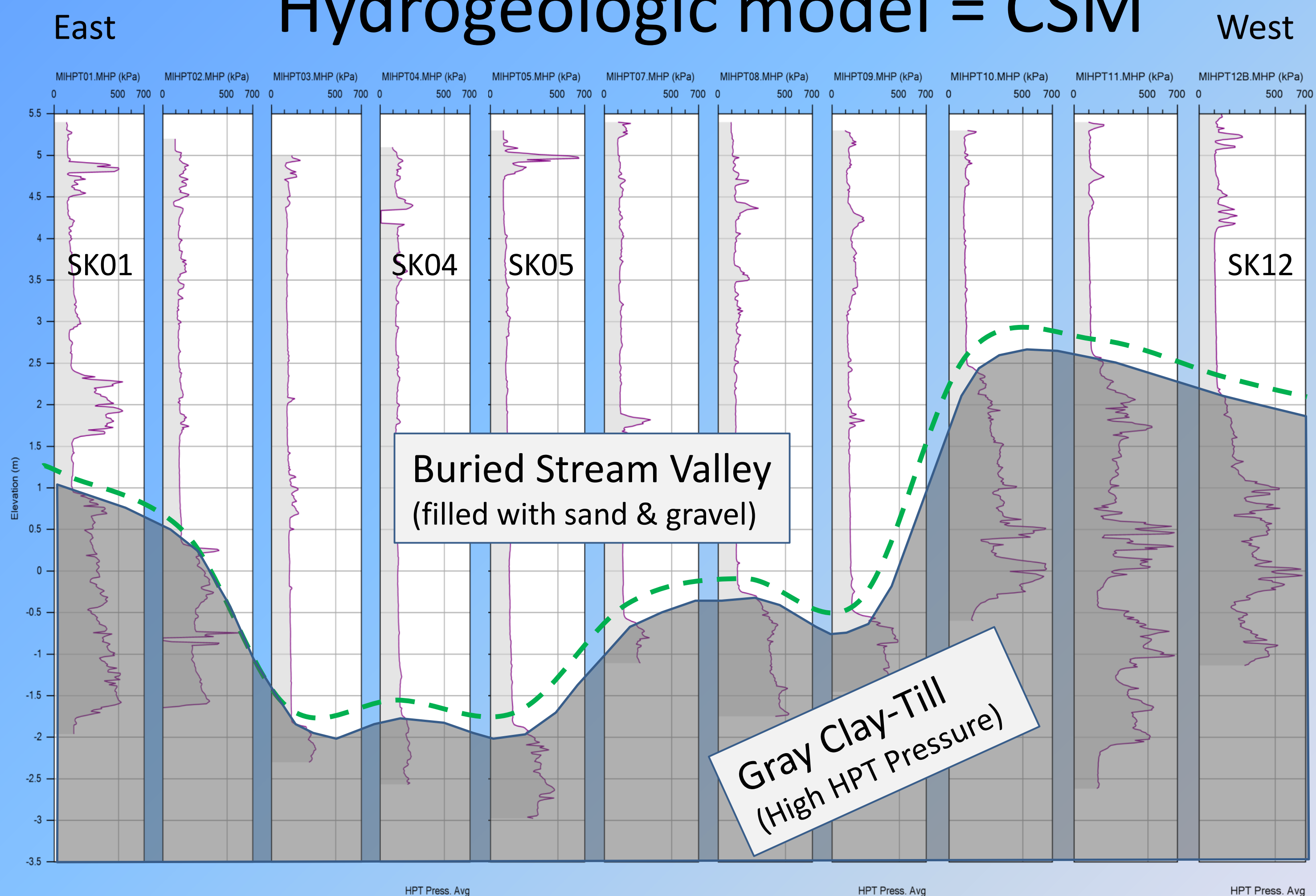
Skuldelev HPT Pressure X-Section

East (Elevation Corrected) West



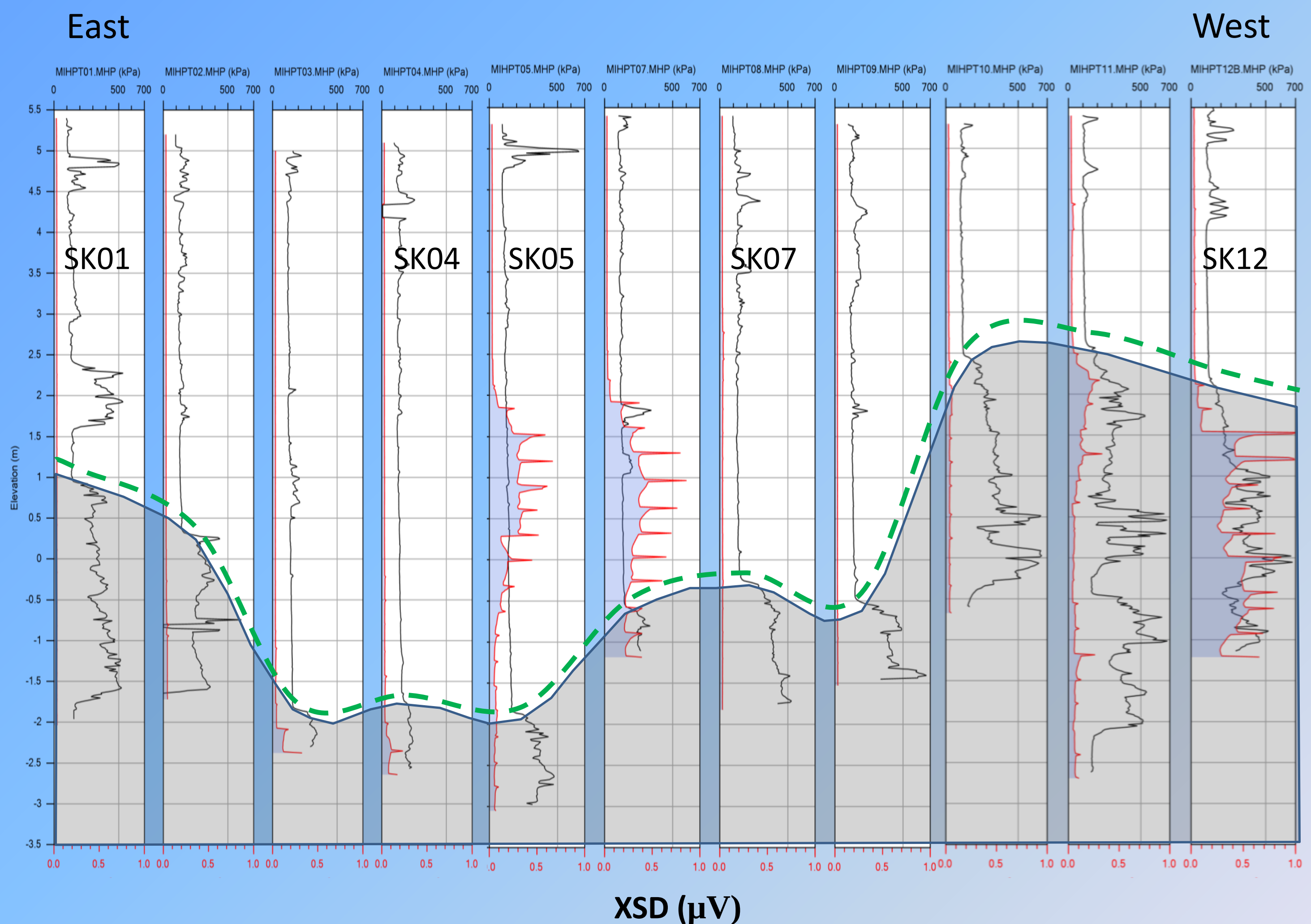
This surface separates the top of the high pressure clay-till from the low pressure, sands and gravels (Aquifer materials). Looking at the profile it looks like a cross section of a stream valley.

Skuldelev HPT Pressure X-Section = Hydrogeologic model = CSM



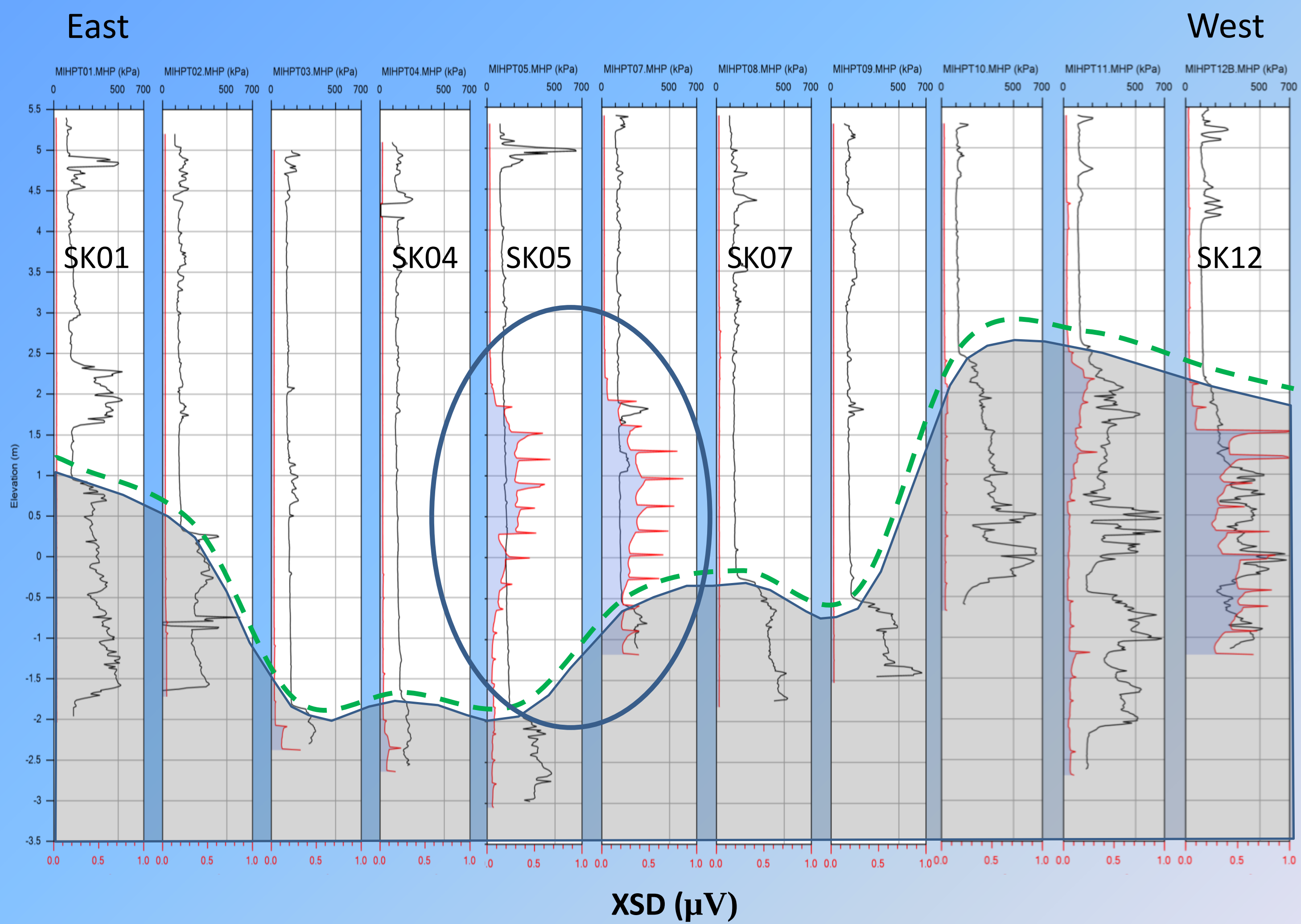
It appears that a post-glacial stream eroded a small valley in the surface of the clay-till that was later filled with sand and gravel, probably from outwash streams as the glaciers receded. Now we have created a detailed hydrogeologic model of the subsurface based on the HPT pressure logs. This becomes the foundation for our hydrogeologic conceptual site model (CSM).

Skuldelev HPT Pressure and XSD Cross Section



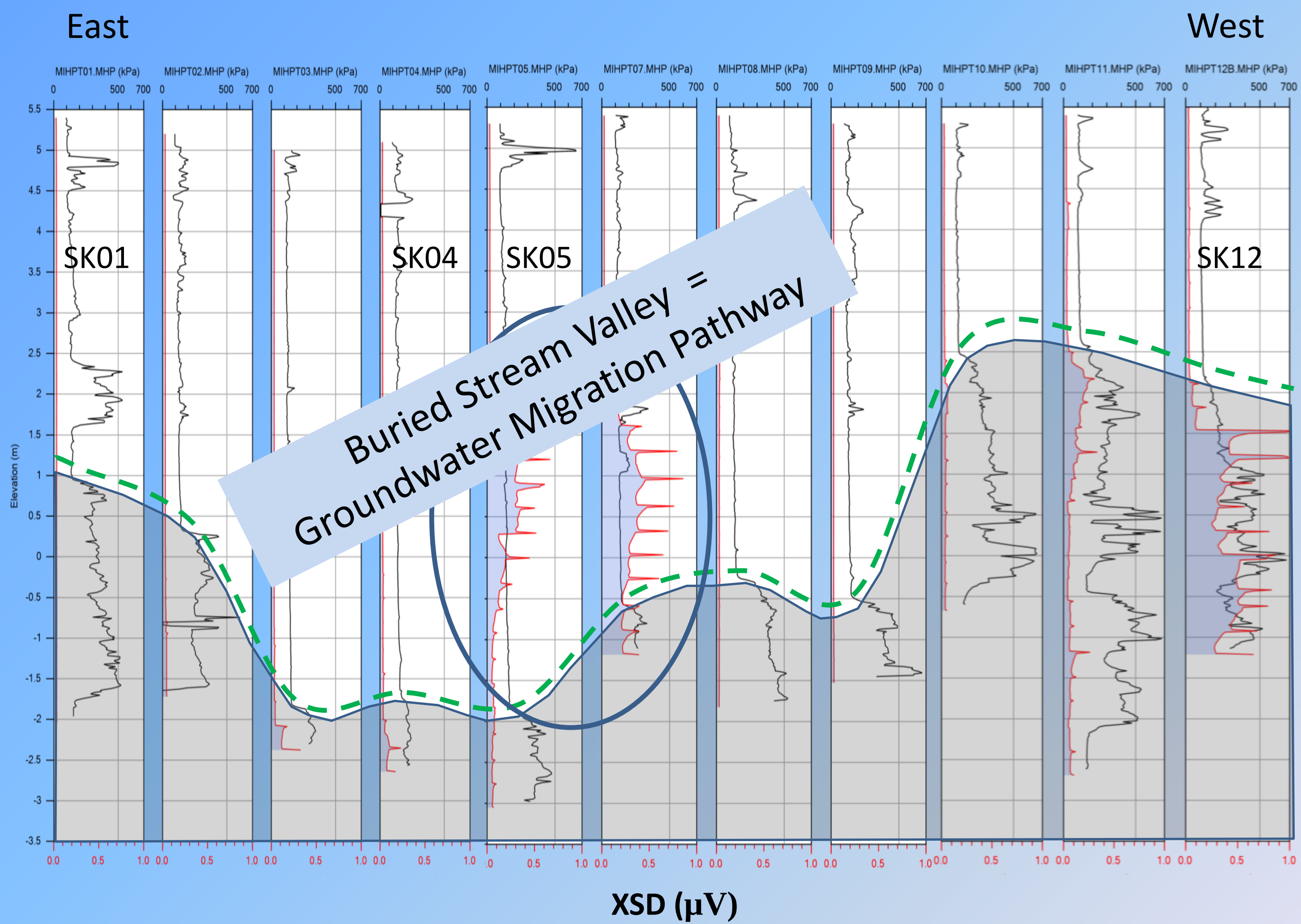
In this hydrogeologic cross section the MIP XSD detector response (red with blue fill) for chlorinated VOCs has been placed over the HPT pressure logs (black) at each location.

Skuldelev HPT Pressure and XSD Cross Section



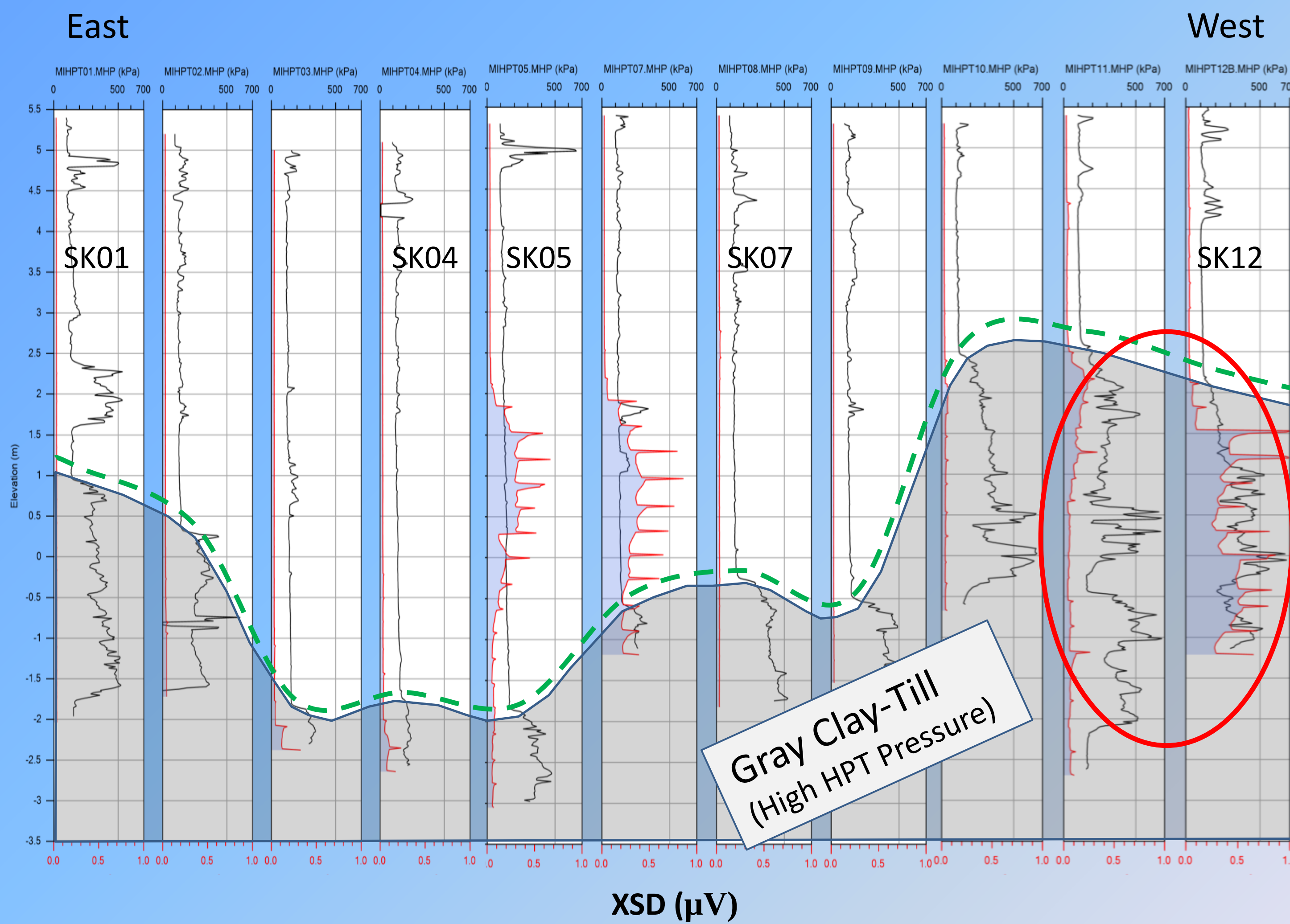
It becomes apparent that the CVOC groundwater plume is migrating down the buried stream valley at locations SK05 and SK07. This was not understood until we had run the HPT logs and constructed this HPT pressure cross section.

Skuldelev HPT Pressure and XSD Cross Section



It becomes apparent that the CVOC groundwater plume is migrating down the buried stream valley at locations SK05 and SK07. This was not understood until we had run the HPT logs and constructed this HPT pressure cross section.

Skuldelev HPT Pressure and XSD Cross Section



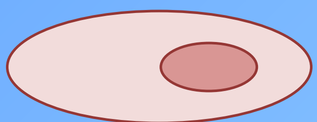
Over at the west end of the cross section (SK11 & SK12) CVOC contamination is present in the clay-till. This “hot spot” formed as the result of a sewer leak after solvents were disposed of in the facility sewer, and is not associated with the groundwater plume.

Skuldelev Site Map

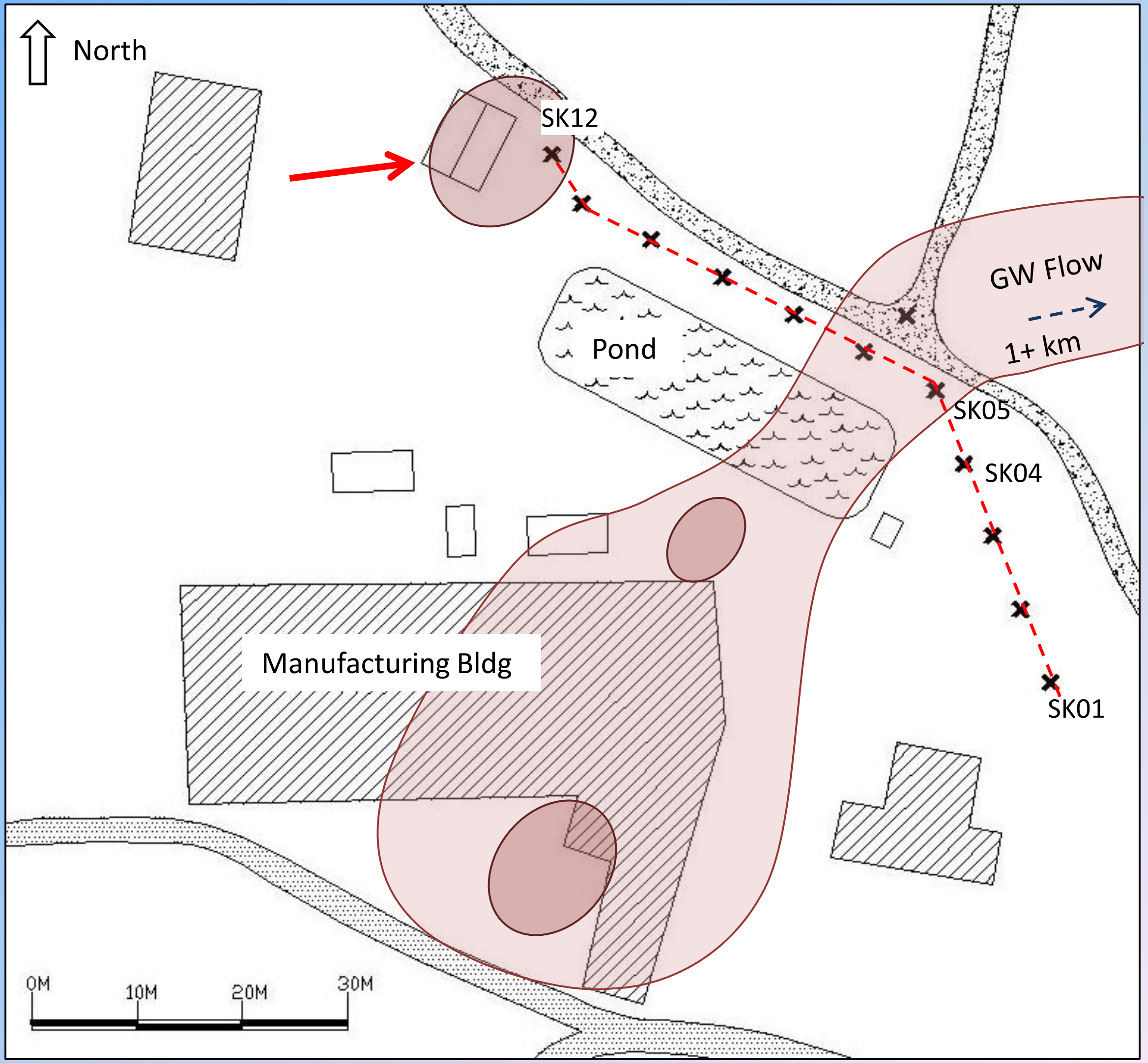
MiHpt Log **X**

Cross section Line

GW Plume & Hot Spot



Here is the hot spot at SK12 shown on the map (red arrow).



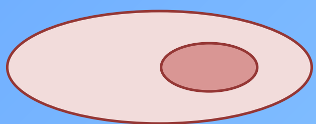
Logs are spaced 8 m (~25ft) apart.

Skuldelev Site Map

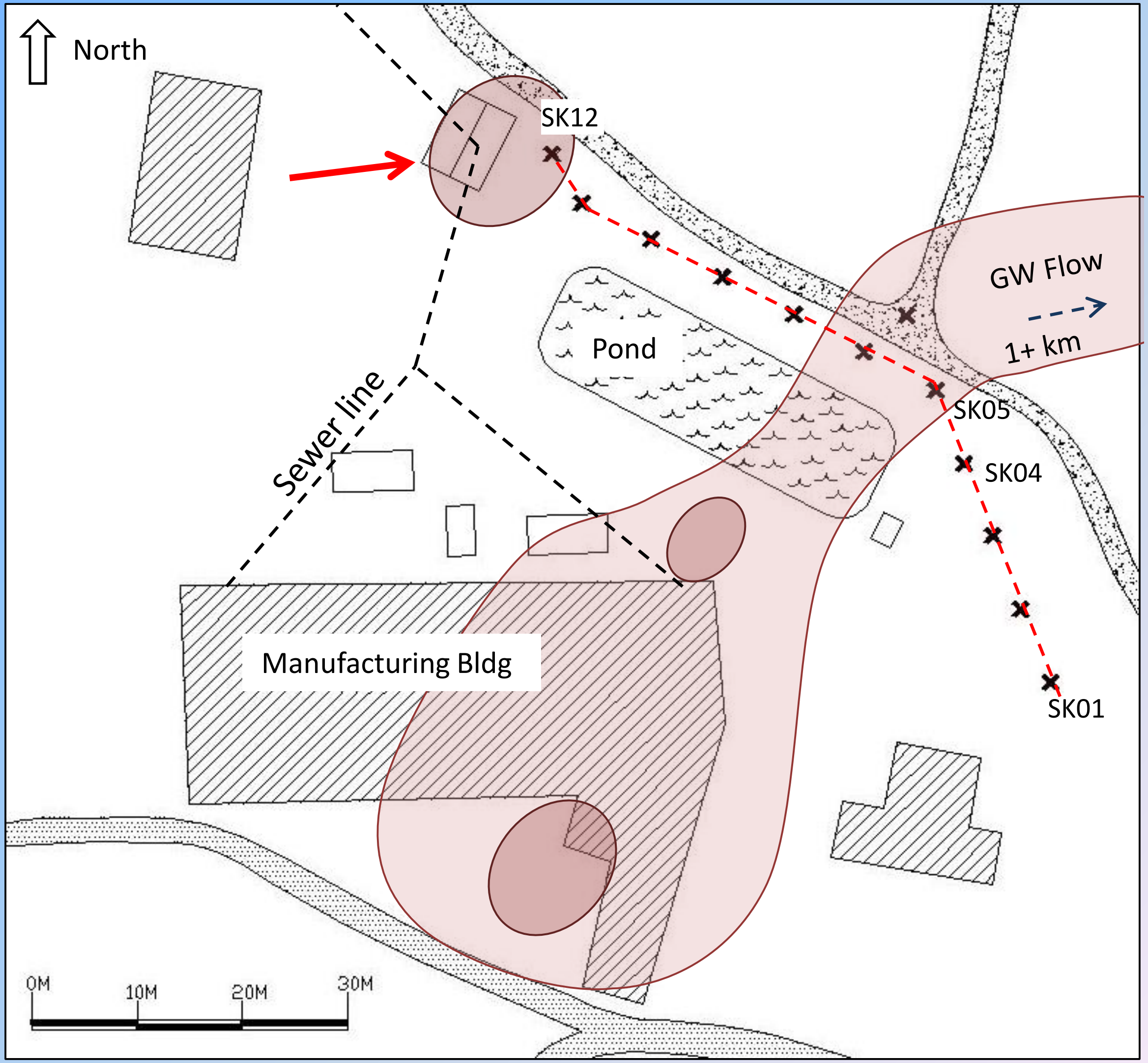
MiHpt Log **X** - - - - -

Cross section Line

GW Plume & Hot Spot



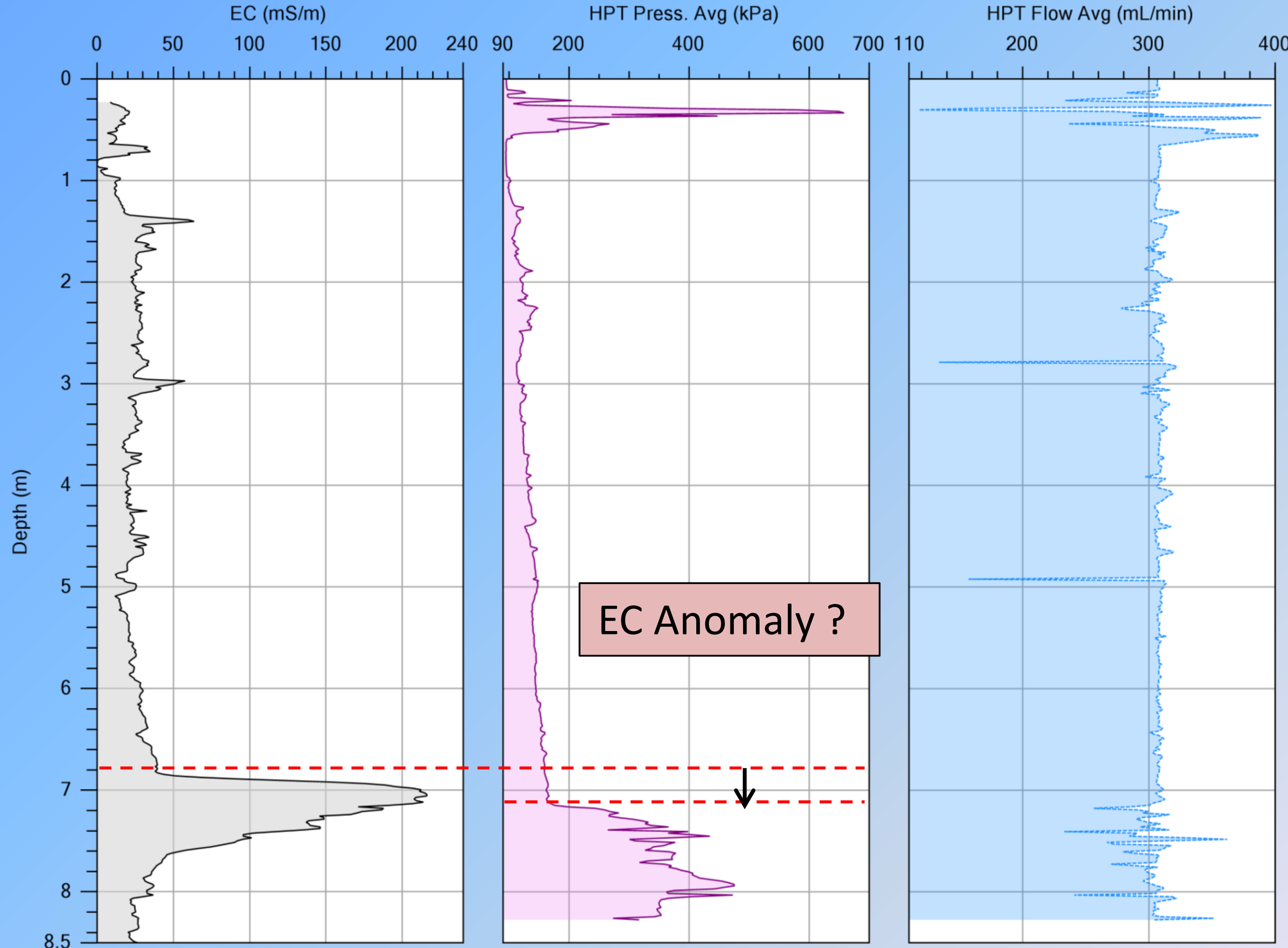
PCE, TCE,
DCE & VC



Here the sewer line juncture where the leak occurred that resulted in the hot spot at SK12 is shown on the map (red arrow). Sewer lines/back filled ditches led to vapor intrusion in some homes.

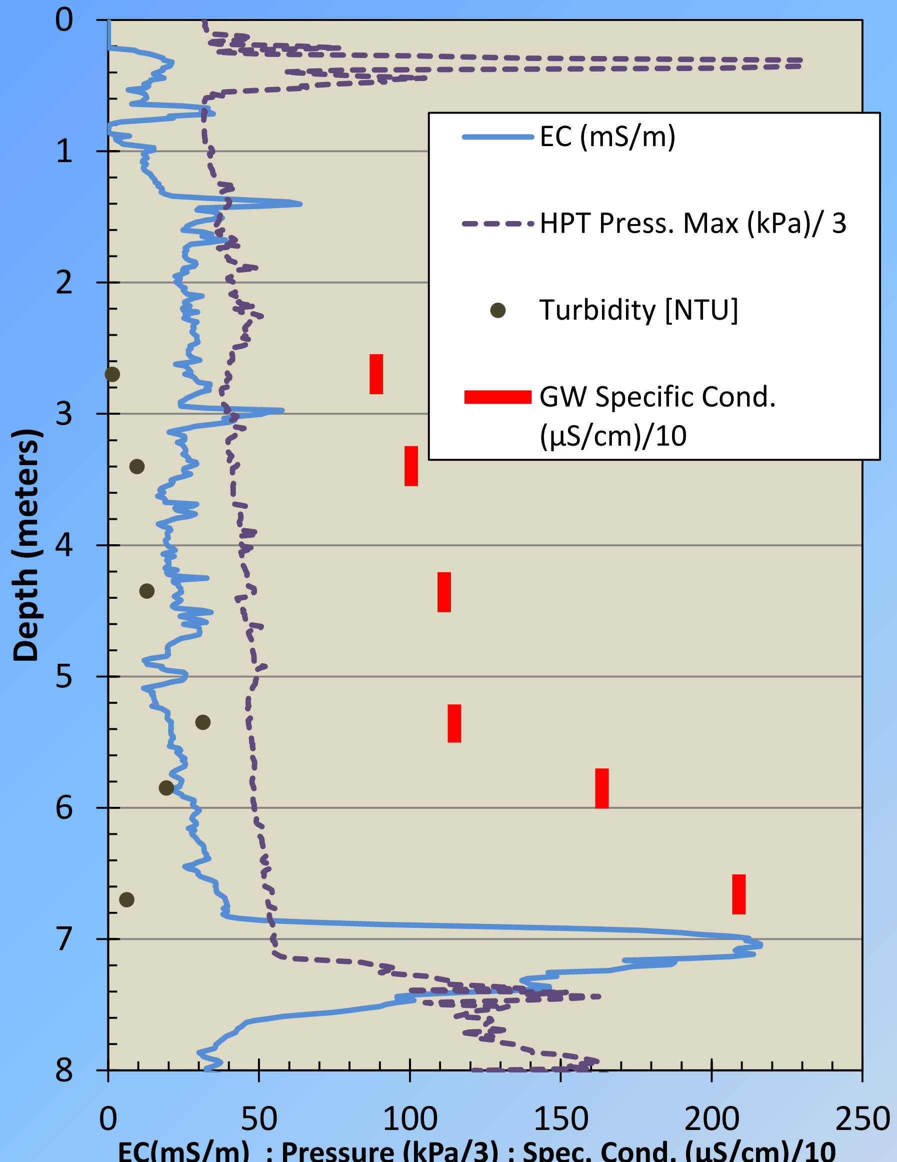
Logs are spaced 8 m (~25ft) apart.

Example HPT Log: Skuldelev SK05



When EC increases before HPT pressure, it may indicate an EC anomaly, caused by ionic contaminants.

SK05 Location



EC & HPT Pressure

Groundwater specific conductance

We conducted groundwater profile sampling at SK05 for CVOCs with SP16 groundwater samplers. The 30 cm (1 ft) piezometer screens were developed prior to sampling. Water quality parameters, including specific conductance, were monitored to stability at each interval. Here we see the specific conductance is increasing as we approach the EC anomaly. This suggests that an ionic contaminant in the formation is causing an increase in the bulk formation electrical conductivity.

Skuldelev Site Map

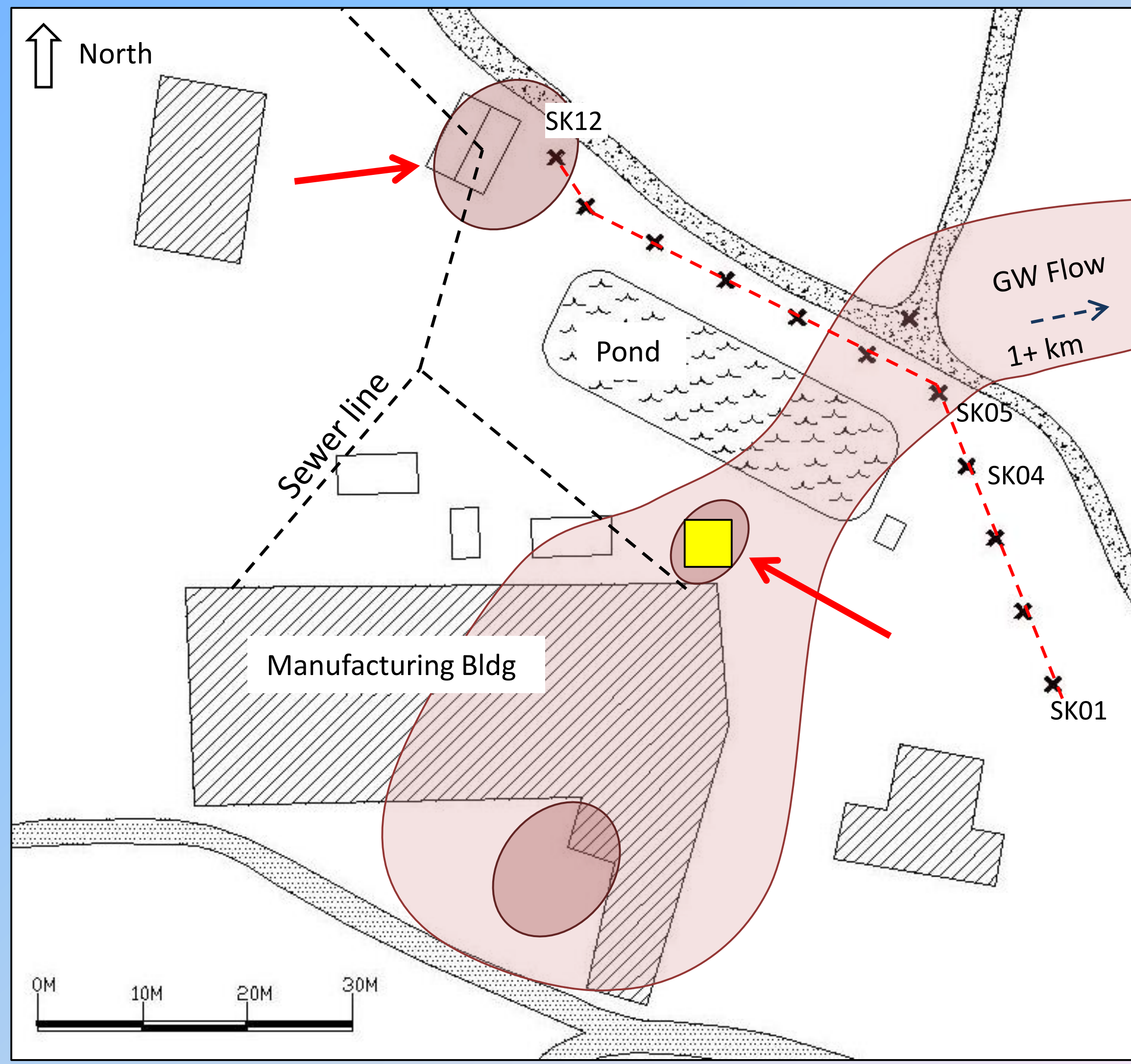
MiHpt Log X

Cross section Line

GW Plume & Hot Spot

PCE, TCE, DCE & VC

Persulfate Injection



Logs are spaced 8 m (~25ft) apart.

During discussions with the NIRAS project managers (Klaus Weber and Anders Christensen) we learned that a pilot study with persulfate injection had been conducted at one of the DNAPL hot spots upgradient of the MiHpt cross section.

Skuldelev Site Map

MiHpt Log X - - - -

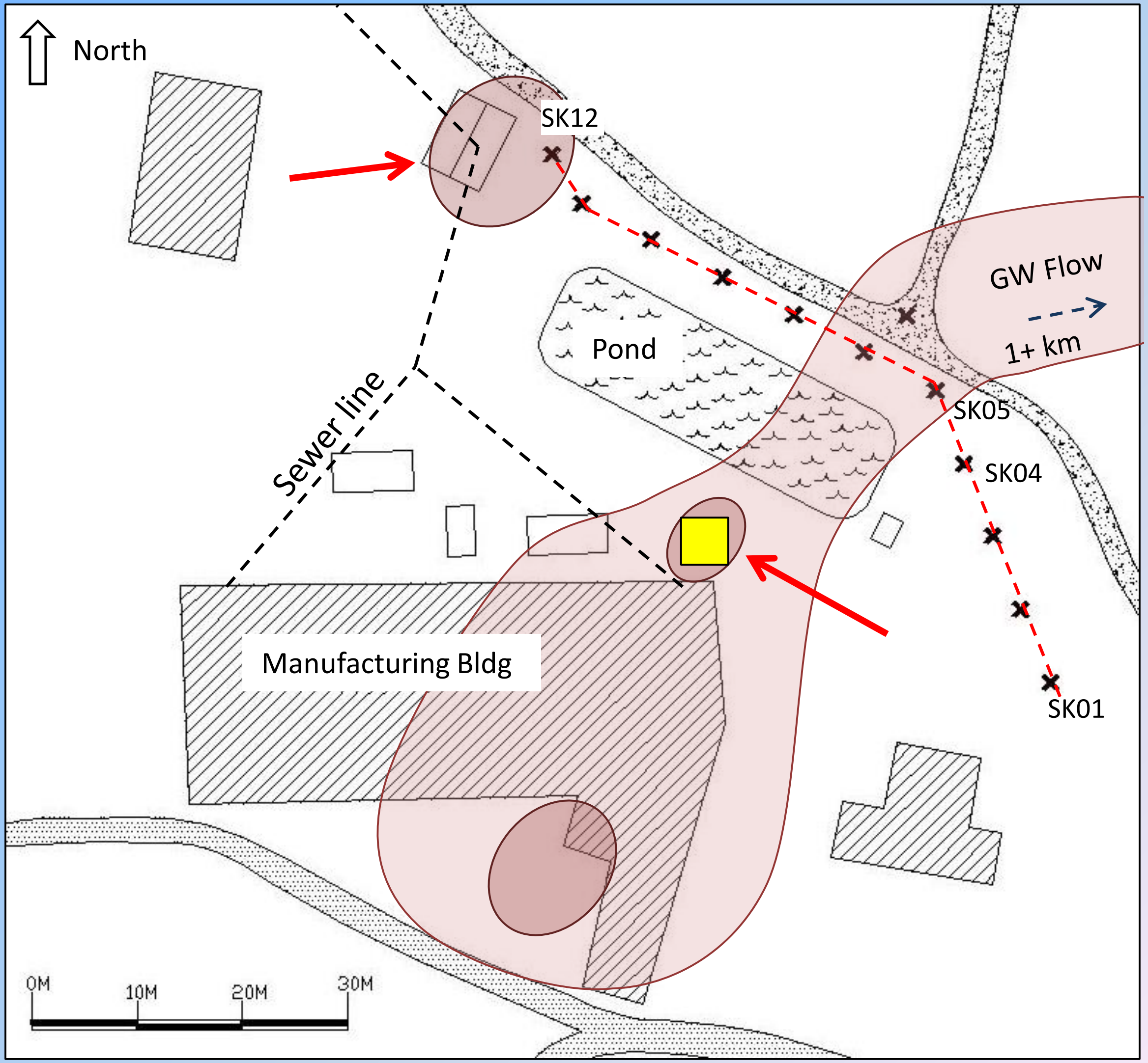
Cross section Line

GW Plume & Hot Spot

PCE, TCE, DCE & VC

Persulfate Injection

Anders indicated that well sampling after the injection program had confirmed the presence of persulfate in several monitoring wells. Well and boring logs appeared to indicate it was moving in a thin basal conglomerate present at the top of the clay-till in some areas across the site.



Logs are spaced 8 m (~25ft) apart.

Skuldelev Site Map

MiHpt Log X

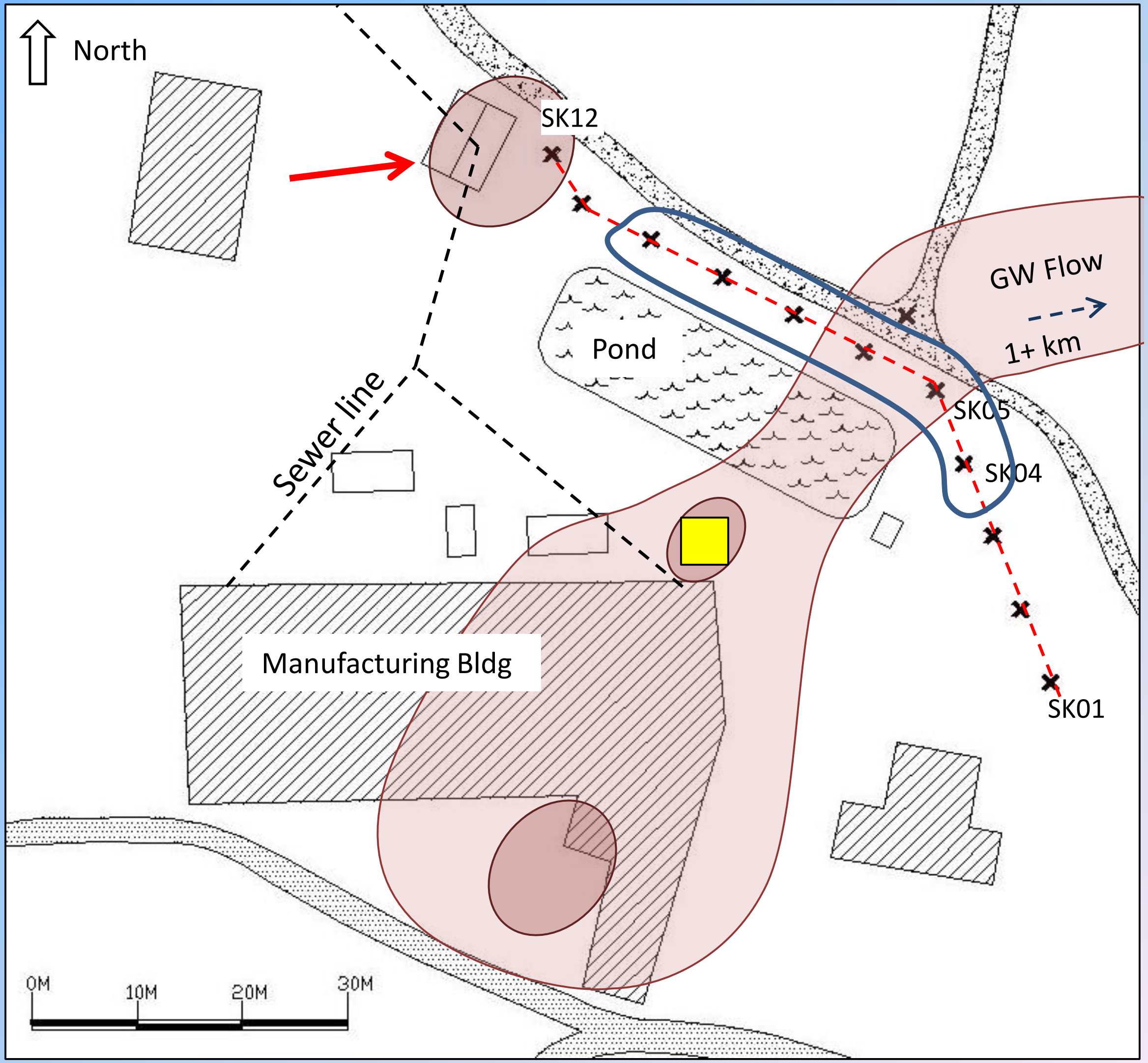
Cross section Line

GW Plume & Hot Spot

PCE, TCE, DCE & VC

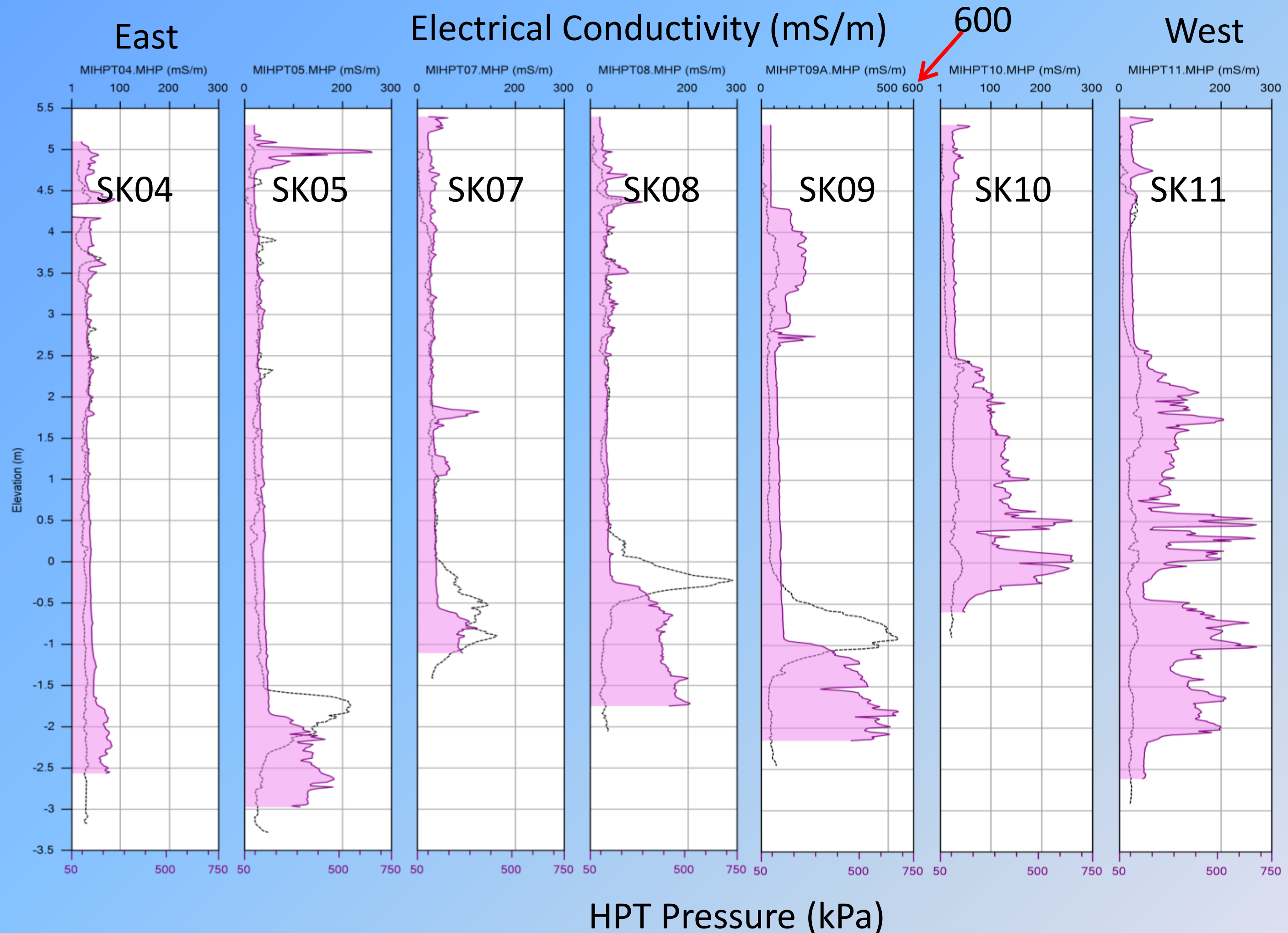
Persulfate Injection

Now, let's look at a cross section from SK04 over to the SK10 location, focusing on EC and HPT pressure.



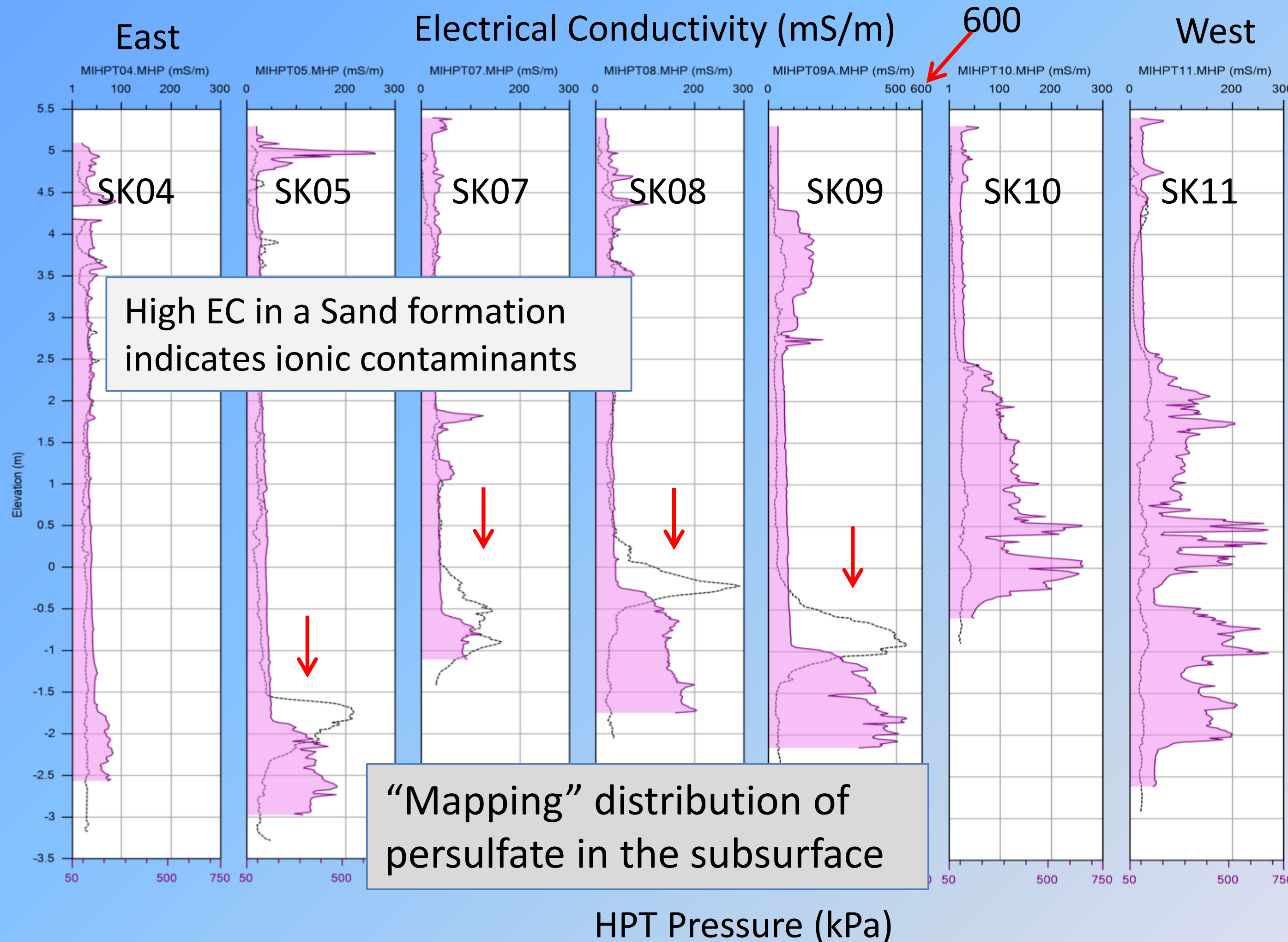
Logs are spaced 8 m (~25ft) apart.

Cross Section with HPT Pressure & EC



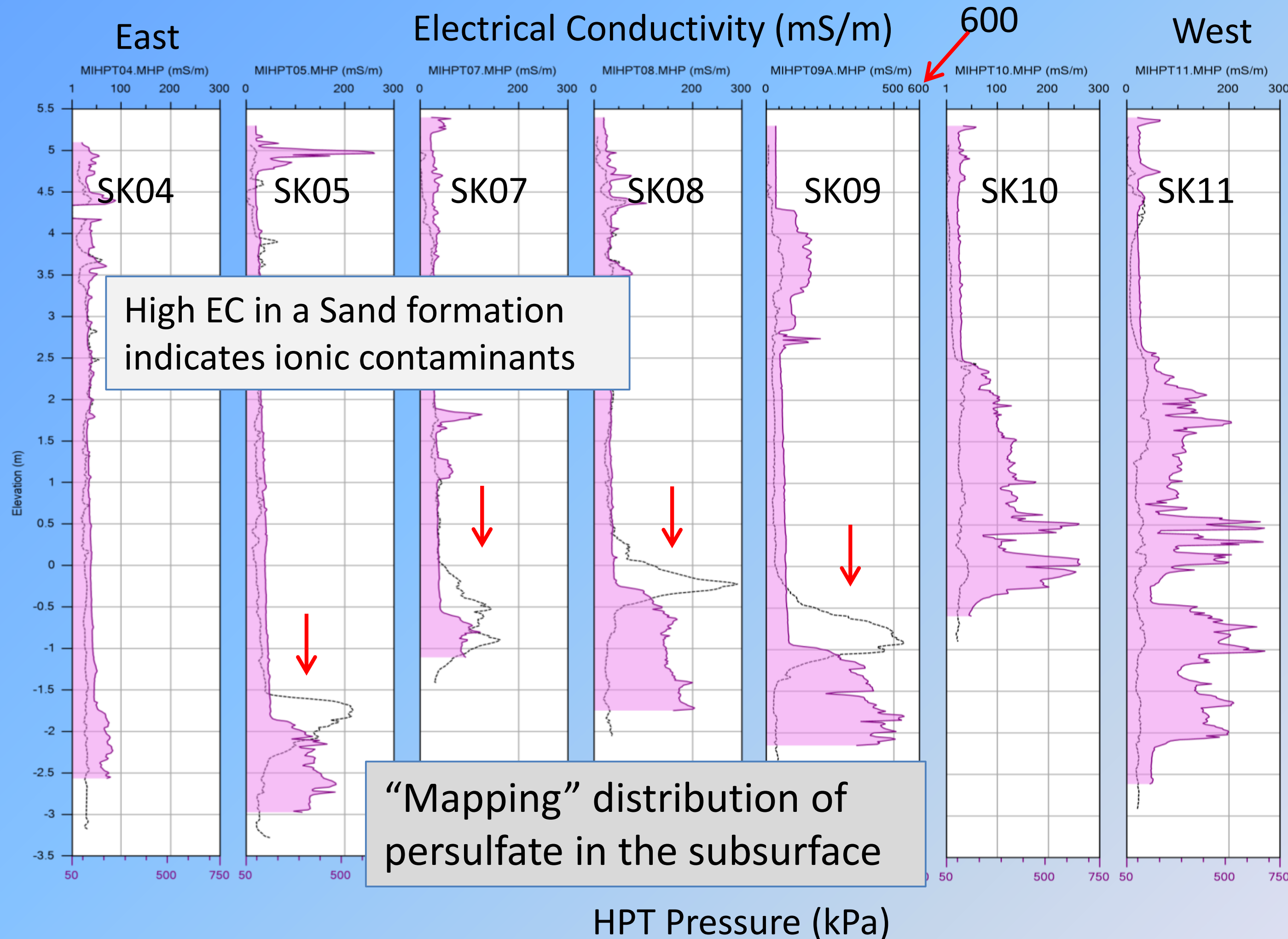
HPT pressure is in purple and EC is black dashed line. Background EC at SK04 and SK10 & 11 are relatively flat, and below HPT pressure.

Cross Section with HPT Pressure & EC



However, between the SK05 to SK09 locations we see that EC clearly increases above the clay-till. In several cores across the area we observed a “basal conglomerate” at the boundary between the clay-till and the overlying sands and gravels.

Cross Section with HPT Pressure & EC



For high concentration brines the bulk formation, EC can be several hundred or even a few thousand milliSiemens/ meter, becoming very obvious in the EC logs.

It appears this very permeable layer maybe providing a conduit for rapid movement of the persulfate in the subsurface. Detecting the EC anomaly by combining HPT pressure and EC logs provides a method for mapping ionic contaminants in the subsurface.

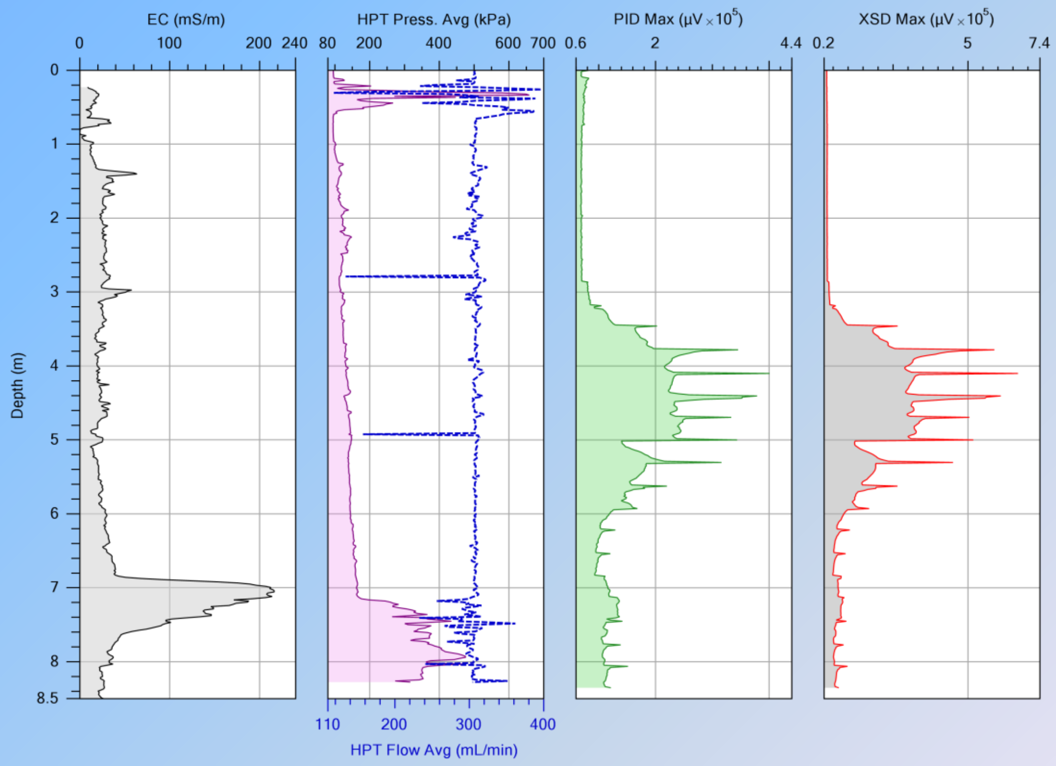
MiHpt Summary

Combined MIP + HPT Probe Simultaneously Provides:

MIP Detector Logs (where is it ? how much?)

HPT Pressure Log (lithology, hydrostartigraphy)

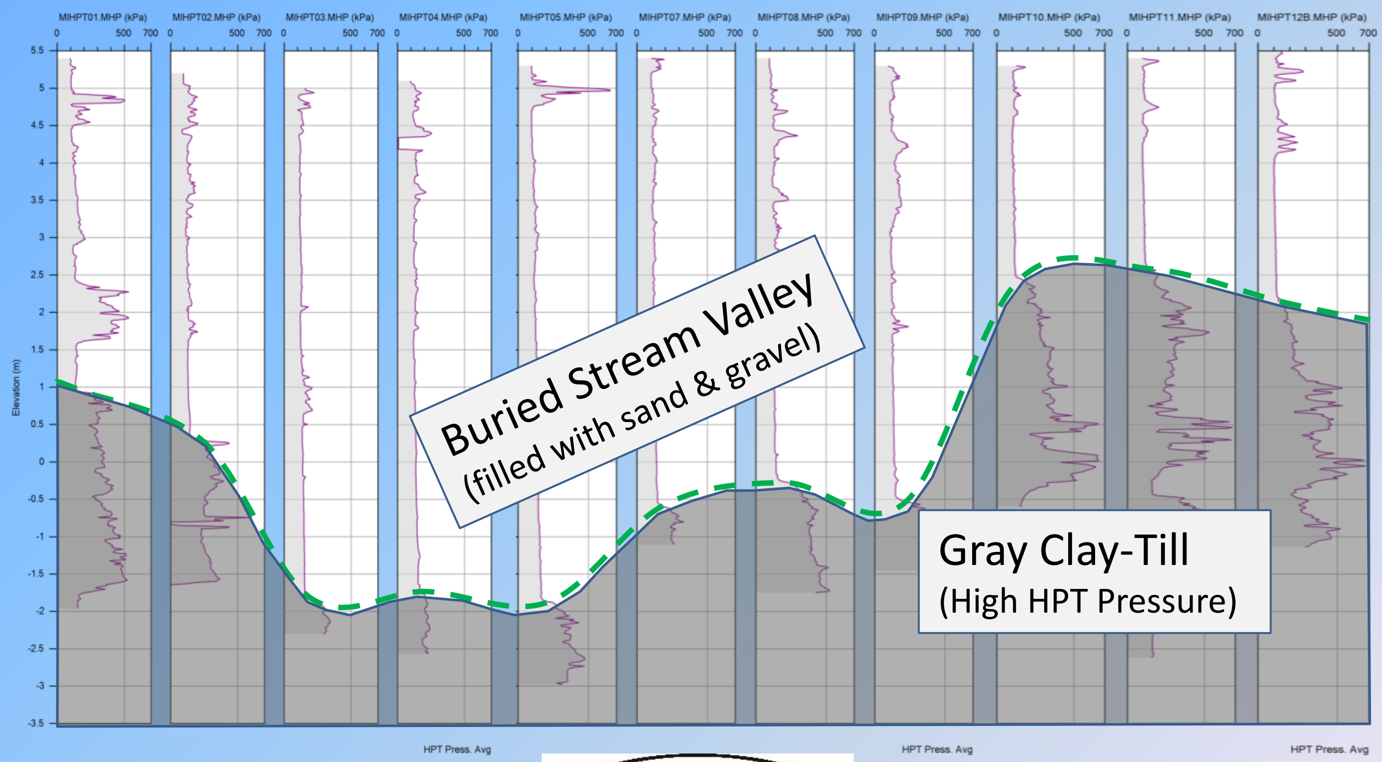
EC log



MiHpt Summary

Cross Sections with HPT Pressure Logs Provide:

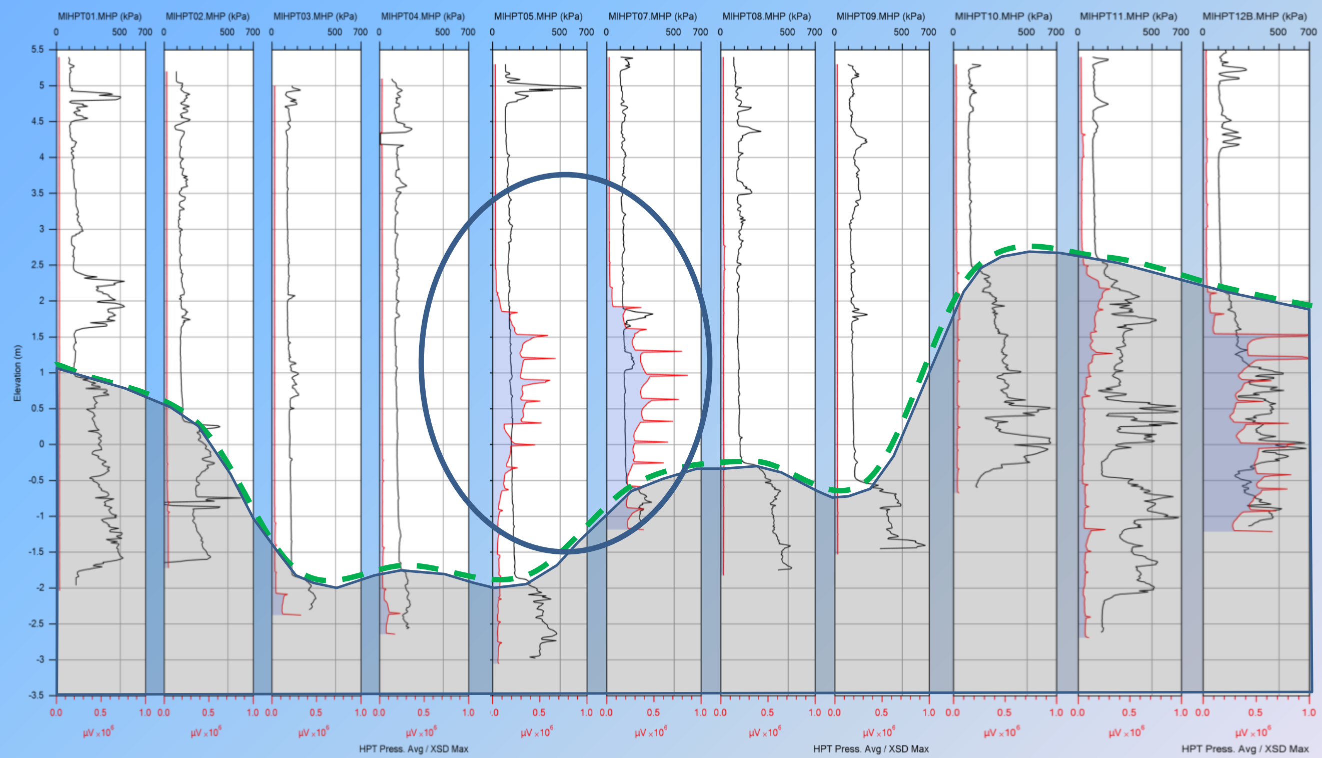
- Lithologic information
- Hydrogeologic model for the site
- Geologic cross sections



MiHpt Summary

Cross Sections with MIP Detector Logs and HPT P Logs:

- Lithologic control on contaminant migration (migration pathways)
- Conceptual site model development



Genuine Geoprobe