MIHPT

The addition of the

Hydraulic Profiling Tool to the Membrane Interface Probe

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NIRAS, Denmark

Danish Capital Region





MIHPT
Membrane Interface Probe
+
Hydraulic Profiling Tool



This project has been presented at:

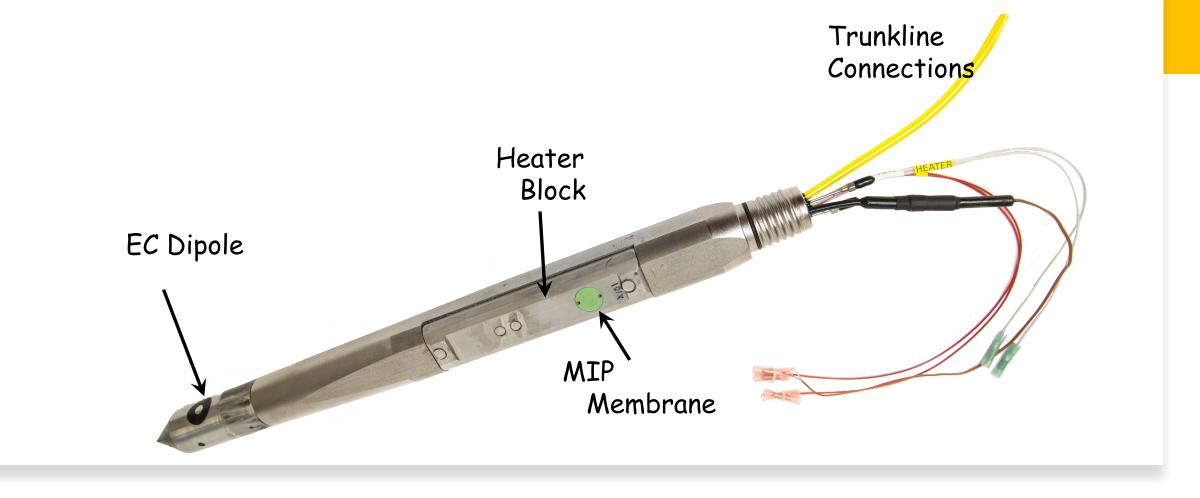
- Battelle Bioremediation Symposium, Jacksonville, FL June 2013
- RemTech Remediation Technology Symposium, Banff Alberta, Canada October 2013
- Published: Groundwater Mon. & Rem.
 Vol. 34, No. 2, pages 85-95.



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

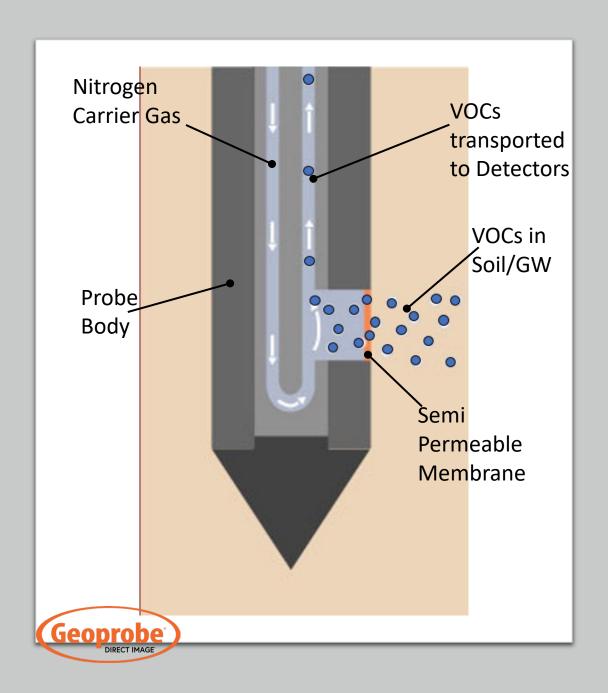




MIP Probe



The heater block heats up to 120C to help "extract" volatiles from the formation. A thermocouple is used to monitor & control the temperature. Supply and return gas lines in the trunkline connect to the fittings at the probe and transport VOCs to gas phase detectors at the surface.



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







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.) is injected into 500ml of clean water.

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

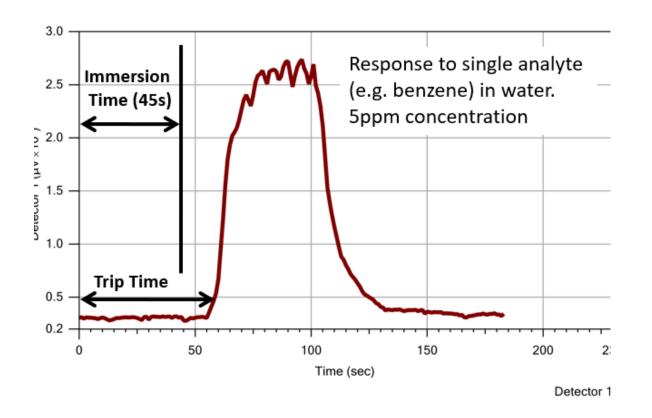










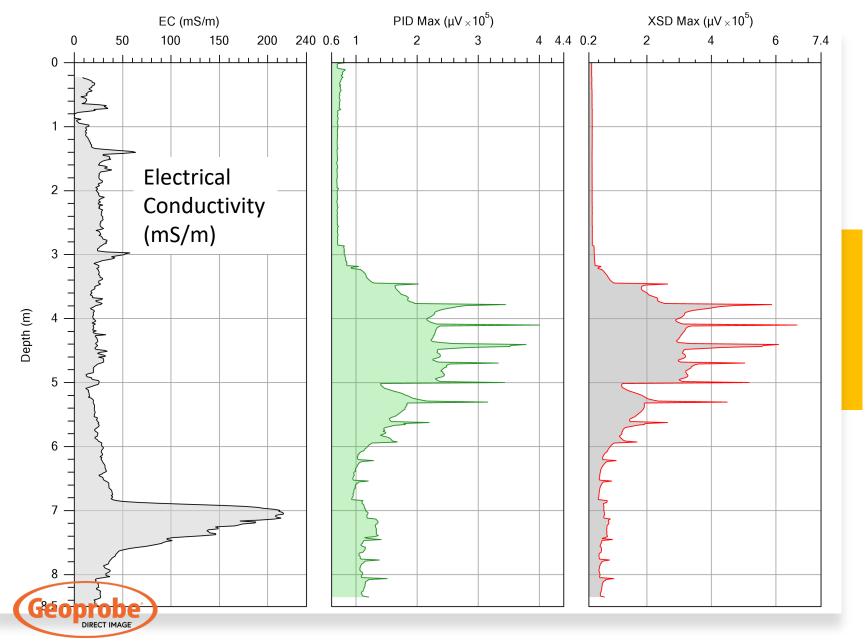


Trip time is the time required for analyte to travel across the membrane and through the trunkline to its first observation at the detector. The trip time is entered into the software to allow for accurate tracking of contaminants in the log.



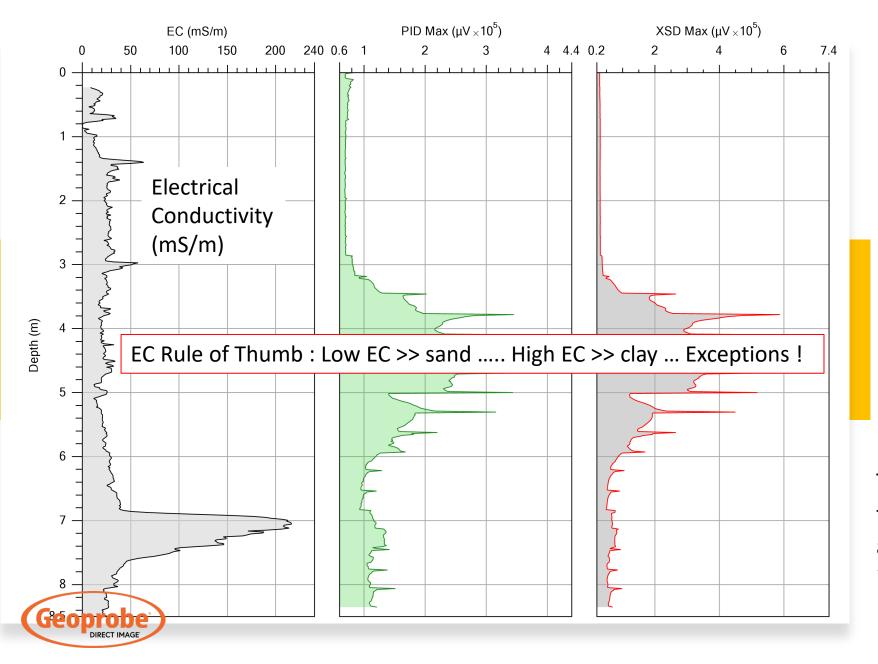
Typical Chemical Response Test





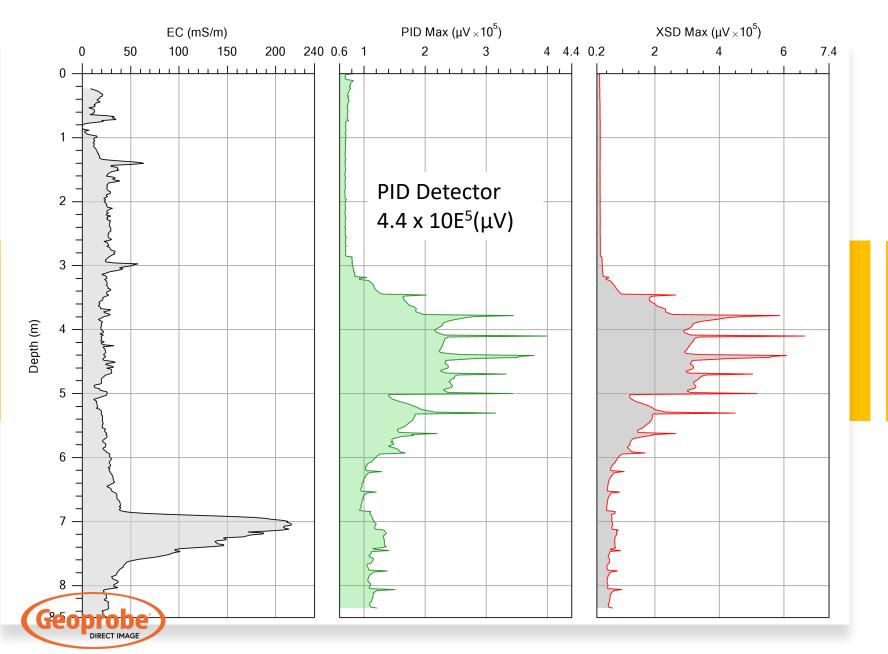
Here is a fairly typical MIP log. EC graph on the left, units are milli Siemens per meter.



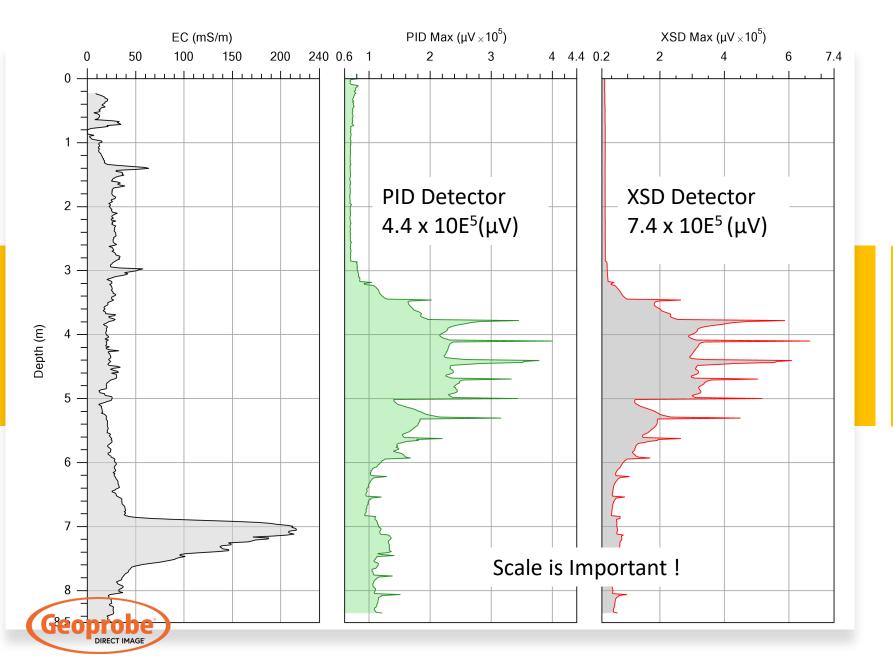


The EC rule of thumb is for freshwater formations. There are exceptions to the EC rule ... ionic contaminants can cause hi EC even in a clean sand.

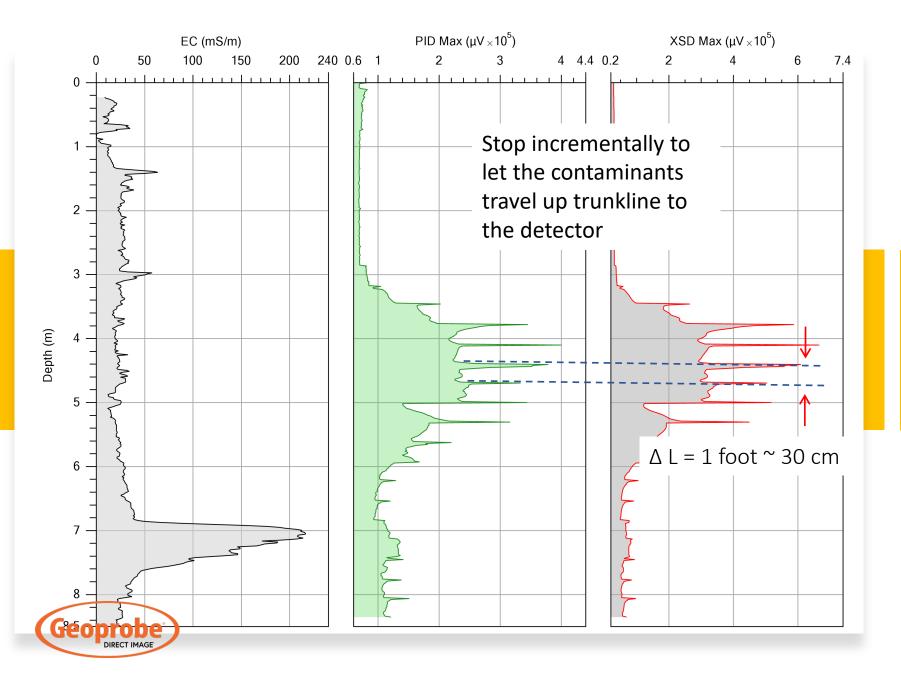






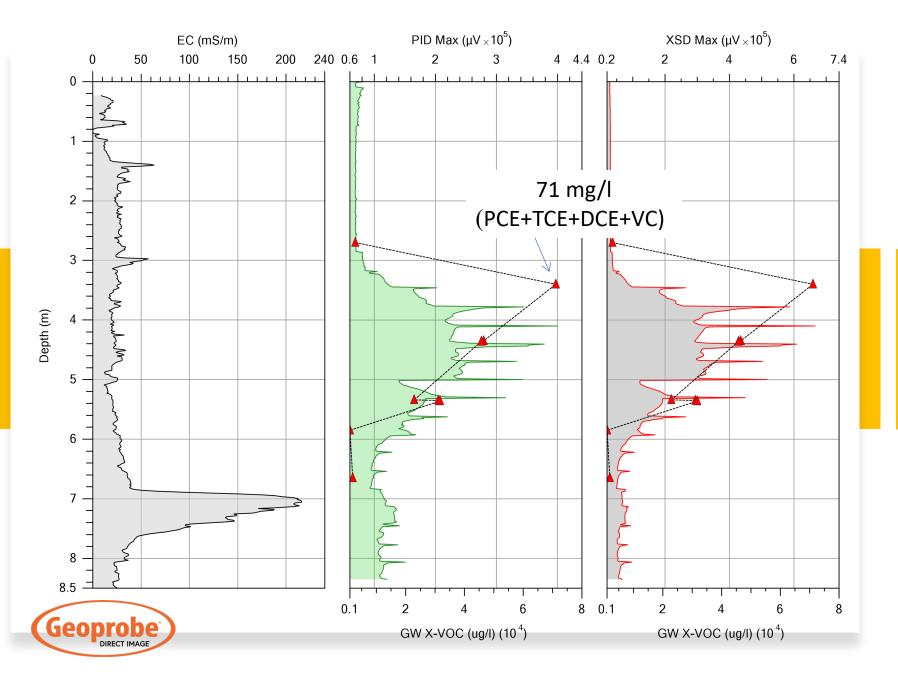






The peaks or "spikes" in the detector logs are caused by the incremental probing. Stopping at each depth interval for about 45 seconds to allow time for the probe to reach temperature and diffuse contaminants across the membrane.

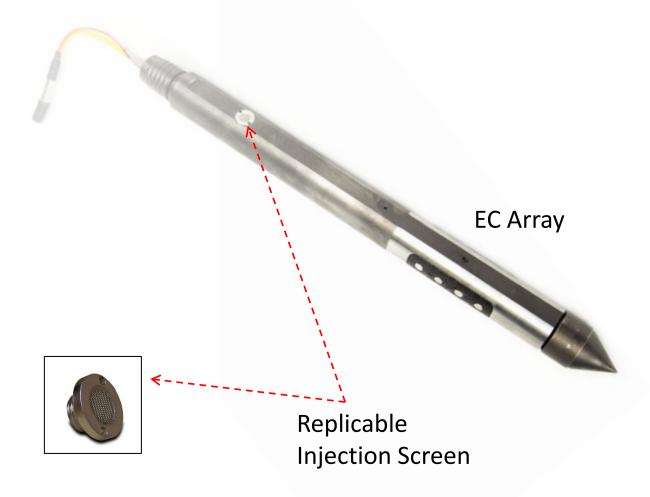




How does the MIP detector response correlate with groundwater sample results? At the Skuldelev site the results correlate pretty well. We used a direct push piezometer with a 1-foot screen interval to collect discrete samples for this comparison.

The HPT Probe

Trunkline Connections



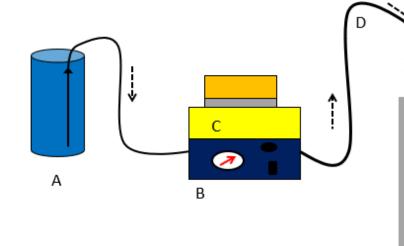


HPT Equipment and Operating Principles

Inject Water at 300 ml/min

Advance Probe at 2 cm/sec





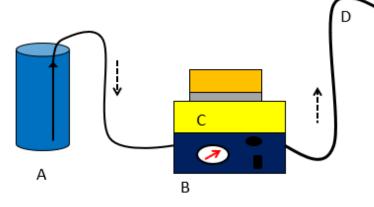
- A) Water Tank
- B) Pump & Flow Meter
- C) Electronics/computer
- D) Trunkline
- E) Pressure Sensor
- F) Screened Injection Port
- G) Elec. Conductivity Array

HPT Equipment and Operating Principles

Inject Water at 300 ml/min

Advance Probe at 2 cm/sec





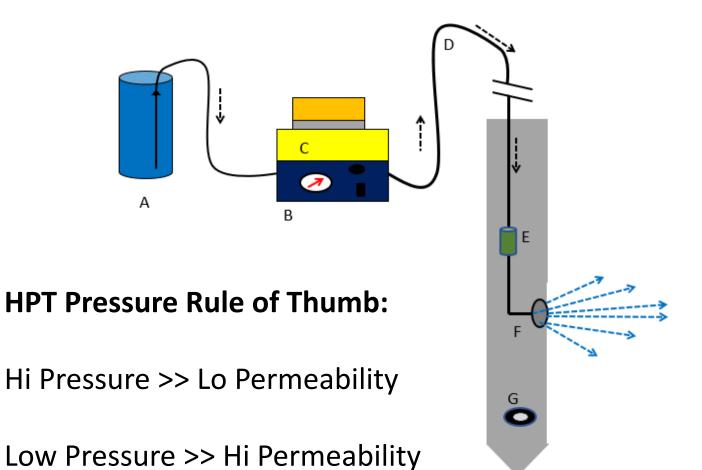
The pump in the HPT flow module (B) draws water from the supply tank and pumps water down the trunkline at a constant flow rate. An inline flow meter measures the flow rate. The downhole pressure sensor (E) monitors the pressure generated by injecting water into the formation matrix. The HPT probe includes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

HPT Equipment and Operating Principles

Inject Water at 300 ml/min

Advance Probe at 2 cm/sec

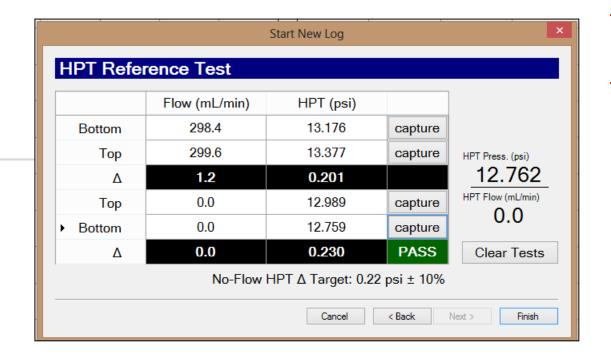


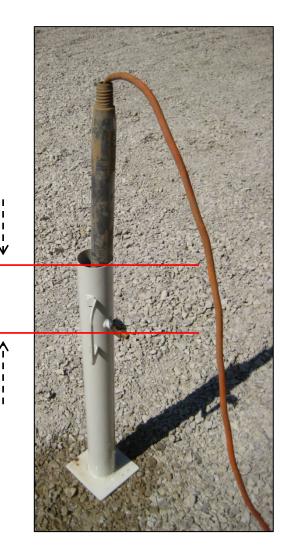


HPT Probe in Reference Tube to Verify $\Delta 6$ " Water Pressure = 0.22 psi (1.52kPa)

HPT QA/QC

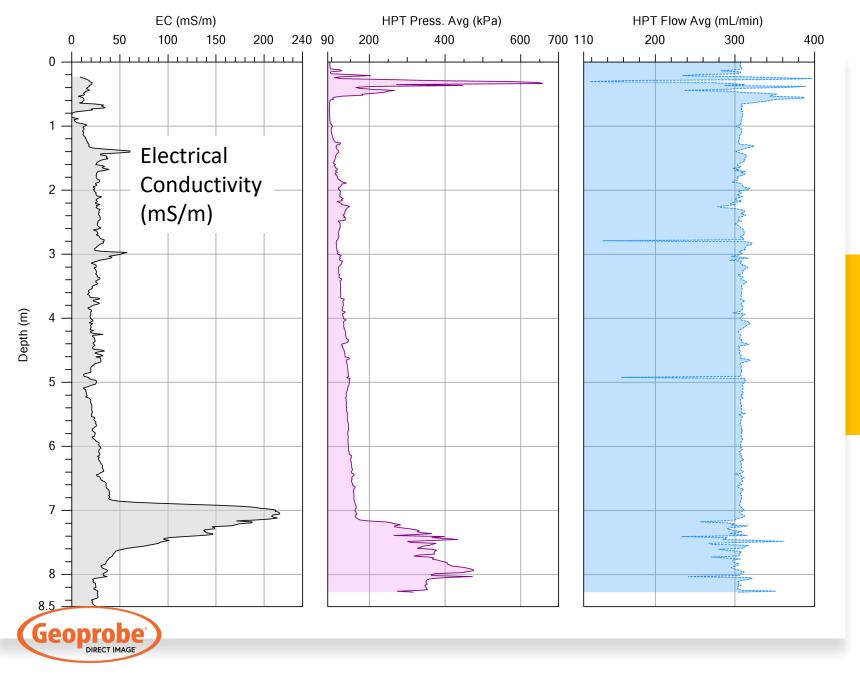
HPT Pressure Transducer Onscreen QA Report (data saved to log file)



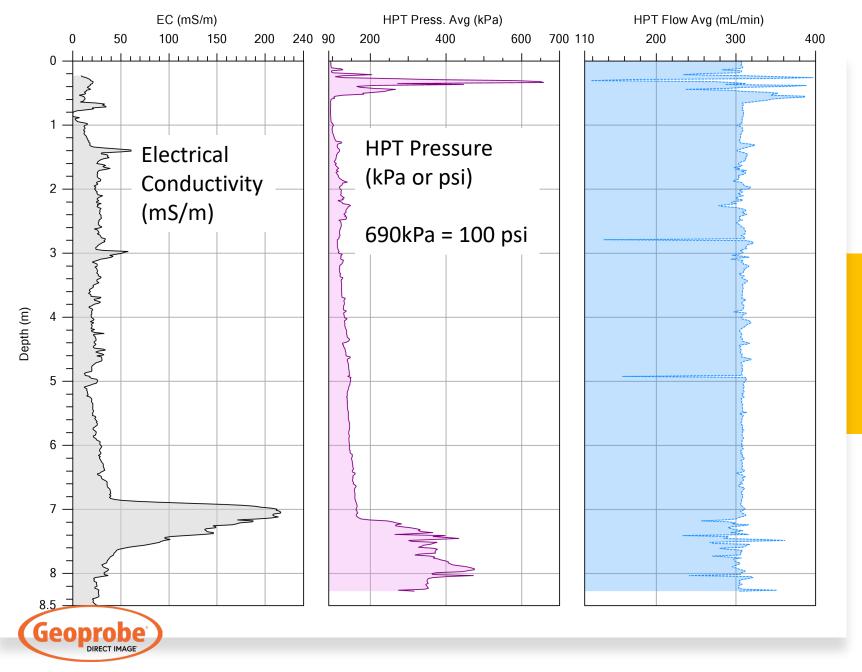




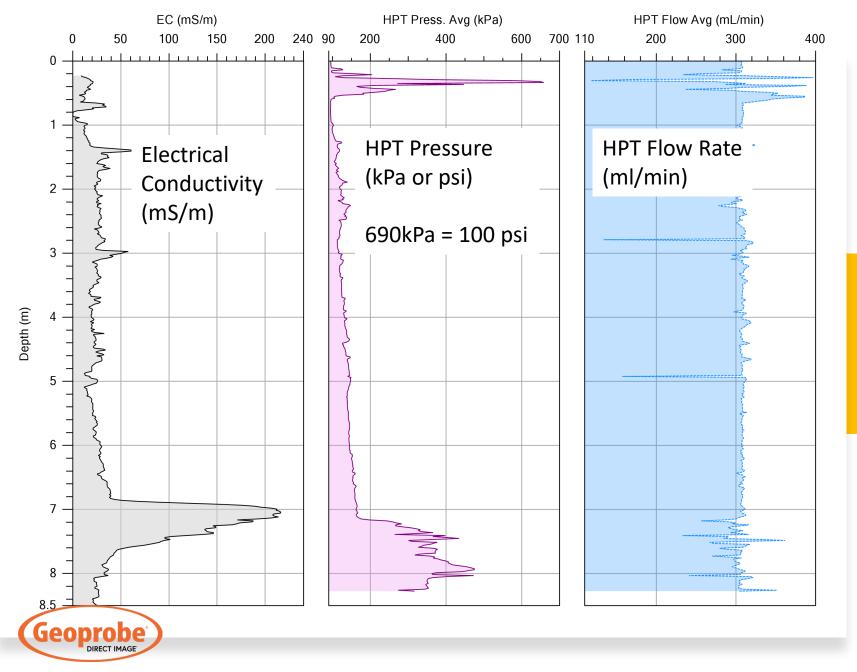




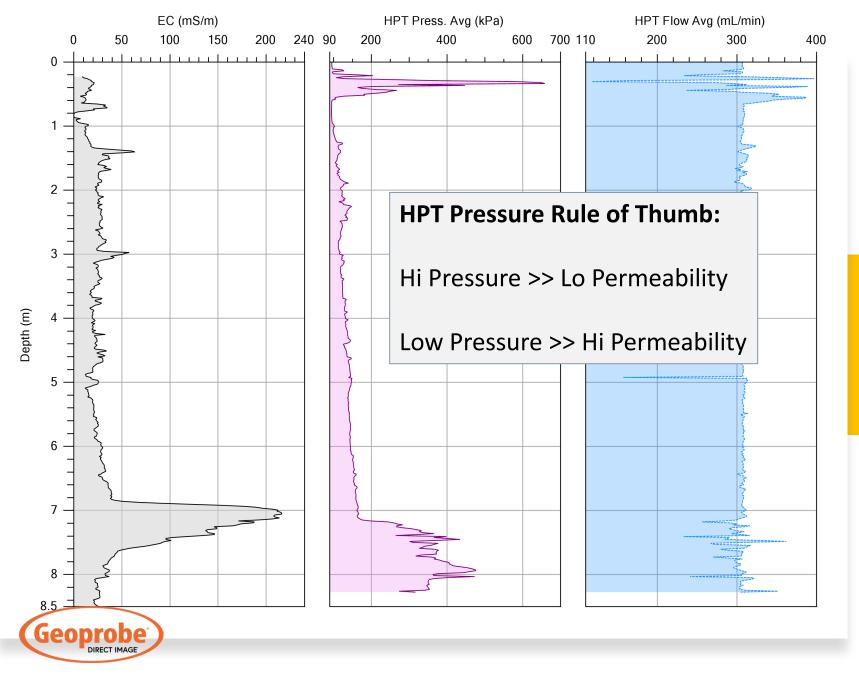




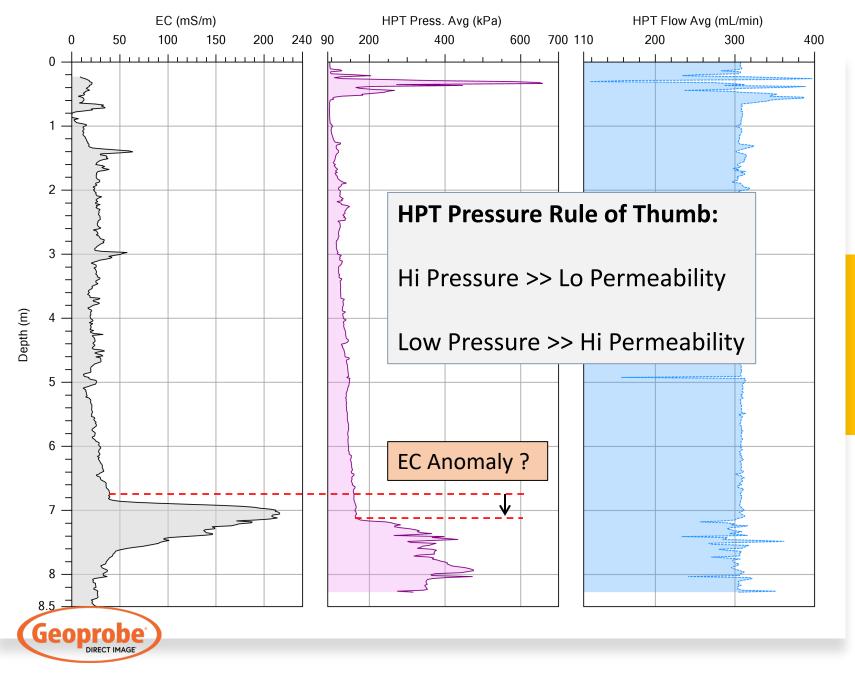










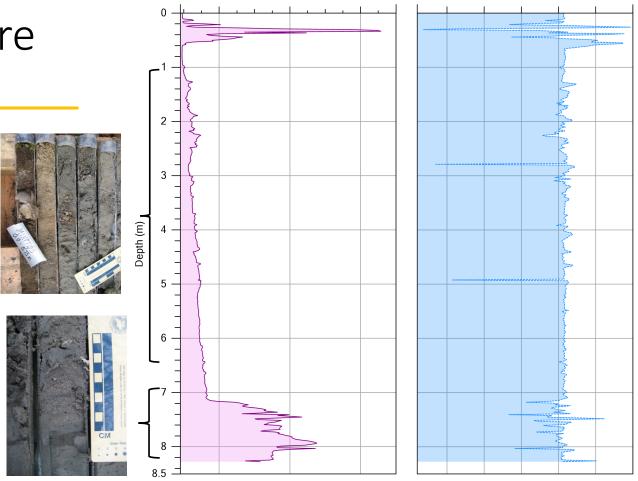




Correlating HPT Pressure to Soil Cores

Skuldelev SK05

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 Press. Avg (kPa)



HPT Flow Avg (mL/min)

700 110 150



HPT and Hydrostatic:

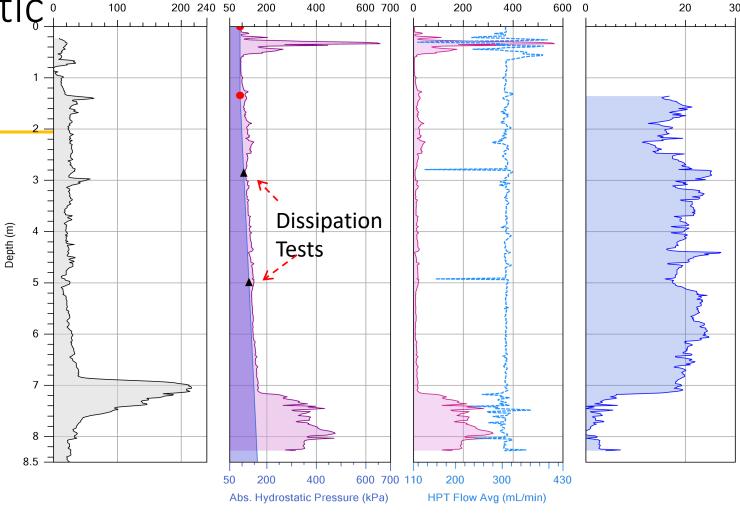
EC (mS/m)

- Corrected

Pressure - Est K

Skuldelev SK05

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.



Corr. HPT Press. (kPa)

HPT Press. Avg (kPa)



Est. K (m/day)



HPT and Hydrostatic:

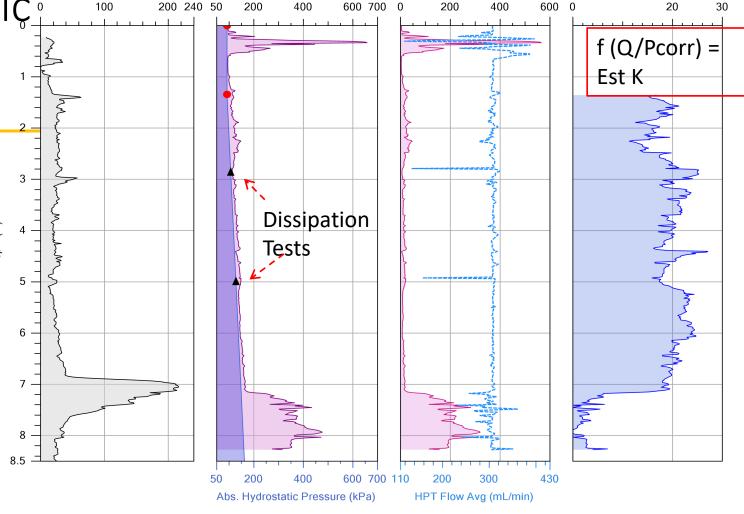
EC (mS/m)

- Corrected

Pressure - Est K

Skuldelev SK05

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.



Corr. HPT Press. (kPa)

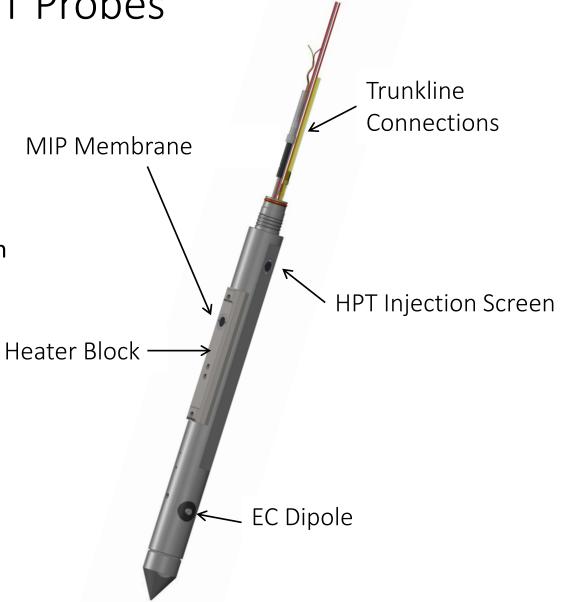
Est. K (m/day)

HPT Press. Avg (kPa)



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.







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.



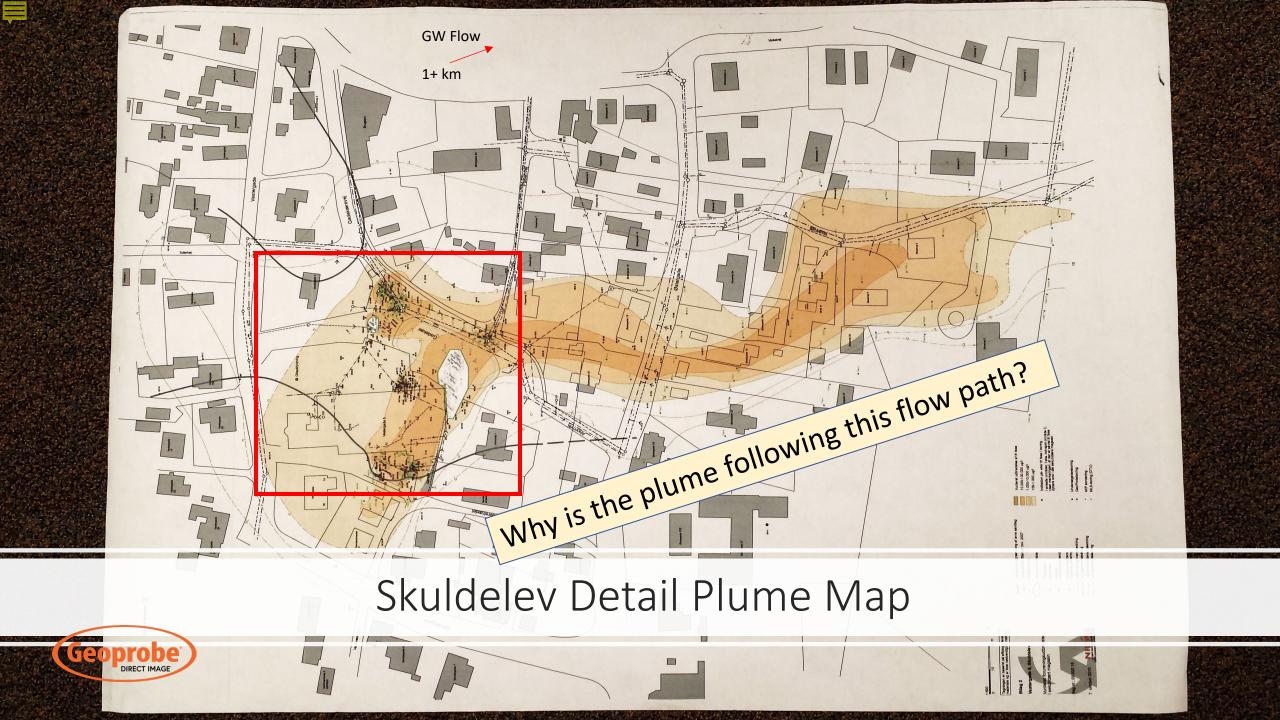




Skuldelev Geology

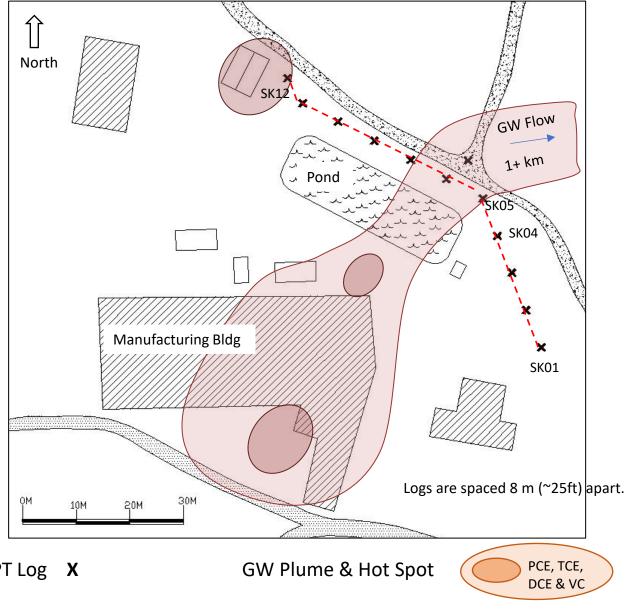


- Glaciated Region
- Site underlain by glacial till and related unconsolidated deposits



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.

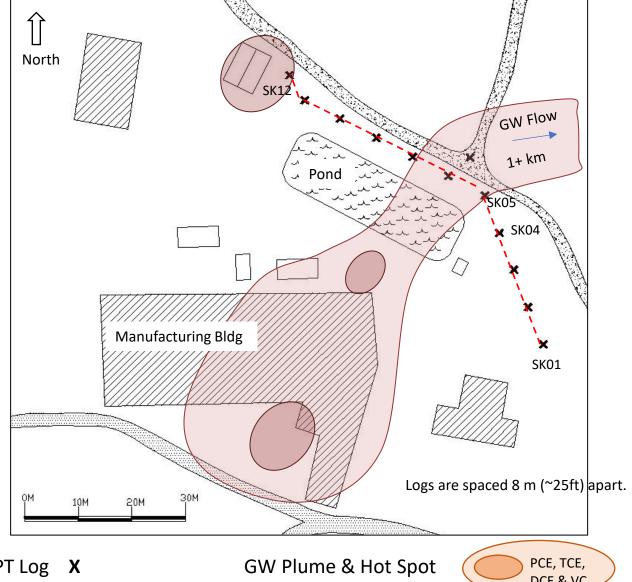




MIHPT Log X

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.



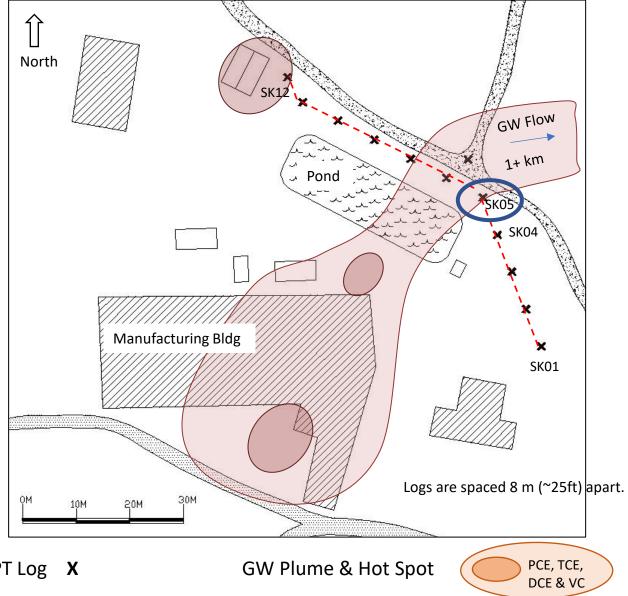


MIHPT Log X



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

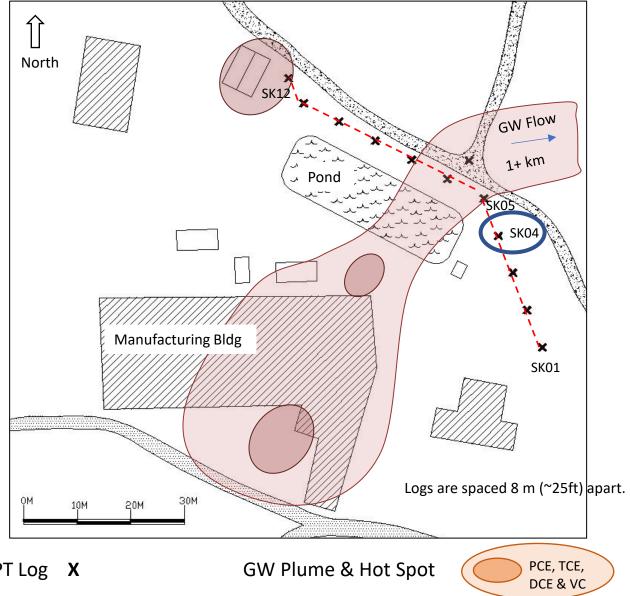




MIHPT Log X

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





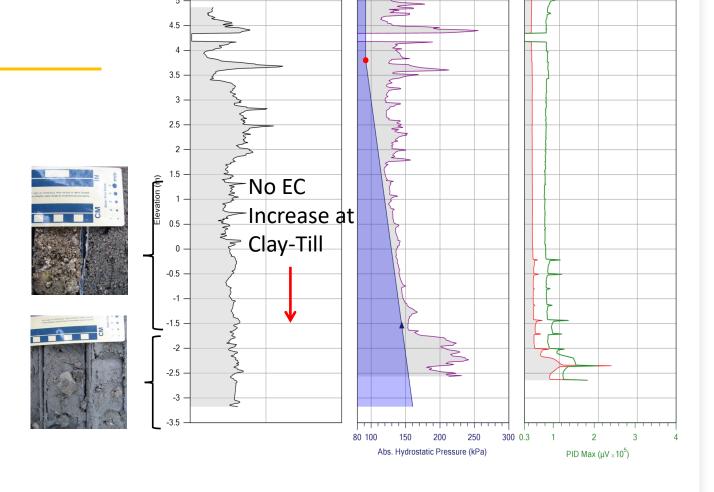
MIHPT Log X





Skuldelev SK04 Log Location

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?

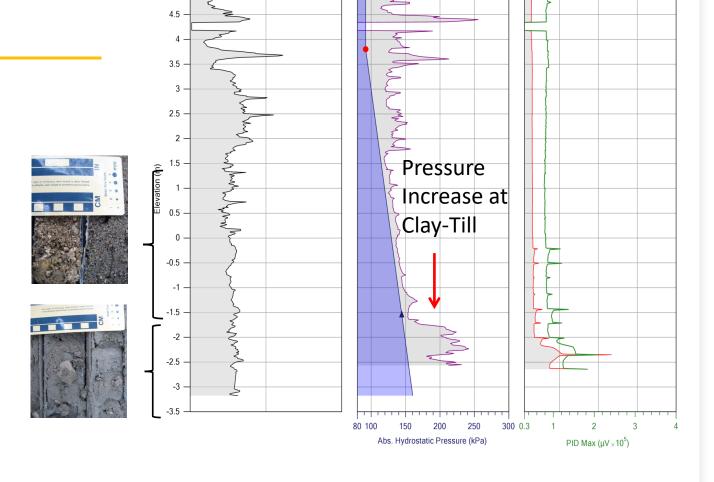






Skuldelev SK04 Log Location

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

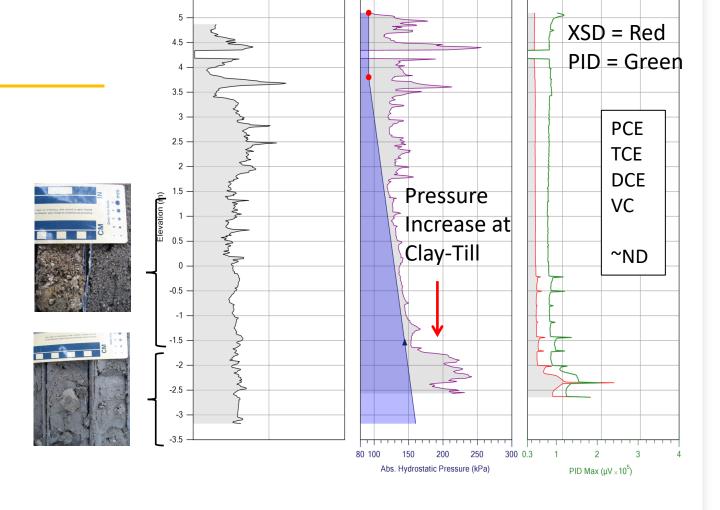






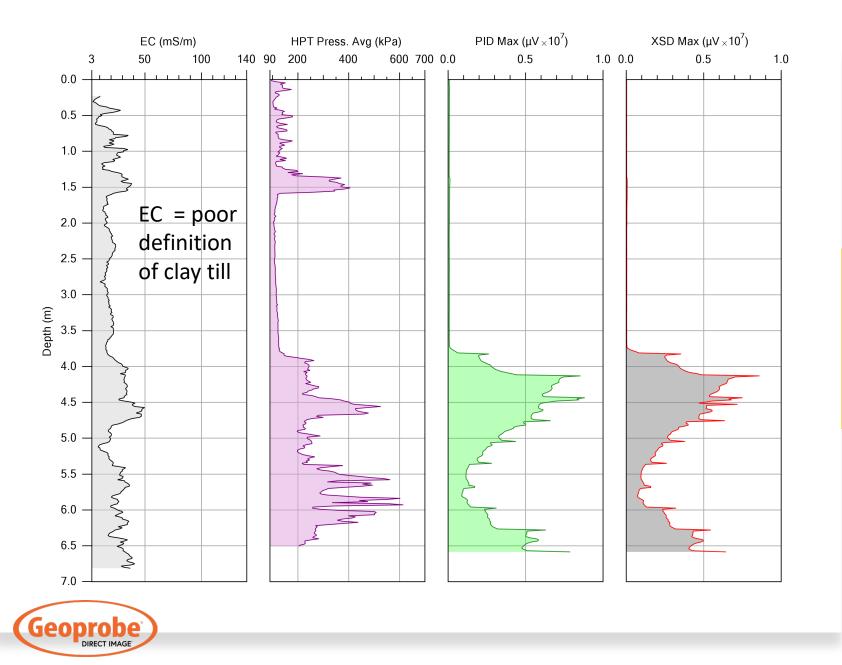
Skuldelev SK04 Log Location

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



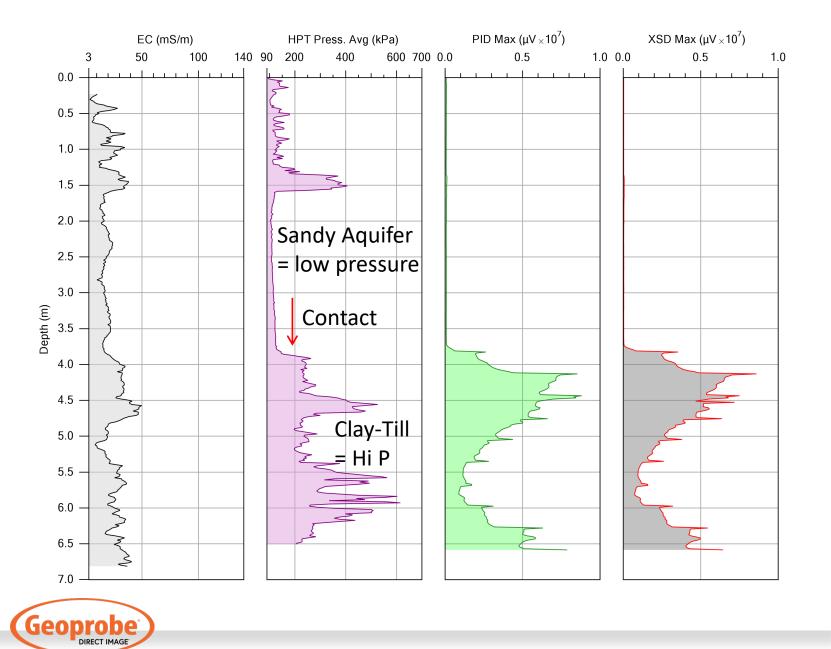






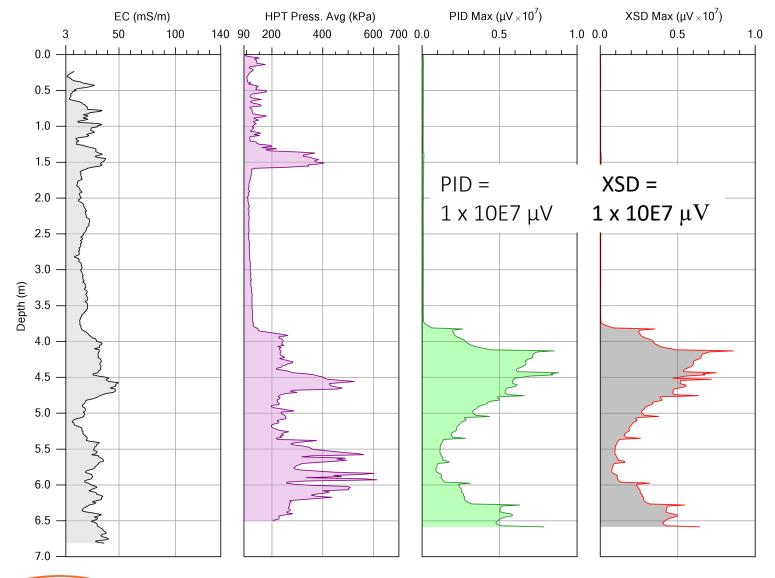
Example MIP Log: Skuldelev SK12





Example MIP Log: Skuldelev SK12





Example MIP Log: Skuldelev SK12

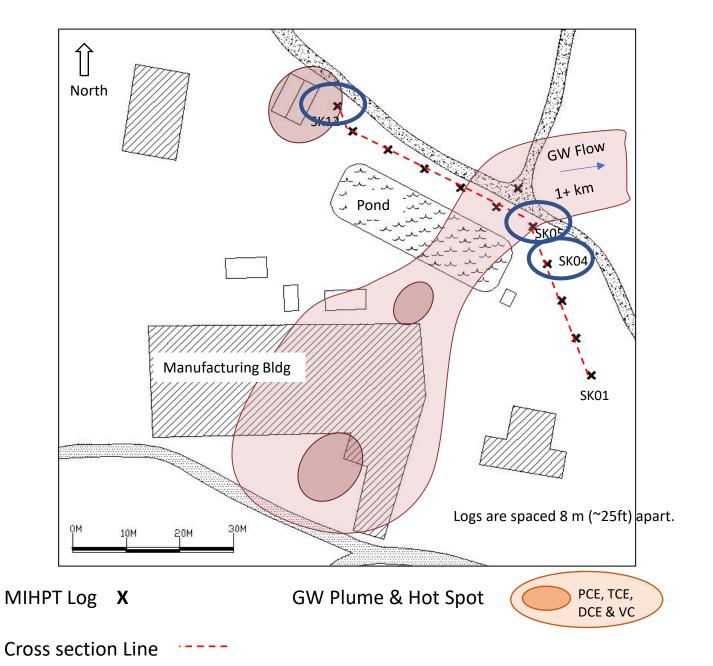
Notice that the detector responses are almost exclusively in the clay-till at this location. The detector responses are high, almost at the maximum of the detector range for both detectors.





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

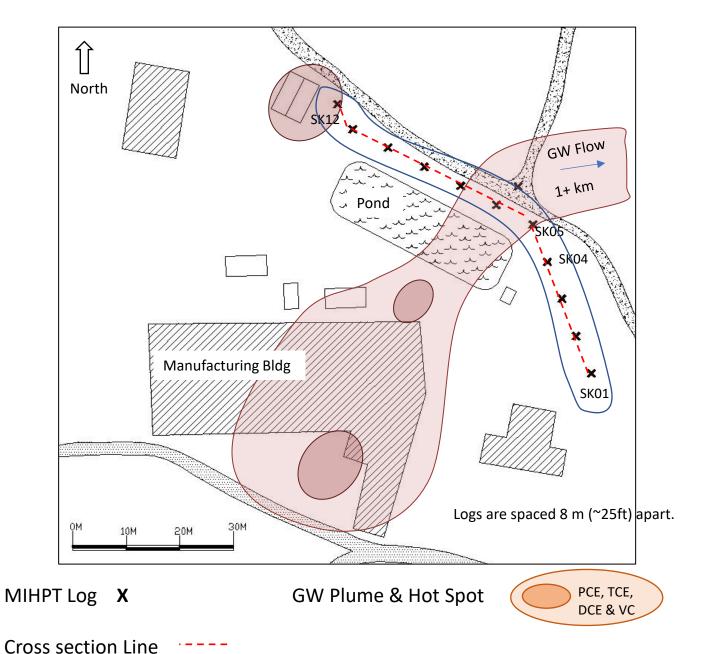






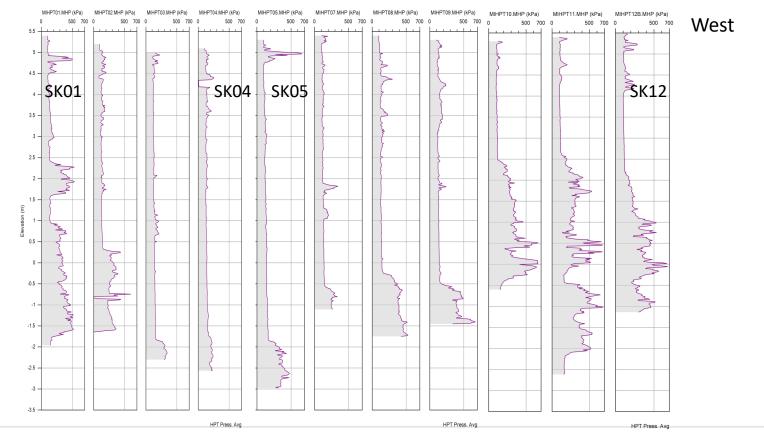
Now, let's look at a cross section of HPT pressure, looking from the northeast to the south west.











Skuldelev HPT Pressure Cross-section

(Elevation Corrected)

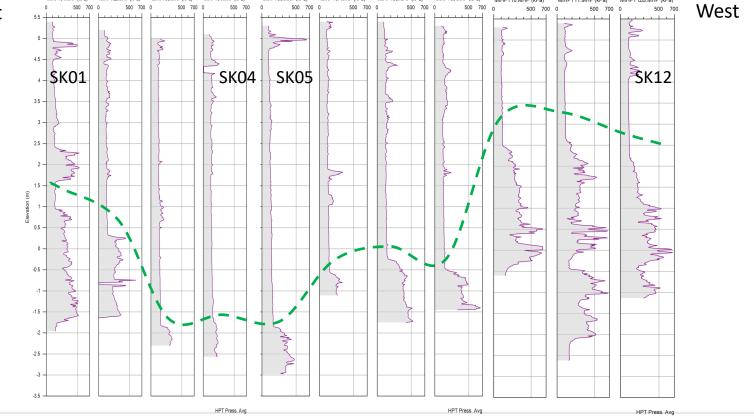
(Facing ~ Southwest)

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 Cross-section
(Elevation Corrected)

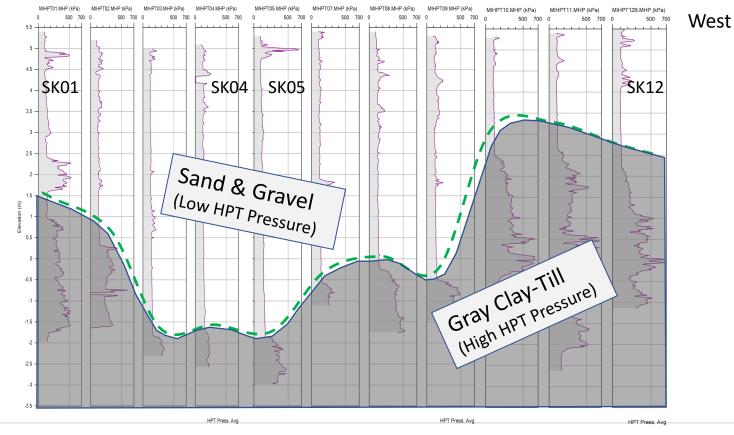
(Facing ~ Southwest)

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









(Facing ~ Southwest)

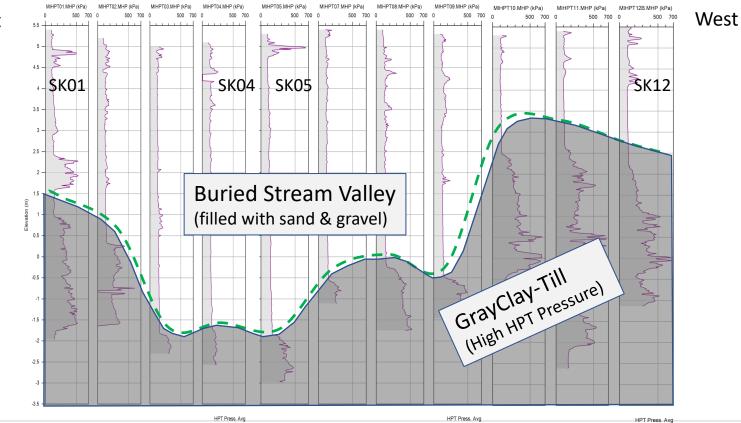
Skuldelev HPT
Pressure Cross-section
(Elevation Corrected)

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.





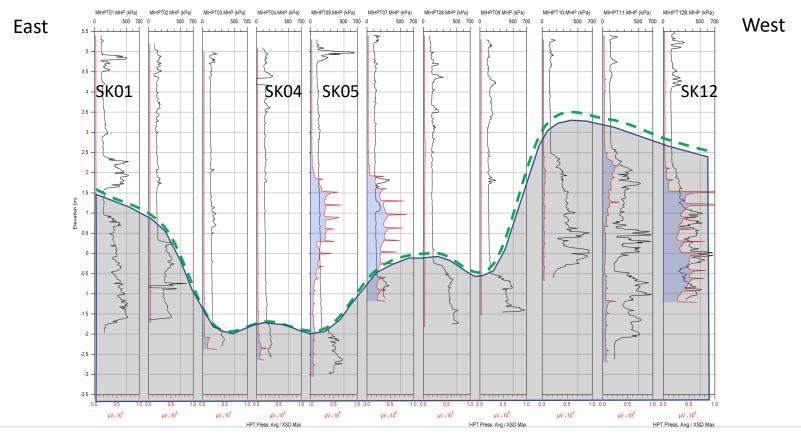




Skuldelev HPT Pressure Cross-section Hydrogeologic model = CSM

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).





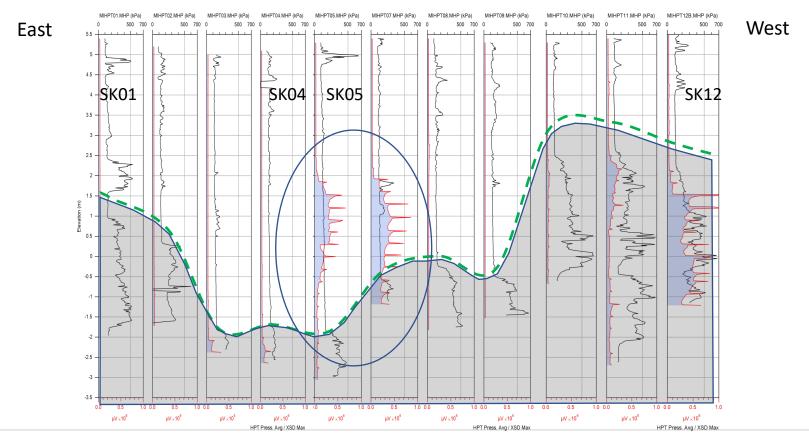
XSD (μV)

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.







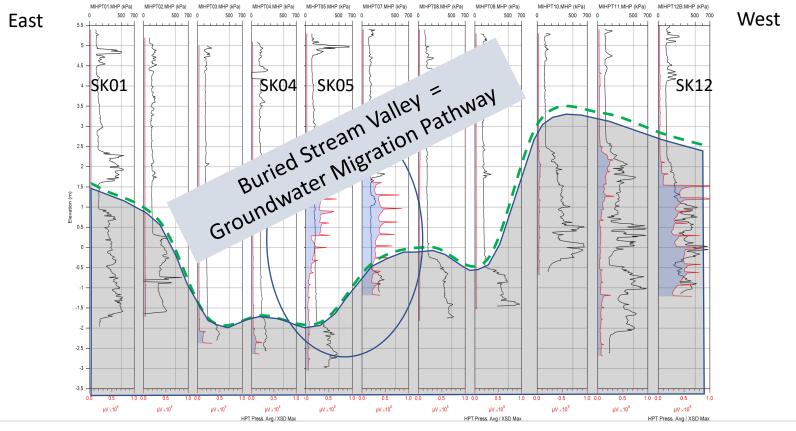
XSD (μV)

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.







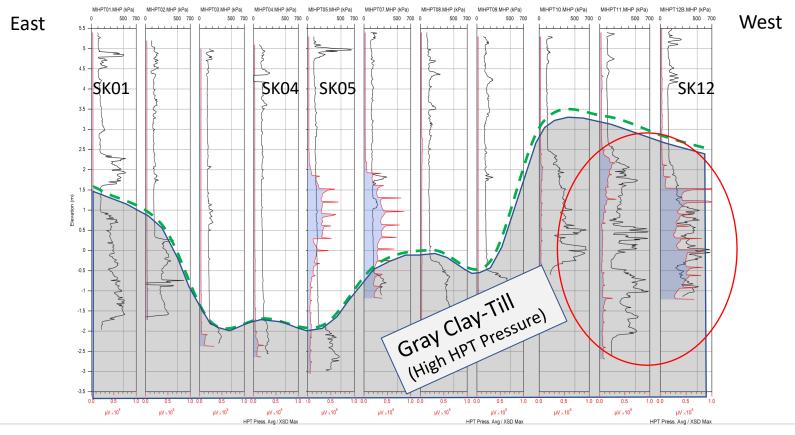
XSD (μV)

Skuldelev HPT Pressure and XSD Cross-section

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XSD (μV)

Skuldelev HPT Pressure and XSD Cross-section

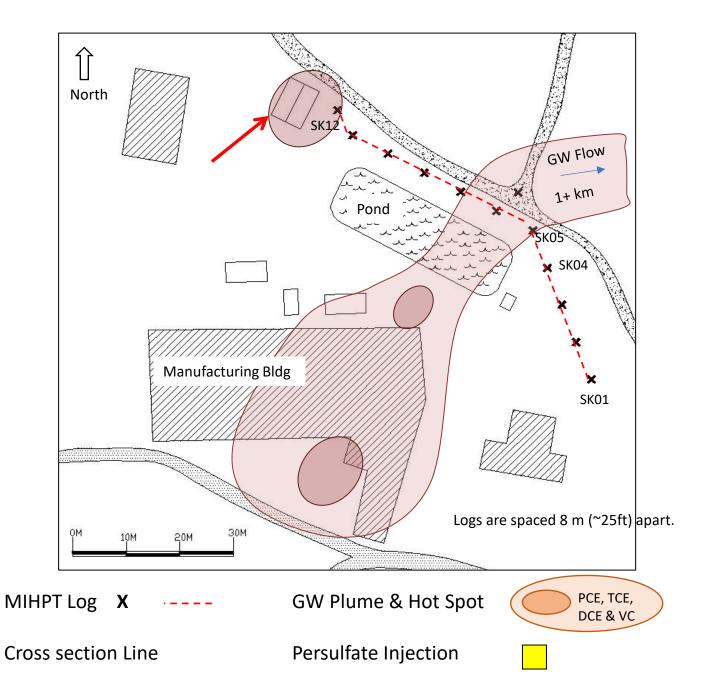
Over at the west end of the cross section (SK11 & SK12) CVOC contamination is present in the clay-till. This "hot spot" formed as the result of a sewer leak after solvents were disposed of in the facility sewer. It is not associated with the groundwater plume.





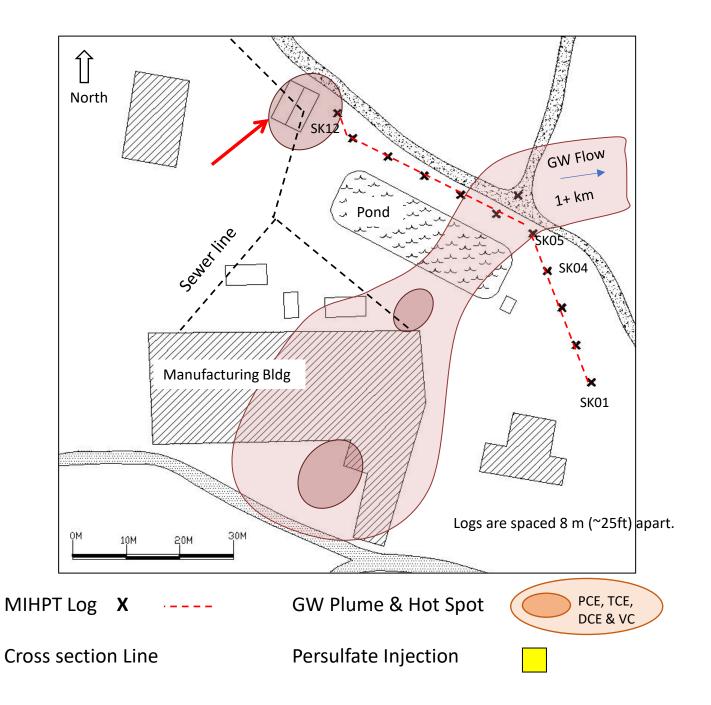
Here is the hot spot at SK12 shown on the map. (red arrow)





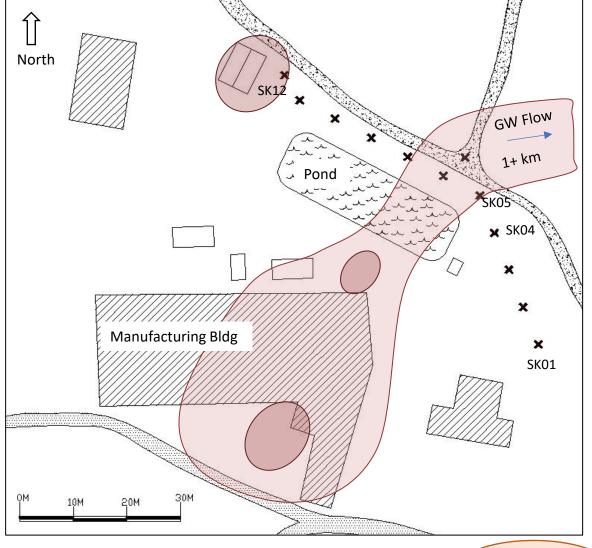
Here the sewer line juncture where the leak occurred that resulted in the hot spot at SK12 is shown on the map (red arrow). Sewer lines/back filled ditches led to vapor intrusion in some homes.





EC at this site did not differentiate between the clay-till and the sand & gravel





MIHPT Log X

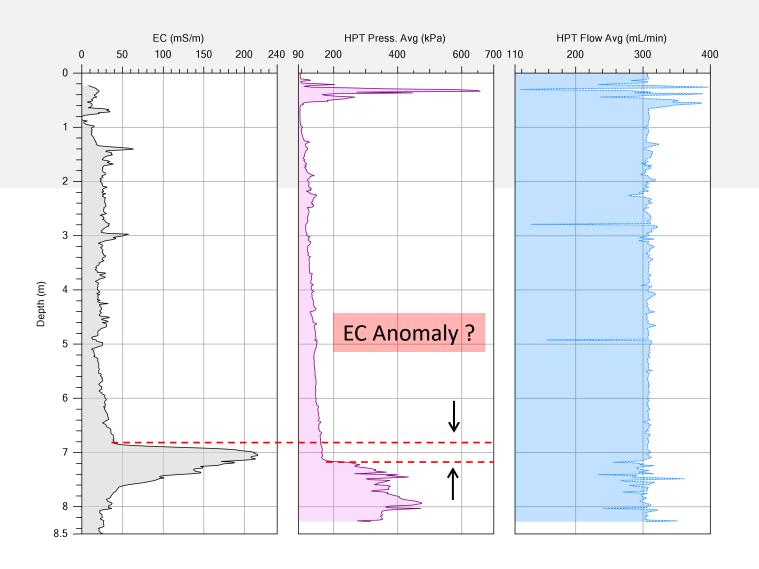
GW Plume & Hot Spot



Cross section Line



Example HPT Log: Skuldelev SK05



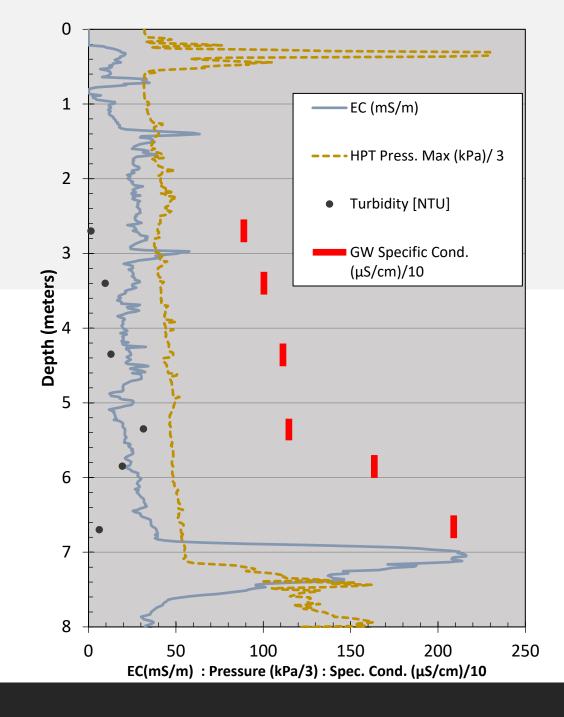




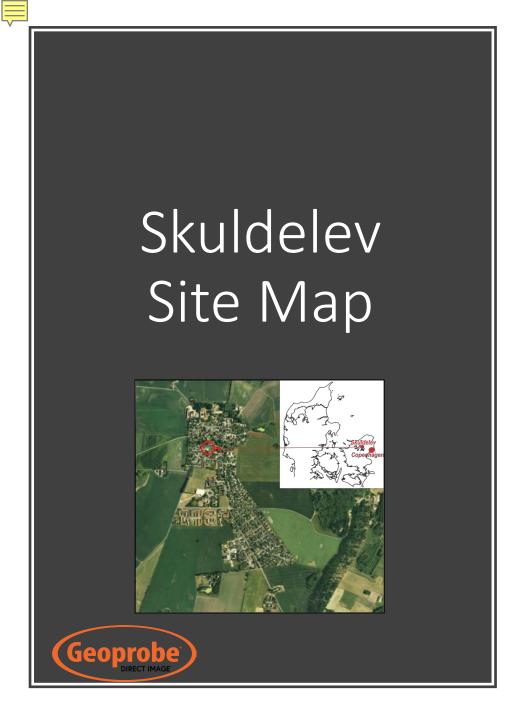
SK05 Location

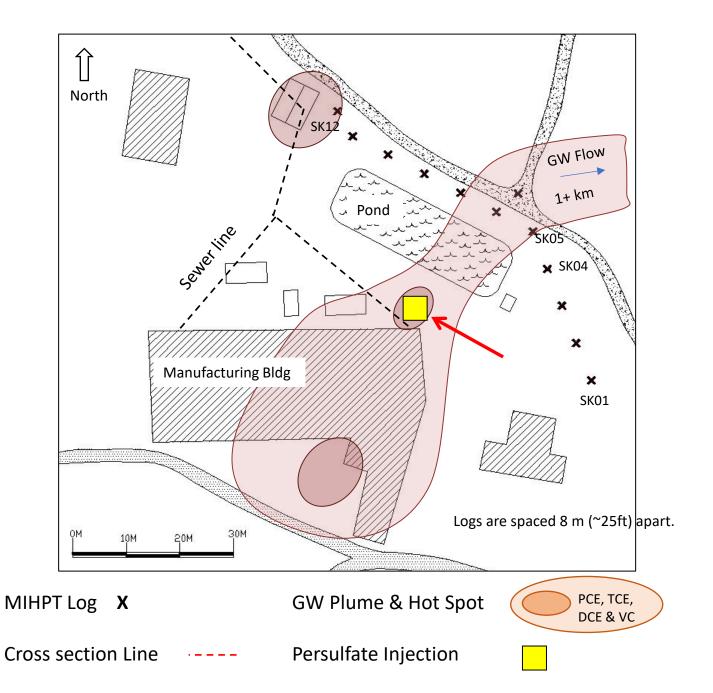
EC & HPT Pressure

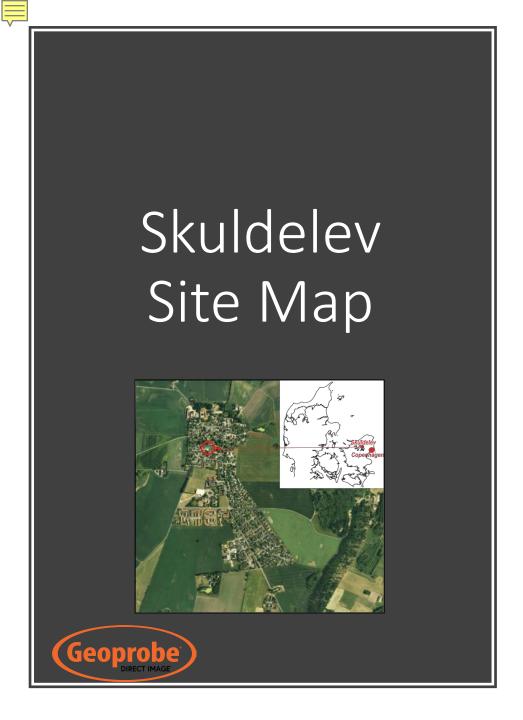
Groundwater specific conductance

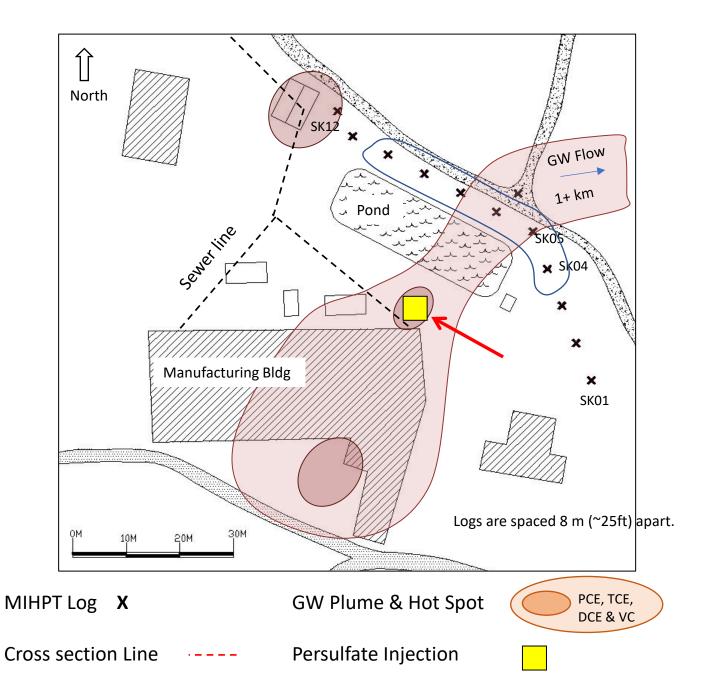








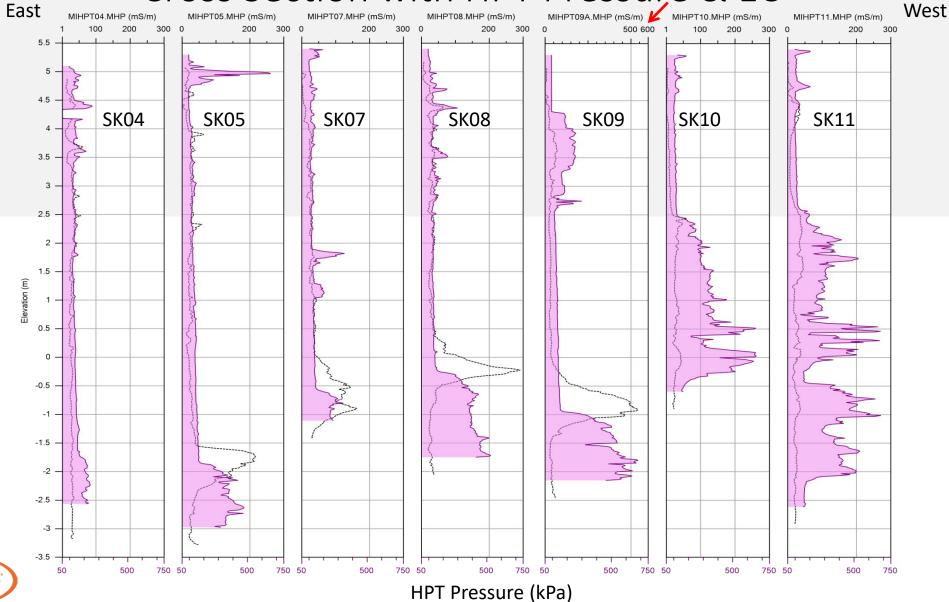






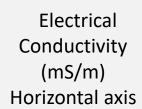
Cross Section with HPT Pressure & EC

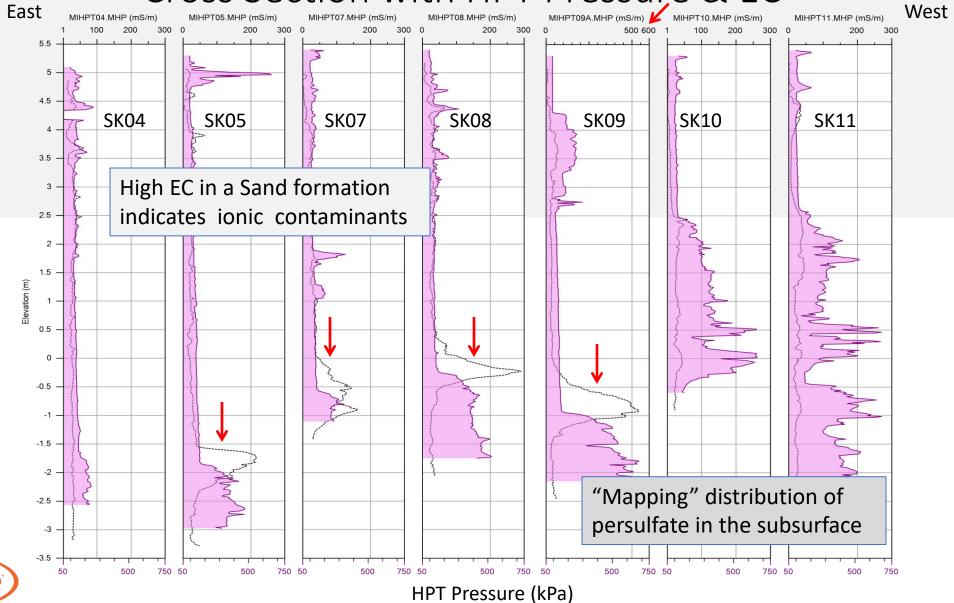
Electrical
Conductivity
(mS/m)
Horizontal axis



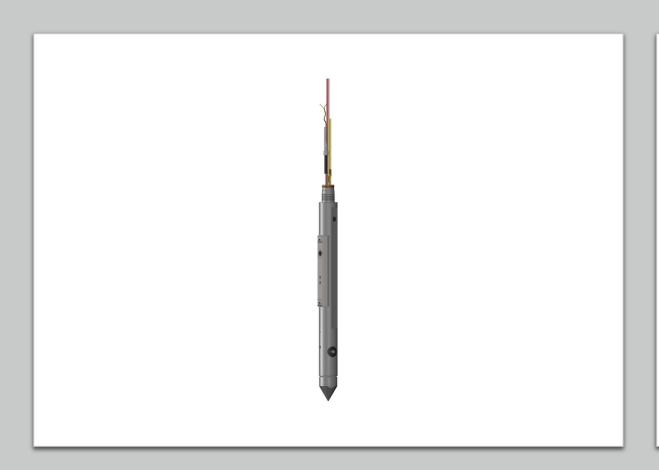


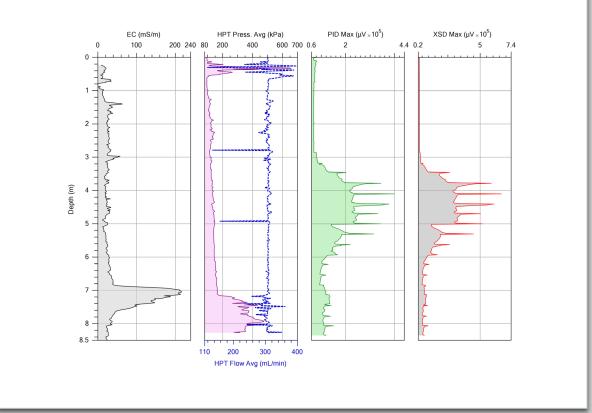
Cross Section with HPT Pressure & EC









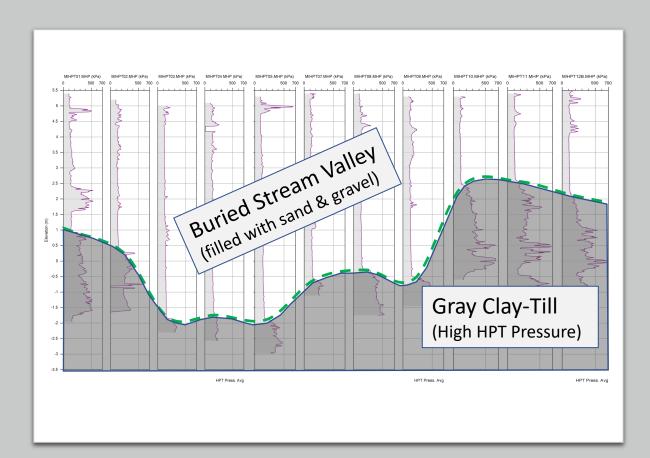


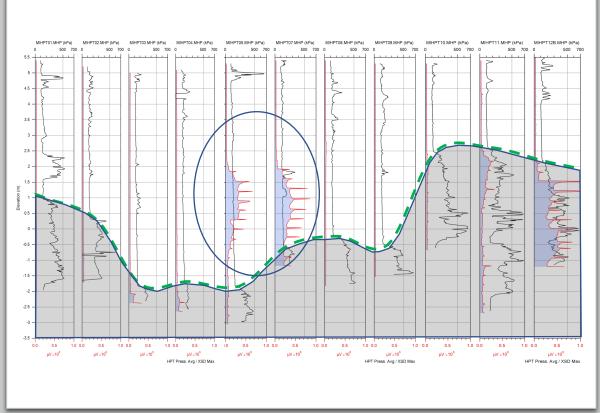
MIHPT Summary



Combined MIP + HPT Probe Simultaneously Provides:

- MIP Detector Logs (where is it ? how much?)
- HPT Pressure Log (lithology, hydrostartigraphy)
- EC log





MIHPT Summary

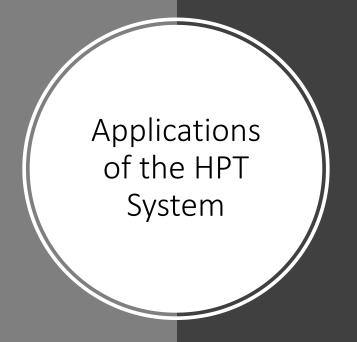
Cross Sections with HPT Pressure Logs Provide:

Lithologic information Hydrogeologic model for the site Geologic cross sections

Cross Sections with MIP Detector Logs and HPT Pressure Logs:

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





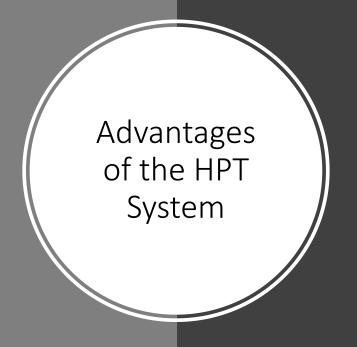
- Define lithology/hydrostratigraphy
- Qualitative estimation of permeability
- Contaminant migration pathways
- Guide selection of well screen intervals
- Guide injection of remediation fluids
- Estimation of hydraulic conductivity (K)
- Seawater intrusion/brine plume detection (with EC)
- Estimate of Specific Conductance





- Requires about 1 hour for 60ft log with 2-person team
- Pre- & Post Response test provide QA and ambient atmosphere pressure
- Dissipation tests provide hydrostatic pressure & SWL
- HPT probe is robust and hammering is possible
- System provides simultaneous EC log with HPT for independent confirmation of log results
- Targeted soil sampling is recommended
- Targeted slug testing is recommended for site specific confirmation of K estimates





- Probe can be hammered or pushed
- Sensitive to permeability
- Not sensitive to mineralogy or chloride concentration
- Simultaneous EC, P, and Q logs
- EC and HPT logs independently confirm each other
- Real time logs
- Field QA/QC checks for log verification
- Determine static water level





ASTM Practice D8037 Hydraulic Logging (HPT)

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Publication: MIHPT at the Skuldelev Site







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