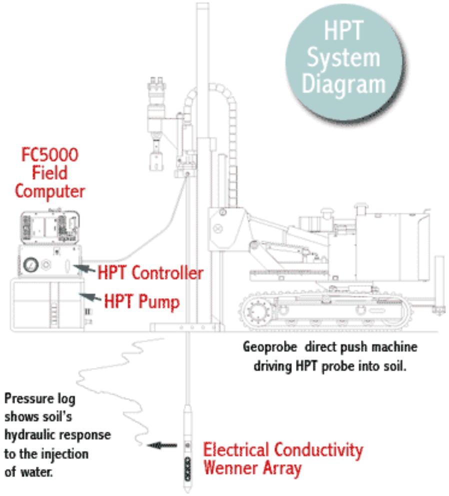
ZEBRA ENVIRONMENTAL
Always Looking Toward the Future
"Hydraulic Profiling Tool "

HPT System


Water Pump
Pre Strung Rods
HPT System
Generator


HPT System Diagram
FC5000 Field Computer
HPT Controller
HPT Pump
Geoprobe direct push machine driving HPT probe into soil.
Pressure log shows soil's hydraulic response to the injection of water.
Electrical Conductivity Wenner Array

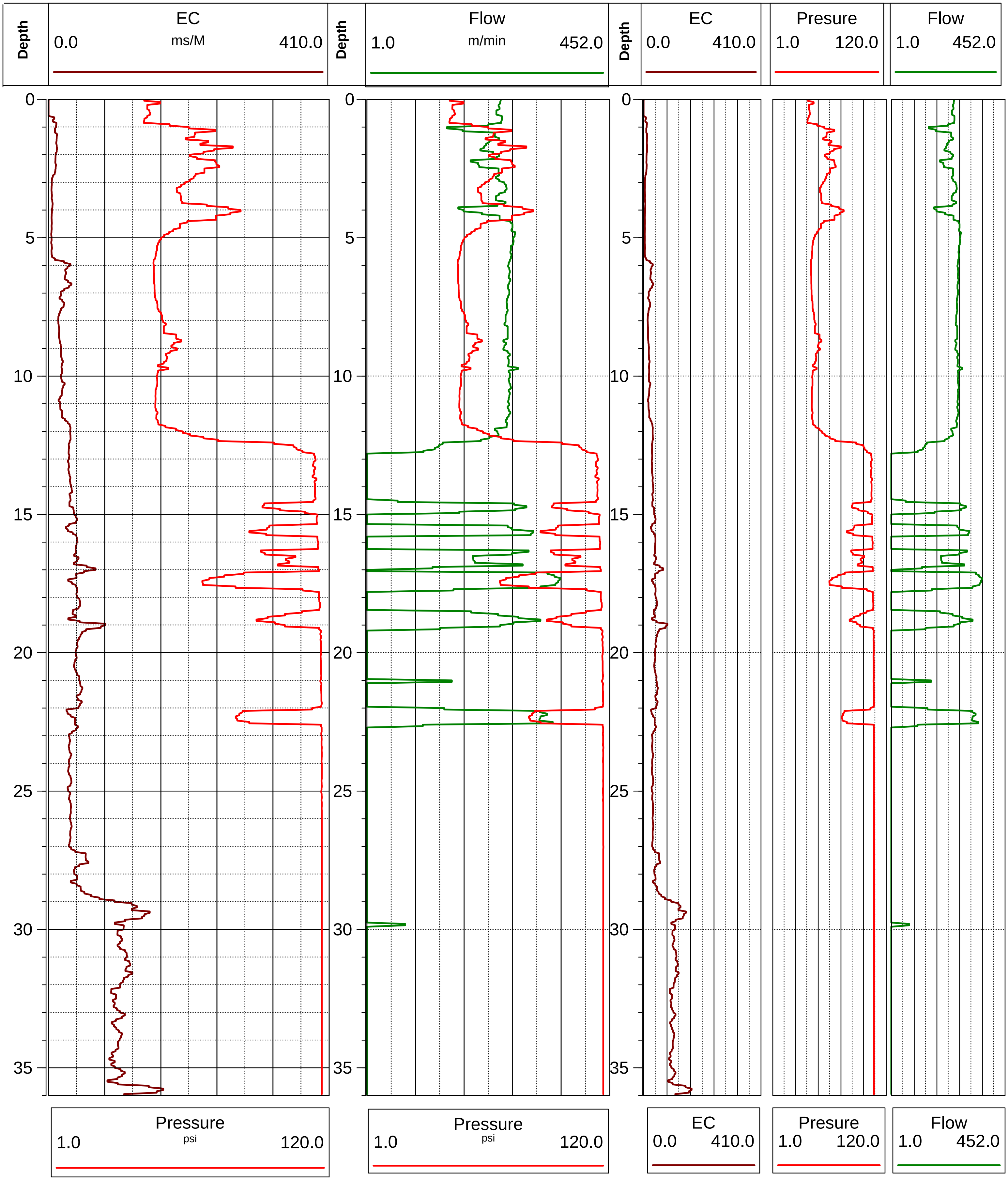

K6000 HPT Controller

ZEBRA ENVIRONMENTAL

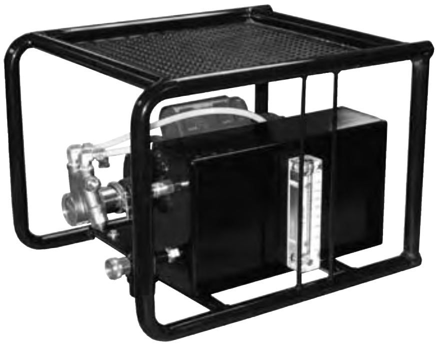
FOR XYZ

Zebra Defense Center HPT PROJECT

MIP Operator: **Walter Moore**
Point Name: HPT7
Total Depth: 36



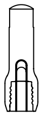
Field Computer (top), P/N FC5000
HPT Controller (bottom), P/N K6000



HPT Pump
(K6100)

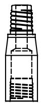
SC Probe Test Jig
(SC463)

Stringpot Cordset, 30-ft (9.1 m)
(SC161)

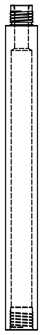


Slotted Drive Cap
(15607)

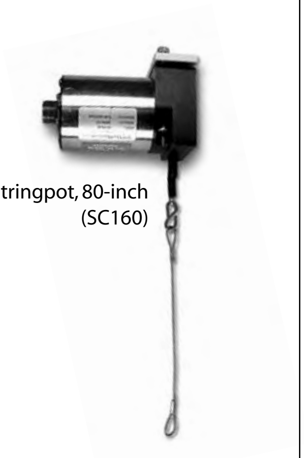
HPT Service Kit
(29028)



MIP Adapter and Drive Head
(20712)

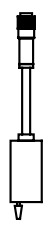


MIP-LB Connection Tube
(20712)



Stringpot, 80-inch
(SC160)

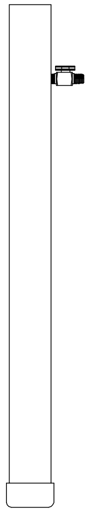
Membrane Wrench
(16172)



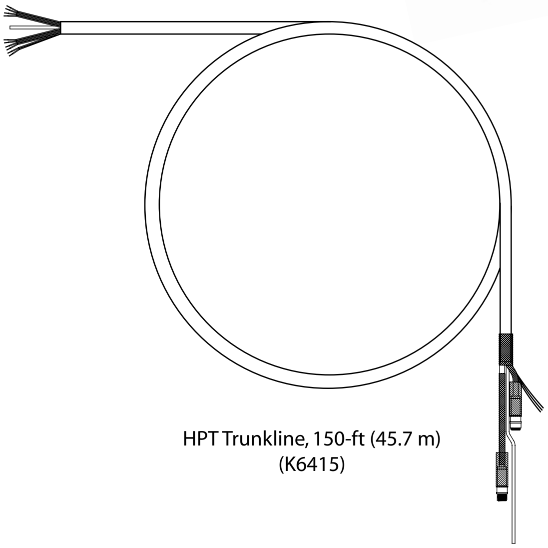
HPT Sensor
(28262)

HPT Screen
(28895)

HPT Shell Assembly
(K6050)



HPT Reference Tube
(29105)



HPT Trunkline, 150-ft (45.7 m)
(K6415)

Figure 3.1
HPT Parts and Accessories

Hydrostratigraphic Characterization using the Hydraulic Profiling Tool (HPT)

Steve Knobbe, Geoprobe Systems

Abstract

Rapid, accurate subsurface characterization is key to any site investigation. The Hydraulic Profiling Tool (HPT) allows a user to create fast, continuous, real-time profiles of soil hydraulic properties in both fine- and coarse-grained material. The HPT uses a sensitive downhole transducer to measure the pressure response of the soil to injection of water. Users advance the HPT probe and inject water at a constant rate (less than 300 mL/min) while automatically measuring the resulting formation pressure with depth. Static pressure measurements can also be made by stopping at discrete intervals, allowing users to determine static water level. Parameters are displayed and stored on a field computer for future analysis.

The HPT probe can either be pushed (static probing) or hammered (dynamic probing) into the subsurface. HPT data appears to correlate well with other investigation methods, including cone penetration testing (CPT) and electrical conductivity (EC).

The Hydraulic Profiling Tool has many field applications. One primary use of this new device will be to locate and define preferential migration pathways for contaminants in the subsurface. It can also be used to target zones for injection of remediation material. In addition, the HPT can be used to select well screen intervals, evaluate locations to conduct slug tests, and measure static water conditions across a site.

Introduction

Direct push technology allows scientists and engineers to quickly and efficiently characterize subsurface conditions in unconsolidated materials. Initially, direct push tools were designed to collect soil and soil vapor samples, but the tooling developed to include sensitive instrumentation that could make direct measurements of soil properties. CPT, a push-only probe that predates the development of percussion driven direct push sensing tools, is used to measure and evaluate the physical properties of soils. The percussion drivable direct push tools include electrical conductivity (EC), which measures the bulk electrical conductance of soil; membrane interface probe (MIP), which detects the presence of volatile compounds; and the hydraulic profiling tool (HPT). HPT is a new tool designed to evaluate the hydraulic properties of unconsolidated materials.

Operational Theory

As the probe is advanced at 2 cm/s, clean water is injected through a screen on the side of the HPT probe at a low flow rate, usually less than 300 mL/min (Figure 1). Injection pressure, which is monitored and plotted with depth, is an indication of the hydraulic properties of the soil. That is, a relatively low pressure response would indicate a relatively large grain size, and the ability to easily transmit water. A relatively high pressure response, however, would indicate a relatively small grain size, and the lack of ability to transmit water. The HPT system operates using principles very similar to those of Dietrich (2003).

Before and after the probe is used, data is collected to measure screen loss, which can be used during data reduction. This test is designed to ensure that the sensor is accurate and responding quickly, as well as to evaluate how much the screen has changed while advancing the probe.

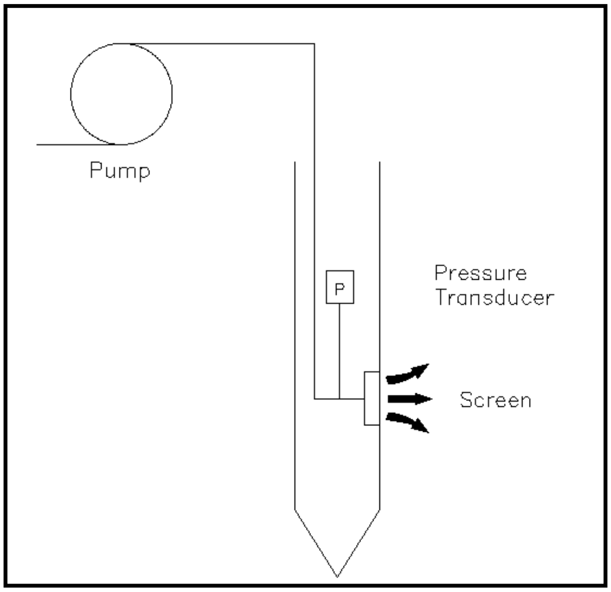


Figure 1. Schematic of HPT system. Water is pumped through a trunkline to the screen, and the resulting pressure is measured by a downhole transducer.

HPT Features

The HPT system features a downhole pressure transducer, which allows the user to quickly measure formation response and to accurately measure static water level. Static water level readings are made by advancing the probe to a layer below the static water level, stopping the probe advancement, and shutting off flow. Over time the excess pore pressures will dissipate, and the static water level can be calculated from the measured static pressure and probe depth. Typically, these measurements are taken in sands and gravels (with a relatively low HPT pressure response) where excess pore pressure dissipation takes seconds or minutes, instead of hours or days as in clays.

Integrated into the probe body is an electrical conductivity dipole. In general, electrical conductivity is inversely proportional to grain size; that is, a low EC value corresponds to a larger grain size, while a high EC value corresponds to a smaller grain size. It is important to note that other factors can affect electrical conductivity values, such as mineralogy and pore water conductivity (Christy, 1994).

Electrical conductivity compliments the HPT transducer measurements. If the EC and pressure measurements disagree, the user can note this and take a discrete soil sample to determine why there is a difference in the two profiles. For instance, advancing through sand typically results in a low EC value and a low HPT pressure. However, if the sand pore spaces contain brine, the EC value will be increase while the HPT pressure remains low.

All data is recorded and displayed in real-time, which allows the site investigator to make dynamic sampling and probing decisions in the field.

Advantages and Limitations

The primary advantage of the HPT system is that the probe can be hammered to depth, despite housing a sensitive downhole pressure transducer. In addition, the components required to control and convey water through the probe are modular and easily transported.

Only soil conditions and the downhole pressure transducer limit the HPT system. Since direct push equipment can only advance through unconsolidated materials, the probe is limited to clays, silts, sands and some gravels. The downhole pressure transducer can be used to a maximum theoretical depth of 60 m (200 ft) below groundwater, but in practice the 700 kPa (100 psi) transducer may be limited to 36 m (120 ft) below groundwater, depending on the hydraulic properties of the soil. This issue can be resolved by installing a higher-pressure transducer.

Potential Uses

Since the Hydraulic Profiling Tool can be used to characterize the hydraulic and electrical nature of a site quickly, it is ideal for determining the location and nature of additional sampling. For instance, a disparity between electrical conductivity and injection pressure may result in the collection of a discrete soil or water sample. HPT may also be used to direct slug testing to determine actual hydraulic conductivity values, to locate zones of relatively high permeability for the injection of remedial materials, and to locate potential contaminant migration pathways. Also, since the pressure transducer is located downhole, the HPT system allows a user to determine not only static water levels, but also whether an aquifer is confined or unconfined.

HPT System Components

There are five primary components to the HPT system: the probe assembly, controller, pump, trunkline, and field computer. The probe assembly consists of the section that houses the pressure transducer and water and electrical connections, as well as the probe body (Figure 2) with the injection screen and electrical conductivity dipole.

Injecting water at a constant rate is integral to system operation. A controller box (Figure 3) houses components that monitor and regulate the water injection rate and pressure, as well as pressure transducer signal conditioning electronics. Flow rate is set manually using a knob on the front of the unit, and a valve is present to turn on or shut off flow.

A vane pump (Figure 4) increases system pressure by approximately 620 kPa (90 psi), ensuring adequate flow to the screen. The pump is secured to a frame with an integrated visual flow meter, and connects to the controller using a simple hose with quick connect fittings on each end. Any garden hose can be used to supply the pump.

Figure 2. HPT Probe. A small injection screen is located near the top of the probe, and an electrical conductivity dipole is located near the tip.

Figure 3. HPT Controller and Field Computer. The controller regulates and monitors water injection, while the required parameters are displayed and saved on the field computer.

Water and power are transmitted from the controller to the probe assembly via a trunkline. The trunkline has a nominal diameter of 1.27 cm (0.50 in), which allows it to easily fit within 3.81 cm OD (1.59 cm ID) [1.5 in OD (0.625 in ID)] probe rods. The probe rods must be pre-strung with the trunkline before advancing the probe.

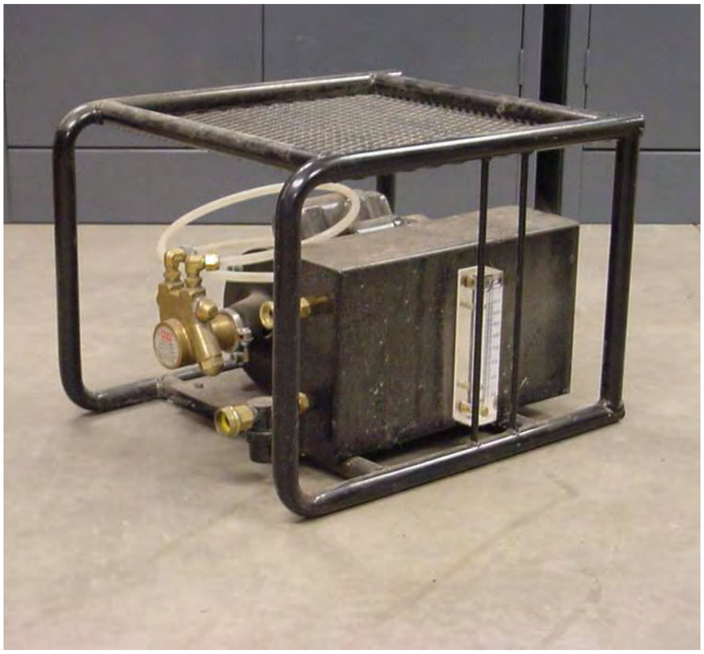


Figure 4. HPT Pump. System pressure is increased to maintain flow to the probe.

Data collection occurs in real time by connecting the controller to the field computer. The field computer collects, stores and displays transducer pressure, flow rate and electrical conductivity, the sensor parameters, and line pressure and probe rate, the diagnostic parameters, with depth.

Field Data and Data Comparison

Four sets of field data are presented in the following sections. The first site, located in Lawrence, KS, compares HPT/EC data to hydraulic conductivity values derived from slug tests. Two additional sites, located in Salina, KS, consist of HPT/EC logs and CPT data. HPT logs and static water level data are presented for the fourth site, located in northern Wisconsin.

Lawrence, KS

HPT data (Figure 5) was collected at the Geohydrologic Experimental and Monitoring Site (GEMS) operated by the Kansas Geological Survey in Lawrence, KS, which is located in the Kansas River floodplain. The upper 11.3 m (37 ft) is primarily silts and clays, with a sand layer at 7.6 m (25 ft). Sands and gravels are predominant between 11.3 and 20.7 m (37 – 68 ft), but minor fines are present.

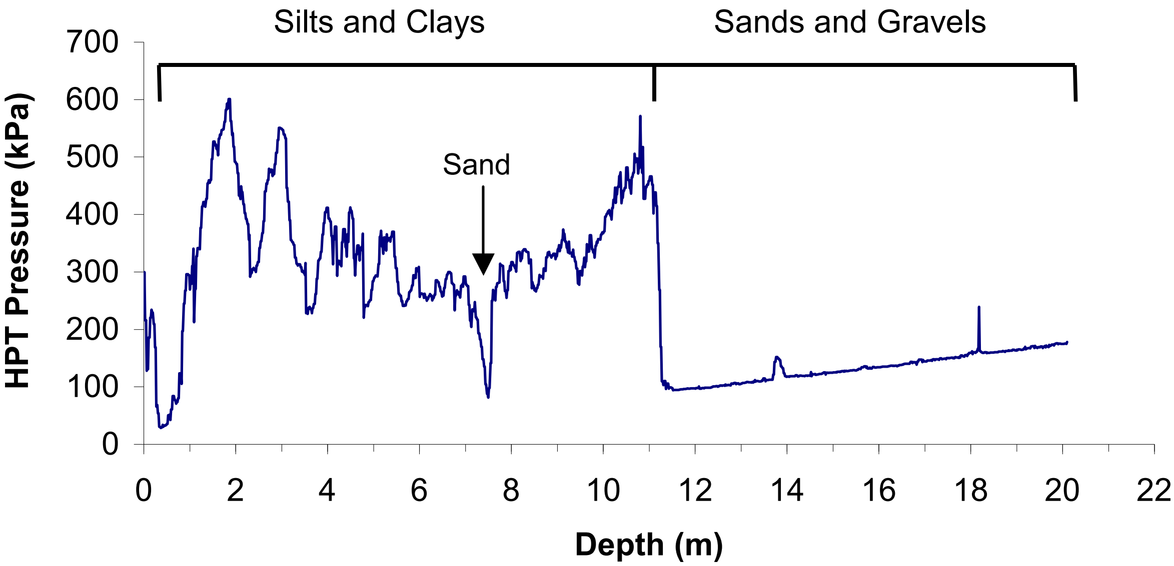


Figure 5. Lawrence, KS. HPT Pressure and Hydraulic Conductivity Profiles. The HPT profile is plotted, and general soil types are outlined.

The hydrostatic line is clearly visible in the sands and gravels, as noted by the increasing pressure trend in the HPT raw data plot. In this profile, the pressure increase in the sands and gravels over hydrostatic was 19 to 107 kPa (2.8 – 16 psi), silts ranged from 107 to 345 kPa (16 – 50 psi), and clays had a pressure response greater than 345 kPa (50 psi).

Hydraulic conductivity values, previously measured at the site using slug tests, ranged from 7.6 to 240 m/day (25 – 780 ft/day) between 12.2 and 20.1 m (40 – 66 ft) (Sellwood, 2005). The low HPT pressure response in this zone is indicative of these very high K-values, which is in contrast to the relatively high HPT pressure responses and lower hydraulic conductivity values in the upper silt and clay zone.

Geoprobe Systems, Salina, KS

This site, located in the Smoky Hill River floodplain, consists of about 10.7 m (35 ft) of silts and clays overlying about 9.1 m (30 ft) of sands and gravels with some fines. Shale bedrock is located at about 19.8 m (65 ft). A CPT log and a HPT/EC log (Figure 6) were run in close proximity. At this location, the HPT and EC logs both closely mimic each other. A visual evaluation of CPT friction ratio data indicates a correlation to HPT and EC data.

North St. Farm, Salina, KS

Located only 0.8 km (0.5 mi) from the Geoprobe Systems site, the North St. Farm site has very similar geology. The upper 11.6 m (38 ft) consists of silts and clays, and is underlain by sands and gravels. The HPT/EC probe was easily pushed through the most of the upper silts and clays without anchoring the probing machine, but hammering was required to probe through the sands and gravels down to approximately 18.3 m (60 ft). A CPT log was generated at this location as well. The probing machine was anchored 1.5 m (5 ft) into the soil, and the cone was pushed to approximately 13.7 m (45 ft). At this point, the soil around the anchors failed, so probing was ended.

Visually, the HPT and EC logs (Figure 7) correlate to each other in the silts and clays, but correlate better in the sands and gravels. The exception is the apparent low hydraulic conductivity layer at about 16.9 m (55.5 ft). The magnitude of the response of this layer is much higher with the HPT log than the EC log. The CPT friction ratio profile, although the cone was not pushed as deep as the HPT probe, does generally agree with the HPT/EC logs.

Iron River, WI

Located at a fish hatchery, this site consists of silts and clays to about 10.7 – 12.2 m (35 – 40 ft), underlain by sands and gravels. Two logs are presented (Figure 8). The HPT probe was stopped and static water levels were recorded approximately every

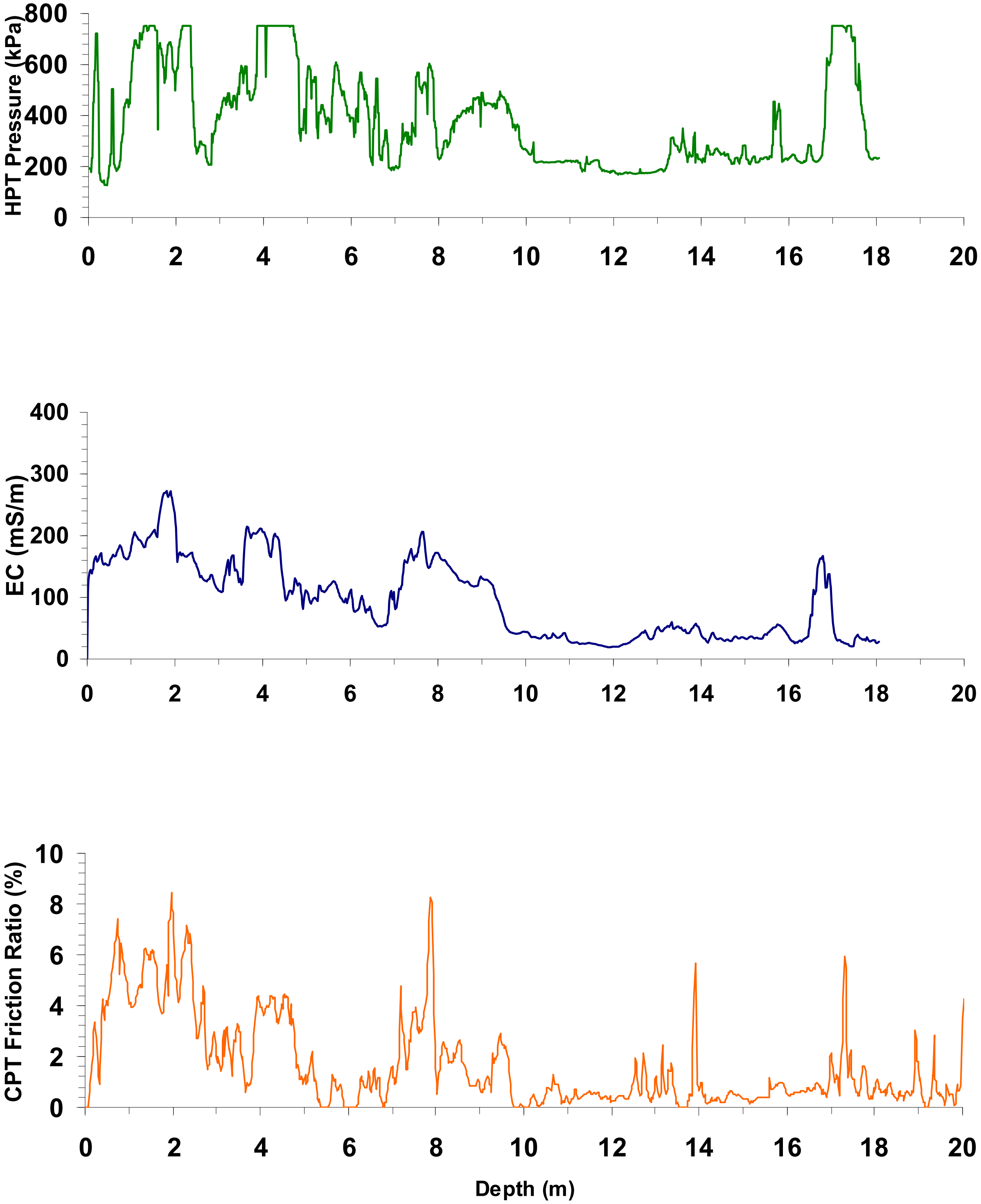


Figure 6. Geoprobe Systems, Salina, KS. HPT pressure, electrical conductivity and CPT friction ratio data.

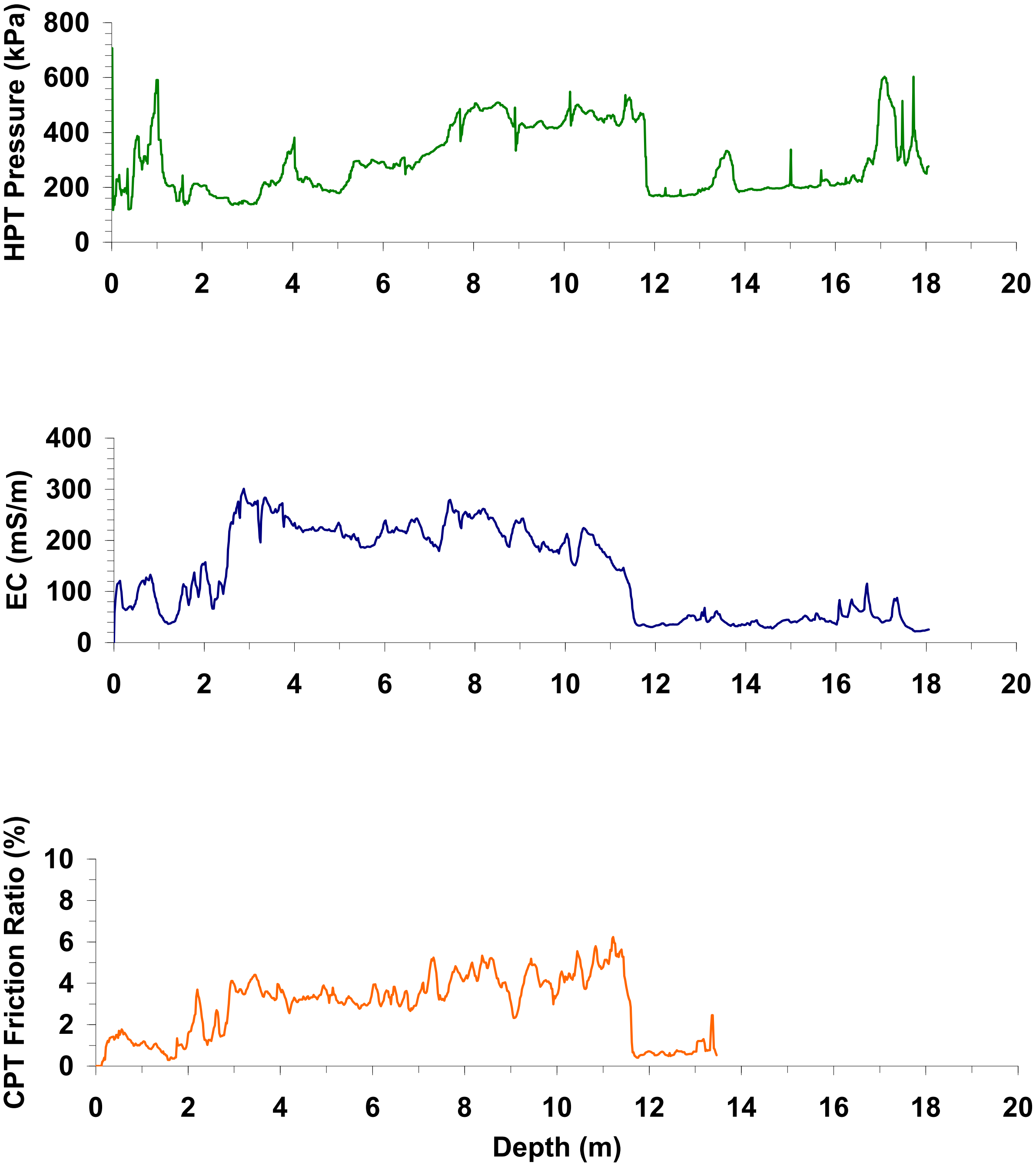
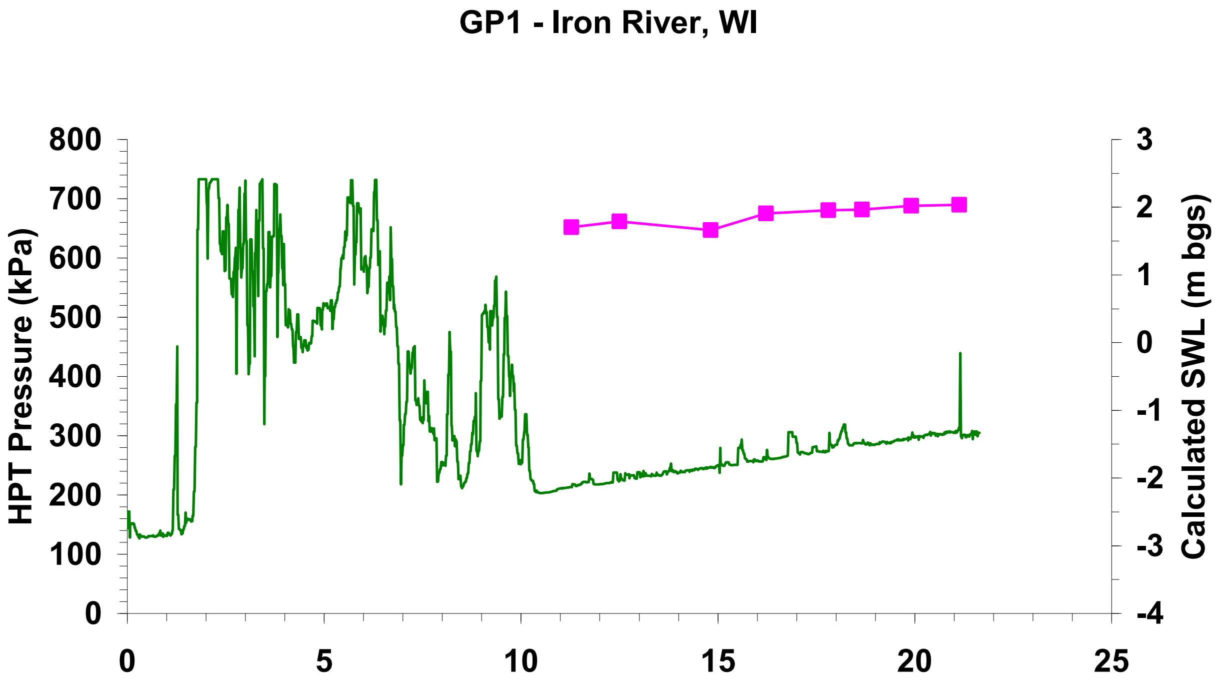


Figure 7. North St. Farm, Salina, KS. HPT pressure, electrical conductivity and CPT friction ratio data.


GP1 - Iron River, WI

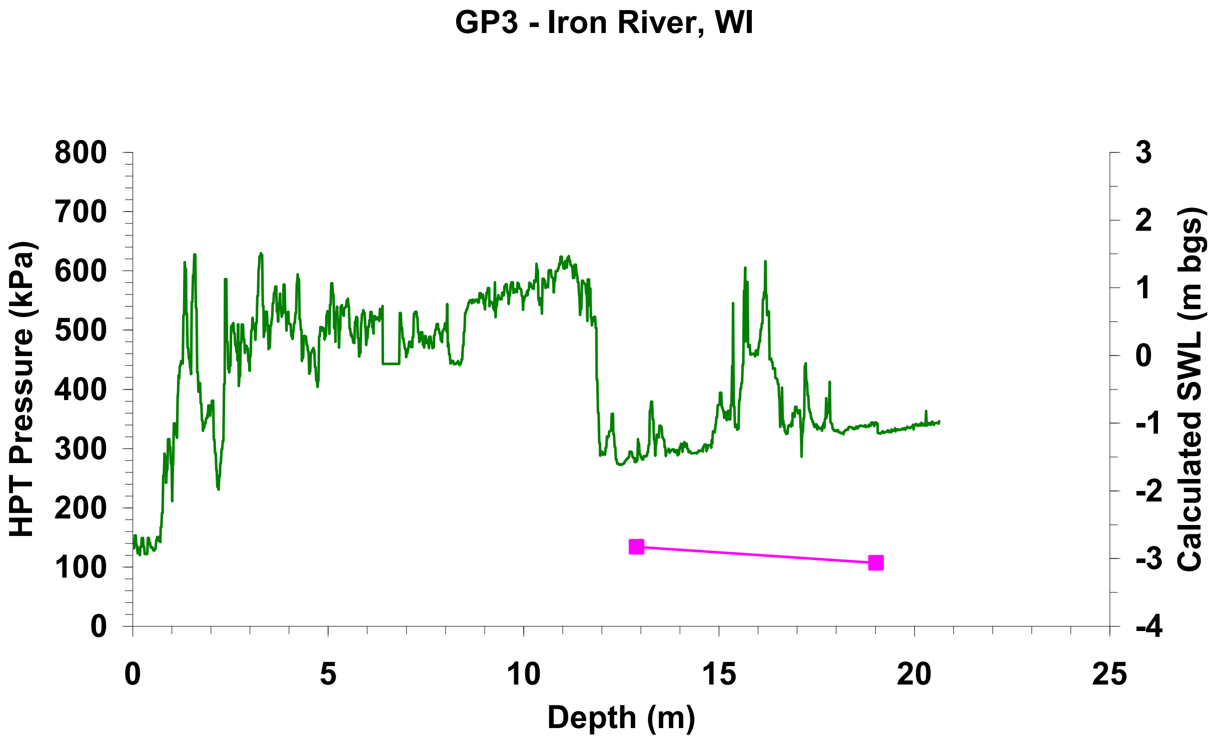

GP3 - Iron River, WI

Figure 8. Iron River, Wisconsin. HPT pressure and calculated static water levels.

meter in the sand and gravel layer, which showed that the water level was about 1.8 m (6 ft) below ground surface. However, static water levels recorded at location GP3 showed that the piezometric level was approximately 2.9 m (9.5 ft) above ground surface.

Summary

The hydraulic profiling tool creates a continuous profile of injection pressure with depth, which allows a user to evaluate soil hydraulic properties. In addition, it can make static water level measurements and examine the electrical conductivity of the soil. The probe can be used to quickly evaluate subsurface conditions, which is useful for directing other sampling or remedial programs.

Biographical Sketch

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Mr. Knobbe is a research and development engineer with Geoprobe Systems in Salina, Kansas. There he is a member of the Direct Image group, specializing in innovative methods for the direct measurement of soil properties. He earned his BS and MS degrees in Geological Engineering from the University of Missouri – Rolla.

References

Christy, C.D., T.M. Christy, and V. Wittig. 1994. A percussion probing tool for the direct sensing of soil conductivity. In *Proceedings of the Eighth Annual National Outdoor Action Conference and Exposition on Aquifer Remediation, Ground Water Monitoring, and Geophysical Methods*, May 23–25, Minneapolis, Minnesota, 381–394. Dublin, Ohio: National Ground Water Association.

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Sellwood, S.M., Healey, J.M., Birk, S., Butler, J.J., 2005, Direct-Push Hydrostratigraphic Profiling: Coupling Electrical Logging and Slug Tests, Ground Water, Vol. 43, No. 1, pp. 19 – 29.