Borehole HRSC tools

Shallow (unconsolidated)	Detects	How it works	Limitations
CPT (Cone Penetrometer Technology)	grain size, unconsolidated vs bedrock, hydraulic head	Screening level tool for geology -- CPT uses two strain gauges in a tip that is pushed into the subsurface using hydraulic downpressure in a large heavy truck. The ratio of the tip resistance to the sleeve resistance is commonly used to interpret a “soil behavior type”. CPT can also provide pore pressure (hydraulic head) data and through pressure dissipation tests can provide hydraulic conductivity measurements at selected intervals in the hole.	Refusal in bedrock and rocky formations. Limited depth of penetration because the tool cannot be used with a hydraulic hammer (<100').
HPT (Hydraulic Profiling Tool)	hydraulic conductivity, collect water samples	The HPT pumps water at a constant rate (about 200 – 300 mL/minute) and measures the pressure required to maintain the flow using a down hole pressure sensor. As the tool is advanced, clean water is injected into the formation while depth, pressure, and flow rate are monitored. From these data, a real-time continuous log of the Index of Hydraulic Conductivity is calculated. The HPT-GWS (groundwater sampler) can also collect water samples. Note: it may not be able to collect samples in low permeability zones.	K measurenent not effective in coarse sediment. GWS not effective in tight clays or crystalline rock.
Waterloo-APS (Advanced Profiling System)	hydraulic conductivity, collect water samples	As the tool is advanced, clean water is injected into the formation while depth, pressure, and flow rate are monitored. From these data, a real-time continuous log of the Index of Hydraulic Conductivity is calculated. WaterlooAPS can be used to collect water samples in the same push as hydraulic conductivity information. Groundwater samples are pumped from the stainless steel screened tip to the surface for analysis.	K measurenent not effective in coarse sediment. GWS not effective in tight clays or crystalline rock.
MIP (Membrane Interface Probe)	VOCs/CVOCs, hydrocarbons (see FID, PID, XSD)	Qualitative tool -- The MIP probe consists of a thin, composite metal and a semi-permeable, Teflon membrane in a stainless steel screen on the face of a probe. The probe also has an electrical heating element for stimulating volatile vapors and an EC dipole array for lithologic logging. The probe is mounted on a standard, direct-push rod. A carrier gas line runs inside of the tool from the probe to the surface where it can be connected to FID, PID, XSD, or direct sampling ion trap mass spectrometry (DSITMS).	Free product causes issues.
FID (Flame Ionization Detector)	BTEX, PCBs, PAHs, hydrocarbons, ~1,4-Dioxane	Laboratory grade gas chromatograph connected to MIP -- FID uses a hydrogen-air flame to ionize a sample gas and determine its concentration. The device is a sensitive detector for hydrocarbons. PID is more sensitive to functional groups, whereas FIDs respond to the length of the carbon chain.	Not suitable for PFAS.
PID (Photoionization Detector)	Chlorinated compounds, BTEX, ~1,4-Dioxane	Laboratory grade gas chromatograph connected to MIP -- Unlike FIDs, which completely burn the sample collected, PIDs ionize only a small portion of the sample, so the remaining sample can be further analyzed with another type of detector in series (typically FID and/or XSD).	PID results are sensitive to humidity. Not suitable for PFAS.
XSD (Halogen Specific Detector)	CVOCs, halogenated hydrocarbons, freons	Laboratory grade gas chromatograph connected to MIP -- Oxidative pyrolysis efficiently converts compounds containing halogens to their oxidation products and free halogen atoms (bromine and chlorine mainly). A fourth detector, ECD (Electron Capture Detector) is used by some MIP contractors in conjuction with the other three. The ECD is also halogen-specific. It tends to max out at relatively low concentrations, which makes it good for low-level contamination, but bad for high concentrations.	Not suitable for PFAS
EC (Electrical Conductivity)	grain size, rock type, saturation	Electrical conductivity (and its inverse, resistivity) is influenced by lithology, minerology, porosity, permeability, saturation, and concentration of dissolved ions within the groundwater.	Log provides non-unique solution that can respond to different subsurface factors

XRF (X-Ray Fluorescence)	Metals: As, Cu, Pb, Zn	Downhole CPT-XRF platforms collect simultaneous stratigraphic profiling and screening-level metals concentration data.	High lead levels may interfere with arsenic readings. Soil Moisture may interfere with XRF readings.
OIP (Optical Image Profiler)	NAPL, oil, dyes, PAH	A small camera in the optical interface probe takes pictures of soil through a window in the side of the probe every 15 millimeters. The camera can use two light sources to view soil: a UV light and a visible light. The UV light allows the user to see hydrocarbon fluorescence in real time. The system also logs the soil using an electrical conductivity meter to evaluate soil type. OIP produces a detailed log of induced fuel fluorescence while a downhole camera operates at 30 frames per second to capture fluorescence activity. Acquisition software analyzes each image and determines the percent of image area (up to 100%) that displays fuel fluorescence.	Can't specify product type; not suitable for chlorinated DNAPL detection
LIF-UVOST (Laser Induced Fluorescence -Ultraviolet Optical Screening Tool)	gasoline, diesel, jet fuel, kerosene, motor oil, cutting fluids, and hydraulic fluid	LIF tools are advanced using a direct push rig. A sapphire-windowed probe is advanced steadily down into the soil column at approximately 2cm/second and pulses of laser light are sent down the rod string via fiber optics, where they exit the window and into the surrounding soil. Hydrocarbon molecules can be excited by the laser, emitting fluorescence that is detected and filtered by the window and brought up-hole by a second fiber, where the light is processed and analyzed in real time. UVOST and TarGOST produce waveform "fingerprints" that are useful in identifying and differentiating compounds, which is an advantage over OIP.	Not suitable for aviation gasoline, chlorinated DNAPL, Heavy PAH NAPL, PCBs, dissolved phase detection. Calcite, peat and other calcareous matrix material may interfere with reading. Confirmation soil borings required due to false positives.
LIF-TarGOST (Tar Specific Green Optical Screening Tool)	PAH, coal tar, creosote, bunker C	TarGOST® follows the same principle of measurement as the UVOST® but uses a different laser wavelength of light that causes coal tar and creosote range PAHs to fluoresce. UVOST and TarGOST produce waveform "fingerprints" that are useful in identifying and differentiating compounds, which is an advantage over OIP.	Not suitable for light PAH NAPL, chlorinated DNAPL detection. Confirmation soil borings required due to false positives.
DyeLIF (Dye Laser Induced Fluorescence)	Halogenated DNAPL	The Dye-LIF tool works by injecting fluorescing, hydrophobic dye through a small injection port located several inches below the detection window of a standard LIF probe as the probe is advanced into the subsurface. The injected dye partitions into the NAPL (if present) and fluorescence in the presence of a light source, allowing the same LIF tooling (lasers, optical reading and processing equipment) to be used to detect chlorinated solvent DNAPLs	Can't specify product type. Does not detect dissolved phase.
Deep (through bedrock)			
PDB (Passive Diffusion Bag)	VOCs, SVOCs, metals, ions, 1,4-Dioxane, PFAS	The bottom portion of the sample chamber is constructed from a polyethylene membrane that allows diffusion of VOCs into the sampler. The upper portion of the sampler is formed by a membrane with larger pores that allows larger and polar molecules to diffuse into the sampler.	Lag time for results-- 2 weeks. Not good at acetone, MTBE, or styrene measurement.
Packers	hydraulic conductivity, collect water samples	Packer tests isolate sections of a bedrock borehole with bladders (packers) so water-quality samples can be collected and aquifer tests can be performed.	Limited to screened intervals in cased wells. Packers may leak, and boreholes create preferential vertical pathways.
CMT (Continuous Multichannel Tubing)	collect water samples	Uses 3-7 tubes down the borehole to take samples from discrete intervals. The intervals are separated by sand, bentonite, or a proprietary material.	Intervals may leak; difficult to reset tubing.

FLUTe (Flexible Liner Underground Technologies)	Free NAPL, dissolved phase NAPL, transmissivity	The NAPL FLUTe is a liner containing a dye that will bleed when it contacts separate phase NAPL. Once the NAPL FLUTe has been retrieved, the depths where it encountered separate phase NAPL are visible as stains on the liner. The newer FAC FLUTe has a strip of activated carbon that adsorbs dissolved phase NAPL over 2 weeks, then can be retrieved and sampled. Transmissivity is measured using a transducer placed at the bottom of the liner during installation. FLUTe liners have been deployed down to 1400 ft.	Transmissity measurement can only be made in unconsolidated sediment. Can't specify NAPL or dissolved phase constituents. Dissolved phase test takes 2 weeks.
NMR (Nuclear Magnetic Resonance)	hyraulic conductivity, water vs hydrocarbon saturation	The instrument creates a magnetic field, and the induction coil pulses a perpendicular magnetic field. Hydrogen nuclei tilt with the pulse, then "relax" back to the original orientation. Long relaxation times correspond with large pores and more mobile water, while shorter relaxation times correspond with small pores and less mobile water.	Requires existing wells that are 2" or larger. Can not use in steel wells.
Soil/Rock Core	Lithologic descriptions, Solid media samples	Can be collected via percussion or static driven DPT, hollow stem auger with sampler, sonic, bedrock coring methods.	Limited recovery in some lithologies. Boring logs that record the core can be subjective or qualitative.

Adapted from https://asct-1.itrcweb.org/