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Fiber optic DTS in sealed and heated boreholes for active groundwater flow characterization

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In recent years, advances in technology have allowed temperature profiling to evolve to offer new insight into fractured rock hydrogeology. Temperature profiles in open boreholes within fractured rock have long been used to identify and characterize flow in the rock formation and/or in the borehole. An advance in temperature logging makes use of precision temperature profiles collected using wireline trolling methods in a heated borehole to identify fractures with active groundwater flow by creating a thermal disequilibrium and monitoring the temperature response. A second development is based on collecting wireline temperature profiles within a sealed borehole to eliminate short circuiting effects caused by the open borehole conduit. The borehole is temporarily sealed with a flexible impervious fabric liner so that the water column in the borehole is static and cross-connection is eliminated. Though highly precise temperature and spatial measurements are possible using these techniques, the temporal resolution is limited by the rate at which the wireline probe can be raised and lowered in the borehole. There is a need to measure temperature profiles continuously over time to characterize transient processes.

Fibre optic distributed temperature sensing (DTS) is a technique that allows for collecting temperature profiles continuously. This tool was advanced by the oil and gas industry for collecting temperature data in multi kilometer deep boreholes over relatively coarse measurement scales. In contrast, very fine spatial and temperature resolutions are needed for freshwater contaminant fractured rock hydrogeology where the scale of interest is much more acute. Recent advances in the spatial, temperature, and temporal resolution of DTS systems allow this technology to be adapted well to the shallow subsurface environment.

This project demonstrates the first application of DTS used in conjunction with flexible borehole liners in a heated borehole environment. The integration of DTS, active heating, and lined boreholes was tested in the context of fractured rock site characterization. DTS heat pulse tests were carried out in two boreholes located at a well characterized research site in Guelph, ON, Canada. The capabilities for long-term and high temporal resolution site monitoring and characterization from the developed methods were assessed. The results of this technique are promising and indicate evidence for identifying active groundwater flow. Advancements to the DTS heat pulse method are possible to offer further improved insight into natural groundwater flow systems.