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Monitoring borehole flow dynamics using heated fiber optic DTS in a fractured rock aquifer

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Temperature profiles in fractured rock have long been used to identify and characterize flow in the rock formation or in the borehole. Fiber optic distributed temperature sensing (DTS) is a tool that allows for continuous borehole temperature profiling in space and time. Recent technology advancements in the spatial, temperature, and temporal resolutions of DTS systems now allow temperature profiling methods to offer improved insight into fractured rock hydrogeologic processes.

An innovation in shallow borehole temperature logging utilizes high resolution DTS temperature profiling in sealed and heated boreholes to identify fractures with natural gradient groundwater flow by creating a thermal disequilibrium and monitoring the temperature response. This technique can also be applied to open well conditions to monitor borehole flow distributions caused by hydraulic perturbations such as pumping or injection. A field trial was conducted in Guelph, Ontario, Canada to determine the capabilities of heated DTS for flow monitoring in both open and sealed wells. Intelligent distributed acoustic sensing (iDAS) measurements for vertical seismic profiling were carried out simultaneously with the DTS measurements to assist with characterization of the fractured aquifer system.

DTS heat pulse tests were conducted in a single well under sealed conditions for natural gradient flow measurements and open conditions to monitor flow distributions during injection and pumping. The results of these tests indicate that borehole flow distributions can be monitored using DTS and that active heating allows for further information about the hydrogeologic system to be determined than from the passive measurements alone. Depth-continuous transmissivity data from the borehole correlate well with the DTS testing results. DTS based flow monitoring systems may be useful for monitoring transient production and injection processes for a variety of applications including groundwater remediation, aquifer storage and recovery, and geothermal systems. Further advancements to this method are possible to allow for quantitative flow distributions to be determined.