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The impact of fractures on heat transfer in an aquifer used for shallow geothermal energy applications

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Vertical borehole heat exchangers (VBHEs) are increasingly used for space conditioning and thermal storage in ground-source heat pump schemes. Current models for VBHE performance often assume homogeneous ground conditions, whereas the ground, especially bedrock, is commonly fractured.

Numerical analyses are used to investigate a range of possible hydrogeological scenarios in which an open fracture may influence the long-term thermal performance of VBHEs. Sensitivity analyses then examine the effect of the volumetric flow rate through the fracture, the geometry of the fracture and its orientation with respect to the VBHE and the groundwater flow direction.

When the bedrock matrix has a high groundwater velocity, the groundwater velocities near the mid-length of the fracture may be significantly slowed as flow from the permeable matrix is concentrated in the fracture. This causes a significant reduction in the VBHE thermal performance, compared with the homogeneous aquifer scenario; specifically, an increase in the temperature change at the VBHE wall and in the size of the thermal plume, and an increase in time taken to reach stable conditions. Ignoring a fracture with a small volumetric flow rate can significantly underestimate the length of thermal plume.
In summary, the influence of an open fracture on the long-term thermal performance of a VBHE may be significantly positive or negative, depending on the effectiveness of the fracture in advecting heat and its ability to change local groundwater flow velocities.