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Temperature and energy deficit in the ground during operation and recovery phases of closed-loop ground source heat pump system: Effect of the groundwater flow

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The advection/dispersion mechanism of the groundwater flow in the ground has a significant effect on a borehole heat exchanger (BHE) to enhance its thermal performance. However, the amount of energy extracted from the ground never disappears and only shifts with the magnitude of the effective thermal velocity in the infinite domain. In this work, we focus on the temperature and the energy balance of the ground in an advection/dispersion dominated heat transfer system during the operation period of a BHE and the subsequent recovery phase when the system is idle. The problem is treated with single BHE and multi-BHEs systems, for different representative geology and different groundwater flow velocity. In order to assess the thermal energy deficit due to heat extraction from the ground, we used the finite line source analytical model, developed recently (Erol et al., 2015) that provides the temperature distributions around the boreholes for discontinuous heat extraction. The model is developed based on the Green's function, which is the solution of heat conduction/advection/dispersion equation in porous media, for discontinuous heat extraction by analytically convoluting rectangular function or pulses in time domain. The results demonstrate the significant positive impact of the groundwater flow for the recovery in terms of temperature deficit at the location of the borehole. However, the total thermal energy deficit is not affected by the groundwater movement. The energy balance of the ground is the same no matter the prevailing heat transfer system, which can be only conduction or advection/dispersion. In addition, the energy balance of the ground is not based on either the duration of the production period operation or of the recovery phase, but depends on the total amount of heat that is extracted and on the bulk volumetric heat capacity of the ground.