Detecting and quantifying the influence of natural convection on a thermal response test carried out in a groundwater-filled borehole heat exchanger

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In Finland and Scandinavia, borehole heat exchangers (BHEs) do not require grouting because they are typically located almost entirely in hard crystalline bedrock. The space between the heat collector pipes and the borehole wall in such BHEs is naturally filled with groundwater that is a fluid capable of convecting heat. The occurrence of natural convection in the borehole water of a BHE was investigated using data from a thermal response test (TRT) carried out in a groundwater-filled BHE constructed in Southern Finland. The TRT was first evaluated using the conventional infinite line source method which yielded a borehole thermal resistance estimate that was significantly lower than the estimates obtained using analytical expressions and finite element model simulations only taking into account conductive heat transfer. This discrepancy was interpreted as an indication of the occurrence of natural convection in the borehole water of the BHE during the TRT. Then, the finite element models were fitted to the TRT data keeping the groundwater thermal conductivity as a free parameter. Using the best-fit effective groundwater thermal conductivity values, the influence of natural convection on the TRT was estimated to be 63-71% depending on the locations of the heat collector pipes. According to the results, natural convection is a factor that is likely to significantly enhance the total heat transfer taking place during TRTs carried out in groundwater-filled BHEs.