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Potential and limits of using analytical solutions for Thermally Affected Zone (TAZ) assessment in Open-Loop Groundwater Heat Pump Systems

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Open-loop Groundwater Heat Pump systems (GWHPs) currently represent one of the most energy efficient and environmentally friendly air-conditioning systems for densely urbanized areas in temperate zones such as the Italian peninsula. However, the increasing implementation of GWHPs can potentially cause, even in short terms, a significant environmental impact associated with thermal interferences especially in shallow aquifers.
Thermal perturbation produced by GWHPs must be predicted and constantly controlled, in order to guarantee plants' long-term sustainable use and to avoid adverse effects on adjacent geothermal systems.

Transient geothermal plant-operating conditions can be successfully modelled by means of numerical modelling tools. As developing simulation models require the use of complex, expensive and time-consuming numerical calculation software, an analysis about the potentialities in applying available analytical solutions to a real hydrogeological and plant context for predicting TAZ size was proposed.

The Politecnico di Torino open-loop geothermal plant was modelled by using the finite-element code FEFLOW® 6.2, performing heat-transport simulations over its annual operating period (from May to September) and estimating the average cooling thermal-load at the end of two different monitored seasons. Transient condition modelling results were then validated through a comparison with the groundwater temperature available data, also collected through a temperature-measuring chain installed in a 35m deep monitoring piezometer.
The validity of using steady state analytical solutions proposed by Banks, 2009 to predict the TAZ development was subsequently tested by reconstructing an equivalent stationary state.

For the considered hydrogeological system and the analysed geothermal plant of the Politecnico di Torino, the analytical solutions proposed by Banks, 2009 were found to be a possible alternative to the use of numerical simulation software for TAZ sizing at the end of the selected system-functioning seasons. The validation of the described approach for different GWHPs could represent the object of further future analysis works.

Keywords : Groundwater heat pumps, Thermally affected zone, FEFLOW, Analytical solutions

References

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