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Preface

FLOWPATH 2019, the 4th National Meeting on Hydrogeology, was held in Milan from 12th to 14th June 2019. According to the aim of the previous Editions of FLOWPATH, held in Bologna (2012), Viterbo (2014) and Cagliari (2017), the conference is an opportunity for Italian hydrogeologists to exchange ideas and knowledge on different groundwater issues.

The objectives of the conference are:

- To promote dialogue and exchange of scientific knowledge among young hydrogeologists;
- To deepen the theoretical and practical aspects of our understanding on groundwater;
- To update all the stakeholders, researchers and professionals on recent challenges in the hydrogeological sciences;
- To encourage researchers, professionals and administrators to contribute to the improvement of water resources management.

This Volume of Conference Proceedings contains the abstracts of oral and poster contributions accepted to FLOWPATH 2019. The abstract were evaluated by the Scientific and Organizing Committees. This volume contains 99 abstracts, submitted by Authors coming from Universities, Public Authorities and Private Companies of Italy and many other countries, such as Australia, Belgium, Croatia, Czech Republic, Greece, Hungary, Israel, Malta, Morocco, Nigeria, Spain, Switzerland, The Netherlands, U.K., and U.S.A.

The conference focuses on four themes of great importance:

1. Groundwater Resource Management
2. Fractured Rocks and Karst Aquifers
3. Contaminated Sites
4. Urban Hydrogeology

The content of the Conference Proceedings is organized according to the four topics of the conference. The keynote lectures open the sessions were they were presented, followed by the scientific contributions in alphabetical order by first author's family name.

Editors:
Luca Alberti
Tullia Bonomi
Marco Masetti

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Thermodimensional assessment of GWHPs: compare with analytical and numerical simulations approach

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ABSTRACT

Is there a simpler methodology respect the numerical simulations that allows to define the dimensions of the thermal plume?

METHODS

A Groundwater Heat Pump system (GWHPs) is a technology that withdraws water from a well or a surface water source, passes it through a heat exchanger and discharges the water into an injection well or nearby river, developing a thermal plume of colder/warmer re-injected water, known as the Thermal Affected Zone (TAZ).

The increasing implementation in several urban areas of the world of the open-loop groundwater heat pump systems for cooling and heating buildings which discharge into the aquifer could potentially cause, even in the short term, a significant environmental impact associated with thermal interference with groundwater, particularly in the shallow aquifers.

The discharge of water at different temperatures compared to baseline (warmer in summer and colder in winter) poses a number of problems especially in the more densely urbanized. The national and regional current legislation related to withdrawals and discharges into aquifers, despite design a framework suitable for the protection of groundwater and allow to decide the best configuration of the plant with a case by case approach, make the administrative procedures quite complex. In effect, timing for obtaining permits are not always consistent with the timelines for urban planning and buildings construction.

Currently, in order to constantly verify the possible impact of the geothermal plant about some activities or pre-existent uses, the competent authorities require 1) a specialized hydrogeological investigations and characterization of the subsoil at the considered site; 2) the processing of a complex numerical model that simulate propagation mode and estimate the thermal plume size which develops in the shallow aquifers.

However, as to develop a simulation model it is required the use of complex, expensive and time consuming numerical calculation tools, we focused the analysis about the possibilities to apply available analytical formulae for predicting the size, the thermal plume speed propagation and the occurrence of thermal feedback phenomena.

In 2009, Banks was one of the authors to deal with the potential external risk to other aquifer users located down-gradient of the doublet, in the path of the thermal plume emanating from the recharge well.

Assuming that 1) the doublet spacing is *2d*; 2) the wells fully penetrate the aquifer; 3) the aquifer is homogeneous with a uniform thickness *m*, he demonstrated that there is minimal risk of internal feedback if:

$$d > d_{critical} = \frac{Q}{mU\pi} \qquad (1)$$

where *U* is the regional Darcy velocity.
In 2011, Banks also derived 2D analytical solutions for thermal plume evolution: plume length (L_{pl}) for long distance can be approximated as Eq. 2; the maximum down-gradient width (W_{pl}) was given by the following Eq. 3:

$$L_{pl} = v_{th}t = \frac{v_e}{R_{th}}t = \frac{U}{neR_{th}}t \qquad (2)$$

$$W_{pl} = \frac{Q}{mU} \qquad (3)$$

where v_{th} is the thermal advective velocity; v_e is the groundwater effective flow velocity (m/s); *t* is the simulation time; R_{th} is the thermal retardation coefficient and *ne* is the effective porosity.
In this research work, the Politecnico di Torino open-loop geothermal system was modelled by using the finite-element code FEFLOW® 6.2 (Diersch, 2010), performing a heat-transport simulation over an operating time of (153) days (May to September) and estimating the average cooling thermal-load P(t) at the end of the monitored period (t).
Subsequently, the simulated values of thermal plume L_{pl} and W_{pl} were compared with those obtained by applying 2D analytical formula provided by Banks in 2011 (Eq. 2-3).

RESULTS

In this first phase, the results obtained from the simulations of GWHP plant (May-September) were compared to the analyses obtained through the analytical method, maintaining an equivalent thermal load for both cases. From the results, it was possible to define that the analytical methodology derives to be comparable with the most complex and expensive methodology of numerical simulations.

CONCLUSIONS

The analytical formulae result to be a good option for simplifying the national and regional current legislation related to withdrawals and discharges into aquifers about the open-loop geothermal systems.
A next step of this work will be to establish what is the best value of Q and T (daily or monthly average) and what is the statistical relationship among them, in order to obtain an optimal comparison between the simulated and the analytical data.

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