Low temperature geothermal energy: heat exchange simulation in aquifers through Modflow/MT3DMS codes **(16 pt, 1.25 spacing, align center, font Times New Roman, bolder font)**

Alberti, L., Angelotti, A., Antelmi, M., Licata, I., Legrenzi, C., 2012. Low temperature geothermal energy: heat exchange simulation in aquifers through Modflow/MT3DMS codes. *AQUA mundi*, 039–051. **(12 pt, 1.25 spacing, justify text, font Times New Roman)**

Presenter: xxx

Advisor: Prof. xxx

Date: xxxx/xx/xx **(12pt, 1.25 spacing, align right)**

Abstract **(14pt, 1.5 spacing, 0.5pt before and after line spacing, align center, bolder font)**

Geothermal energy and in particular low temperature resources, have a rising worldwide importance. Ground-Source Heat Pumps (GSHP) have been used increasingly because they are among the cleanest and most energy efficient heating and cooling systems for buildings. Simulation models can be applied for a more effective use of the subsoil for geothermal purposes. In fact, they are useful tools for the design of efficient systems considering also the need to avoid abnormal temperature distributions in soil and aquifers.

In the hydrogeology field MODFLOW/MT3DMS are the most widespread programs to face environmental problems and to forecast quantity and quality impacts on groundwater resources. Although MODFLOW/MT3DMS are used to represent open circuit heat pumps, they are hardly used to represent borehole heat exchangers (BHE). The aim of this study is to simulate BHEs through two computer codes. The first one is TRNVDSTP, coupled to TRNSYS, which is often used in GSHP design in pure conduction cases. A methodology to take groundwater flow into account was added to TRNVDSTP, but a validation is still missing. The second one is MODFLOW/MT3DMS, suitable for groundwater flow and transport models, but whose reliability in BHE simulation is today unknown. The two software have been compared in terms of predicted exchanged energy and temperature distribution in the aquifer.

The first runs have been performed without a groundwater flow and a good agreement has been observed between the results of the two software, both in relation

to exchanged energies and temperature distribution into the model domain.

Thus, some simulations considering the presence of the groundwater flow have been performed. In this latter case the results in terms of exchanged energy differ of about 150%.

The study demonstrates the suitability of MODFLOW/MT3DMS for BHEs design when groundwater flow is not accounted for. Further efforts are needed to understand the different results when groundwater flow cannot be neglected, exploring the role of the different heat transport phenomena. **(12pt, 1.5 spacing, 0pt before line spacing, 0.5pt after line spacing, justify text, font Times New Roman)**

Keywords: **(14pt, 1.5 spacing, 0.5pt before line spacing, justify text, bolder font)** Geothermal energy, Borehole heat exchanger, MODFLOW, MT3DMS, TRNSYS **(12pt, 1.5 spacing, font Times New Roman)**

Note: If the abstract is two pages long, there is no need to include the original title page. Otherwise, it is required to adopt the title page as an example in the next page. Also, please enlarge it as the example and keep it as clear as possible.

Low temperature geothermal energy: heat exchange simulation in aquifers through Modflow/MT3DMS codes

Luca Alberti, Adriana Angelotti, Matteo Antelmi, Ivana La Licata, Cesare Legrenzi

Abstract: Geothermal energy and in particular low temperature resources, have a rising worldwide importance. Ground-Source Heat Pumps (GSHP) have been used increasingly because they are among the cleanest and most energy efficient heating and cooling systems for buildings. Simulation models can be applied for a more effective use of the subsoil for geothermal purposes. In fact they are useful tools for the design of efficient systems considering also the need to avoid abnormal temperature distributions in soil and aquifers.

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Riassunto*La risorsa geotermica ed in particolare lo sfruttamento del terreno come sorgente/pozzo termico a bassa temperatura stanno assumendo crescente rilevanza. Gli impianti a pompa di calore geotermica (GSHP) sono in continuo aumento poiché trattasi di una metodologia tra le più pulite ed efficienti dal punto di vista energetico per il raffrescamento ed il riscaldamento di edifici. Vi è la possibilità di sviluppare modelli di simulazione al fine di uno sfruttamento più efficace del terreno per scopi geotermici. Infatti tali modelli sono strumenti utili per la progettazione di sistemi efficienti che considerino anche la necessità di impedire lo sviluppo di temperature anomale in terreni ed acquiferi. Nel campo dell'idrogeologia i codici Modflow/MT3DMS sono tra i programmi più diffusi per affrontare problemi ambientali e prevedere dal punto di vista quantitativo e qualitativo gli impatti sulle risorse idriche sotterranee. Sebbene Modflow/MT3DMS vengano utilizzati per rappresentare pompe di calore a circuito aperto, essi sono ancora poco utilizzati per riprodurre sonde geotermiche (BHE). La ragione probabilmente risiede nel fatto che la rappresentazione della sonda geotermica attraverso questi codici richiede una geometria estremamente complicata ed un pesante raffinamento della griglia del modello. Lo scopo di questo studio è simulare le sonde geotermiche attraverso due codici di calcolo. Il primo è TRNVDSTP, associato a TRNSYS, il quale è spesso utilizzato per la progettazione di pompe di calore geotermiche in casi di sola conduzione. E' stata da poco aggiunta al codice TRNVDSTP una metodologia che considera la presenza di un flusso di falda, ma ancora non è stata convalidata. Il secondo codice è Modflow/MT3DMS, adatto per modelli di trasporto e per il flusso di acque sotterranee, ma la cui affidabilità nella simulazione di sonde geotermiche è oggigiorno sconosciuta. I due software sono stati confrontati dal punto di vista dell'energia scambiata e della distribuzione di temperatura previste nell'acquifero. Si è così implementata nei due programmi una sonda geotermica, costituita da un tubo ad U di lunghezza pari a 100 m e posizionata all'interno di un acquifero sabbioso saturo con spessore pari a circa 200 m. Si sono quindi eseguite simulazioni per il periodo di un anno al fine di rappresentare il funzionamento invernale ed estivo di una GSHP. Le prime simulazioni sono state effettuate senza considerare la presenza del flusso di falda e si è osservata una buona corrispondenza tra i risultati dei due software, sia dal punto di vista delle energie scambiate sia da quello della distri-*

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Received: 12 april 2012 / Accepted: 12 may 2011
Published online: 30 june 2012

DOI 10.4409/Am-042-12-0042