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Interactive comment on "Thermal management of an urban groundwater body" *by* J. Epting and P. Huggenberger

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The article "Thermal Management of an Urban Groundwater Body" by Epting and Huggenberger provides a cursory overview of the thermal state of the Basel's subsurface. However, it falls short of the ambitious goal of providing a thermal management plan. The manuscript does not build upon previous work as much as it could and the physical processes are not dealt with as rigorously as they are in other works.

The simulations produced in this study only consider infrastructure that extend beneath the water table as heat sources It is not clear what percentage of buildings and other structures do this but this will result in an underestimation of heat flow from these sources. Sources from the surface and within the unsaturated zone will penetrate

downward as well, in most cases nearly as effectively as those in the saturated zone. Thermal diffusivity does not vary a huge amount between saturated and unsaturated geological materials because changes in heat capacity and thermal conductivity counteract each other. The geological heat flow literature contains numerous of studies examining the effect of changes in the ground surface temperature boundary condition (Ferguson and Woodbury, 2004, 2007; Taniguchi et al., 1999, 2005) and this should be considered more explicitly here. This is mentioned in passing on lines 24-25 of p. 7204 but warrant more discussion given the potential error this omission introduces to this study.

Other works have attempted to deal with the policy side of this work in a slightly different manner than those examined here. Some of these works have focused on the interplay between open loop heat pump systems (Fry, 2009) while others have taken a comprehensive view of subsurface heat sources (Bonte et al., 2011). There have been numerous other studies examining heat and groundwater flow resulting from withdrawal and subsequent injection related to thermal use of groundwater. Early theoretical studies focusing on analytical models (Gringarten and Sauty, 1975; Gringarten, 1978) might be of particular interest from a preliminary planning perspective. Later studies focusing producing calibrated models of production and injection (Bridger and Allen, 2010; Clarkson et al., 2009; Ferguson and Woodbury, 2005, 2006) suggest that producing meaningful models will take more data than was available to the researchers in the Basel area. Calibrating the model to situations involving well hydraulics is likely more important than the background case. It should also be noted that there is considerable uncertainty associated with the movement of groundwater and heat resulting from such projects (Bridger and Allen, 2010; Ferguson, 2007, 2012). Creation of a management plan based on more detailed models is probably unrealistic but uncertainty and upscaling issues should be considered here.

While there is a need to develop these sorts of plans, Basel appears to be a less than ideal area to develop the first comprehensive geothermal management scheme.

Efforts to manage shallow subsurface thermal resources are scattered and there is little that have been done in terms of comprehensive planning (Haehnlein et al., 2010). However, there are other locations where there has been far more work done to support these developments. Cities such as London, UK (Ampofo et al., 2006; Clarkson et al., 2009; Fry, 2009; Gandy et al., 2010; Gropius, 2010; Headon et al., 2009), Winnipeg, Canada (Ferguson and Woodbury, 2004, 2005, 2006, 2007; Ferguson, 2012; Zhu et al., 2010) and Tokyo, Japan (Nakayama and Hashimoto, 2011; Nam and Ooka, 2010, 2011; Taniguchi et al., 1999, 2005) have been studied in detail and could provide much better opportunities to develop such a plan. A recent overview of the history of geothermal development of the Dogger aquifer in France (Lopez et al., 2010) may also be of interest. This aquifer has been supporting geothermal energy development for 40 years and may provide some interesting lessons. Development of a management plan based on a single study of Basel is could be possible. However, such a manuscript would need a more comprehensive treatment of the processes involved, uncertainties associated with development and a more thoughtful consideration of the experience in more extensively studied areas.

References

Ampofo, F., Maidment, G. G. and Missenden, J. F.: Review of groundwater cooling systems in London, Applied Thermal Engineering, 26(17-18), 2055–2062, 2006.

Bonte, M., Stuyfzand, P. J., Hulsman, A. and Van Beelen, P.: Underground Thermal Energy Storage: Environmental Risks and Policy Developments in the Netherlands and European Union, Ecology and Society, 16(1), 22, 2011.

Bridger, D. W. and Allen, D. M.: Heat transport simulations in a heterogeneous aquifer used for aquifer thermal energy storage (ATES), Canadian Geotechnical Journal, 47(1), 96–115, 2010.

Clarkson, M. H., Birks, D., Younger, P. L., Carter, a. and Cone, S.: Groundwater cooling at the Royal Festival Hall, London, Quarterly Journal of Engineering Geology

and Hydrogeology, 42(3), 335–346, doi:10.1144/1470-9236/08-080, 2009.

Ferguson, G.: Heterogeneity and thermal modeling of ground water., Ground water, 45(4), 485–90, doi:10.1111/j.1745-6584.2007.00323.x, 2007.

Ferguson, G.: Characterizing uncertainty in groundwater-source heating and cooling projects in Manitoba, Canada, Energy, 37(1), 201–206, doi:10.1016/j.energy.2011.11.045, 2012.

Ferguson, G. and Woodbury, A. D.: Subsurface heat flow in an urban environment, Journal of Geophysical Research, 109(B2), 1–9, doi:10.1029/2003JB002715, 2004.

Ferguson, G. and Woodbury, A. D.: Thermal sustainability of groundwater-source cooling in Winnipeg , Manitoba, Canadian Geotechnical Journal, 1301, 1290–1301, doi:10.1139/T05-057, 2005.

Ferguson, G. and Woodbury, A. D.: Observed thermal pollution and post-development simulations of low-temperature geothermal systems in Winnipeg, Canada, Hydrogeology Journal, 14(7), 1206–1215, doi:10.1007/s10040-006-0047-y, 2006.

Ferguson, G. and Woodbury, A. D.: Urban heat island in the subsurface, Geophysical Research Letters, 34(23), doi:10.1029/2007GL032324, 2007.

Fry, V. a.: Lessons from London: regulation of open-loop ground source heat pumps in central London, Quarterly Journal of Engineering Geology and Hydrogeology, 42(3), 325–334, doi:10.1144/1470-9236/08-087, 2009.

Gandy, C. J., Clarke, L., Banks, D. and Younger, P. L.: Predictive modelling of groundwater abstraction and artificial recharge of cooling water, Quarterly Journal of Engineering Geology and Hydrogeology, 43(3), 279–288, 2010.

Gringarten, A. C.: Reservoir lifetime and heat recovery factor in geothermal aquifers used for urban heating, Pure and Applied Geophysics PAGEOPH, 117(1-2), 297–308, 1978.

Gringarten, A. C. and Sauty, J. P.: A Theoretical Study of Heat Extraction From Aquifers With Uniform Regional Flow, Journal of Geophysical Research, 80(35), 4956–4962, 1975.

Gropius, M.: Numerical groundwater flow and heat transport modelling of open-loop ground source heat systems in the London Chalk, Quarterly Journal of Engineering Geology and Hydrogeology, 43(1), 23–32, 2010.

Haehnlein, S., Bayer, P. and Blum, P.: International legal status of the use of shallow geothermal energy, Renewable and Sustainable Energy Reviews, 14(9), 2611–2625, doi:10.1016/j.rser.2010.07.069, 2010.

Headon, J., Banks, D., Waters, a. and Robinson, V. K.: Regional distribution of ground temperature in the Chalk aquifer of London, UK, Quarterly Journal of Engineering Geology and Hydrogeology, 42(3), 313–323, doi:10.1144/1470-9236/08-073, 2009.

Lopez, S., Hamm, V., Le, M., Schaper, L., Boissier, F., Cotiche, C. and Giuglaris, E.: Geothermics 40 years of Dogger aquifer management in Ile-de-France , Paris Basin , France, Geothermics, 39(4), 339–356, doi:10.1016/j.geothermics.2010.09.005, 2010.

Nakayama, T. and Hashimoto, S.: Analysis of the ability of water resources to reduce the urban heat island in the Tokyo megalopolis., Environmental Pollution, 159(8-9), 2164–73, 2011.

Nam, Y. and Ooka, R.: Numerical simulation of ground heat and water transfer for groundwater heat pump system based on real-scale experiment, Energy and Buildings, 42(1), 69–75, 2010.

Nam, Y. and Ooka, R.: Development of potential map for ground and groundwater heat pump systems and the application to Tokyo, Energy and Buildings, 43(2-3), 677–685, 2011.

Taniguchi, M., Shimada, J., Tanaka, T., Kayane, I., Sakura, Y., Shimano, Y., Dapaah-Siakwan, S. and Kawashima, S.: Disturbances of temperature-depth profiles due to

surface climate change and subsurface water flow: 1. An effect of linear increase in surface temperature caused by global warming and urbanization in the Tokyo Metropolitan Area, Japan, Water Resources Research, 35(5), 1507, 1999.

Taniguchi, M., Uemura, T. and Sakura, Y.: Effects of urbanization and groundwater flow on subsurface temperature in three megacities in Japan, , 2(December 1992), 320–325, doi:10.1088/1742-2132/2/4/S04, 2005.

Zhu, K., Blum, P., Ferguson, G., Balke, K.-D. and Bayer, P.: The geothermal potential of urban heat islands, Environmental Research Letters, 5(4), 044002, doi:10.1088/1748-9326/5/4/044002, 2010.

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