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The effect of soil heterogeneity on ATES performance

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Due to an increasing demand for sustainable energy, application of Aquifer Thermal Energy Storage (ATES) is growing rapidly. Large-scale application of ATES is limited by the space that is available in the subsurface. Especially in urban areas, suboptimal performance is expected due to thermal interference between individual wells of a single system, or interference with other ATES systems or groundwater abstractions. To avoid thermal interference there are guidelines on well spacing. However, these guidelines, and also design calculations, are based on the assumption of a homogeneous subsurface, while studies report a standard deviation in logpermeability of 1 to 2 for unconsolidated aquifers (Gelhar, 1993). Such heterogeneity may create preferential pathways, reducing ATES performance due to increased advective heat loss or interference between ATES wells.

The role of hydraulic heterogeneity of the subsurface related to ATES performance has received little attention in literature. Previous research shows that even small amounts of heterogeneity can result in considerable uncertainty in the distribution of thermal energy in the subsurface and an increased radius of influence (Ferguson, 2007). This is supported by subsurface temperature measurements around ATES wells, which suggest heterogeneity gives rise to preferential pathways and short-circuiting between ATES wells (Bridger and Allen, 2010).

Using 3-dimensional stochastic heat transport modeling, we quantified the influence of heterogeneity on the performance of a doublet well energy storage system. The following key parameters are varied to study their influence on thermal recovery and thermal balance: 1) regional flow velocity, 2) distance between wells and 3) characteristics of the heterogeneity.

Results show that heterogeneity at the scale of a doublet ATES system introduces an uncertainty up to 18% in expected thermal recovery. The uncertainty increases with decreasing distance between ATES wells. The uncertainty in the thermal balance ratio related to heterogeneity is limited (smaller than 3%). If thermal interference should be avoided, wells in heterogeneous aquifers should be placed further apart than in homogeneous aquifers, leading to larger volume claim in the subsurface. By relating the number of ATES systems in an area to their expected performance, these results can be used to optimize regional application of ATES.

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

Ferguson, G. (2007). "Heterogeneity and thermal modeling of ground water." Ground Water **45**(4): 485-490.

Gelhar, L. W. (1993). Stochastic Subsurface Hydrology, Prentice Hall.