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Fault zones in pumping tests – quantification of flow regime transitions through parametric analysis for the Upper Jurassic aquifer of the North Alpine Foreland Basin by utilization of numerical simulations on an HPC cluster

Florian Konrad (1), Kai Zosseder (1), and Alexandros Savvatis (2)
(1) Technical University of Munich, Hydrogeology, Munich, Germany (florian.konrad@tum.de), (2) Erdwerk GmbH

The area of Munich in southern Germany represents a favorable location for deep geothermal exploration. Currently 37 completed wells can be found here while more are being planned or already under construction. They all tap into the Upper Jurassic aquifer of the North Alpine Foreland Basin (also called Malm aquifer). Since fault zones in this area are generally thought of as regions with possibly increased hydraulic properties they are often a key component of a wells exploration concept (Savvatis, 2012). Data gathered in pumping tests however shows that only three out of the 37 exhibit hydraulic proof for the presence of such a fault zone (bi-/linear flow).
Besides technical effects (e.g. well bore storage, skin) that can prevent the detection of a fault zone in the pumping test data it is also possible that the contrast in hydraulic properties is the reason. A fault zone with hydraulic conduit properties, that is directly tapped by a well, ideally causes a linear or bilinear flow regime. Through the investigation of the pressure change induced by a pumping test with the tools of modern pressure transient analysis like the Bourdet Derivative an explicit identification of these flow types is possible (Bourdet, 2002).
We constructed and calibrated a simplified but realistic numerical model to observe the presence of linear and bilinear flow in dependence of the Malm aquifers parameter space. Sampling the possible hydraulic property-combinations with the help of an HPC cluster and automating the detection of the corresponding main flow type allowed us to quantify the areas in parameter space where the fault zone related flow regimes of interest are present.
We used the software packages MeshIT, Paraview and MOOSE Framework together with GOLEM to construct the numerical simulation (Ahrens, Geveci, & Law, 2005; Blöcher & Cacace, 2013; Cacace & Jacquey, 2017; Gaston, Newman, Hansen, & Lebrun-grandié, 2009). For automated parameter sampling we applied RAVEN Framework (Alfonsi et al., 2017).
The investigation of 30492 combinations between fault zone permeability, matrix permeability, fault zone storage, matrix storage and fault zone thickness in the Malm aquifers possible range showed that fault zones, which have better hydraulic properties than the surrounding matrix, can indeed be hidden in pumping tests due to the parameter setting. Additionally we found that for the Malm aquifer a bilinear flow can only be observed if the matrix permeability is lower than 2.0 x 10-13 m^2 and a linear flow only for matrix permeability values below 7.0 x 10-14 m^2.