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Geoelectrical monitoring of fresh water injection into a limestone aquifer

R. von Bülow(1)*, N. Klitzsch(2), D. Burs(3), and F. Wellmann(1)

(1) Aachen Institute for Advanced Study in Computational Engineering Science (AICES), RWTH Aachen University, Aachen, Germany
(2) Institute for Applied Geophysics and Geothermal Energy (GGE), RWTH Aachen University, Aachen, Germany
(3) Lehr- und Forschungsgebiet Hydrogeologie (LFH), RWTH Aachen University, Aachen, Germany
* rvonbuelow@eonerc.rwth-aachen.de

We present results of a field study investigating the possibility to detect fresh water, injected into a limestone aquifer, using geoelectrical methods. Our analysis is based on a threedimensional subsurface model for a complex aquifer domain located in the Hastenrather Graben near Eschweiler, NRW.
As only few direct groundwater monitoring wells exist in the area, an injection test was performed with the aim to ensure and validate groundwater flow direction and to infer permeabilities in a part of the aquifer, strongly deformed by tectonics. Since the injection borehole is in a groundwater protection area, the only allowed tracer is water with a lower salinity than the groundwater. During injection, we performed geophysical monitoring with electrical resistivity tomography (ERT).
Prior to the field study, we investigated the feasibility for detecting the injected water in a numerical experiment. We performed a flow simulation which also considers injection in a discretized model of 250 m x125 m x 40 m in size, using SHEMAT-Suite. The geological model was extended from three to four layer cases to cover possible scenarios with varying properties. The salinity concentration of groundwater and injected water reflected actual field conditions. After the simulation, concentrations were converted into resistivity values and tested against varying ERT survey designs using the codes DC2DInvRes and Res3DMod. In order to monitor the injected plume, a spacing of 2 m and a monitoring rate of 2 days seemed to be sufficient under the applied assumptions.
Based on the results of this feasibility study, we performed a field test in November 2014. We injected approximately 390 m³ of drinking water into the limestone aquifer over a time period of 9 days with a mean injection rate of 1.8 m³/h. In total, 300 electrodes were used on 5 parallel profiles on 15 m interval with 2 m spacing for the geoelectrical measurements. In addition, one borehole electrode was placed into the injection well. Groundwater sampling and ERT measurements in Dipole-Dipole and surface-borehole configuration were performed within 2-3 days interval over a total period of 16 days.
First quality assessment took place in the field. We repeated measurements with negative or unrealistic large values or divergent currents larger than 5. The data was kept for the upcoming inversion when it was reproducible in the field and when it was similar to its neighbor values.

Furthermore, we excluded all data points where the ratio between data and the reference measurement exceeded 25% of highest simulated ratios. We processed the remaining data points as timelapse series using the software Res3DInv.
Changes in resitstivity over time are not only visible in the top layer but also within the aquifer. Here, resistivity increases over time driven by the higher resistive pore filling of the less saline injected water and decreases again after the injection stopped. Our results suggest that the injected water spread out laterally into all directions, even against the steady-state groundwater flow direction.