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High resolution aquifer characterization: An integrated approach coupling hydraulic and seismic tomography

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Slug tests have traditionally been utilized as a means to determine the hydraulic conductivity of an aquifer at a relatively small scale. When performed in a cross-hole mode using a tomographical measurement array, however, slug tests can be used to gain information about the two or three dimensional distribution of hydraulic properties between two or more wells. Despite the common perception, that a slug test only affects a small volume of the aquifer in the vicinity of the test well, response data with a reasonable signal to noise ratio can be collected at distances of over several hundred times the radius of the screen of the test well. For the evaluation of the cross-hole slug tests we have applied a hydraulic travel time approach. The approach, which is based on the inversion of travel times, is analogous to seismic ray tomography. The key element of this procedure is a travel time integral relating the square root of the peak travel time to the inverse square root of the hydraulic diffusivity for a Dirac point source.

The potential of hydraulic tomography using cross-hole slug tests was investigated at a well-characterized sand and gravel aquifer located in the Leine River valley near Göttingen, Germany. The data base for the inversion consists of 400 pressure cross-hole slug tests performed between five wells in which the positions of the sources (injection ports) and the receivers (observation ports), isolated with double packer systems, were varied between tests. It was possible to reconstruct a three dimensional area of 5 m * 5 m * 2 m by applying the hydraulic travel time inversion technique to the 400 transient pressure response curves.

The advantage of hydraulic tomography using cross-hole slug tests is to perform a large number of tests, at low cost in terms of time and effort. In cases where a dense well network is available e.g. control planes which are installed downstream of a contaminant plume, the method can provide detailed information about the structure and spatial variability of hydraulic properties between the wells. However, the limited volume affected by slug tests hinder their general applicability as an aid for a wider variety of environmental and engineering applications. In order to overcome this shortcoming we have decided to perform seismic tomography.

For the performance of seismic cross-well measurements direct-push technology has been applied. We have installed four temporary wells in which we have generated a high frequency p-wave using a small diameter sparker, whereby the response has been recorded in a 0.05 m ID PVC well. Altogether we have recorded four seismic profiles overlapping half the hydraulic tomograms. The validation of the velocity tomograms by means of the hydraulic tomograms enables us to identify the spatial position of the main hydraulic features within the reconstructed velocity distribution. The results have shown that the coupling of hydraulic tomography with high resolution geophysical methods such as seismic tomography is a promising approach to provide a problem adapted scale and accuracy for the prediction of contaminant transport.