Integration of spatially variable riverbed hydraulic conductivity from Electrical Resistivity Tomography (ERT) and Induced Polarization (IP) into a groundwater flow model using multiple-point geostatistics

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Abstract

Interactions between surface water and groundwater play an essential role in hydrology, hydrogeology, ecology and water resources management. For modelling these interactions and correctly estimating the exchange fluxes between aquifers and rivers, estimating of the spatial distribution of hydraulic conductivity (K) in riverbeds is essential. Several direct and indirect field methods are available to determine hydraulic conductivity in riverbeds but investigating local distributions and spatial heterogeneity of riverbed K is a complex and time-consuming task and the uncertainty on obtained K values is often large because of the large variability of K.

In this work, we suggest using Electrical Resistivity Tomography (ERT) and time-domain Induced Polarization (IP) geoelectrical methods to map the spatial distribution of hydraulic conductivity within riverbeds. We compare the obtained images with direct measurements of hydraulic conductivity obtained through slug tests. We demonstrate our approach on a test site situated in a typical lowland. The site of investigation is 25 m long and 15 m wide. In general, high values of K are observed in the middle of the river and lower values towards the borders, while the opposite is true for chargeability and normalized chargeability. Based on visual assessment, there is therefore an inverse correlation between K and IP geophysical parameters. These inverse correlations are confirmed in scatterplots of K versus geo-electrical data, although the trends are relatively weak due to scaling effects. Furthermore, geostatistical analyses using variograms show that all parameters have ranges of similar magnitudes. The strong correlation between K and chargeability or normalized chargeability can be explained by the fact that all three parameters are mainly determined by clay and organic matter content. This shows that geoelectrical methods can be efficient in the qualitative assessment of hydraulic conductivity in riverbeds.

The continuous images obtained through ERT and IP provide spatial patterns of riverbed hydraulic conductivity. These images are used as training images for multiple-point geostatistical simulations of riverbed hydraulic conductivity. Multiple-point geostatistics is a technique that has proven to be very suitable for simulating the spatial distribution of non-Multi-gaussian parameters such as hydraulic conductivity of sedimentary deposits. In multiple-point geostatistics, spatial simulation at unsampled locations is based on the use of a “training image”. A training image is a conceptual explicit representation of the expected spatial distribution of hydraulic properties or sediment types. The main idea is to borrow spatial patterns from these training images and generate simulations that are not

only reproducing measured data, mean, variance and variogram of the measured data but are also consistent with the spatial patterns of the training image. Multiple-point statistics are borrowed from the training image to simulate multiple realizations of riverbed hydraulic conductivity.

Subsequently, these fields of simulated riverbed hydraulic conductivity are used as input to a fine-scale spatially distributed 3D local MODFLOW groundwater flow model. With this model the effect of riverbed heterogeneity on river-aquifer exchange fluxes is quantified.