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## Is high-resolution inverse characterization of heterogeneous river bed hydraulic conductivities needed and possible?

[Kurtz, W.](#); [Hendricks Franssen, H. -J.](#); [Brunner, P.](#); [Vereecken, H.](#)

River-aquifer exchange fluxes influence local and regional water balances and affect groundwater and river water quality and quantity. Unfortunately, river-aquifer exchange fluxes tend to be strongly spatially variable, and it is an open research question to which degree river bed heterogeneity has to be represented in a model in order to achieve reliable estimates of river-aquifer exchange fluxes. This research question is addressed in this paper with the help of synthetic simulation experiments, which mimic the Limmat aquifer in Zurich (Switzerland), where river-aquifer exchange fluxes and groundwater management activities play an important role. The solution of the unsaturated-saturated subsurface hydrological flow problem including river-aquifer interaction is calculated for ten different synthetic realities where the strongly heterogeneous river bed hydraulic conductivities ( $L$ ) are perfectly known. Hydraulic head data (100 in the default scenario) are sampled from the synthetic realities. In subsequent data assimilation experiments, where  $L$  is unknown now, the hydraulic head data are used as conditioning information, with the help of the ensemble Kalman filter (EnKF). For each of the ten synthetic realities, four different ensembles of  $L$  are tested in the experiments with EnKF; one ensemble estimates high-resolution  $L$  fields with different  $L$  values for each element, and the other three ensembles estimate effective  $L$  values for 5, 3 or 2 zones. The calibration of higher-resolution  $L$  fields (i.e. fully heterogeneous or 5 zones) gives better results than the calibration of  $L$  for only 3 or 2 zones in terms of reproduction of states, stream-aquifer exchange fluxes and

parameters. Effective  $L$  for a limited number of zones cannot always reproduce the true states and fluxes well and results in biased estimates of net exchange fluxes between aquifer and stream. Also in case only 10 head data are used for conditioning, the high-resolution characterization of  $L$  fields with EnKF is still feasible. For less heterogeneous river bed hydraulic conductivities, a high-resolution characterization of  $L$  is less important. When uncertainties in the hydraulic parameters of the aquifer are also regarded in the assimilation, the errors in state and flux predictions increase, but the ensemble with a high spatial resolution for  $L$  still outperforms the ensembles with effective  $L$  values. We conclude that for strongly heterogeneous river beds the commonly applied simplified representation of the streambed, with spatially homogeneous parameters or constant parameters for a few zones, might yield significant biases in the characterization of the water balance. For strongly heterogeneous river beds, we suggest adopting a stochastic field approach to model the spatially heterogeneous river beds geostatistically. The paper illustrates that EnKF is able to calibrate such heterogeneous streambeds on the basis of hydraulic head measurements, outperforming zonation approaches.

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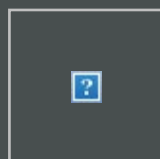
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