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Implementation and influence of heterogeneous riverbed hydraulic conductivity in groundwater flow models

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Characterization of groundwater-surface water exchange fluxes is important for assessing riparian ecology, determining quantity and quality of pumped groundwater close to rivers, modeling groundwater flow, predicting flood peaks and low flows, and river water quality. The exchange fluxes between river and aquifer are strongly influenced by the hydraulic conductivity of the riverbed which can vary several orders of magnitude and shows a strong spatial variation. Direct measurement of riverbed hydraulic conductivity is cumbersome and therefore often indirect data such as temperature data or calibration of groundwater models are used to constrain riverbed hydraulic conductivity. In these approaches, the riverbed is usually represented as a homogeneous geological structure and the spatial variation of riverbed hydraulic conductivity is thus neglected. However, neglecting this spatial variation can lead to systematic underestimation of net river-aquifer exchange fluxes and may have important implications for the estimation of peak mass flows, for the hydrochemistry of streambed sediments, nutrient cycling and biogeochemical gradients.

The MODFLOW software is the most wide-spread package used for groundwater modelling. In MODFLOW rivers are usually modelled using the River-package. However, in this package no distinction can be made between horizontal and vertical riverbed hydraulic conductivity and the riverbed cannot be subdivided into layers with different hydraulic characteristics. Riverbed sediments are strongly layered and thus another approach is advised. Different ways of introducing heterogeneous riverbeds in MODFLOW groundwater flow models are explored and compared.

The influence of heterogeneous riverbeds on groundwater-surface water exchange fluxes is analyzed for two case studies: the Aa River in the Nete catchment and a stretch of the Dijle River near the nature reserve ‘de Doode Bemde’ (Belgium). For both cases fine-scale distributed local groundwater flow models are available. Heterogeneous riverbeds are introduced in these models and riverbed hydraulic conductivity is modeled based on different stochastic simulation techniques. Several scenarios are explored based on variogram parameters of streambed hydraulic conductivity found in literature. Main goal is to quantify the effect of riverbed heterogeneity on river-aquifer exchange fluxes. This study will determine whether neglecting or simplifying this heterogeneity can lead to significant under- or overestimation of exchange fluxes between river and groundwater. As outcome some guidelines on how to incorporate heterogeneous riverbeds in groundwater flow models will result.