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Using Geostatistics and kinematic Waves to assess the Effects of geologic Heterogeneity on River-Aquifer Interactions

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Managing rivers and their underlying aquifers for minimum flows, riparian habitat or aquifer recharge requires an understanding of the spatial patterns and temporal dynamics of river-aquifer exchange. The study presented here investigates the effects of geologic heterogeneity on river-aquifer exchange and minimum river flows in an alluvial fan system in the western USA. A geostatistical approach, based on transition probability and Markov Chains, was used to describe hydrofacies in the alluvial fan. Due to groundwater overdraft, much of the river is hydraulically disconnected from the regional water table. A kinematic wave approach was used to simulate vertical unsaturated flow beneath the river. This approach is implemented in a new stream package for the groundwater flow model MODFLOW.

Different hydrofacies models were created from sequential indicator simulations and incorporated into a MODFLOW model for a 50 km reach of the lower Cosumnes River in California. The effects of different hydrofacies arrangements on minimum river flows for salmon migration were evaluated for a three year period. We found that total annual river seepage was relatively insensitive to geologic heterogeneity. However, the majority of seepage occurred over small portions of the river channel due to permeable pathways beneath the river, which was extremely important with regards to groundwater levels below the river. Due to the interplay between the river boundary condition and geologic heterogeneity local reconnections developed seasonally in some heterogeneous models. The period with sufficient fall flows for salmon migration varied by up to 21 days between the models. The results suggest that geologic heterogeneity can be very important for river-aquifer exchange on the meso-scale. The common notion that no feedback exists from a deep water table to an overlying river might not apply in heterogeneous systems. The geostatistical technique provided an efficient means to create realistic images of subsurface hydrofacies distributions. Computational costs for simulating variably saturated flow between the river and aquifer were held at a reasonable level by using the kinematic wave approach.