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# How important is geologic Heterogeneity in River-Aquifer Exchange?

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Interactions between surface water and groundwater are often highly variable in space and time with important consequences for surface water flow (e.g. minimum flows, fish migration) riparian ecology (e.g. moisture distribution in the riparian zone, riparian vegetation) and water management (e.g. groundwater recharge, conjunctive use). Geologic heterogeneities at the interface between rivers and their underlying aquifers can exert strong controls on the spatial patterns of exchange. Those effects are rarely addressed in numerical models of river-aquifer exchange. In this work we demonstrate how geologic heterogeneities at the scale of alluvial hydrofacies (100m to 1500m) affect the dynamics of river-aquifer exchange in an alluvial river-aquifer system with deep regional water table (Cosumnes River, California, USA) . Results are presented from simulations of river- and subsurface flow on a regional- (50km) and two different reach-scales (100m and 5000m) using the numerical codes MODFLOW, MODHMS, TOUGH2 and PARFLOW. The geologic structure of the alluvial fan system (hydrofacies distribution) was characterized with a geostatistical approach, based on transition probabilities and Markov Chains. Sequential indicator simulations were used to create different hydrofacies models. Parameter variations within individual hydrofacies were addressed with Gaussian simulations on a sub-grid scale. Effects of sub-grid heterogeneities on seepage, base flow generation and riparian moisture distribution were evaluated in a Monte Carlo framework. The simulations revealed complex patterns of surface-subsurface exchange, including reaches with cyclic changes between hydraulic connection and disconnection, formation of perched aquifers supporting ri-

parian vegetation, and complex patterns of moisture in the riparian zone. In all models seepage patterns were strongly linked to distinct spatial arrangements of alluvial hydrofacies. On the regional scale those patterns also impacted minimum river flows with implications for salmon migration. Sub-grid heterogeneities affected total seepage volumes and groundwater recharge. Overall, simulation results suggest that geologic heterogeneities at the scale of alluvial hydrofacies (1500m) and below significantly affect river-aquifer exchange processes with important implications for the management of riparian systems even at much larger scales.