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Hyporheic exchange for emerging and submerged alternate bars under neutral, gaining and losing ambient groundwater

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Abstract

Surface water-groundwater exchange (hyporheic exchange) has been widely investigated over the last decades. Different types of morphology were considered to examine the hyporheic exchange behavior through. In particular, alternate bars morphology has been introduced experimentally and numerically in many of previous studies. Nevertheless, the condition of emerging alternate bars that corresponds to the most frequent condition of river flow (i.e: mean flow) has not been so well investigated in previous numerical studies, where the submerged case of alternate bars was regularly considered to represent the hyporheic exchange characteristics in such a morphology type. In the current study, we develop a hydrodynamic flow model to numerically investigate the hyporheic zone characteristics within the emerging bars as well as the submerged bars. In addition, gaining and losing conditions effect is also introduced with different values of groundwater flow. The differences in hyporheic zone characteristics between emerging and submerged bars that emerge from the hydrodynamic simulations, are analyzed and demonstrated comparatively.

The results show the separation of the hyporheic zone for both submergence cases into two zones; a shallow zone with quasi-lateral flow paths, and a deep zone with longitudinal flow paths. Higher hyporheic flux in emerging bars than submerged bars is observed which lowers with increasing groundwater flow in both gaining and losing condition. In comparison to the submerged bars, in emerging bars the shallower hyporheic zone is more mixed with the stream water and has shorter residence times, while the deeper zone has the same residence times with deeper extent.

The differences in hyporheic zone characteristics between the both studied submergence cases imply, consequently, a distinction in biogeochemical properties. We expect that higher hyporheic flux indicates higher solutes transport through the microbially active area in streambed. Additionally, the residence time plays a key role in determining the efficiency of nutrient removal within the streambed, as it determines how long the solutes will be exposed to the bacteria in the streambed. Higher solutes transport with less residence time, specially within the shallow hyporheic zone, is more expected for the emerging bars than for the submerged case. The residence time as well as the hyporheic zone extent would spatially and temporally define the nitrification and denitrification zones. We speculate that the deeper extent of hyporheic zone favors the existence of a deeper nitrification zone, as more oxygen is expected to be delivered to the deeper parts of the streambed. Therefore, in emerging bars, the nitrification zone is more likely to be deeper than in submerged bars. Finally, each submergence case has its unique characteristics and can not be a surrogate for the other or generalized for such a morphology type.