Impacts of engineering baffles on the hyporheic exchange in a straight channel with floodplain

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The hyporheic zone (HZ) is the region of saturated sediment surrounding a stream which connects surface water and groundwater flow. The overlying water with dissolved matters infiltrates into the HZ, stays there for some time and interacts with groundwater, and exfiltrates out of the HZ, resulting in hyporheic exchanges (HEs). The HEs support physicochemical and biological reactions that are essential to river ecosystem functions. In recent decades, more and more stream restoration projects involve the recovery of HE, however, effective guidance in restoring HE is still missing. Therefore, this study aims to examine the effectiveness of different engineering baffle designs in restoring HZ in a straight channel with floodplain. Both flume and numerical models coupling stream and groundwater flow were built. The flume model was built in a recirculating box to simulate different hydrological conditions (e.g., streamflow and groundwater flow) and baffle designs (e.g., baffle amplitude, interval). Tracer experiments were performed, and results were used to quantify the impacts of baffles designs on the HE fluxes. For the numerical models, the surface flow was simulated by solving Reynold-average Navier-Stokes (RANS) equations in two phases using volume of fluid method (VoF) in Fluent, while the groundwater flow was simulated by solving Richard's equation in COMSOL. The numerical models were calibrated with experiments, and could output the flux, scale and median residence time (MRT) of the HE. For fixed baffle interval of four times the stream width, the flux and scale of HE peaked at baffle amplitude of around one third of stream width, while the MRT increased with increasing amplitude. For fixed baffle amplitude of one third of the stream width, the flux of HE peaked at baffle interval of around four times the stream width, the scale of HE was positively correlated to interval while the MTR had the lowest value at the interval of around two times the stream width. The results of this study directly benefit the development of practical baffle designs of river restoration. The coupled models developed are also generally applicable to investigate the efficiency of different stream rehabilitation designs in restoring HZ.