Geophysical Research Abstracts
Vol. 12, EGU2010-13113, 2010
EGU General Assembly 2010

Hyporheic flow, solute transport, and heat flux in the stream bed around cross-vane restoration structures

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Natural channel design restoration projects in streams often include cross-vanes, which are low, stone, dam-like structures that span the active channel. The change in water elevation over a cross-vane decreases the static pressure head across the structure from upstream to downstream. It is hypothesized that, as a result, a cross-vane increases the local hyporheic exchange of water through the stream bed. Stream beds are the permeable interface between surface water in streams and groundwater in fluvial aquifers. The hyporheic zone includes the area of the bed where water from the active channel mixes with pore water in shallow sediments and returns to the channel. Channel forms, such as steps, pools, and riffles, intensify the flux of water through the hyporheic zone. Flow paths that redirect stream water through the hyporheic zone increase the residence time of dissolved oxygen, organic material, and nutrients in the stream bed, where enhanced geochemical and biological processes alter the water chemistry and create distinct gradients of redox-sensitive solutes. Hyporheic exchange therefore influences surface water quality, and impacts the health of aquatic species and ecosystems. Few studies have investigated the impact of static restoration structures on hyporheic exchange fluxes or water chemistry.

Here we present the results of an investigation of hyporheic flow, solute transport, and heat flux at the locations of two cross-vanes and one natural riffle in a second-order stream in central New York State, USA. Pore water temperatures and water samples from the stream bed were collected in a meter-scale grid at 20-cm depth surrounding the structures and riffle. Temperature was also recorded every 10 minutes for over 2 weeks at several different depths at a subset of points at each site. The time-series temperature data and meter-scale grid temperature measurements were used to calculate vertical water flux rates using an analytical heat transport model. Water samples were analyzed for major ions and nutrients using ion chromatography. The spatial patterns of water and solute fluxes were not consistent with a single hyporheic flow cell caused by the difference in static pressure head over the cross-vane. Instead, the spatial patterns of upwelling and downwelling were distributed in smaller cells around pool and riffle bed forms above and below the structure. These patterns are more consistent with dynamic pressure head difference caused by the bed forms themselves. These results suggest that shallow hyporheic flow near cross-vanes is controlled by secondary bed forms created or augmented by the cross-vane, rather than by the cross-vane itself.