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Spatial patterns of water, heat and solute fluxes through the hyporheic zone at stream restoration sites

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Rapid exchange of water between streams, groundwater and the hyporheic zone generates hotspots where enhanced biogeochemical cycling of redox sensitive solutes occurs. In streams, naturally occurring topographic features, such as pool-riffle sequences, and anthropogenic features, such as small dams, drive hyporheic exchange through the streambed. Stream restoration projects often include the addition of in-stream structures that create hydraulic steps, similar to dams, and generate streambed topography in the form of step-pool-riffle sequences. As such, we expect restoration to enhance the flux of water, solutes and heat between the stream and the subsurface. There are few detailed studies of the increased heterogeneity of water and solute fluxes through the hyporheic zone and associated patterns of biogeochemical processes at stream restoration sites. Here, we examine the patterns of water, heat and solute fluxes in the hyporheic zone around several stream restoration structures to relate spatial patterns of flux to bed morphology and biogeochemical processes occurring in the hyporheic zone. Restoration projects considered here include the installation of small, low-head dams and natural channel design restoration, which includes the installation of large boulder cross-vanes. We collected hydraulic gradient, temperature, and geochemistry data at meter-scale spatial resolution at these sites. Analysis of spatial data included the use of principal component analysis (PCA) to characterize different biogeochemical zones in the streambed. The PCA results from one site showed that two principal components summarized 83% of the variance in the original data set. Using PCA, streambed pore water was characterized as oxic (indicating production of nitrate), anoxic (indicating sulfate, iron and manganese reduction), or stream-like (indicating there was minimal change in the stream water chemistry in the bed). Regardless of season of the year, anoxic zones were predominantly located upstream of the structure, in a low-velocity pool, and oxic zones were predominantly located downstream of the structure, in a turbulent riffle. We expect structures that span the full channel, are impermeable, and permanent, such as those installed in natural channel design restoration will similarly impact biogeochemical processing in the streambed. The installation of these types of restoration structures may be a way to increase the degree of biogeochemical cycling in stream ecosystems