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Challenges and Advancements in Linking Hyporheic Flow with Ecological Processes in Streams and Rivers

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Similar types of groundwater-surface water interactions occur across a diversity of landscapes, ranging from steep mountain streams to lowland rivers and floodplains, coastal wetlands, and subtidal marine ecosystems. This presentation focuses on the relatively rapid, bi-directional exchange that occurs between surface and subsurface water (i.e. hyporheic exchange) and its relevance to ecological processes. Researchers have faced a number of challenges on the path to improved prediction of hyporheic flow and greater understanding of its ecological linkages. One of those challenges is the limited "window of detection" of measurements that are intended to quantify hyporheic fluxes and residence times. No matter whether a method is based in hydrometric or tracer measurements, it likely characterizes only a narrow part of the entire distribution of hyporheic exchange flows that are occurring. Another challenge relates to the "disparity in spatial scales" that arises due to the order of magnitude difference between the fine-scales of variability in the processes controlling hyporheic flow compared with the much larger scales at which the cumulative effects on chemical and ecological conditions are evident. Consequently, although it has become increasingly feasible to predict hyporheic flow at small spatial scales, there has been relatively little progress applying that knowledge to ecologically relevant scales of river reaches and watersheds. Lastly there is the challenge of quantifying "hot spots and moments" for biogeochemical processing of nutrients and organic matter in watersheds. Hyporheic flow is effective in delivering reactants such as organic matter, dissolved nutrients, and oxygen into contact with microbe-rich sediments, which fuels high rates of biologically mediated reactions. However, a predictive framework for the enhancement of biogeochemical reactions in hyporheic flow is largely lacking. As a consequence, it may be possible to anticipate changes in hyporheic flow that may result from changes in land use or stream restoration, but predicting the ultimate effects on water chemistry, stream metabolism, and aquatic food webs, remains a daunting problem. Recently, notable advancements have been made that unify essential physics with ecologically relevant measurements in ways that are useful at multiple spatial scales across a variety of aquatic ecosystems. The examples provided illustrate the use of data synthesized from many field experiments and laboratory studies, as well as progress made by large investigative teams who bring together a variety of techniques implemented at multiple scales.