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Reach-Scale Hydrologic Exchange Flows and Their Impacts on Hyporheic Thermal Regimes

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This element of the PNNL SFA seeks to study the effects of river morphology and sediment permeability on river corridor hydrologic exchange flows (HEFs) and seasonal thermal dynamics under hydropeaking and thermopeaking. Water temperature in the hyporheic zone can powerfully impact river biogeochemistry and ecology through, for example, controls on dissolved oxygen levels supporting fish health or modification of microbial reaction rates. We have previously shown that HEFs strongly control hyporheic zone temperature in local domains. To extend this knowledge to larger scales, we developed a 3-D numerical model using PFLOTRAN for a large (75-km) regulated river corridor of the Hanford Reach. This model was used to evaluate the impacts of dam-regulated flow conditions and hydrogeomorphic features on HEFs, the associated river corridor thermal regime, and its implications for river ecology. Our results revealed highly variable intra-annual spatiotemporal patterns in HEFs along the reach, as well as strong interannual variability with larger exchange volumes in wet years than dry years. The magnitude and timing of river stage fluctuations controlled the timing of high exchange rates. Both river channel geomorphology and the thickness of a highly permeable river bank geologic layer controlled the locations of exchange hot spots, while the latter played a dominant role.

River corridor thermal regime was strongly influenced by high-frequency flow variations interacting with river temperature dynamics. As HEFs exhibit hot spots and hot moments, so also river corridor thermal regime exhibited strong spatiotemporal variability. Riverbed temperature lagged behind surface water temperature and the amplitude of riverbed temperature fluctuations was ~60% less as compared to that of surface river temperature. Riverbed morphology such as islands and gravel bars created areas of upwelling and downwelling that affected the penetration depth of the thermal signal. In general, thermal signals penetrated deeper at the upstream end of morphologic features where strong downwelling occurred. Thermal signals also penetrated deeper where highly permeable sediments existed causing larger exchange flux, creating colder zones in the winter and warmer zones in the summer. These simulated changes in river corridor thermal regime would impact the selection of the spawning area by salmonids and their survival rate. Our results demonstrated that upstream dam operations enhanced the exchange between surface water and groundwater and changed river corridor thermal regime with strong potential influence on river ecology.