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SLAC Groundwater Quality SFA: Modeling and Scaling of Biogeochemical Responses to Hydrologic Transitions in Floodplain Aquifers

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Alluvial aquifers exhibit complex geological structures such as fine-grained sediment lenses, owing to their depositional and post-depositional histories. These features translate into highly variable hydraulic and geochemical properties that mediate subsurface and surface water quality. In the U.S. intermountain West, large shifts in hydrologic conditions associated with seasonal snowmelt additionally trigger important fluctuations in the biogeochemical functions of alluvial aquifers, which are strongly influenced by these subsurface structures. Recent studies have pointed out that fine-grained, organic-enriched sediments (*i.e.* naturally reduced zones, NRZs, and transiently reduced zones, TRZs) can exert outsized control on groundwater geochemistry because their large inventories of C, S, and Fe, as well as contaminants like U, Mo, Zn, and Pb, can be released by diffusion into the advective zones (AZs) of the aquifer during water table fluctuations that alternately deliver oxygen-rich water to the system or create reducing conditions. In spite of the importance of NRZs and TRZs, there is much that we don't know about rates of reactions occurring within and the various mechanisms of coupling between abiotic and biotic processes and between biogeochemical processes and hydrologic changes that trigger redox and groundwater quality responses.

Here we develop detailed reactive transport simulations of a contaminated alluvial aquifer system at a DOE legacy uranium ore-processing plant in the Wind River Basin near Riverton, WY. By explicitly accounting for N, C, Fe, S and U cycling across the AZ-NRZ interface at the scale of a single NRZ, we evaluate the fundamental processes that control the transfer of elements to and from AZs, including the biogeochemical network, the relative length scales, and the physical and chemical properties of the porous media. We aim at a systematic simplification of the functioning of NRZs that could be integrated into larger scale models, for instance by linking spatial and temporal variability through the use of characteristic transport and reaction timescales. Such an approach could allow for large-scale simulations of water quality, ideally in combination with highly resolved reactive transport simulations.