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Exploring Relationships Between Lateral, Vertical, and Longitudinal Connectivity in River Corridors Through Modeling Sediment Exchanges With Off-Channel Alluvial Storage Reservoirs

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The timing and magnitude of suspended sediment movement downstream through river corridors is an expression of the connectivity between upstream and downstream reaches. Downstream sediment routing is often directly controlled by storage into and remobilization from alluvial deposits such as floodplains and quiescent storage zones adjacent to river channels that collectively define lateral sediment connectivity, and hyporheic storage zones below the water column that define vertical connectivity. These storage zones, however, are rarely explicitly included in sediment routing schemes, so quantitative connections between the different dimensions of connectivity remain unexplored. I have developed a new approach to quantifying the behavior of off-channel alluvial sediment reservoirs. The approach is based on two hypotheses: 1) a deposition law that relates movement into storage as a function of sediment variables (concentration, settling velocity) and the available unfilled accommodation space, and 2) an erosion law specifying removal of sediment based on age category, the amount of stored material in an age category, an erosion rate constant, and a function defining the extent to which stored material of different ages is exposed to erosion. These two laws, when combined with appropriate initial and boundary conditions, provide dynamic equations governing the amount of stored sediment as a function of time and the age and transit time distributions of stored material. Unlike traditional reservoir theory, age and transit time distributions vary through time, and are fully predicted. I demonstrate, using data from the meandering Little Missouri River in North Dakota, how the parameters governing the two storage “laws” can be estimated using chronostratigraphic data from the Little Missouri’s floodplain. This calibrated model is then used to predict floodplain storage and downstream migration of As-rich mine tailings introduced from 1876-1977 into the meandering Belle Fourche River in South Dakota. While these examples focus on floodplains of meandering river systems, the approach is quite general and can be readily extended to include any alluvial storage reservoir, providing relatively simple methods to quantify lateral and vertical sediment exchanges and to define how these exchanges influence the downstream movement of sediment pulses through river corridors.