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Experimental rivers: from braided towards meandering by the addition of cohesive floodplain material

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Meandering rivers have proven to be difficult to reproduce experimentally, while braided rivers are relatively easily formed in the laboratory. Our objective is to create self-formed dynamic braided and meandering rivers in a laboratory, and to understand and quantify the necessary and sufficient conditions for meandering. We designed experimental conditions that minimize the most important scaling issues. We applied a transverse moving inlet funnel for flow and sediment at the upstream boundary, mimicking meanders migrating into the control section. Initial and boundary conditions in the meandering and braided experiment were exactly equal except that slightly cohesive silt-sized silica flour was added to the feed sediment of the meandering channel. This was to test the hypotheses that 1) meandering rivers have relatively narrower and deeper channels due to bank cohesion, and 2) that floodplain-filling sediment fills potential chute channels that would otherwise lead to braiding.

The experiments were carried out in a flume of 6 m wide and 11 m long, which was split up into two separate fluvial plains (each 3x10 m). The parallel setups have identical cycled discharge regimes with a longer duration low flow and a shorter duration high flow simulating floods. The bed sediment consisted of a poorly sorted sediment mixture ranging from fine sand to fine gravel. The evolution was recorded by high-resolution line-laser scanning and Digital Single Lens Reflex (DSLR) camera used for channel-floodplain segmentation, water depth approximation, silica flour distribution and particle size estimation. Further, we tested in a small setup the erosion rate of different sediment mixtures and the influence of a silica drape on a non-cohesive bed.

In agreement with earlier work, the experimental river without silica flour evolves from alternate bars to a multi-thread braided river. Addition of silica flour to the feed resulted in a single-thread meandering river with chute cutoffs. Large bends developed with scroll bar complexes and sinuosity reached maxima of 1.4. The silica flour introduces cohesive self-formed floodplains filling up potential chutes and overbank deposition decreased bank erosion rates, which was confirmed with the small setup for erosion rates. In contrast, the non-cohesive experiment is dominated by much more rapid channel shifting and displacement, so that much more sediment was reworked. We conclude that the increase of fine cohesive material leads to a decrease in chute cutoffs and the tendency to braid. The upstream moving inflow boundary was a necessary condition for dynamic meandering and braiding.