Dynamics and Morphodynamic Implications of

Chute Channels in Large, Sand-Bed Meandering Rivers

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ABSTRACT

Chute channel formation is a key process in the transition from a single-thread meandering to a braided channel pattern, but the physical mechanisms driving the process remain unclear. This research combines GIS and spatial statistical analyses, field survey, Delft3D hydrodynamic and morphodynamic modelling, and Pb-210 alpha-geochronology, to investigate controls on chute initiation and stability, and the role of chute channels in the planform dynamics of large, sand-bed meandering rivers. Sand-bed reaches of four large, tropical rivers form the focus of detailed investigations; the Strickland and Ok Tedi in Papua New Guinea, the Beni in Bolivia, and the lower Paraguay on the Paraguay/Argentina border. Binary logistic regression analysis identifies bend migration style as a key control on chute channel initiation, with most chute channels forming at bends that are subject to a rapid rate of extension (elongation in a direction perpendicular to the valley axis). Bend extension rates are shown to track variation in potential specific stream power, such that reaches and sub-reaches of the rivers studied fit within a planform continuum expressed though increasing bend extension rates and chute initiation frequency, and driven by increasing stream power relative to bedload calibre.

Field observations of point bar geomorphology and vegetation dynamics illustrate the importance of rapid bend extension in forming wide sloughs between scroll bars that are aligned with the direction of over-bar flow, and in breaking the continuity of vegetation encroachment on point bars. Bathymetric surveys and Delft3D simulations for the Strickland River provide insight into flow and sediment division at bifurcate meander bends. Coupled with GIS analyses, these simulations show that stable chute channels have higher gradient advantages than chute channels subject to infill, but that upstream and downstream changes in bend orientation can also influence chute stability. The process of bend extension is typically associated with an increase in the chute gradient advantage, further elucidating the role of bend migration style in chute

stability. At the reach scale, rivers with higher sediment loads (Qs/Q) are characterised by higher rates of chute infill.

Strickland River floodplain sedimentation rates derived through Pb-210 alpha-geochronology are substantially higher adjacent to single-thread bends than adjacent to bifurcate bends, potentially due to an observed increase in channel capacity (and reduction in floodplain inundation frequency) associated with bend bifurcation. Further research is needed to determine whether this observation is significant in light of high uncertainty in the spatial variability of sedimentation rate estimates, but the data presented highlight a need for carefully considered stratified sampling approaches in floodplain coring campaigns, and illustrate the complexity of possible sediment dispersal mechanisms, and associated ecological responses.

GIS analysis of the response of the Ok Tedi in Papua New Guinea to direct addition of mine tailings elucidates interplay between channel steepening due to the propagation of a tailings sediment slug, and mid-channel bar formation induced by the increased sediment load, with associated topographic forcing of bend and chute development. A temporal pattern of increased chute initiation frequency on the Ok Tedi mirrors the inter- and intra-reach spatial pattern of chute initiation frequency on the Paraguay, Strickland and Beni Rivers, where increased stream power is associated with increased bend extension and chute initiation rates. The process of chute formation is shown to be rate-dependent, and the threshold value of bend extension for chute initiation is shown to scale with reach-scale stream power, reminiscent of slope-ratio thresholds in river avulsion. However, Delft3D simulations suggest that chute formation can exert negative feedback on shear stress and bank erosion in the adjacent mainstem bifurcate, such that the process of chute formation is also rate-limiting. Chute formation is activated iteratively in space and time in response to changes in river energy, selectively targeting sites of greatest change, and thereby mediating the river response.

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