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Predicting reach-scale flow patterns using reduced complexity cellular schemes

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Computational simulation of flow and sediment transport offers a methodology for investigating the evolution of alluvial rivers, avoiding the limitations of field monitoring, laboratory modelling and morphometric analysis. Such a numerical model would need to have the capability of simulating both meandering and braided conditions, to allow autogenic progression of planform depending on a combination of boundary and initial conditions and internal feedback links. However, while the theory of water flow is relatively well understood at the small scale, in practice high data requirements and computational complexity currently restrict the applicability of the Navier-Stokes equations to space and time scales appropriate for geomorphic evolution.

An alternative modelling strategy uses reduced complexity cellular automata (CA) to combine a foundation of physical theory with efficient computation. Recent work on CA flow routing schemes have shown the potential of grid-based models for generating realistic channel dynamics from simple rules of interaction, predicting flow patterns using water depth and local elevation differences. This research presents an evaluation of three popular CA approaches: Murray & Paola (1997), Thomas & Nicholas (2002), and Coulthard (2000). The schemes are assessed for low-flow conditions using a high-resolution terrain and distributed flow dataset for the braided River Feshie, surveyed in July 2003 and 2004. Model predictions are tested using measurements of distributed flow depth, cross-sectional flow and allocation between anabranches.

Low flow simulations reveal the importance of accounting for both local topography and flow depth in water routing, with both the T&N and Caesar models out performing the simpler M&P scheme. However, while these more sophisticated algorithms behave similarly in low flow conditions, they become increasingly disparate at significant

channel forming discharges. In the absence of high stage field data, a comparative evaluation is undertaken using a 2d CFD code to generate predictions of flow depth and discharge around a 100m scale sub-reach. Finally, a series of artificially-generated meandering and transitional channel geometries are used to examine the potential of CA schemes for modelling evolution between planform types.