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How Do Bifurcations in Engineered Rivers Respond to Sea level Rise?

M. K. Chowdhury[1], A. Blom[1], C. Ylla Arbós[1], and R. M. J. Schielen[1,2]

[1] Delft University of Technology, The Netherlands. m.k.chowdhury@tudelft.nl; astrid.blom@tudelft.nl; C.YllaArbos@tudelft.nl

[2] DG Rijkswaterstaat, Ministry of Infrastructure and Water Management, The Netherlands. ralph.schielen@rws.nl

1. Introduction

River bifurcations divide the water and sediment over two downstream branches or bifurcates. As the changing climate adjusts the boundary conditions (i.e., base level, hydrograph, and sediment flux) for bifurcations, it will affect their flow and sediment partitioning over the bifurcates. Our objective is to provide insight into the response of a bifurcation to sea level rise (SLR). To this end, we compare the response of an idealized bifurcation in an engineered river (i.e., with a fixed planform and width) to SLR to the one of a single channel, using a one-dimensional numerical model system.

2. The Model

Flow and conservation of bed sediment are described using, respectively, the steady solution to the St Venant equations and the Exner equation. The transport rate of unisize sediment is computed using the Engelund-Hansen relation. In a one-dimensional model, the partitioning of sediment over the bifurcates is described using a nodal point relation. The cross-sectional profile is rectangular. Both the single channel and the upstream branch of the bifurcation case are 315 m wide and, respectively, 250 and 150 km long. Bifurcate lengths and widths are, respectively, 100 km and 250 m. The sediment grain size is 1 mm. The non-dimensional friction value is 0.004.

Flow rate and upstream sediment flux are kept constant at 4000 m^3/s and 0.01 m^3/s, respectively. We use a simple nodal point relation (Wang et al., 1995) with exponent k equal to 3 and prefactor equal to 1. This allows for a stable bifurcation with a symmetric partitioning of flow and sediment. In both cases, the initial state is an equilibrium state associated with a SLR rate of 0 mm/year. From the start of the run, the SLR rate is set equal to 4 mm/year over 100 years. Time and space steps are 1 day and 500 m.

3. Results

For both cases, SLR leads to an aggradation wave migrating upstream (Fig. 1). At the downstream end, the single channel case aggrades more slowly than the bifurcate. This is because of its larger flow depth and, therefore, the relatively smaller impact of water level rise on sediment mobility.

Interestingly, in the bifurcation case, a second aggradation wave forms right downstream of the bifurcation and migrates downstream (Fig. 1b). This wave results from the flow depth difference over the bifurcation. More specifically, the fact that the flow depth in the bifurcate is smaller than in the upstream channel makes the relative water level increase due to SLR larger for the bifurcate than in the upstream channel. As a result, sediment mobility is more heavily reduced right downstream of the bifurcation than upstream from it, which causes a depositional wave that migrates downstream.

Sea level rise does not change the flow and sediment partitioning for the bifurcation case, as the bifurcates are symmetric. This implies that the response to SLR does not differ between the bifurcates.

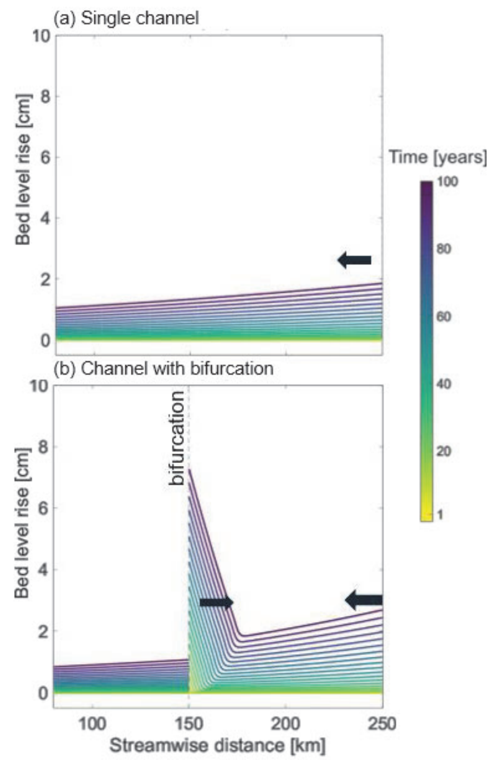

Figure 1. Response of (a) a single channel and (b) a channel with a bifurcation to a SLR rate of 4 mm/year.

4. Conclusions

Based on our simple analysis, SLR induces, besides an upstream migrating aggradational wave, a downstream migrating aggradational wave starting at the bifurcation. Bifurcation response also depends on the nodal point relation, hydrograph, branch width and length, and rate of SLR, which we are currently focussing on.

References

Wang, Z. B. et al. (1995). Stability of river bifurcations in 1D morphodynamic models. Journal of Hydraulic Research, 33 (6), 739–750.