# How is the length of symmetrical branches affecting the stability of riverine bifurcations?

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## Abstract

Riverine bifurcations play a crucial role in controlling the flow and sediment distribution in the downstream branches and may lead to channel avulsion.

Previous studies on the morphodynamic equilibrium and stability of these bifurcations have relied on a quasi-2D model approach originally developed for gravel bed rivers by *Bolla Pittaluga et al.* (2003) and later extended to the case of suspended dominated rivers by *Bolla Pittaluga et al.* (2015), hereafter BCK, finding that bifurcation stability is crucially dependent on the Shields stress ($\vartheta$) and the half-width to depth ratio ($\boldsymbol{\beta}$) of the upstream channel. The Authors were able to include a nodal point condition for the transverse flow at the bifurcation under the assumption that the water levels between the upstream channel and downstream branches at the node are all equal. Here we relax the latter hypothesis proposing a new nodal condition that conserves energy rather than free surface elevation at the bifurcation node. Therefore, through a linearization procedure, we study the stability of river bifurcation closing the problem with the Strickler relation for the friction coefficient and employing the total sediment discharge relation of Engelund and Hansen.

The linear solution is obtained performing a Taylor expansion around the basic state (i.e., the uniform flow conditions in the upstream channel and symmetrical water and sediment discharge partitioning in the branches).

The procedure allows for an algebraic relation for the critical aspect ratio $\beta_{cr}$, reading:

$$\beta_{cr} = \frac{4}{3}\frac{\alpha r}{\sqrt{\theta}}\frac{(6L+3Fr^2+4LFr^2)}{\left({}^{7}/_{3}L-{}^{3}/_{2}Fr^2\right)}.$$

where two new parameters appear, the dimensionless branch length **L** (scaled with the backwater length) and the Froude number in the upstream channel **Fr**.

The dependence of critical aspect ratio $\beta_{cr}$ on the branch length **L** is plotted in Figure 1a for fixed values of the other parameters. Results suggest that the stability of the bifurcation increases as the length of the branches decreases. Note that the stabilizing effect of relatively short downstream channels in loop systems has been already pointed out by *Ragno et al.* (2021).

Figure 1b shows the equilibrium diagram of the symmetric bifurcation in terms of the discharge asymmetry **ΔQ** between the branches for different values of **L**. Noteworthy, configurations where final **ΔQ** is equal to 0 are stable, while final **ΔQ** equal to 1 indicates that one branch closes completely, and channel avulsion occurs.

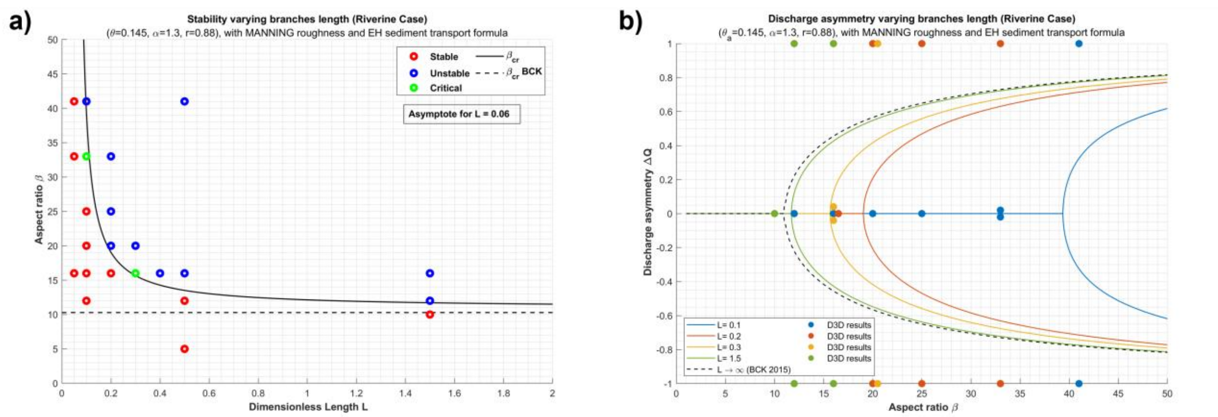


***Figure 1**: Panel a) shows the neutral stability diagram as function of aspect ratio β and dimensionless length L for the present theory and BCK (2015). The theory has been verified through numerical simulations, with stable configurations shown as red dots, unstable configurations as blue dots, and critical configurations as green dots. Panel b) depicts the equilibrium diagram of a symmetrical bifurcation with equal-length branches, where various dimensionless lengths (L) are represented by different colored lines. The numerical results are displayed as filled dots of the corresponding color for each configuration.*

To validate the theory, we performed systematic numerical simulations using Delft3D (*Lesser et al.*, 2004) considering different configurations. In particular, the upstream flow discharge per unit width, slope, and sediment diameter were kept constant, while the width and length of the branches were varied to consider different values of the parameters **β** and **L**. We observed a good agreement between the theoretical predictions and the numerical results.

Further implications of the results will be discussed at the conference.

**Keywords**: Morphodynamics; River bifurcations; Deltas; Sediment transport; Equilibrium; Avulsion

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