Investigation of the impact of river interventions on fluvial morphodynamics

Gergely T. Török[1,2,3,*] and Gary Parker[3,4]

[1] Budapest University of Technology and Economics, Department of Hydraulic and Water Resources Engineering
[2] TKI - Water Management Research Group
[3] Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign
[4] Department of Geology, University of Illinois at Urbana-Champaign
* Corresponding: torok.gergely@epito.bme.hu

Abstract

Our study is based on 3D CFD model examinations of the impact of wing dams. We look for characteristics that are expected to play an important role (e.g., bed material, geometry) in the morphodynamic changes caused by such interventions. Based on these characteristics our 3D model tests can be performed. Using schematic 3D models with real morphodynamic parameters, the morphodynamic, geometric and water level changes resulting from a given intervention can be quantified[2]. However, our goal is to develop an analytical procedure that allows the results to be generalized. Based on our 3D model result analysis, we are looking for relationships between sensitive parameters, e.g., wing dam width, longitudinal wing dam density, characteristic bed material, etc.

Keywords: Wing dams; 3D CFD; high water level

Introduction

Several studies (e.g., Pinter et al., 2008) have investigated the impact of interventions such as wing dams on high water levels. The fintings of these mainly statistical analysis-based examinations are based on trend analysis of measured data. To complement these, we attended to develop a methodology that allows conclusions to be generalized using physical-based considerations.

Methods

3D CFD modeling of bed changes plays a crucial role in our study (Török et al., 2017). Using schematic channel models with real river morphodynamic parameters, we investigate what new equilibrium bed geometries are formed due to different wing dam placement and width.

Our study's ultimate goal is to determine the additional resistance to flow in the altered bed geometry caused by the wing dams. For this, we apply the so-called Einstein Partition (Garcia, 2008). The method says that the effective resistant coefficient (C_f) can be split into two parts: the one represents the resistance caused by the skin friction (C_{fs}) and the other characterizes the resistance resulting by the bed forms (C_{ff}). Respectively, the total depth (H) can be separated for H_s and H_f (Eq. 1 and Eq. 2). Furthermore, Eq. 3 and 4 create relationships between the different roughnesses (C_f, C_{fs} and C_{ff}) and the depths (H, H_s and H_f) associated with them.

$$C_f = C_{fs} + C_{ff} \tag{1}$$

$$H = H_s + H_f \tag{2}$$

$$\rho C U^2 = \rho g H S \tag{3}$$

$$C = \left[\frac{1}{\kappa}\ln\left(11\frac{H}{k_s}\right)\right]^{-2} \tag{4}$$

where ρ is water density, U is depth-averaged velocity, g is gravity acceleration, κ is von Karman's constant and k_s is effective roughness height.

Finally, based on the appropriate form of the equations, the resistance caused by the wing dams (C_{ff}) can be derivated as a function of the H, S, and S values that can be determined from the 3D model results.

Results

Our investigations were carried out with the Hungarian Danube parameters: with a bed material of a sand-gravel mixture, assuming a 200m wide riverbed. The herein presented results belong to a wing dam length one-eighth of the channel width. We examined the resistance caused by the wing dams at different longitudinal densities. The longitudinal wing dam density is characterized by the number of wing dams per 1000 meters of the channel.

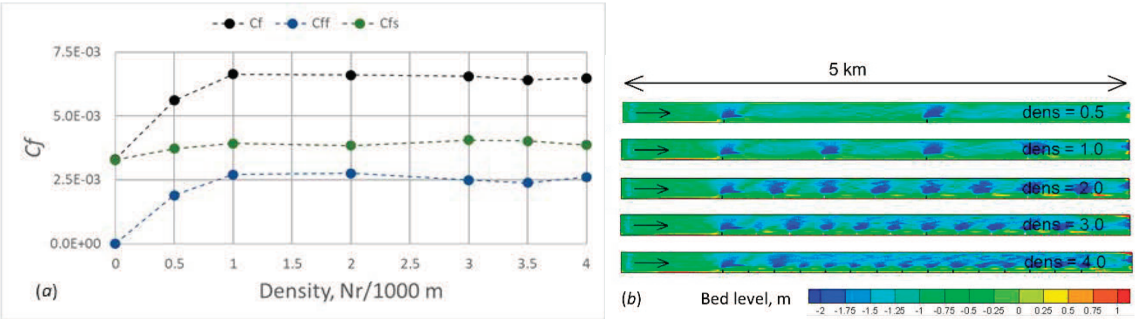

Fig. 1. (*a*) Relationship between intervention longitudinal wing dam density and additional resistance and (*b*) the equilibrium bed geometry formed by the wing dams.

Conclusions

The estimated case results show that there may be a limit in the intervention density above which the value of the resistance resulting by the bed forms (C_{ff}) does not increase further. In this quasi-constant range, the effective resistance coefficient (C_f) roughly doubles the value without the wing dams (Density = 0).

As a result of the narrowed bed, the bed material becomes rougher, due to which the surface roughness increases slightly.

Knowing the altered channel width, bed material and partitioned resistance coefficient, 1D model investigations become possible[4], which allow the calculation of the changes in the bed slope and water level on a large scale.

Acknowledgment

The OTKA PD 135037 grant supported this work. The first author's funding is also acknowledged from the János Bolyai fellowship of the Hungarian Academy of Sciences.

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