

# Impact assessment of river regulations of the past century using 1D morphodynamic modeling on the Upper Hungarian Danube

Emese Nyíri<sup>1</sup>, Gergely T. Török<sup>1,2</sup> and Baranya Sándor<sup>1</sup>



## Introduction

In the case of all rivers, morphological changes can be observed over time, the effect of which can be characterized by comparing it to the dynamic equilibrium state. Changes can be caused by artificial intervention or natural phenomena. Nowadays, we are placing more and more emphasis on forecasts, which primarily concern the morphological characteristics of rivers, as well as changes in bed geometry and hydraulics. In connection with the interventions carried out on the Upper Danube, it can be observed that the individual interventions induced changes in the bed geometry that could not be reliably taken into account in the design. For example, when deposition and gravel bar formation is caused by excess downstream sediment related to bed erosion from an upstream intervention, or a rise in the bed level. In such a case, the upstream intervention may cause downstream navigational difficulties, which will require further river regulation works in the river section, thus becoming problematic.

## 1D calculations

- 1D governing equations:

Hydrodynamics calculation:

$$H = \left( \frac{Q^2 \cdot C_f}{g^2 S} \right)^{1/3}$$

Normal flow assumption

$$\frac{\partial H}{\partial x} = \frac{Q^2 \cdot C_f}{g^2 S^2}$$

Backwater formulation

$$\frac{\partial H}{\partial x} = \frac{Q^2 \cdot C_f}{g^2 S^2}$$

Bed shear stress calculation:

$$\tau_b = \rho C_f U^2$$

Evolution of bed elevation (Exner equation):

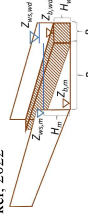
$$(1 - A_p) \cdot \frac{\partial H}{\partial t} = \frac{\partial Q_b}{\partial x}$$

- Wing dam implementation by Török & Parker, 2022

$$B_{initial} = B_m + B_{wd}$$

$$\frac{U_m + z_{ws,m}}{2g} = \frac{U_{wd}^2}{2g} + z_{ws,wd}$$

$$Q_{total} = Q_m + Q_{wd}$$



## Conclusions

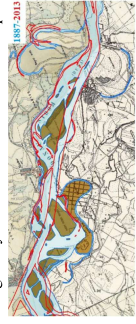
We have created a conceptual 1D model, which can consider the mixed bed material grain composition, which is a significant factor in the case of the examined section of the Danube River. The 1D model can help design river regulations and future impact estimation of a specific intervention. In addition, the model can provide help and boundary conditions for different disciplines.

Model results showed good agreement:

- When cutting through the braided channel system, the change in bed levels is well represented by a mean difference of ~ 5 cm
- Model results show suitable characteristics at estimation the effect of wing dam fields and gives an accurate estimate of 3 cm
- By implementing the effect of various interventions in a 1D morphodynamic environment, morphodynamic process trends can be reliably predicted
- An impact assessment on water levels can also be carried out.

## Investigated interventions on the Upper Danube in Hungary

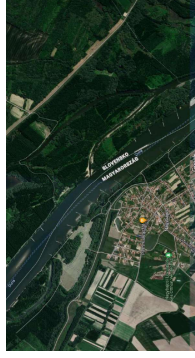
The Danube River has already experienced many regulatory operations. For example, during the 19th-century regulation, a main channel was created from the then braided branch system, which was expected to improve navigability conditions and rebound flood protection.



1. Upper Hungarian Danube before 19th century regulation



2. Upper Hungarian Danube today

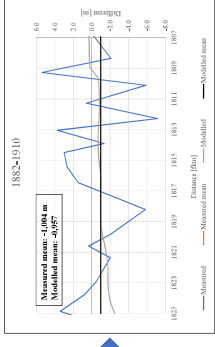
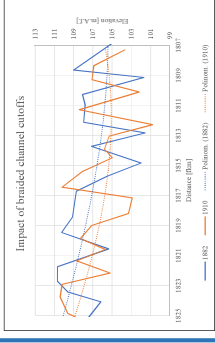


3. Wing Dams in the Danube river

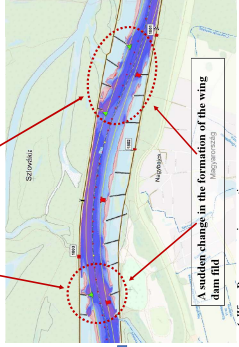
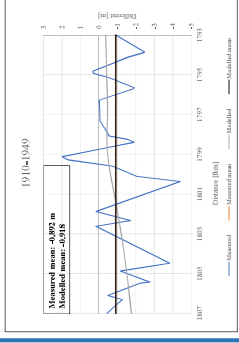
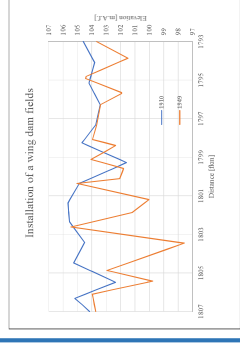
As illustrated in Figure XX, wing dam fields were built on some sections, which are expected to trigger morphodynamic processes that are primarily beneficial for navigability.

## Examination of bed change calculation, model validation

As a result of the cutoffs, the riverbed incision occurred by an average of more than 1 m between 1882 and 1910.



Due to the construction of the wing dam fields, the bed level decreased, which is one of the expected effect of wing dams:



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