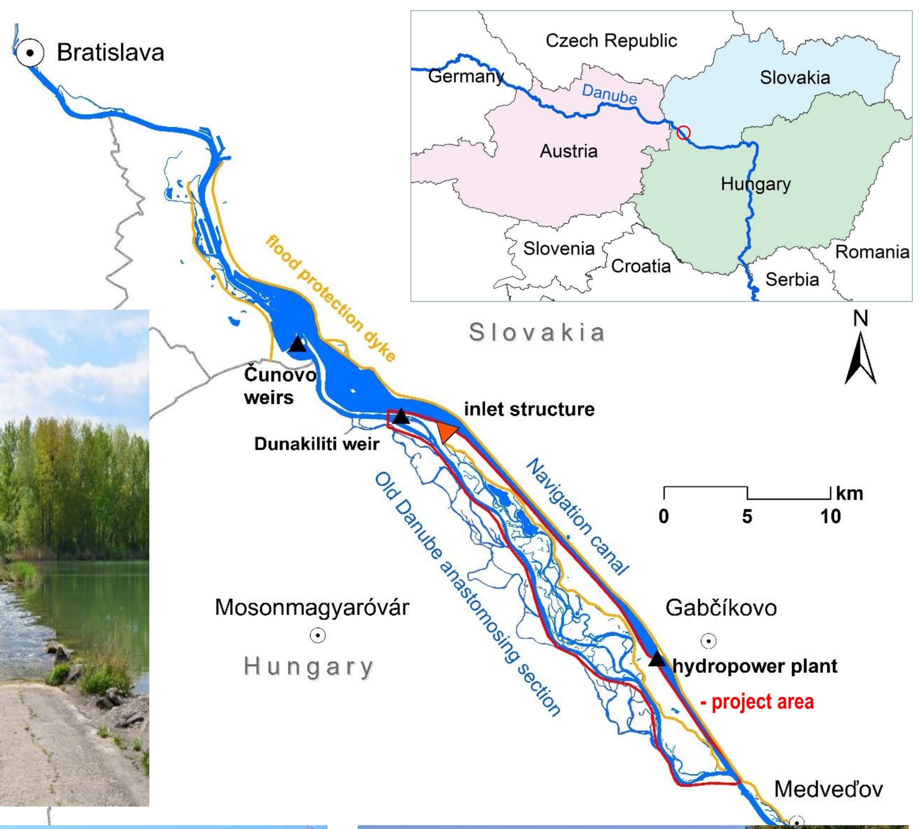
Mitigation measures to improve flow regime within the Slovak part of the anastomosing Danube section

Katarína Holubová, Marek Čomaj, Miroslav Lukáč, Katarína Mravcová, Vladimír Polák, Marek Ando

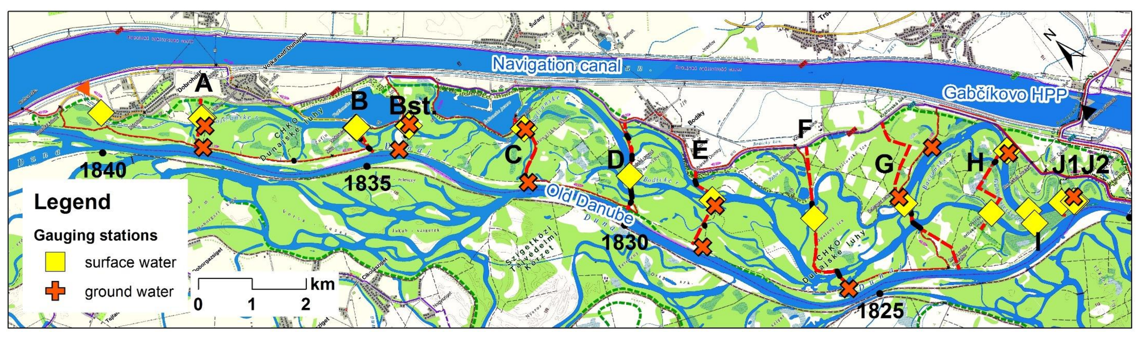
INTRODUCTION: The subject of this poster is an ongoing LIFE project (LIFE14 NAT/SK/001306, 2015-2021) focusing on the rehabilitation of key natural habitats and the introduction of sound and sustainable management for floodplain in a heavily modified anastomosing section of the old Danube river, forming the Slovak-Hungarian border between rkm 1,840 and rkm 1,820.

Habitat rehabilitation is expected to be attained through water regime improvement within the river's anabranch system and through direct interventions made to achieve a favourable conservation status for the targeted habitats.

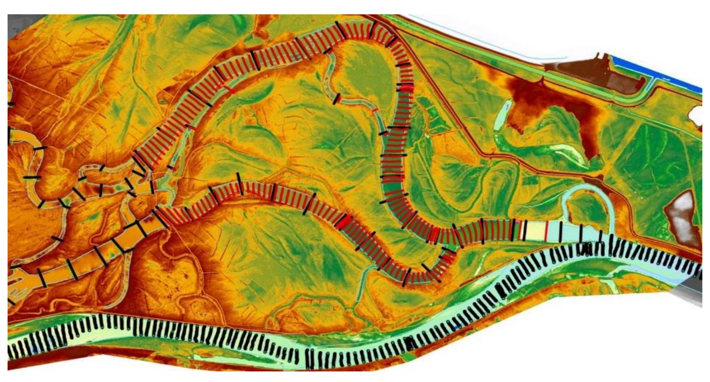


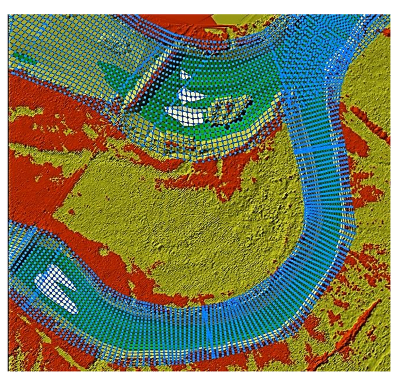
METHODOLOGY: A broad range of field data, numerical and physical models were used to analyse the flow conditions in the project area, to identify the deficits (critical parts) and to optimise in terms of effectiveness the measures proposed to improve the flow conditions.

Monitoring: A special monitoring program was used to monitor the abiotic and biotic processes throughout the project area. A network of temporary observation/gauging stations were built across the floodplain to record the following data: surface water level, groundwater level, meteorological data, sediments, biology (aquatic macrophytes, invertebrates, fish), and water quality. A series of discharge and velocity measurements were carried out under several different flow conditions.



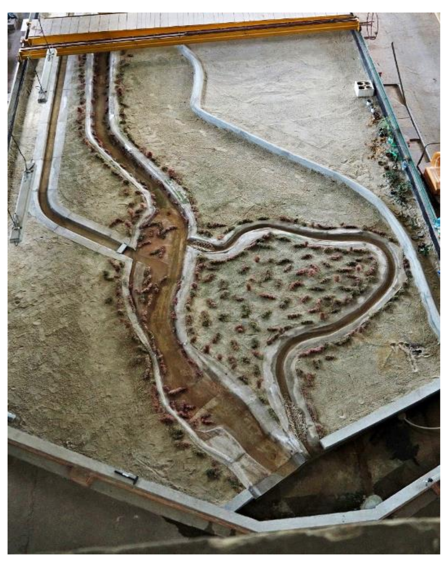
Topographic surveying: LiDAR scanning was applied (in 2014, with an accuracy of less than 10 cm) to make a topographic model of the floodplain terrain for a 2D hydrodynamic model. The digital terrain dataset was extended to include bathymetric data measured by an echo sounder (300 cross-sections). A topographic model of the river bottom was produced using a HEC-GeoRAS extension in ArGIS 10.4. Technical structures were surveyed geodetically.

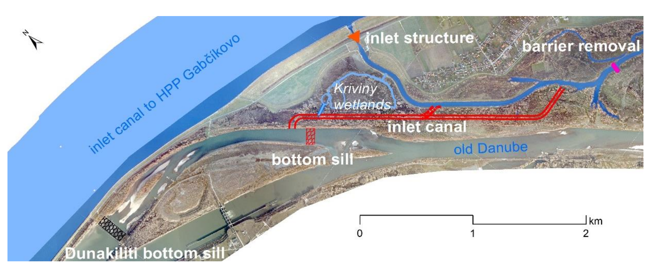




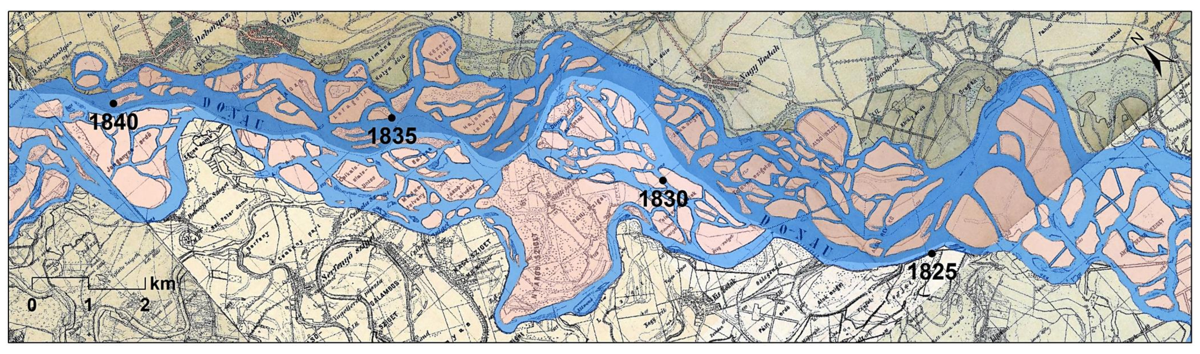
Modelling: The following numerical and physical models were used for the project under review:

- 1D numerical model (HEC-RAS) covering the whole area – for surface water
- 2D numerical model (HEC-RAS) covering the whole area – for surface water
- 3D physical model (scale 1:125/30) covering selected area
- 3D numerical model (MODFLOW) covering the whole area – for groundwater.

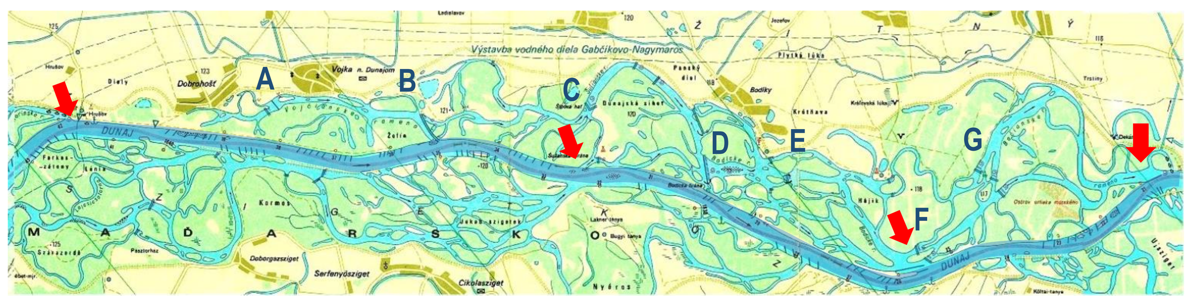




The 1D and 2D models of surface water flows were used to make a detailed evaluation of the current state of the project area and of the efficiency of the measures proposed. The physical model was used to optimise the design of the bottom sills in the old Danube and in the inlet canal, which allow more water to flow into the anabranch system (2nd source). The groundwater flow model served for assessing the interactions between the surface and groundwater levels in the anabranch system under different flow conditions.



HISTORY & PRESENT STATE: An anastomosing river channel has developed downstream of Bratislava over the centuries as a consequence of a rapid reduction in the river valley's gradient creating a unique anastomosing wetland ecosystem, which reflected hydrological, morphological and sedimentary conditions. Since the 18th century, the natural course of the river has been influenced by river engineering works carried out for flood protection and navigation purposes in particular. As a result, the interaction between the river and its floodplains has become quite limited.

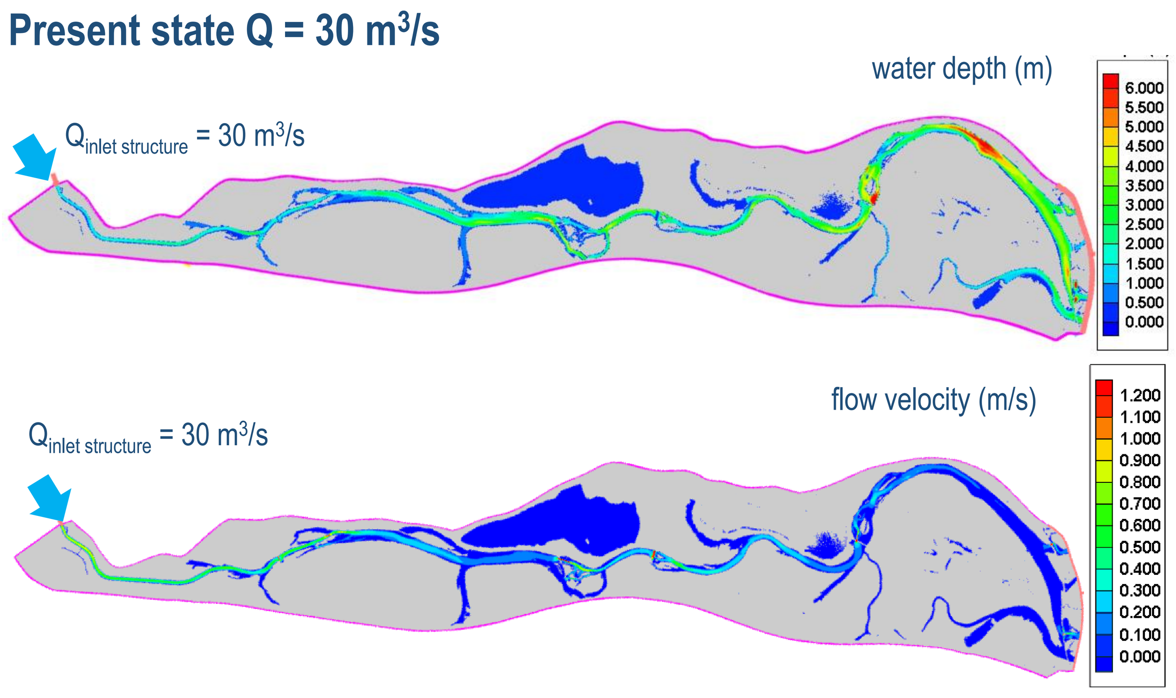


Pre-dam conditions: The cascade of run-of-river hydropower plants built upstream of Slovakia in the 20th century, coupled with dredging, gravel mining and navigation improvement measures, has adversely affected the flow dynamics, sediment transport and morphological conditions in the Danube. These changes have caused a further reduction in hydrological connectivity (limited by Q > 3,000 – 3,500 m³/s, with only 4 branches remaining connected). To improve the water regime and flow distribution, a system of barriers has been built across the Danube floodplain, where they have formed transversal segments (A-E) with impounded water. Flow continuity and water level control are ensured by culverts and broad-crested weirs that are part of those barriers. Danube (at Rajka): $Q_a = 2{,}012\ m^3s^{-1}$; $Q_{bankfull} = 3{,}500–4{,}000\ m^3/s$; $Q_{100} = 10{,}066\ m^3/s$ $i_b = 0.035\%$; w ~ 300 m; d ~ 5–8 m.

Restoration scenarios and constraints: As the project area is located in the common Slovak-Hungarian river section influenced by international issues and by the operation of the Gabcikovo hydropower plant (HPP), the formulation of restoration scenarios had to respect the following constraints:

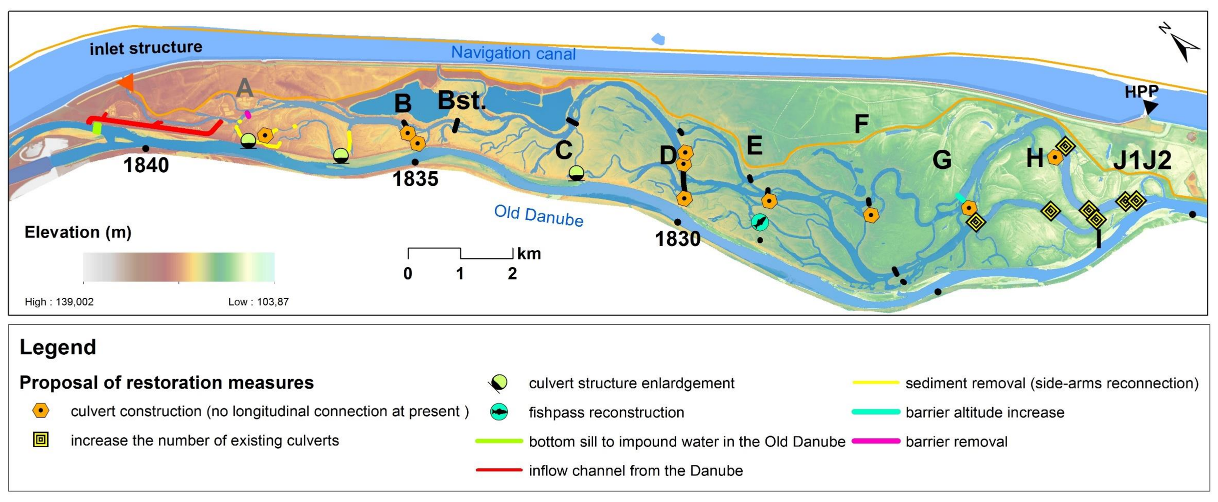
- discharges released through the inlet structure are limited (usually ~ 30 m³/s with a maximum of 60–70 m³/s during a few days/year), due to electricity production at the Gabcikovo HPP and at a small HPP built downstream of the inlet structure
- height of the water level over spilled barriers is limited by the required accessibility for vehicles (max. 40 cm).
- The possibility of considering the whole river system (the old Danube with both floodplains) is restrained by international issues (SK-HU) connected with the operation of the Gabcikovo HPP.

Present state Q = 30 m³/s

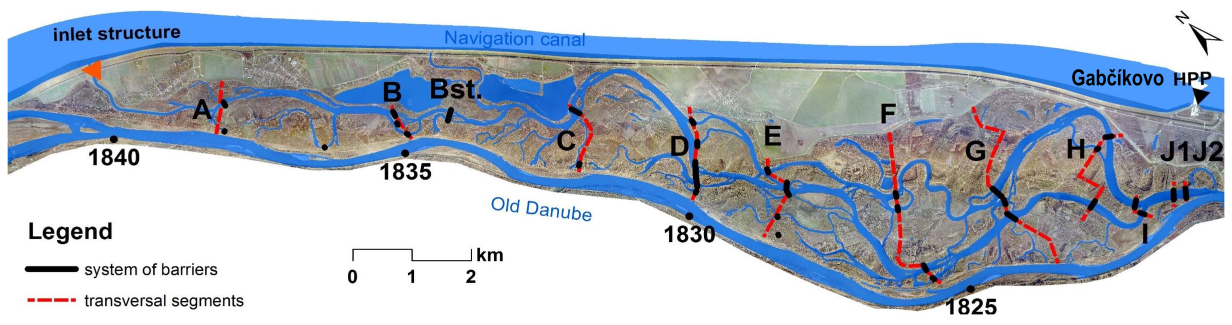


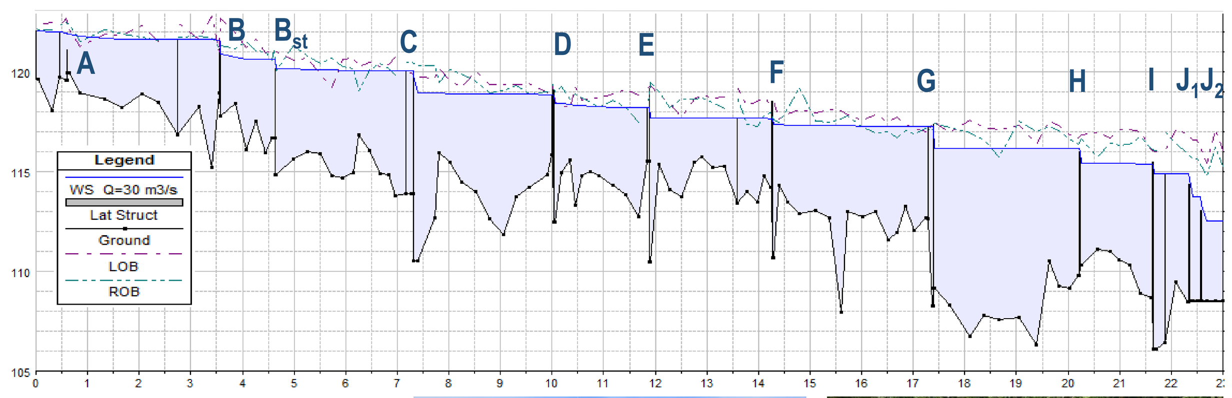
An essential requirement for effective water regime improvement is an increase in the inflow of water into the anabranch system. Hence, two basic scenarios were considered for the flow regime in that system, with regard to the given constraints:

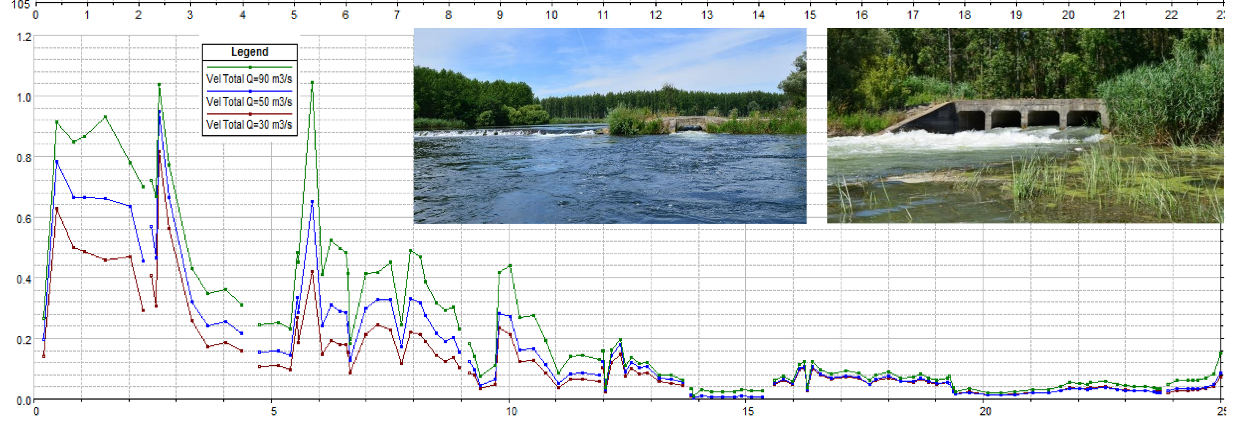
1. Minor changes in the existing flow regime in the anabranch system (~25–30 m³/s, with a frequently occurring discharge of 60–70 m³/s).
2. Major changes in the existing flow regime, which includes an additional inflow of water from the old Danube. This requires that a bottom sill is constructed in the old Danube channel to enable water withdrawal (50–70 m³/s from the old Danube and 30–70 m³/s from the inlet structure).



Post-dam conditions: The operation of the Gabcikovo hydropower plant (since 1992) has completely changed the water balance within the anabranch system, which is enclosed by the old Danube and the bypass canal. Owing to the regulated low flows in the old Danube, the anabranch system is supplied with water from the diversion canal through an inlet structure with a capacity of Q_{max} = 230 m³/s. However, only a constant discharge of 25~30 m³/s is normally released into the anabranches. The maximum discharge (~70 m³/s) is limited by the operation of small hydropower plants built recently downstream of the inlet structure. ***Old Danube (at Rajka):*** a regulated flow of Q_D ~ 400–600 m³/s with a corresponding water level that is 3–3.5 m lower than the water level in the anabranches; higher flows occur only during floods but connectivity is restored at Q_{BA} > 7,000 m³/s in Bratislava, which ensures Q_{Rajka} > 4,000 m³/s in the old Danube.

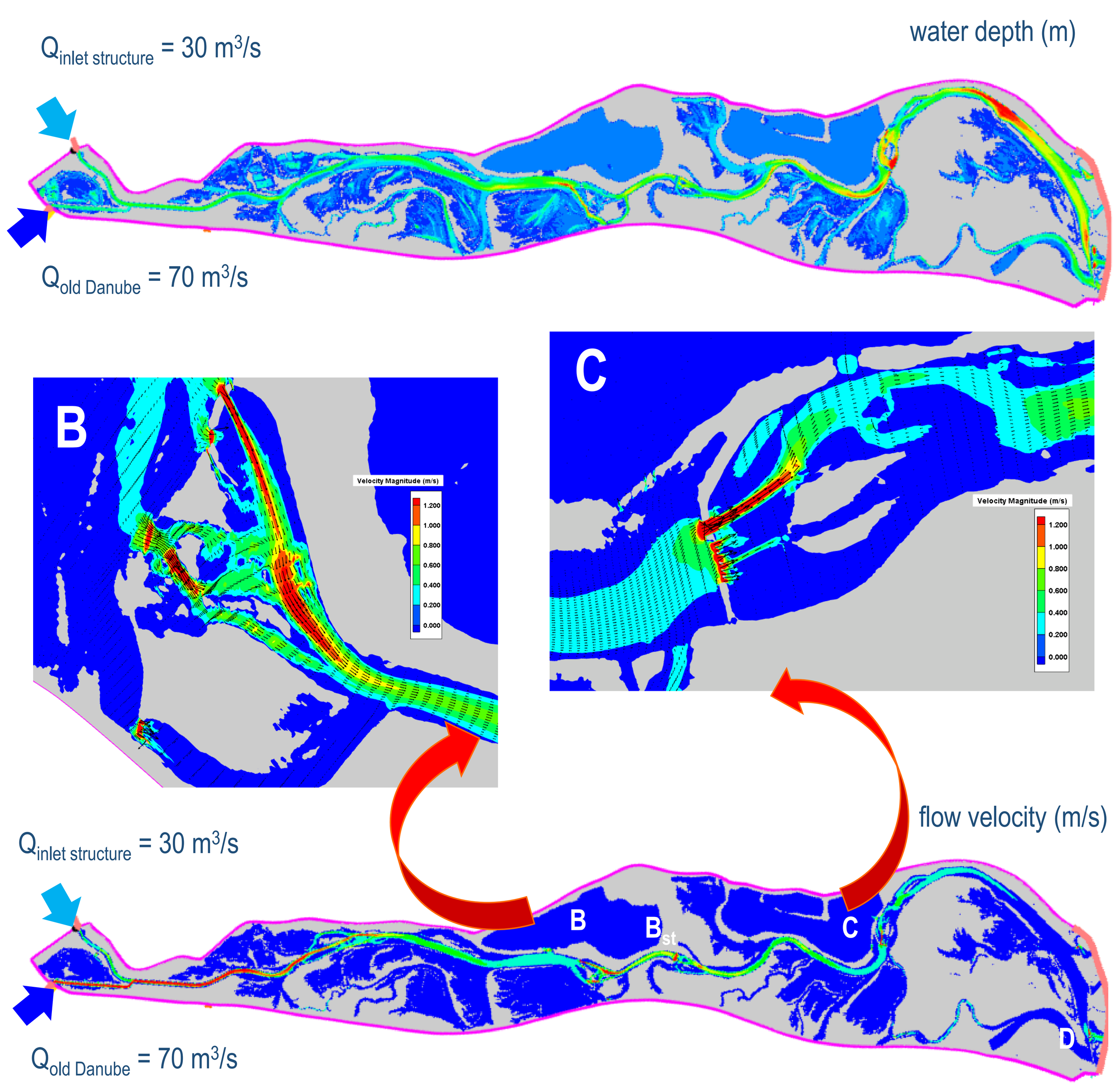






Combinations of structural (modification of existing structures within the barriers) and non-structural measures (reconnection of smaller branches) were proposed in several variants for both flow scenarios and tested using 1D and 2D numerical models. These variants were ranked according to their influence on the flow regime.

Optimal variant Q_{total} = 100 m³/s



Results: The simulation results supported by those of monitoring have shown that no combination of structural and/or non-structural measures would produce the expected improvement without a significant increase in the discharge of water and its seasonal variations. Thus, the optimal variant is represented by the flow conditions from the 2nd scenario, coupled with the most effective combination of mitigation measures applied within the anabranch system. The implementation of these measures would enable a partial improvement in the water regime with higher discharges, seasonal flow variability and flow dynamics in the upper part of the anabranch system (A-D) in particular. In this respect, the construction of a bottom sill in the old Danube, which would enable a discharge increase in the anabranch system, is essential for any major biotic & abiotic improvement in the present state.

CONCLUSIONS:

- The simulation results have proved that, without a flow increase, only a partial water regime improvement can be achieved through relatively simple measures (modification of the existing structures), but only in the upper part of the anabranch system (segments A–D), where the water flow is concentrated in one main branch. A noticeable improvement in the flow dynamics across the entire anabranch system can only be achieved through an increase in the inflow of water from the old Danube. Managing the variability of discharges during the year is equally important. A combination of technical measures and increased discharges (from 30 m³/s to 120 m³/s) may create favourable conditions for biotic and abiotic improvement.
- The Danube river anabranches form a very extensive and complex system. A substantial improvement in the hydromorphological and ecological conditions can only be achieved through an increase in discharges and flow dynamics within the whole river system – the old Danube channel and both floodplain areas (SK & HU). Such a complex approach requires bilateral discussions and agreement by both parties and approval by the bilateral cross-border commission.
- Several restoration variants have been proposed in the past few years for the anastomosing section of the Danube under review. One of these variants involves the construction of relatively large hydraulic structures with navigation locks in the old Danube channel (4 barrages / 40 km). This technical variant has recently been proposed for implementation. It is designed to enable an increase in both the surface and groundwater levels, but on the other hand it may cause numerous problems posed by impounded waters in the old Danube. In this case, the restoration of flow dynamics is highly important for the preservation of the unique wetland biotopes and of the anabranch system's original character. Such goals can be achieved with less technical measures, which may better respect the existing ecosystems of the anastomosing section of the Danube River in accordance with requirements of the Water Framework Directive, Floods Directive and other EU directives concerning nature protection. Therefore, the experts of the Bratislava-based Water Research Institute and other relevant institutions strongly disapprove of the construction of large structures in the old Danube channel.

Water Research Institute Bratislava, Slovakia, holubova@vuvh.sk, comaj@vuvh.sk, lukac@vuvh.sk, ando@vuvh.sk, polak@vuvh.sk

Project partners: Vodohospodárska výstavba