# Changes in connectivity and diversity of the Slovak part of the Danube anabranching reach as response to Gabčikovo water–work construction and remediation scenarios

## Changements de connectivité et de diversité des tronçons anabranchés de la partie slovaque du Danube en réponse à la construction du barrage Gabčíkovo et scénarios de remédiation

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## RÉSUMÉ

Le système en anabranches de la rive gauche du Danube (court-circuité en 1992), zone d'étude, se trouve en aval de Bratislava (1841 -1822 rkm). Une classification de la connectivité hydrologique des bras a été élaborée à partir de l'analyse diachronique de photographies aériennes (1980, 1986, 1990, 1996, 2003 et 2010). Les changements de classes de connectivité, de bande active et de bancs dans les chenaux court-circuités consécutifs à l'abaissement du niveau d'eau ont été estimés pour chaque intervalle de temps. Une approche morphostratigraphique a été appliquée pour identifier les changements de la connectivité sédimentaire entre le chenal et le banc (accrétion verticale) à travers un banc développé après l'établissement du court-circuit. L'analyse granulométrique des dépôts de sédiments et des données de charges en suspension ont été utilisées pour comprendre le fonctionnement de l'accrétion verticale du banc et sa variabilité spatiale selon différentes magnitudes des crues. Pour démontrer l'évolution de la diversité des paysages, de ses conséquences écologiques et des successions végétales, nous avons calculé à l'aide du logiciel FRAGSAT et GUIDOS des métriques reflétant l'occupation du sol sur l'ensemble de la zone d'étude ainsi que pour le banc. Deux types de scénarios de remédiation du système anabranché sont présentés.

## ABSTRACT

The left bank anabranching reach of the Danube River (bypassed in 1992), study area, is located downstream Bratislava (1841 -1822 rkm). Based on the analysis of aerial photographs from time horizons (1980, 1986, 1990, 1996, 2003 and 2010), the classification of channel hydrological connectivity has been worked out. The changes in areas of connectivity classes, bank shifts and benches areas in bypassed channel as responses to water level lowering were estimated by time horizons. The morphostratigraphic approach was applied for the identification of changes in channel/bank sediment connectivity (vertical accretion) through a bench developed after channel bypassing. Grain-size analyses of accreted sediments and suspended load data have been used for understanding the operation of bench vertical accretion and its spatial variability under different flood magnitudes. To demonstrate changes in landscape diversity, its ecological consequences and vegetation succession, land cover landscape metrics for the whole study area as well as for a bench/new floodplain have been computed in FRAGSTAT and GUIDOS softwares. Two kinds of scenarios of the anabranching system remediation are presented.

## KEYWORDS

Connectivity, changes, Danube, Gabčíkovo, remediation

# 1 INTRODUCTION

The study reach, the Slovak-Hungarian section of the Danube River, is classified as a sub-section represented by the inland delta of the section type four “Lower Alpine foothills Danube” of the Danube River classification. In the past it was characterized by meandering, anabranching and braided channels. The dominant substrates consist of medium to coarse gravels overlain by sand and loam in the accumulation zone of the Danube Lowland. In 1992, a massive hydroelectric power project went into operation on the study reach. Damming effectively abolished the active connection between the old main channel and its floodplain side arms, and water now has to be supplied to former side channels via an artificial recharge system. The area incorporates a gradient of laterally connected habitat types ranging from highly dynamic waters in the main channel, through less dynamic waters of the side arms, to stagnant zones. The aim of this research is to identify hydrological connectivity of channels and its changes from 1992, analyse spatiotemporal variability of bypassed channel narrowing, depict channel-new floodplain pocked sedimentary connectivity (vertical accretion) as response to different discharges and suspended load masses, demonstrate the changes in land cover diversity for the whole study area as well as for a new floodplain pocked and to present remediation scenarios of the affected anabranching system.

# 2 METHODS

Spatial data about the left-site bank shift, the channel connectivity and land cover categories were generated from remote sensing images (aerial photographs and orthophotographs). They were analysed in several time horizons (1980, 1986, 1990, 1996, 2003, 2010, 2011) applying the ArcGIS in SJTSK (Krovak East North) coordinate system. Changes in bank line were assessed by overlapping bank positions according to the methodology of Rusnák, Lehotský (2014). Five cross-sections with 3 digging trenches across each of them and three geodetically levelled cross-section with borings have been used for sediment sampling as well as for establishing a relative stratigraphy of accreted deposition-landform units through the floodplain pocked. The FRAGSTAT and GUIDOS softwares have been used for calculation of landscape metrics and demonstration of changes in landscape diversity.

# 3 RESULT AND DISCUSSION

In the actual classification of the connectivity of the Danube river system, we build on the methodology defined by the French school as well as on the typology applied in the National Park Donau-Auen in Austria (Hohensinnt et al. 2010). For more detailed classification of the hydrological connectivity we worked out refined scheme taking into account the size of the discharge, the flow velocity, the nature of the river bed, the width and the depth of the channels. According to these criteria, we identified the following categories of channels:1) Eupotamal - A, B1, B2; 2) Parapotamal - A, B; 3) Plesiopotamal and 4) Paleopotamal. The bypassed Danube channel was qualitatively differentiated by the aggradation or degradation trend of its bed evolution. Decreasing discharge and the disconnectivity in sediment fluxes due to the construction of the Čunovo dam upstream the study reach in 1992 conditioned not only the main channel narrowing (Fig. 1) but also the granulometric change in the vertical accretion stratigraphy which by the positive feedback due to vegetation succession initiates changes in land cover structure.

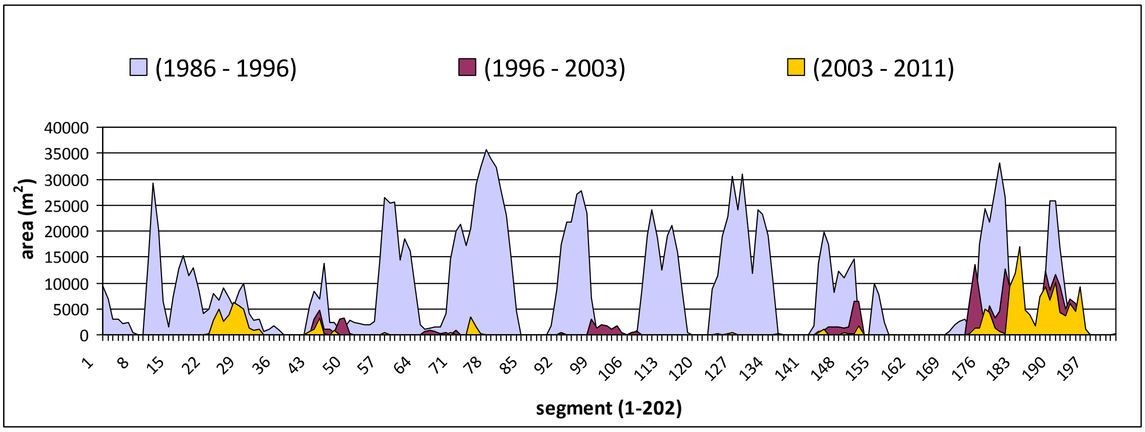


Fig. 1. Spaciotemporal variability of new floodplain areas in the main Danube channel due to water diversion in 1992.

The scroll bar as it could have been seen in 1992 has been developed into new form of floodplain – floodplain pocket. Its morphological differentiation is determined by vertical accretion, i. e. by the input and spatially variable deposition of suspended load during "new" flood regime of the old Danube channel. The identification of the granulometric discontinuity surface covered by accreted fine deposition through the floodplain pocket cross-sections indicates the rate of the vertical accretion (Fig. 2).

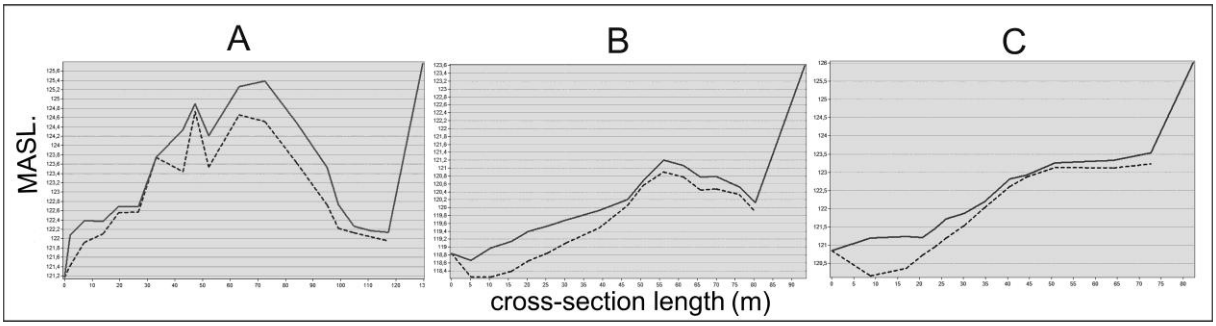


Fig. 2. Former gravel scroll- bar surface (dash line) and variability of vertical accretion (full line) due to channel narrowing - tree cross-sections through new floodplain pocket.

The succession of riparian forest (Fig. 3) and higher values of Shannon's diversity and Simpson's diversity indices indicate increasing diversity throughout new floodplain over time. Two groups of

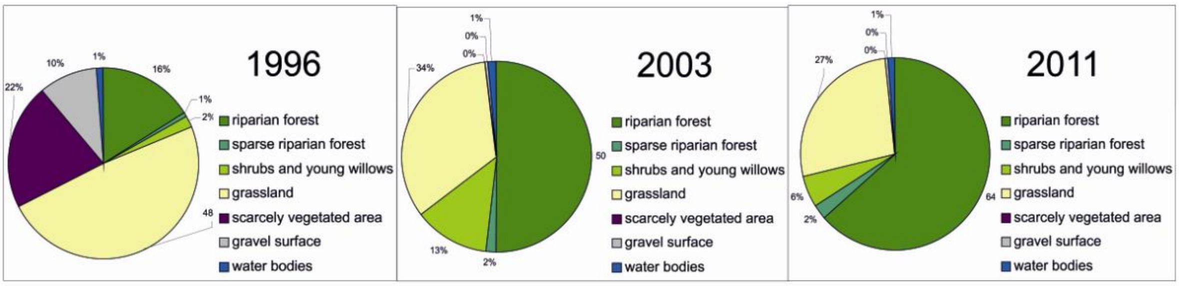


Fig. 3. The diversion of water flow from the main Danube channel in 1992 conditioned the new floodplain pockets development and riparian forest succession through their surfaces – example of the floodplain pocket near the Dobrohošť village.

scenarios proposing several variants of intervention for improving consequences of the dam construction are assessed: 1) the first group proposes 3 variants, i. e. narrowing, optimal filling and increasing in sinuosity of the main channel; 2) the second one suggests 2 variants consisting in the construction of the new complex weirs in the main channel to raise the water level in order to re-connect side-arms, that had been obstructed by closures.

## 4 CONCLUSION

The diversion of water due to dam construction profoundly impacts the original character of channels by altering natural habitat pattern, sediment, and energy flows. The study shows that the construction of the Gabčíkovo HPP in 1992 represents major intervention with fundamental changes of the Danube River anabranching system. The diversion of more than 70 % of the discharge to the bypass canal lowered the mean water level by 2-3 m which conditioned the original channel narrowing, the subsequent development of six new floodplain pockets characterised by the rate of vertical accretion about 6 cm.year$^{-1}$ and the increase in their land cover diversity. Although the main branches of the side-arm system have been fed via an artificial intake (since May 1993) the dramatic changes of channel hydrological connectivity is proved, too.

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