The XXXVIII International School of Hydraulics, 21-24 May 2019, Łąck, Poland

Evaluation of conservation measures impact on flow distribution in the anastomosing river Narew

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ABSTRACT

Anastomosing rivers constitute a rare example of multi-channel systems, which used to be very common before the agricultural and industrial development. Presently, few of them remain worldwide and the only example in Poland is the Upper River Narew within Narew National Park. However, Park Authorities face a problem of side channels extinction in last few decades and therefore a dedicated plan of protection measures (submerged weir construction, dredging and mowing of side channels) was established aimed at anastomosing system conservation. The objective of this study was to develop a 1D water flow model dedicated for multi-channel river and an ex-ante assessment of the impact of proposed protection measures on discharge distribution, flow velocity and sediment transport potential in the anastomosing section of the river (Fig.1). Although hydraulic modelling using 1D models is commonly used to describe water flow in rivers, for multi-channel rivers problem is more complicated. For this type of rivers it is expected that the feedback between process of plants growth and distribution of flow in anabranches is high.

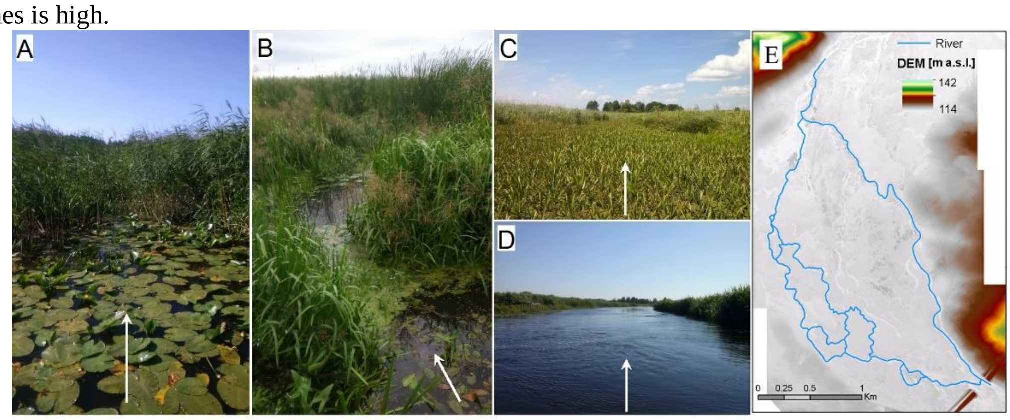

Fig. 1. Abundance of aquatic vegetation (A-D) in the modelled section of the river Narew (E). White arrow indicates the direction of flow.

Field measurements conducted for the purpose of this research included discharge measurements, channel geometry and water level measurements. To capture the impact of vegetation on water level and flow distribution measurements were conducted in two different periods: during high water levels in dormancy season; during low water levels in growing season. In both cases only river flows bellow bankfull stages were considered. 1D steady flow model was developed in the MATLAB computing environment, hereafter referred to as multi-channel flow routing model (MFRM). For the purpose of this research following assumptions were made: steady flow conditions; 1D flow is considered; river flow can be expressed in terms of energy conservation equation; discharge within each river branch is uniform; flow is subcritical. In newly designed MFRM, Bernoulli's energy conservation equation was used. One of the main difficulties in the presented study was the problem of identifying models' parameters, which were Manning's roughness coefficients. A two-step approach included (1) non-linear programming solver finding minimum of constrained non-linear multivariable function to identify Manning's coefficient for all branches based on measured discharge and (2) optimization of the flow (by±10%) in order to ensure energy conservation at re-joining branches. The overall assessment of model accuracy can be expressed by average differences in (1) simulated water levels which for both, growing and dormancy seasons did not exceed 6.6 cm comparing to measured water levels and in (2) energy level between branches which reached accuracy at level of 10^{-5}m.

Following model calibration and validation, proposed protection measures (submerged weir construction, dredging and mowing of side channels) were parametrized and implemented into model computational scheme in different variants.

The variant implementation of protection measures in this study affected the distribution of flow between the channels of the analyzed section of the anastomosing river. Large differences were noted not only between individual protection measures, but also between each variant within one measure. It turned out that vegetation removal (the least invasive measure) was inefficient, contributing to a slight increase in the flow rate and velocity. The implementation of environmentally more invasive dredging and damming was efficient and the efficiency increases with the length of dredged channels.

To take into account a meaningful role of sediment in shaping the fluvial pattern of anabranching rivers an equation of sediment transport potential has been deployed into modeling scheme. Results based on the Engelund-Hansen equation indicate that application of in-stream vegetation removal did not increase the average sediment transport potential significantly. Channel dredging which was assumed to be generally more efficient in altering flow distribution among anabranches caused higher increase in sediment transport potential. As expected the highest influence on sediment transport potential was noted for combined dredging and damming. The most efficient conservation measures applied in the model caused a decrease in sediment transport potential of the main channel. Such change could potentially activate bed scouring processes in side channels and mitigate this process in the dominating channel, which currently overtakes 98% of water discharge.

Given the fact that the River Narew is recognized to be vegetation-controlled and sediment supply was distinguished as one of the causes of anabranches extinction, applied conservation measures were aimed at increasing sediment transport potential of side channels. It turned out that post-conservation alterations of hydraulic properties in side anabranches resulted in a notable increase in sediment transport potential, but only for measures changing channel geometry. Such change could potentially ensure the stability of restoration eliminating the main cause of channels extinction i.e. excessive sediment deposition. It has to be noted however, that this study investigated the efficiency of conservation measures only in hydraulic sense. This does not necessarily mean the optimal solution to be applied. The process of optimal protection strategy selection is multicriterial and should include also environmental and economic aspects.