# Environment-friendly reduction of flood risk and infrastructure damage in a mountain river: case study of the Czarny Dunajec

## Réduction des risques d'inondation et des dommages sur les infrastructures grâce à une approche plus respectueuse de l'environnement : l'exemple de la rivière Czarny Dunajec

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## RÉSUMÉ

Afin de stopper la migration latérale d'un méandre de la rivière Czarny Dunajec (Carpates polonaises) menaçant une route, un recoupement artificiel du méandre fut initialement prévu. Ce recoupement artificiel devait se concrétiser par la création d'un fossé traversant la partie boisée du méandre. Une approche alternative a cependant été proposée pour éviter l'érosion de la berge concave. L'objectif fut d'activer des chenaux secondaires, jusqu'alors inactifs, afin de déplacer l'écoulement principal pour qu'il soit plus éloigné de la route. Les mesures hydrauliques confirment l'efficacité de cette approche alternative. Non seulement cette solution fut beaucoup moins coûteuse à mettre en place, mais elle a également amélioré les fonctions écologiques de la rivière et maintenu le rôle des berges comme « piège à débris ligneux ». La nature hautement instable de cette rivière à chenaux multiples implique que les meilleures pratiques de gestion de cette rivière consisteront à la laisser librement divaguer dans son lit majeur et à renforcer quand nécessaire les limites entre le corridor érodible et les terrasses anthropisées.

## ABSTRACT

To arrest erosion of the laterally migrating channel of the Czarny Dunajec, Polish Carpathians, construction of a ditch cutting the forested neck of the bend was initially planned. An alternative approach to prevent bank erosion was proposed, aiming at activation of flow in inactive side braids to shift the main water current to the position more distant from the road. Hydraulic measurements confirmed efficiency of the implemented scheme in shifting the main water current and reducing the erosional threat to the road. Not only the solution was much less expensive, but it also enhanced ecological functions of the multi-thread channel and the variability of physical habitat conditions and maintained the role of the reach as wood debris trap. The highly unstable nature of the multi-thread channel causes that in the long-term, the best practice of maintaining the river would be allowing free channel migration within the floodplain area and reinforcing, where necessary, the boundary between the erodible river corridor and the managed terrace.

## KEYWORDS

Bank erosion, flood risk reduction, mountain river, multi-thread channel, erodible river corridor

# 1 CONVENTIONAL SOLUTION TO PREVENT CHANNEL MIGRATION

Migration of a mountain river channel may cause erosional threat to infrastructure or settlements on the valley floor. The unmanaged, multi-thread channel of the Czarny Dunajec in the middle river course exhibits different development tendencies during large floods and in the periods between those events. In the longer periods without floods, the main active channel tends to form relatively tight bends, whereas secondary braids operate as chutes. During large floods, the bends of the main channel are cut-off and the channel is straightened. The occurrence of longer periods without large floods may result in the formation of high-amplitude bends of the main channel. Such a situation occurred in 2011, when a cutbank in one of the bends of the main channel neared a local road by 50 m. To arrest erosion of the laterally migrating channel, local water authorities proposed construction of a ditch with reinforced banks, cutting the forested neck of the bend, and damming the main channel with a boulder groyne.

# 2 ENVIRONMENT-FRIENDLY SOLUTION TO REDUCE FLOOD RISK

However, this hard-engineering solution would affect the environment and was disapproved by environmental authorities. This river reach is typified by high abundance and diversity of fish fauna (Wyżga et al., 2009) and high taxonomic diversity of benthic macroinvertebrates (Wyżga et al., 2012a), which reflect considerable complexity of physical habitat conditions within the multi-thread channel. The reach is characterised by high hydromorphological quality and may be considered as representing hydromorphological reference conditions for river restoration projects undertaken in the Carpathians (Wyżga et al., 2012b). Channel regulation in the so far unmanaged reach and undeveloped part of the valley would cause deterioration of the ecological status of the river, thus contradicting the requirements of the EU Water Framework Directive.

Notably, the multi-thread reach traps much woody debris delivered in flood waters from upstream and retains it away from urbanised sections of the valley. This is especially enhanced by the presence of narrow side channels in which the wood is easily anchored. Substituting the network of narrow braids with a wide, regulated channel would preclude ‘filtering’ of woody debris from the flood waters and facilitate its downstream transfer to urbanised valley reaches, where it could constitute a considerable flood hazard.

A different solution to limit the erosional risk to the nearby road was thus proposed. The inlets to side braids located by the neck of the bend of the main channel, silted with gravel or plugged up with wood jams, would be opened to re-establish the flow in the low-flow channels typified by higher slope, leading to the natural cut-off of the main channel and its abandonment. This solution was approved by the water authorities and implemented in the autumn 2011 at the cost of 9000 euro. Directly below the inlets to the side channels, deflectors made of gravel material were constructed to divert the flow into the channels and prevent the water from entering the main channel (Fig. 1). This should enable the opened side channels to take over most of the flow during the next flood, hence leading to the abandonment of the main channel bend. Willow cuttings were also planted on the cutbank within the bend to enhance development of willow shrubs and bank stabilization.

# 3 FUNCTIONING OF THE IMPLEMENTED SCHEME

Following the implementation of the scheme, river cross-sections located at the upstream end and in the middle of the main channel bend were surveyed to compare the hydraulic characteristics of flow and the composition of fish and benthic macroinvertebrate communities with those recorded prior to the project. The hydraulic measurements confirmed that the scheme allowed to shift the main water current, with the highest average velocity and bed shear stress, from the braid closest to the road to the most distant one. The biotic surveys indicated that re-activation of the flow in the side channels was beneficial for fish and benthic macroinvertebrate communities, increasing their diversity in the reach.

In May 2014, a 20-year flood occurred on the river. The flood resulted in the cut-off of the former main channel bend, directing most of the flow to one of the opened braids. However, avulsion of the main channel took place in the immediately upstream river bend, again causing erosional threat to the road, although in different location.

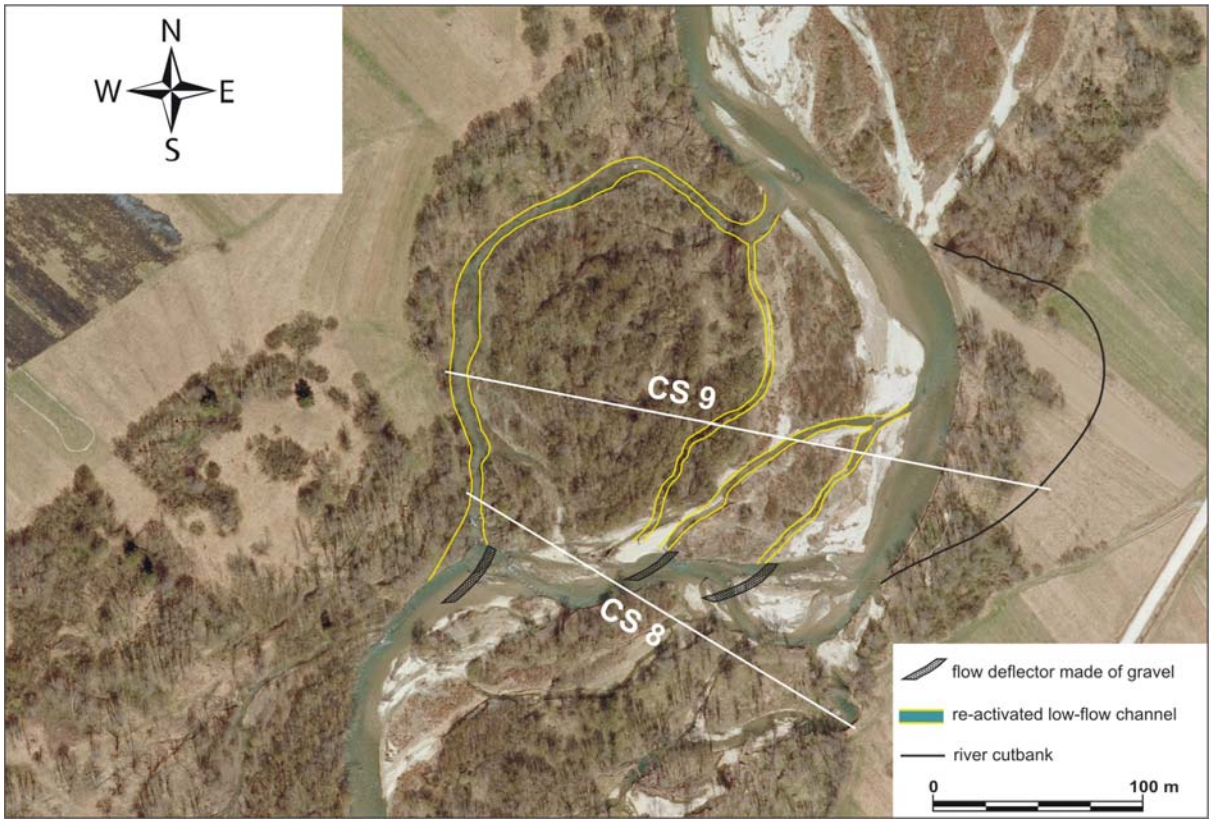


Figure 1. Environment-friendly solution to the erosional threat to the local road, performed in the autumn 2011. Inlets to blocked braids distant from the road were opened and gravelly deflectors were formed in the main channel to direct flow to the re-activated braids.

## 4 CONCLUSIONS

The implemented solution to reduce flood risk and infrastructure damage was significantly less expensive than the traditional, hard-engineering solution, and it also enhanced ecological functions of the multi-thread channel and the variability of physical habitat conditions and maintained the role of the reach as wood debris trap. With the highly unstable nature of the multi-thread river channel in the poorly managed valley reach, the best practice of river maintenance would be allowing free channel migration within the floodplain area and reinforcing, where necessary, the boundary between the erodible river corridor and the managed terrace.

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