Degradation and Rehabilitation of Cut-off Meanders on the Morava River

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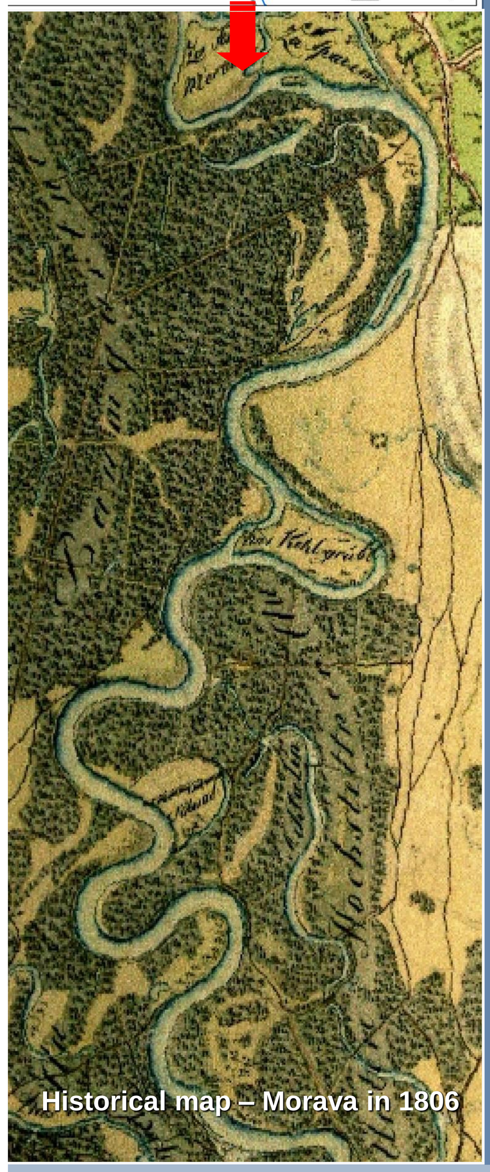


Historical map – Morava in 1806

LOCATION

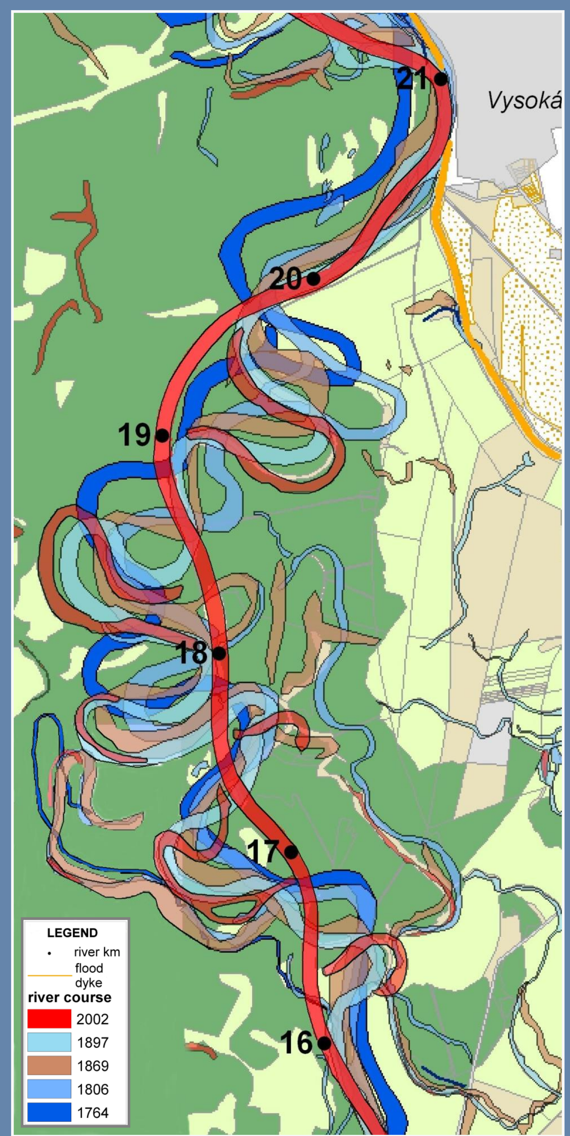
Slovak–Austrian section of the Morava – which is a lowland meandering river with low gradient and sandy- gravel bed material. The river and floodplain create a unique wetland ecosystem which include Ramsar sites and Natura 2000 areas.

Q_a= 114 m^3s^{-1} Q_b= 260 m^3s^{-1} Q_{100}= 1400 m^3s^{-1} i_b= 0,018%
D_{50}= 0,003 m B = 50 m – 80 m H = 3,5 m – 5 m

INTRODUCTION

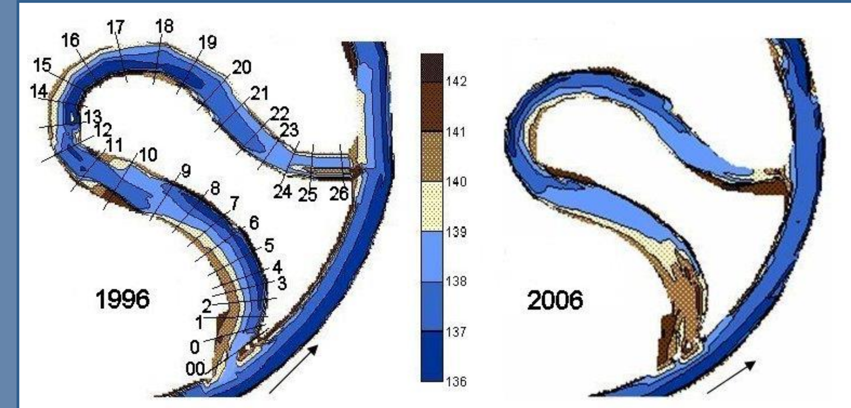
The isolation of meander bends following channel straightening has resulted in the loss of key river habitats and altered the hydrological connectivity between the river and its floodplain. This has adversely affected the riverine ecology. Reconnection of cut-off meanders is often required in order to restore natural river and floodplain functions.

Successful reconnection of cut-off meanders requires detailed knowledge of the morphology, sediment transport and flow dynamics of the river. Long-term monitoring of the river, coupled with physical and numerical modelling, were undertaken in order to develop effective sustainable measures to improve flow dynamics and minimize sedimentation in the restored meanders.

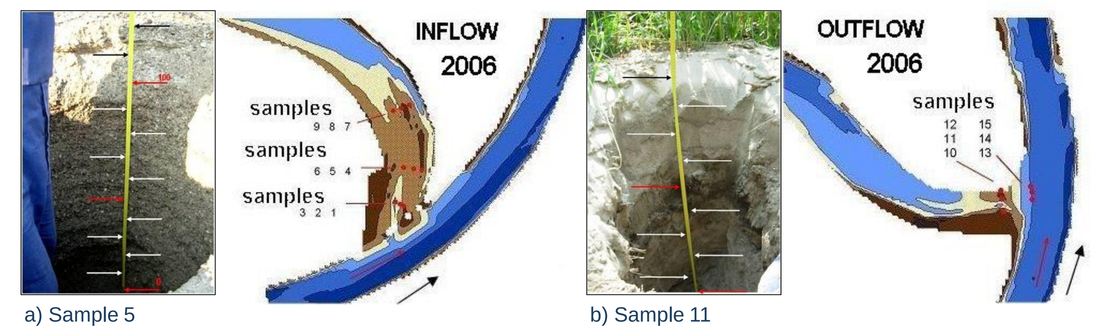


RECONNECTED CUT-OFF MEANDERS

In an attempt to re-establish species richness in the oxbows, selected cut-off meanders were recently reconnected at locations on both sides of the river (four on Slovak side and two on the Austrian side). Paradoxicily, restoraion measures have resulted in significant sedimentation at all localities as they were undertaken without any understanding of natural river processes. Highest sedimention rates were observed in cut-off meanders that had been reconnected at both ends.

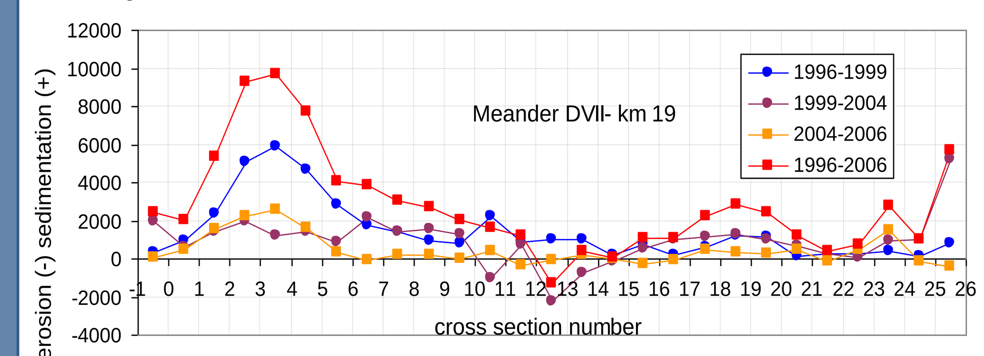


Bed elevations pre-post reconnection of cut-off meander DVII-km 19



Sediment deposited in reopened cut-off meander DVII – km 19 (a) inflow (b) outflow

The most extensive aggradation was observed in the reopened cut-off meander DVII, which was reconnected at its entrance and exit. High sedimentation rate was influenced by its small diversion angle (α), the shape and length of the meander channel and the bedload transport in the river. It was aggravated by the meander being reconnected on the inner part of a river bend where bedload is preferentially transported .



Cut-off meander (no/km)	Meander length (m)	Reconnection		Opening/ plugging (years)	Annual sedimentation rate (m^3/year)	Diversion angle α	Total sedimentation rate $V_{deposits}/V_{total}$ (%)
		type	scheme				
DII (SK) km 12	1 572	both ends		1995/ 2003	4 949	**65**	54 439 / 315 945 **17 %**
DIV (AT) km 16	1 350	exit		2002	higher	**89**	data incomplete
DVI (AT) km 18	1 967	exit		2002	lower	**112**	data incomplete
DVII (SK) km 19	1 695	both ends		1996/ 2004	7 592	**39**	75 925 / 352 147 **22 %**
DXVII (SK) km 65	1 322	both ends		1997/ 2005	6 662	**90**	59 955 / 259 004 **23 %**
DXVIII (SK) km 66	862	both ends		1997/ 2005	5 056 (data-2,5 years)	**66**	15 168 / 140 760 **11 %** data incomplete

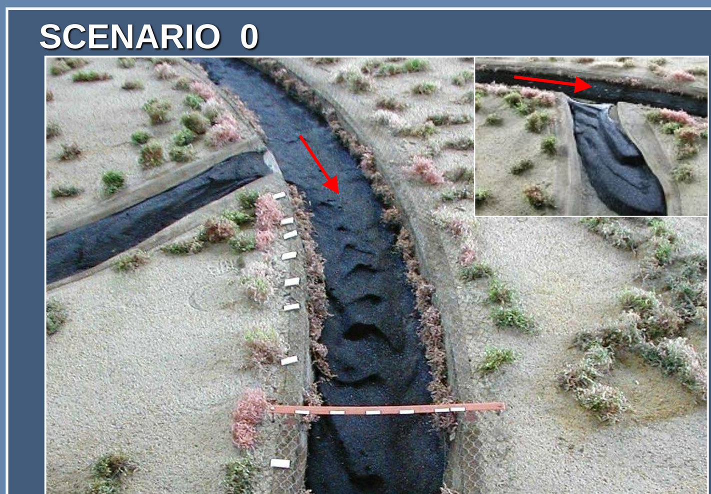
Sedimentation rates were highest during the first 4 years and the entrance was completly plugged after 6 years (DVII). Deposits in the entrance were mostly derived from bedload, gravel and coarser sand, while the exit was blocked by finer sediment; mainly sand, silt and clay.

METHODS

A numerical model FLOW-2D and a physical mobile bed scale model (1:100/160), both supported by field measurments and observations, were used to establish flow conditions, sediment transport and morphological changes within the restored meander bends and, thereby, identify the reason for their rapid rate of sedimentation. The results of these simulations plus the field experience from failed procedures enabled more effective and sustainable designs to be proposed.

Several scenarios were investigated and four arrangements are compared here: simple reconnection - both ends opened (0), upstream closed - downstream opened, instream vane at the exit (1), both ends opened, instream vane at the entrance (2), full cut-off meander integration – main channel fully blocked (3). When vanes were deployed different configurations were investigated for a range of discharges to establish the optimum arrangement to minimize aggradation in the meander.

SCENARIO 0



Simple reconnection – entrance and exit opened

SCENARIO 1

Entrance closed and exit opened -vane at the exit

SCENARIO 2

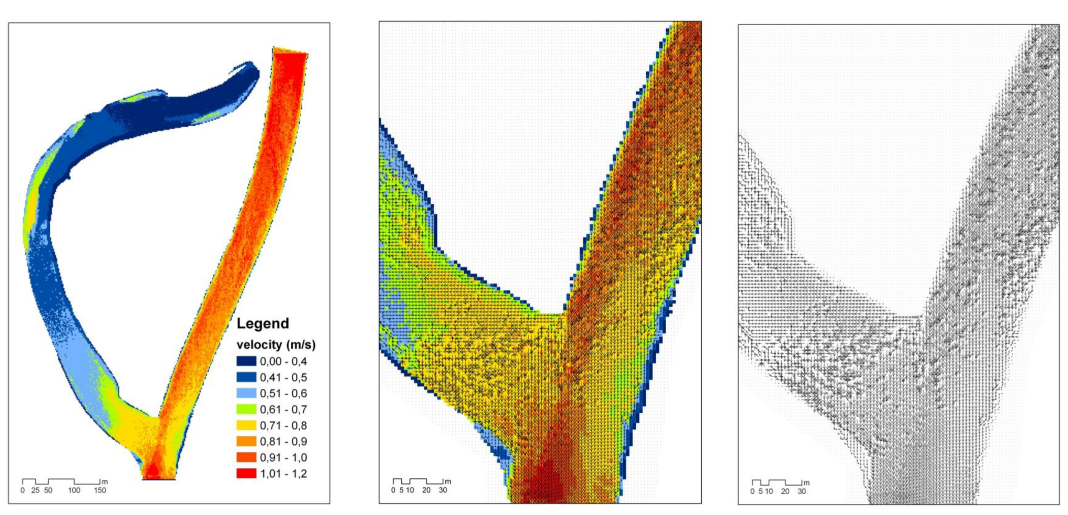
Entance and exit opened - vane at the entrance

SCENARIO 3

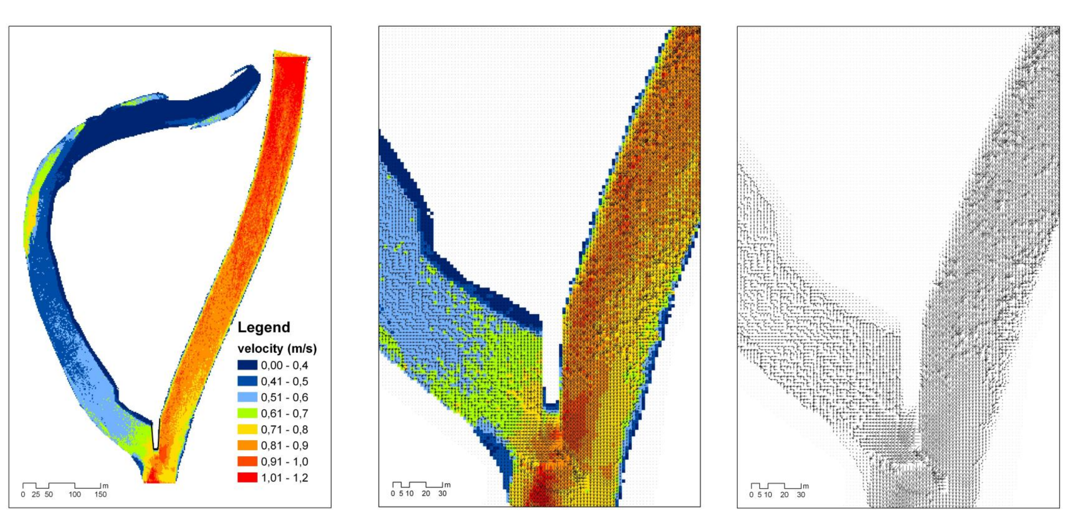
Full meander integration – main channel blocked

RESULTS

Experiments on physical models were combined with simulations on numerical hydrodynamics models (1D, 2D – with model grid 2m x 2m).



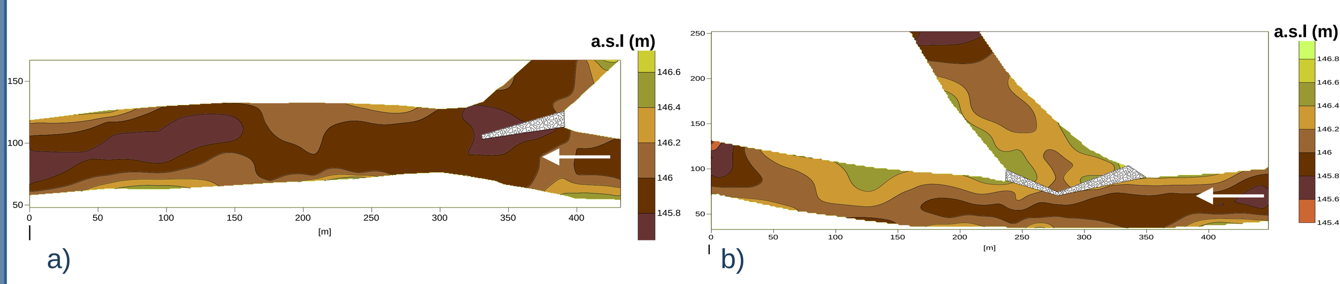
Flow pattern and velocity distribution–open at downstream end Q= 230 $m^{-3}s^{-1}$



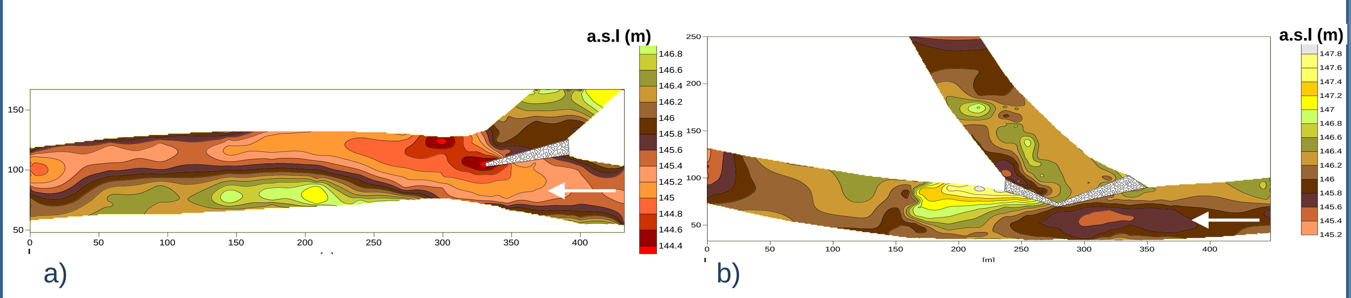
Flow pattern and velocity distribution – instream vane at the exit, Q = 230 $m^{-3}s^{-1}$

SCENARIO - 0: Original higher bed level in the the meander bend was initially lowered to that of the main channel. This increased the flow into the cut-off meander. High discharges transported large volumes of sediment into the entrance section where the decrease in velocity and shear stress due to flow divergence triggered preferential deposition of the coarsest component of the load; bed load. The entrance section rapidly became blocked preventing further inflow. This scenario should not be attempted on rivers which actively transport bedload.

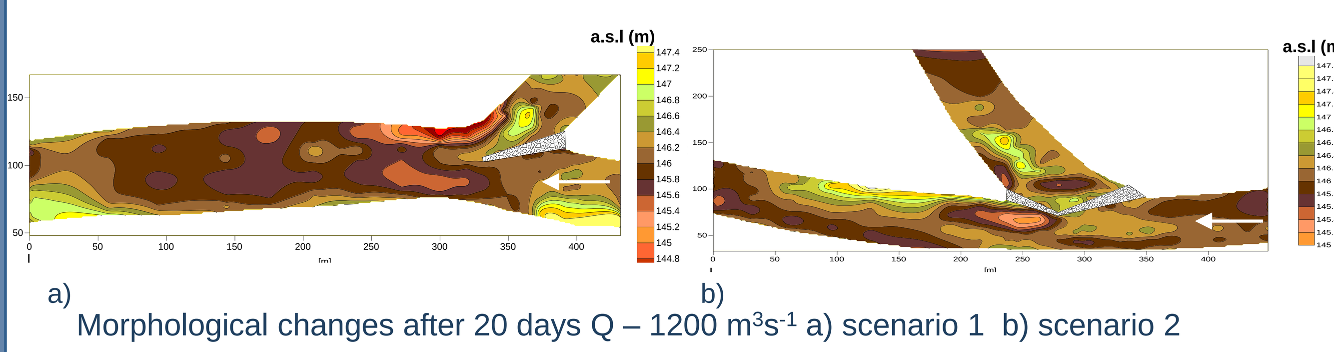
SCENARIO- 1: Entrance closed, exit opened, instream vane located at the exit. The vane was installed to modify the velocity distribution, as flow back filled the meander, to minimize sediment ingress. Model runs with a prolonged bankfull discharge showed no significant sediment input. Minor morphological changes at the exit result from the effect of the vanes on secondary circulation patterns. Permanent changes in bed topography induced by the vane would increase habitat diversity of relatively uniform river channel.



River bed topography – initial state a) scenario 1 b) scenario 2



Morphological changes after 48 days Q_b – 260 m^3s^{-1} a) scenario 1 b) scenario 2



Morphological changes after 20 days Q – 1200 m^3s^{-1} a) scenario 1 b) scenario 2

SCENARIO- 2: Entrance and exit open with instream vanes at the entrance. The vanes, by influencing flow conditions cause local scour and deposition in the main channel. The location and extent of the pools and shallows vary with discharge. Although the vanes reduced the volume of bed load entering the restored meander, some sedimentation occurred in the lee of the vane due to the local decrease in velocity and shear stress.

SCENARIO- 3: Main channel is blocked up to the bankfull stage level and the cut-off meander is fully restored. All discharges up to bankfull are diverted into the cut - off meander thereby re-establishing the natural flow and sediment transport processes within the bend. Former straight channel can either be back filled with material dredged out of the cut-off´s or left unfilled to provide a temporary backwater until it is refilled with material settling out of suspension during flood events.

CONCLUSIONS

- Re-opening cut-off meander leads to rapid sedimentation and plugging. Most sediment is deposited in the first quarter of the meander bend due to reduced velocities and shear stresses: **not recommended**
- Preliminary results with flow backfilling the meander from the downstream end indicated that a suitably designed instream vane is effective in minimizing sediment ingress: for implementation on meanders that cannot be fully re-instated
- With both ends of the meander open and with a vane positioned at the entrance, some sedimentation occurred due to flow divergence; albeit significantly less than with no structure in place: for restoring some flow dynamics prior to a more sustainable solution being implemented
- Full integration of cut-off meanders to restore natural river functions. This arrangement can prevent progressive aggradation and provide long term sustainability. Modifications may be required to the entrance diversion angle to ensure success: recommended solution

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