

Lot 1: Hydraulic and morphological modelling of the SRB-CRO common stretch of the Danube River

Multi-criteria analysis and 2D Modelling

Stakeholders' Forum Meeting 12 (SFHM 12)

11/12/2024

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A3: MCA Definition

Methodology

- Mathematical formulation
- Criteria updated
- Indicators updated
- Acceptable score ranges updated
- Weighting coefficients redistributed
40/(40+5)/15

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
N ₁	DC recommendations	<u>Quantitative</u> - Water depth ratio, Top width ratio, Curve radius ratio	1.5 - 2	0.30
N ₂	Maneuverability	<u>Quantitative</u> - Velocity ratio <u>Qualitative</u> - Hindrance	0.25 - 2	0.05
N ₃	Safety	<u>Qualitative</u> - Visibility of the structures	0.25 - 1	0.05

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
E ₁	Hydro-morphology	<u>Quantitative</u> - Riverbed volume ratio, SHDi ratio, Length of low flow channels ratio, Bankfull discharge water level difference, Near bank velocity ratio, bank erosion length ratio	0.25 - 2	0.15
E ₂	Naturalness of solution	<u>Quantitative</u> - Number of structures difference	0.25 - 2	0.05
E ₃	Sediment and water quality	<u>Quantitative</u> - Dredging volume <u>Qualitative</u> - Effects on physical, chemical and biological parameters of water quality	0.25 - 2	0.05
E ₄	Bird population	<u>Qualitative</u> - Aspects of nesting and wintering	1 - 2	0.05
E ₅	Fish population	<u>Qualitative</u> - Aspects of spawning, migration, growing and living	1 - 2	0.05
E ₆	Flora	<u>Qualitative</u> - Creation of new areas for distribution	1 - 2	0.05

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
F ₁	Technical aspects	<u>Quantitative</u> - Response time and execution of works	0.25 - 1	0.05
F ₂	Financial aspects	<u>Quantitative</u> - Investment and maintenance costs/avoided users costs as benefit	0.25 - 2	0.10

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
C	Climate change vulnerability	<u>Qualitative</u> - Aspects of climate change sensitivity and adaptivity	0.25 - 2	0.05

$$Total\ score = N_1^{0.30} \cdot N_2^{0.05} \cdot N_3^{0.05} \cdot E_1^{0.10} \cdot E_2^{0.05} \cdot E_3^{0.05} \cdot E_4^{0.05} \cdot E_5^{0.05} \cdot E_6^{0.05} \cdot F_1^{0.05} \cdot F_2^{0.15} \cdot C^{0.05}$$

Sub-criteria -> Indicators -> Scoring

- Qualitative and quantitative indicators
- Expert judgment based scoring
- Limitations
- Scoring (+/-)
 - Erosion/Deposition (downstream effects -> scale of the project)
 - Periodic flooding/Flood protection (project scope?)

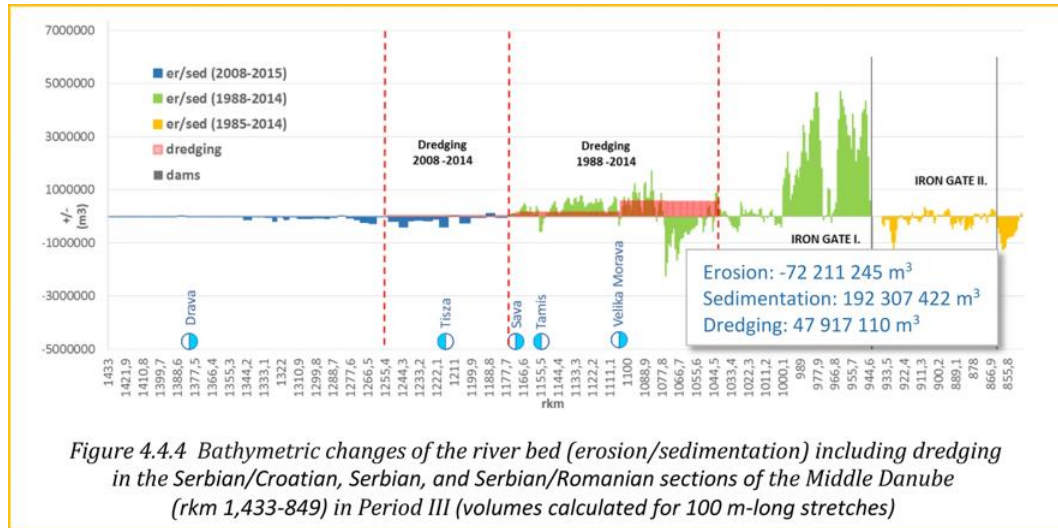


Figure 4.4.4 Bathymetric changes of the river bed (erosion/sedimentation) including dredging in the Serbian/Croatian, Serbian, and Serbian/Romanian sections of the Middle Danube (rkm 1,433-849) in Period III (volumes calculated for 100 m-long stretches)

Environment group of criteria

Scenario	"Do-nothing" (Reference values/state)	Groyne system on convex side of the bend (Indicators -> Score)	Fairway realignment (Explanation -> Score)
Indicators - Subcriteria	"Do-nothing" (Reference values/state)	Groyne system on convex side of the bend (Indicators -> Score)	Fairway realignment (Explanation -> Score)
River bed volume	ref. value: $V = -88500 \text{ m}^3$	diff. = -7000 m^3 ($V = -95500 \text{ m}^3$)	diff. = 0 ($V = -88500 \text{ m}^3$)
SHDi	ref. value: SHDi = 0.78	ratio = 0.96 (SHDi = 0.75) Negative impact on biodiversity (living organisms negatively affected)	ratio = 1.0 (SHDi = 0.78)
Length of LF channels ref. value/ratio	ref. value: $L_{lf} = 250 \text{ m}$	ratio = 0.84 ($L_{lf} = 210 \text{ m}$)	ratio = 1.0 ($L_{lf} = 250 \text{ m}$)
Z(Q _{bankfull})	ref. value: Z = 90.00 m.a.s.l.	diff. = 1 cm (Z = 90.01 m.a.s.l.)	diff. = 0 m (Z = 90.00 m.a.s.l.)
Lateral connectivity	ref. value: $V_b = 1.4 \text{ m/s}$	ratio = 0.64 ($V_b = 0.9 \text{ m/s}$) aquatic-terrestrial fluxes disturbed	ratio = 1.0 ($V_b = 1.4 \text{ m/s}$)
E ₁ - Hydro-morphology	1.0	0.25	1.0
Dredging volume	n.a.	n.a.	n.a.
Water quality parameters	n.a.	slightly negative effects since local stagnant water introduced	n.a.
E ₂ - Sediment and Water quality	1.0	0.5	1.0
Nesting	ref. state	no changes if groyne system is proposed along shallow banks/ negative effect for steep banks	no changes
wintering	ref. state	n.a.	no changes
E ₃ - Birds	1	1 / 0	1
Spawning	ref. state	n.a.	no changes
Migration	ref. state	n.a.	no changes
Growing	ref. state	sheltered	no changes
Living	ref. state	negative due to siltation	no changes
E ₄ - Fish	1.0	1.0	1.0
Creation of new areas for distribution	ref. state	no significant change	no changes
E ₅ - Flora	1.0	1.0	1.0
Climate change sensitivity	ref. state	moderate sensitivity	no changes regarding reference state
Climate change adaptivity	ref. state	moderate adaptivity	no changes regarding reference state
E ₆ - Climate change vulnerability	1.0	0.5	1.0

Navigation group of criteria

- Weighting coefficients updated

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
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Environment group of criteria

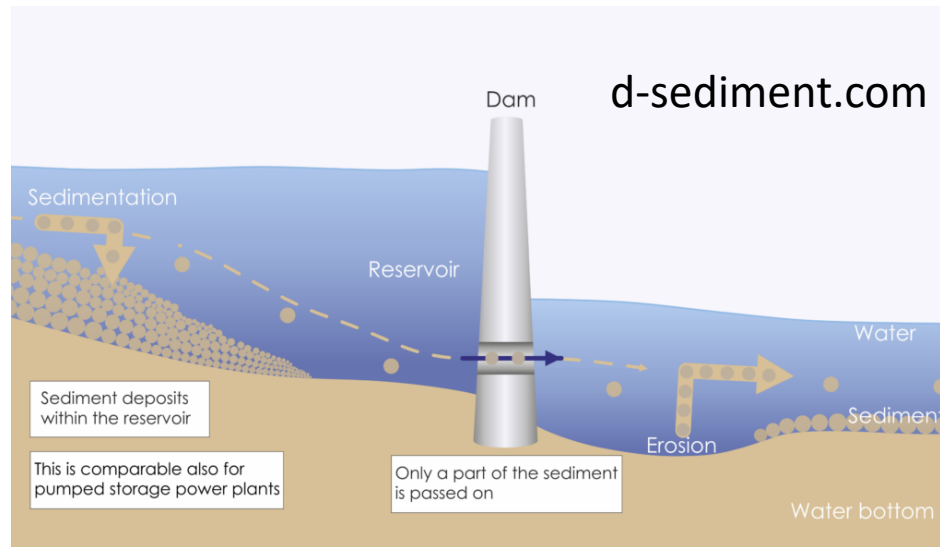
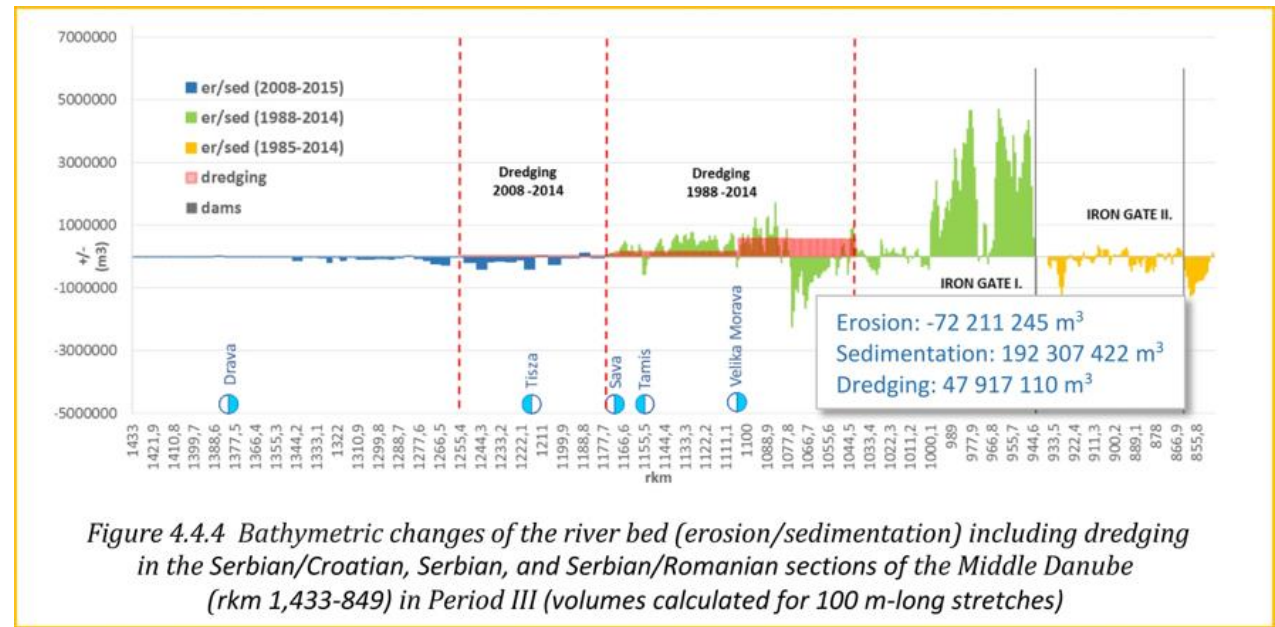
- Weighting coefficients updated
- New criteria included

Code	Criteria	Indicators	Acceptable Score	Weighting coefficient
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E1 - River bed volume ratio

Integrated sediment management planning

- Integrating different use-related needs (Environmental and socio-economic aspects)
- Catchment -> **Local scale** (Deposition at one sector -> increased erosion/reduced sedimentation along downstream sector)



E1&E2 - Lateral connectivity related indicators

- Bankfull discharge water level difference, Near bank velocity ratio, bank erosion length ratio (E1)
- Number of structures difference (E2)
- The domain of measures influence
- Main channel <--> Inundation (out of project scope)
- "Hydraulic" indicator related to mass exchange and conveyance

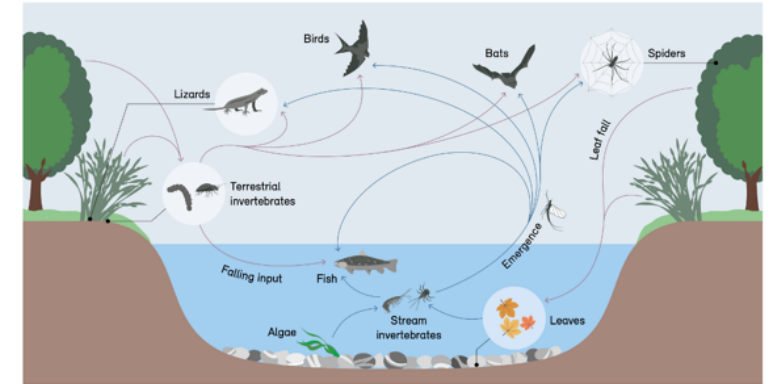


Figure 5: Illustration for aquatic-terrestrial fluxes (Baxter, Fausch and Saunders 2005)

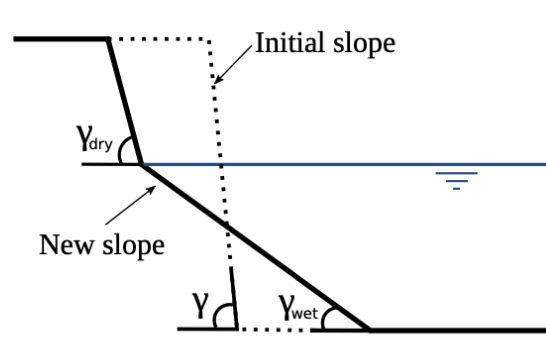


Figure 6: Lateral sediment exchange between main channel and inundation

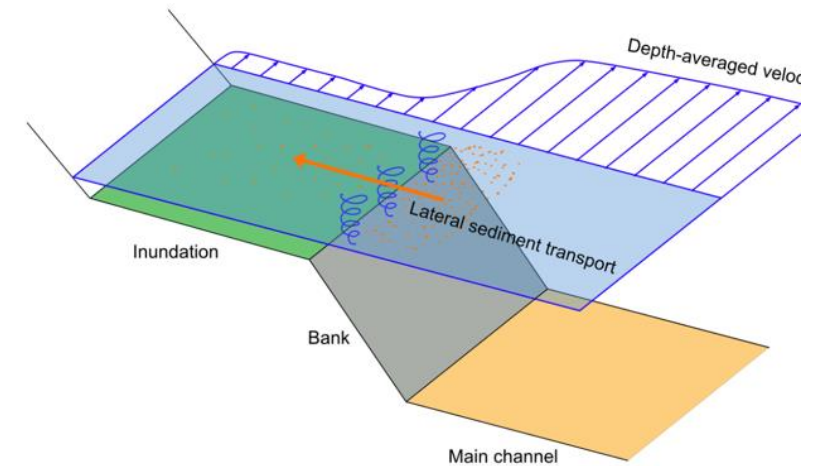
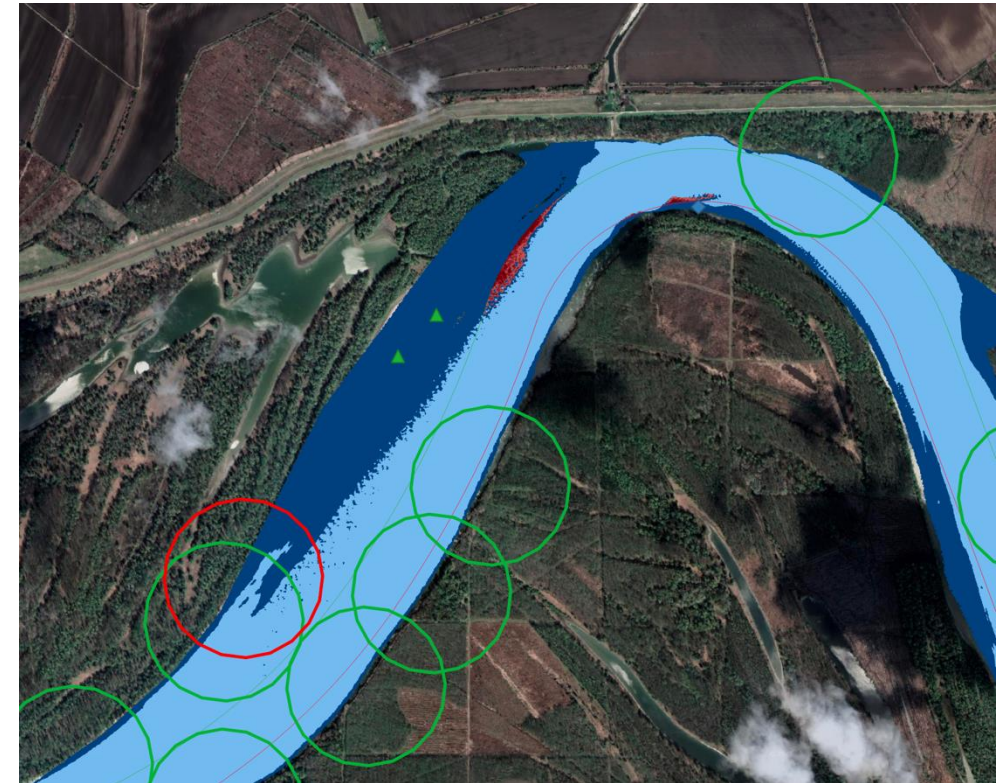
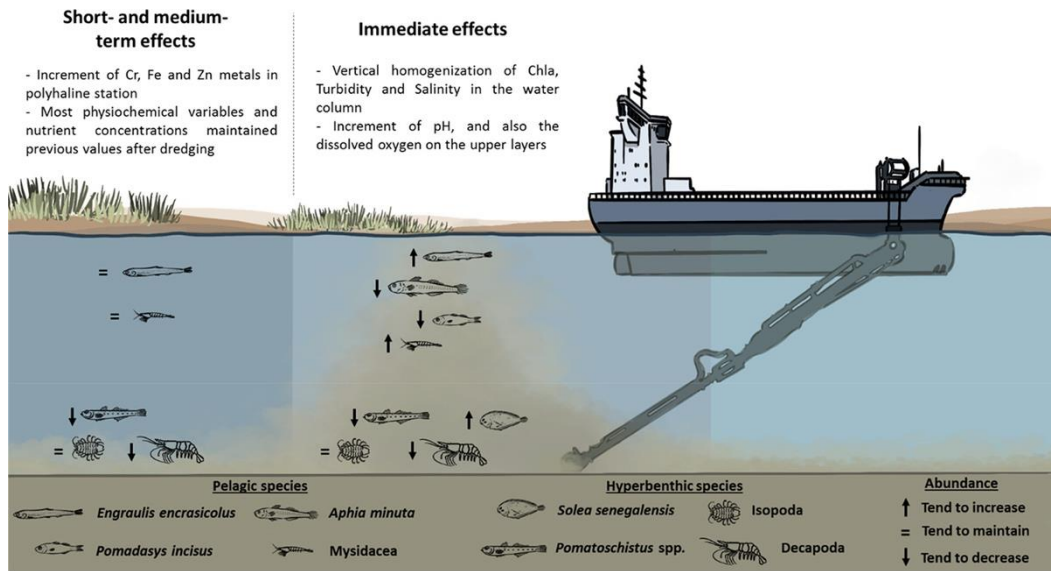


Figure 6: Lateral sediment exchange between main channel and inundation

E3 – Dredging volume

- Volume to be dredged as indicator (Potential problems related to Fauna and flora presence, Pollution, Effects on sediment regime)
- Existing fairway (or Fairway realignment)
- Reference depth 2.5 m



E4 – Bird population related indicators

- Aspects of nesting
- Aspects of wintering

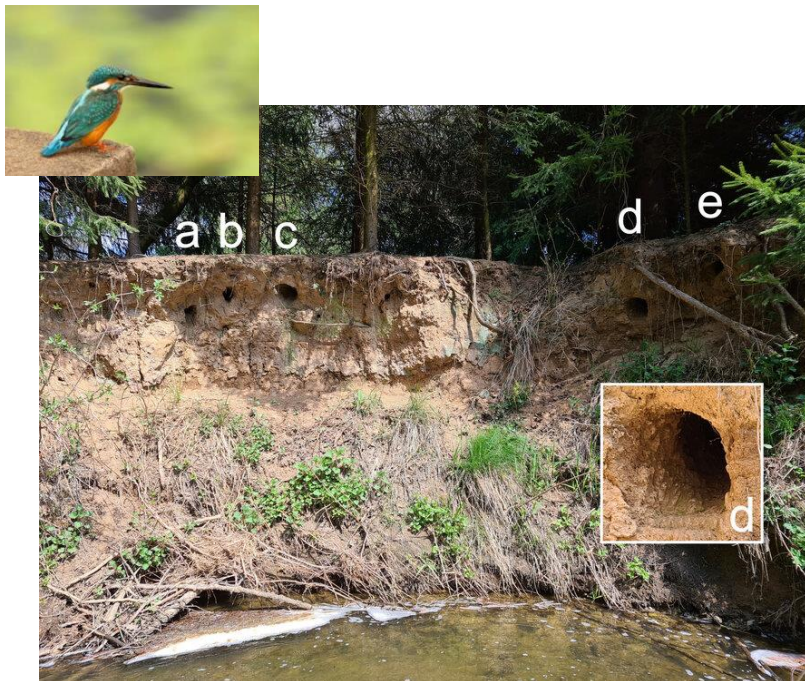


Photo: Martin Čech

Table 5: Selected bird species for MCA in terms of nesting

	Nesting
Waterfowls	Anseriformes (Aythya ferina, Aythya fuligula, Anas crecca, Tadorna tadorna, Branta leucopsis, Cygnus Cygnus)
	Ciconiformes fam. Ardeidae (Ardea cinere, Ardea alba, Arde purpurea)
	Gruiformes fam. Ralidae
	Charadriformes fam. Charadriidae (Charadrius dubius), Sternidae
Roller, bee-eater and kingfisher	Coraciformes (Alcedo atthis)
Birds of prey	Falconiformes (Haliaeetus albicilla, Milvus migrans)

Table 6: Selected bird species for MCA in terms of wintering

	Wintering
Waterfowls	Anseriformes
Birds of prey	Falconiformes (Haliaeetus albicilla)

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Fish populaton related indicators

- Spawning
- Migration
- Growing
- Living

Table 7: Selected fish species for MCA
(Legend: (R) – rheophils; (Li) – lithophils; (L&Ph) - Limnophils & phytophils)

Species name	Latin name	Status (IUCN)	Status (SRB)	Status (HR)	EU Habitat Directive
Asp (R)	<i>Aspius aspius</i>	LC	P	LC	Annex II, V
Common barbel (R)	<i>Barbus barbus</i>	LC	P	LC	Annex V
Balkan loach (L&Ph)	<i>Cobitis elongata</i>	LC	SP	VU	Annex II
Loach (L&Ph)	<i>Cobitis elongatoides</i>		P	VU	Annex II
Danube bleak (R)	<i>Alburnus sava</i>	LC	SP	LC	
Balon's ruffe (L)	<i>Gymnocephalus baloni</i>	LC	SP	VU	Annex II, IV
Schraetzer (L)	<i>Gymnocephalus schraetser</i>	LC	P	CR	Annex II, V
Ide (L&Ph)	<i>Leuciscus idus</i>	LC	P	VU	
Common chub (R)	<i>Squalius cephalus</i>	LC	P	VU	
Cactus roach (R)	<i>Rutilus virgo</i>	LC	P	NT	Annex II, V

Flora indicators

Registered species of the flora that will be analyzed along critical sectors are:

- 91E0* Alluvial forests - *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*) - *Populus alba*, *Populus nigra*, *Salix alba*, *Rubus caesius*, *Carex elata*, *Carex remota*, *Carex riparia*, *Galium palust*, *Polygonum hydropiper*, *Rumex sanguineus*;
- 3130 Oligotrophic to mesotrophic standing waters with vegetation - *Lindernia dubia*, *Eleocharis acicularis*, *Cyperus michelianus*, *Lythrum portula*;
- 3150 Natural eutrophic lakes with Hydrocharition or Magnopotamion type vegetation - *Lemna* spp., *Spirodela polyrhiza*, *Utricularia vulgaris*, *Azolla filiculoides*, *Salvinia natans* (emerged plants);
- 3270 Rivers with muddy banks - *Bidens frondosa*, *Bidens tripartitus*, *Polygonum hydropiper*, *Potentilla supina*.

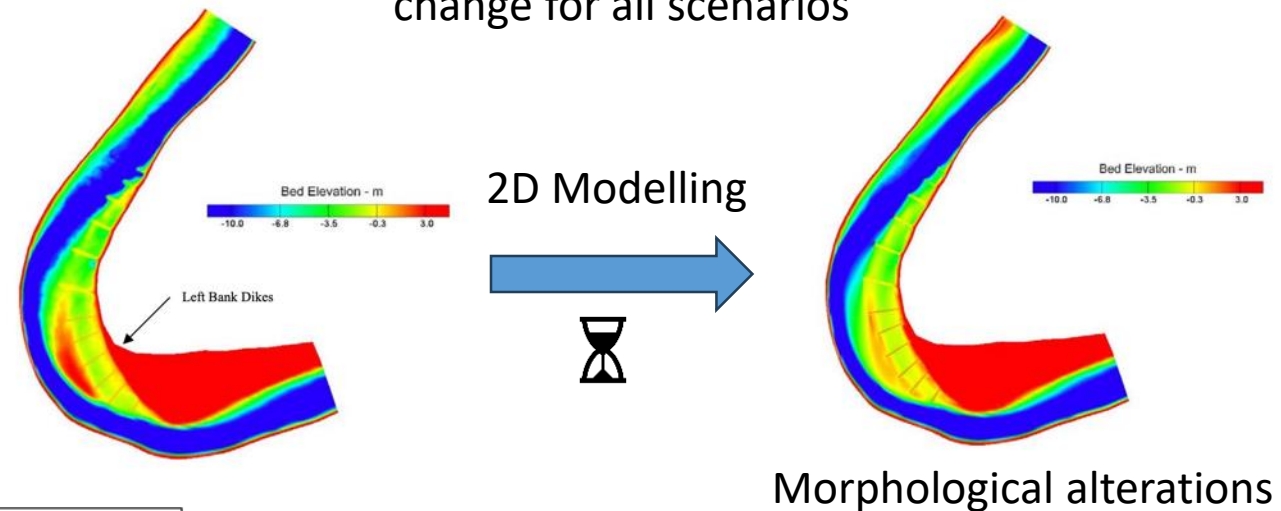
A4: 2D Hydrodynamic and Morphological Modelling

Purpose of the Modelling activity

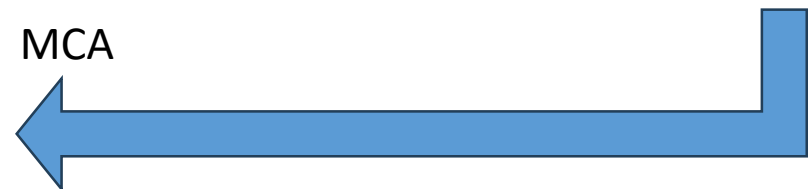
- Evaluation of solutions whose impact is considered over time (scenarios)
- „Do nothing” is base solution (zero alternative)
- 2D Sediment transport model for morphological changes prediction (effects of solutions compared)
- Expert judgment

Do nothing – scenario without measures (even operational or maintenance measures not included)

Numerical simulations of morphological change for all scenarios



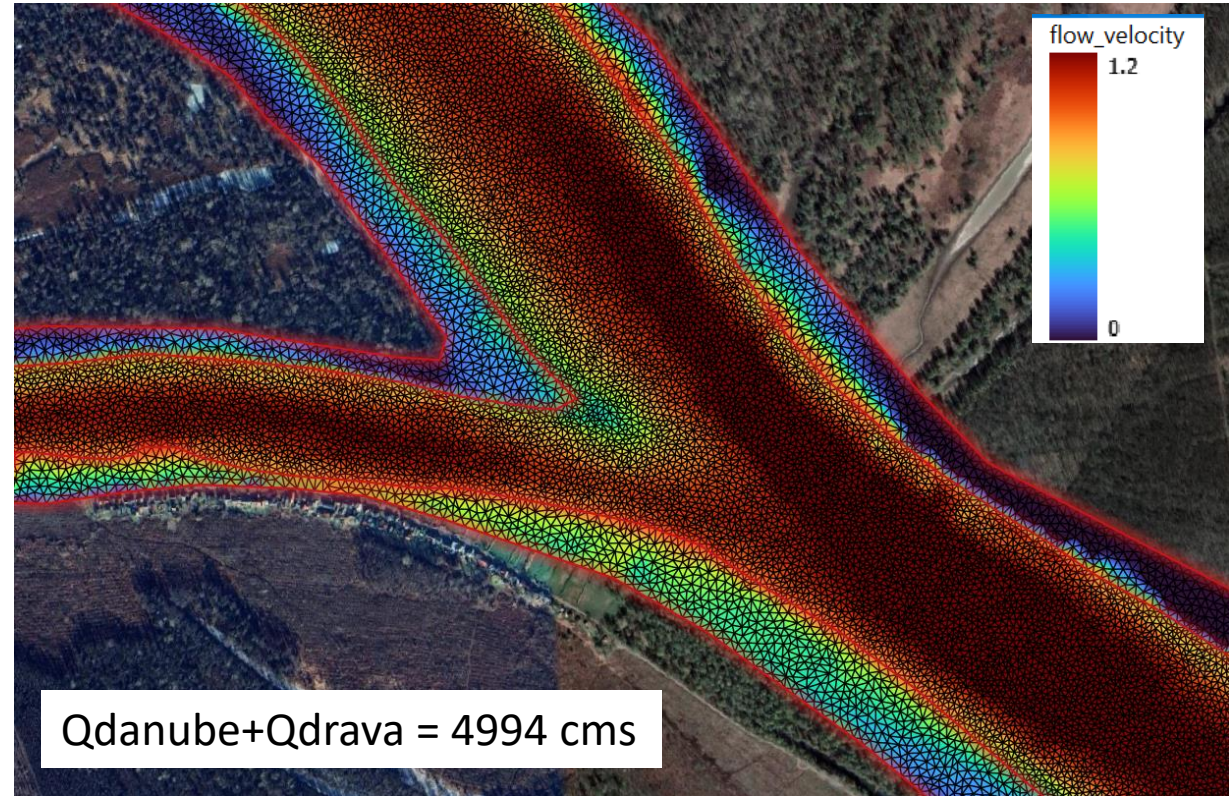
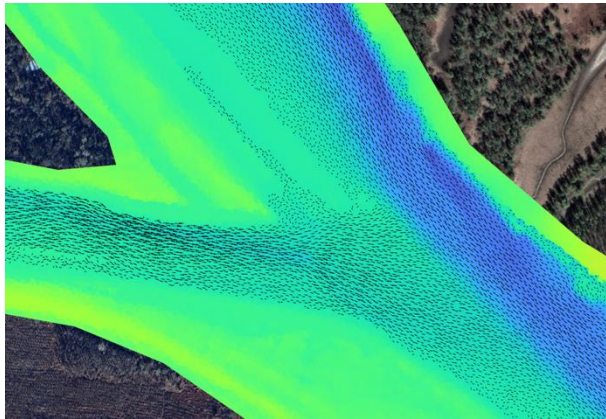
MCA



	Group score for navigation	Group score for environment	Group score for feasibility	Total Score
"Do nothing"	1.00	1.00	1.00	1.00
Groyne system	1.07	0.81	1.04	0.90
Fairway realignment	1.05	1.00	1.06	1.12

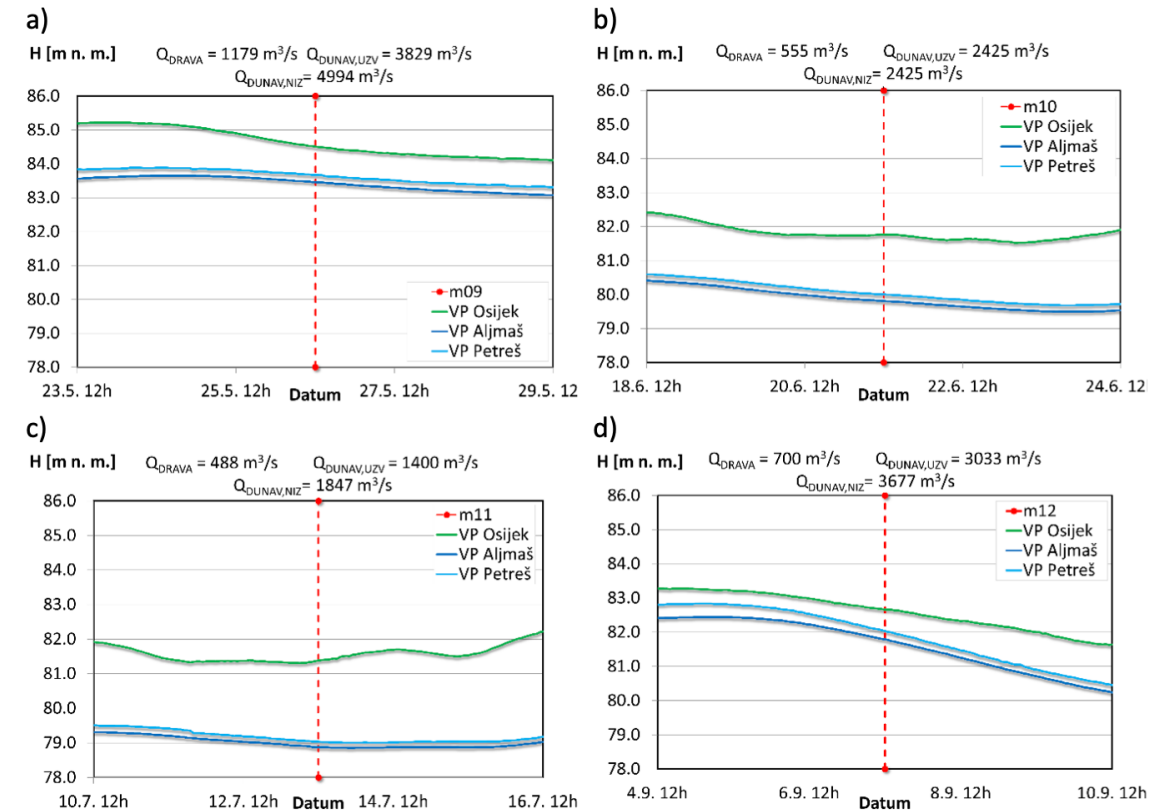
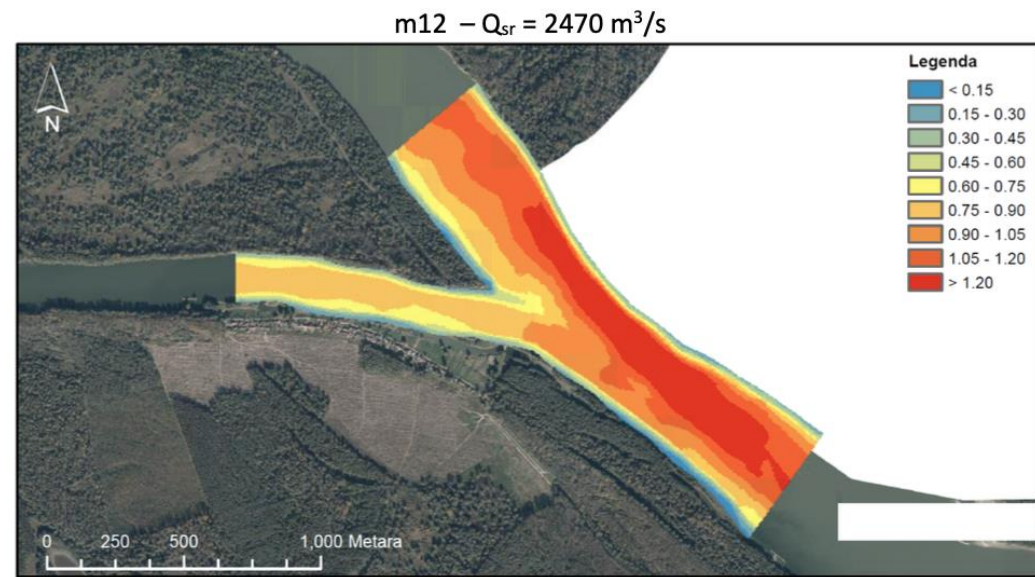
Model setup

- Sectors from Apatin to Staklar
- Basement V4 model tested
- 421033 cells
- HPC version allows massive GPU parallelization
- Hybrid riverbed model
- New data for calibration obtained



Calibration & Verification

- New data provided by Hidroing
- Velocity data for Drava confluence
- 4 surveys
- Calibration using m12 survey (good agreement for m9 survey – verification)



Slika 4.1. Nivogrami s vodomjernih postaja u blizini dionice ušća Drave, za mjerenje m09 (a), mjerenje m10 (b), mjerenje m11 (c) i mjerenje m12 (d)

4 Scenarios

- Doing nothing
- Structural measures included (2 Chevrons, 4 sills and Excavation of 2 secondary river channels)
- Fairway realignment
- Small scale restoration scenario (Removing existing structures and and side channels)



Following steps

- Finalization of MCA definition activity (t1)
- Numerical Simulations for "Doing nothing" (t1)
- Scenarios definition (t2)
- Numerical simulation for all scenarios (t3)
- Scenarios redefinition (t3-t4)
- Numerical simulation for modified scenarios (t5)
- ...
- MCA Application (t6)

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Thank you for your kind attention

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