

## *River bed erosion and sustainable solutions at the Austrian Danube River*

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## Outline

1. Erosion at the Danube River
2. Potential solutions
3. Focus groyne adaptations
4. Conclusions

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Danube River Basin District Overview

DRBM Plan - Update 2015 - MAP 1



This ICPR product is based on national information provided by the Contracting Parties to the ICPR (AT, BA, BG, CZ, DE, HR, HU, ME, MD, RO, RS, SI, SK, UA) and CH. EuroGlobalMap data from EuroGeographics was used for all national borders except for AL, BA, ME where the data from the ESRI World Countries was used; Shuttle Radar Topography Mission (SRTM) from USGS Seamless Data Distribution System was used as elevation data layer; data from the European Commission (Joint Research Center) was used for the outer border of the DRBD of AL, IT, ME and PL.

Vienna, December 2015

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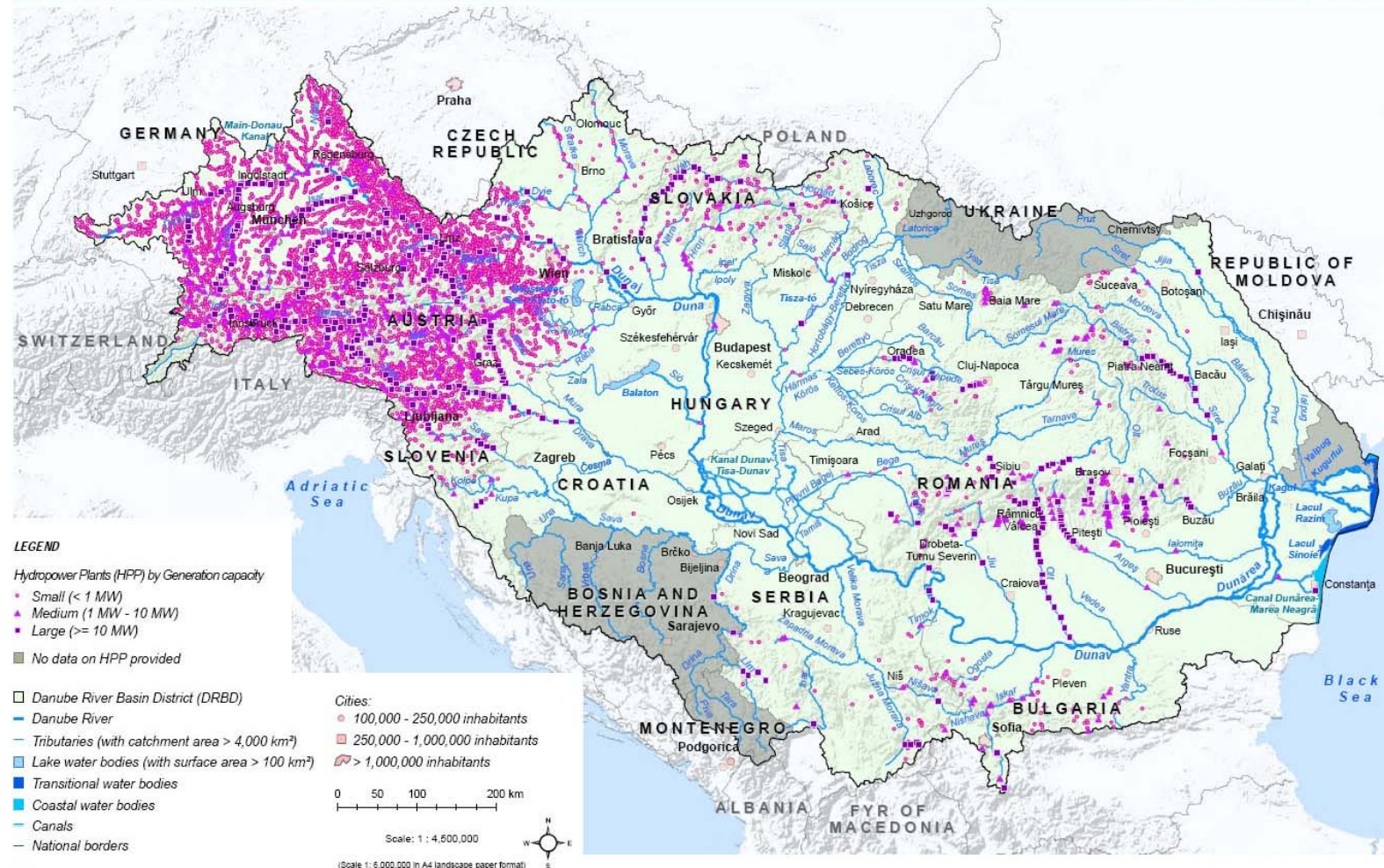
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Hydropower Plants - Reference Situation 2012

DRBM Plan - Update 2015 - MAP 27



**Note:**  
RO: HPP >= 1 MW are multipurpose facilities (water supply, mitigation of floods / droughts, ensuring water resources)  
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AT data provided by: IWW EBCU Habersack et al. (2012)  
Input data: HAO (2007), Federal states of Austria (2010/2011)  
Hydropower operators (2010-2012)

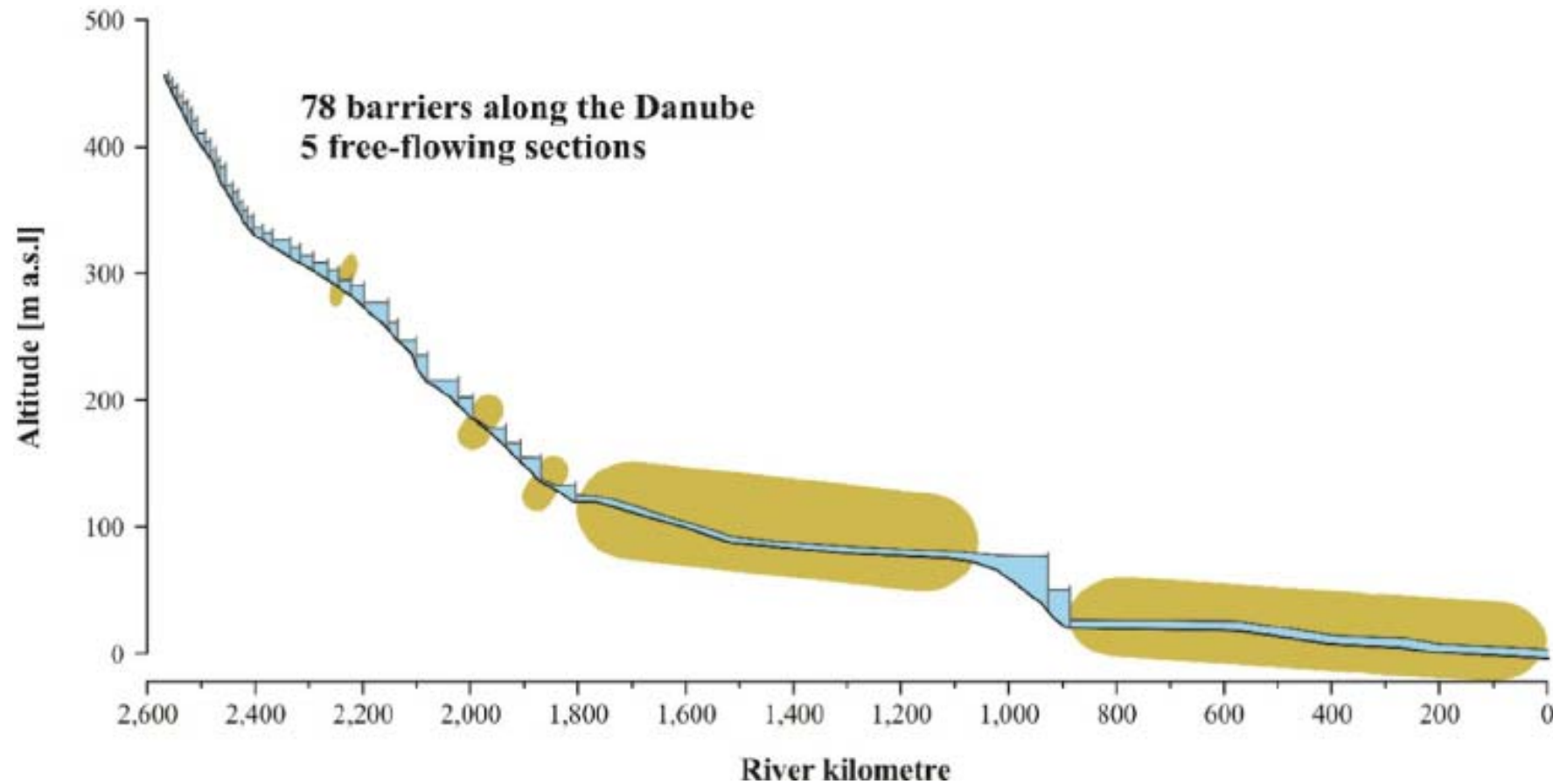
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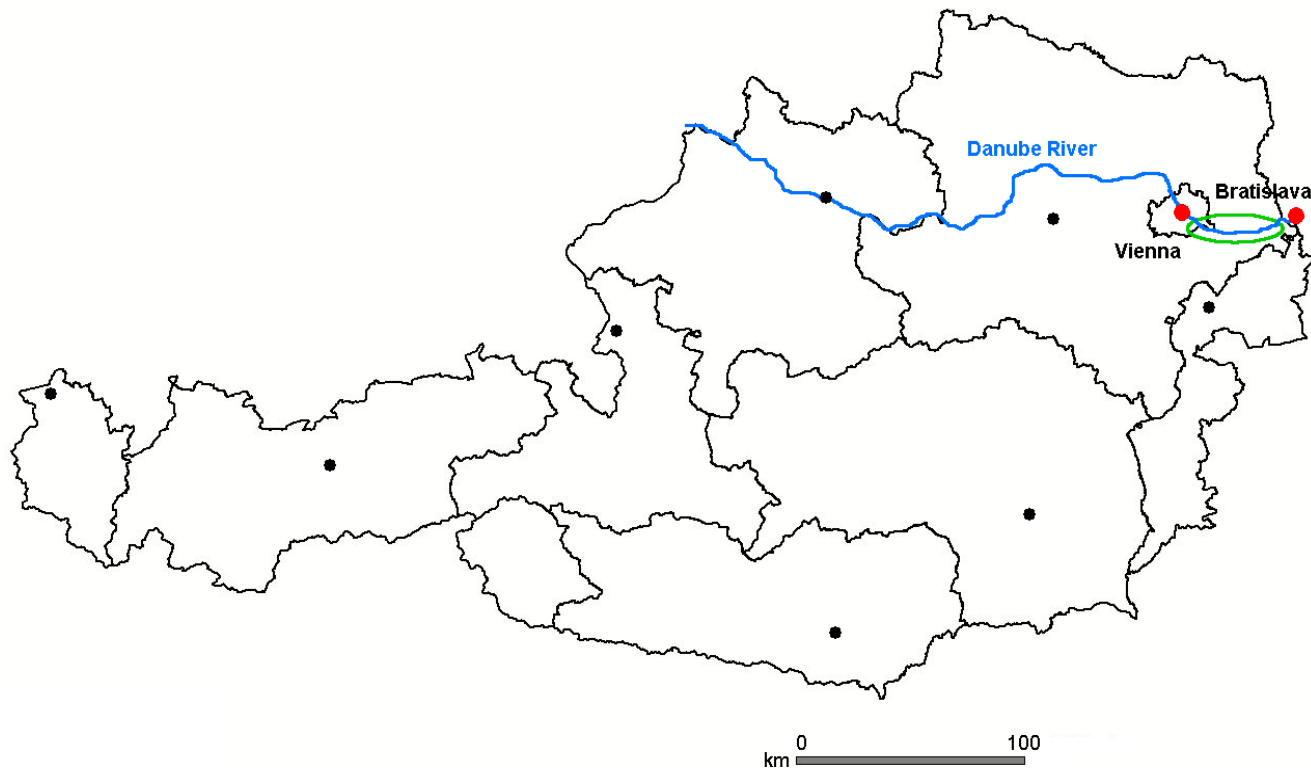
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## Chain of reservoirs at the Danube River



## Study reach – overview

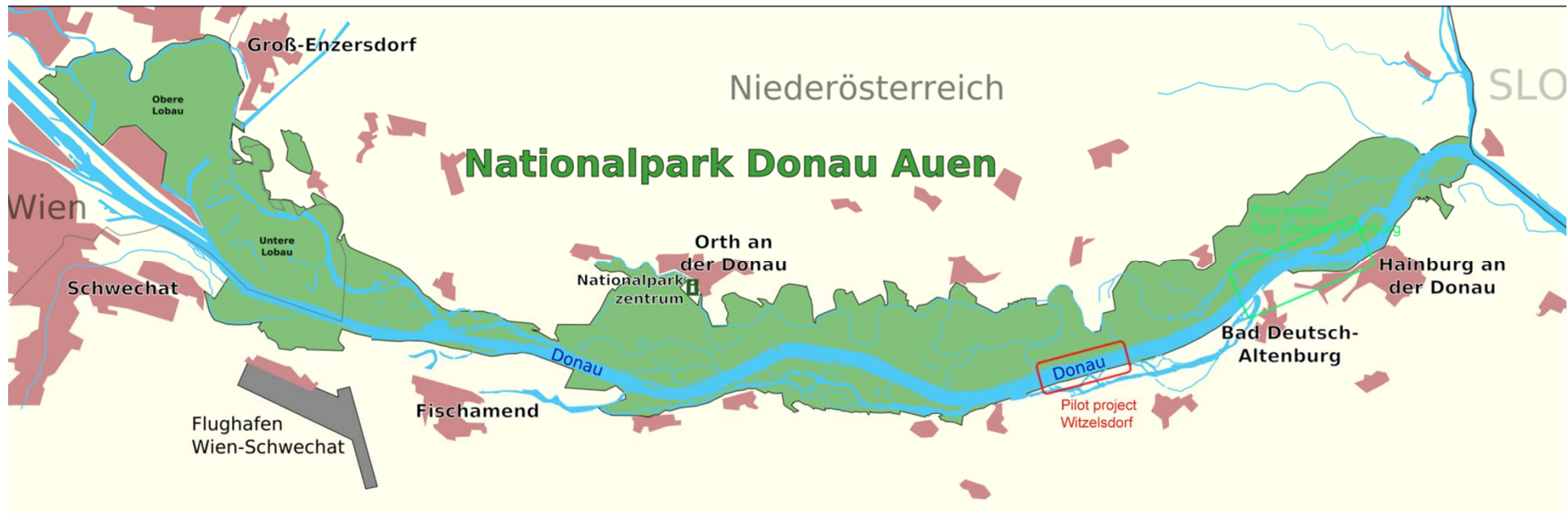


### Location:

- Danube River between Vienna and Bratislava (SK)
- River reach in a National Park
- Integrated River Engineering Project

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## Study reach – detailed view



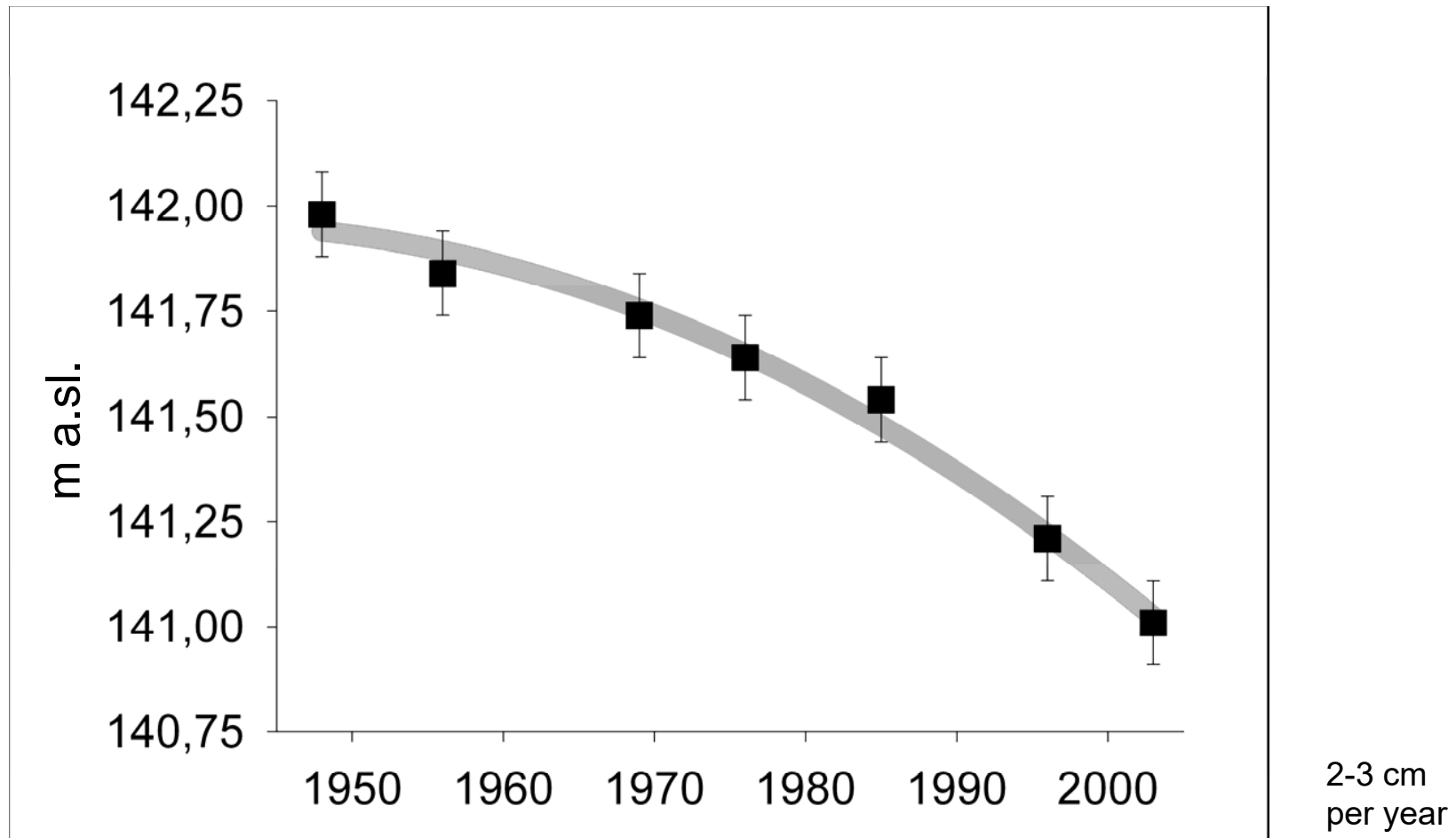
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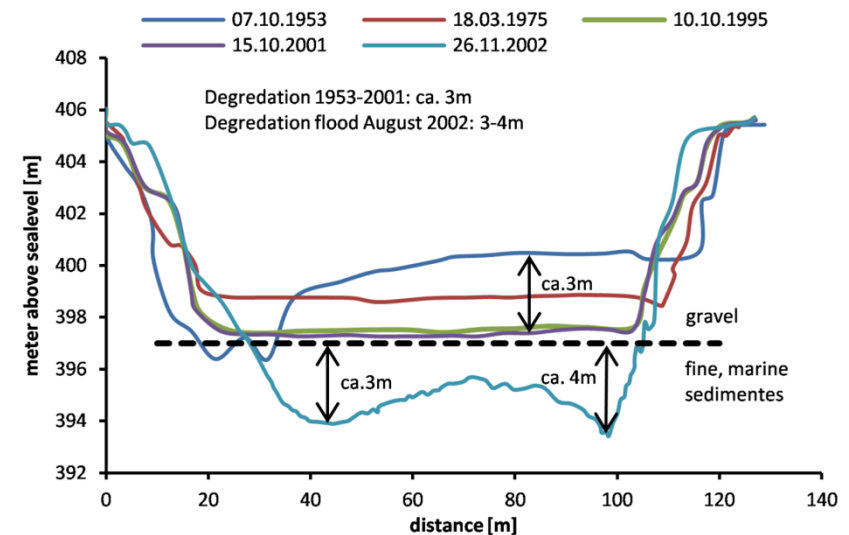
## River bed incision



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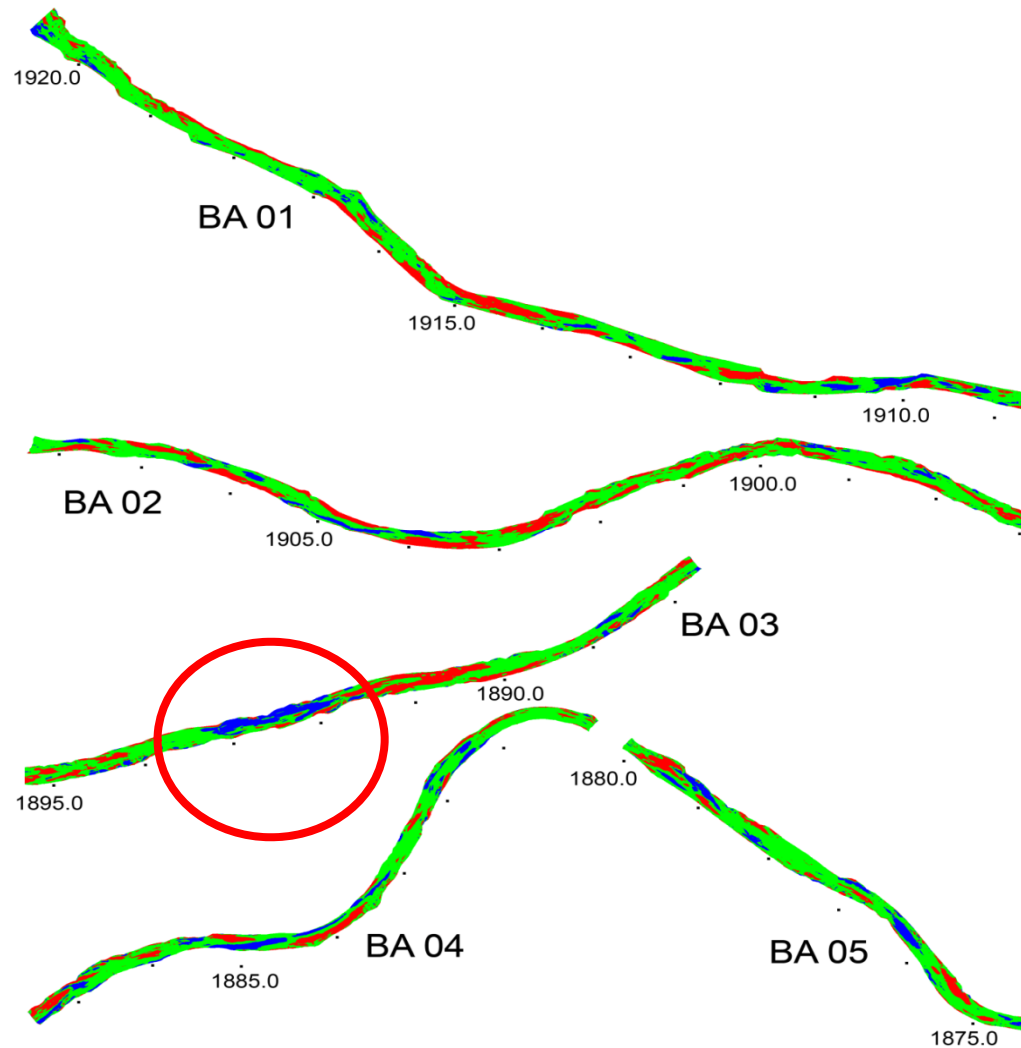


Potential hazard: river-bed breakthrough (e.g. during a flood)



Example: Salzach River in 2002

## Bed level changes of river reach between 2005 – 2014

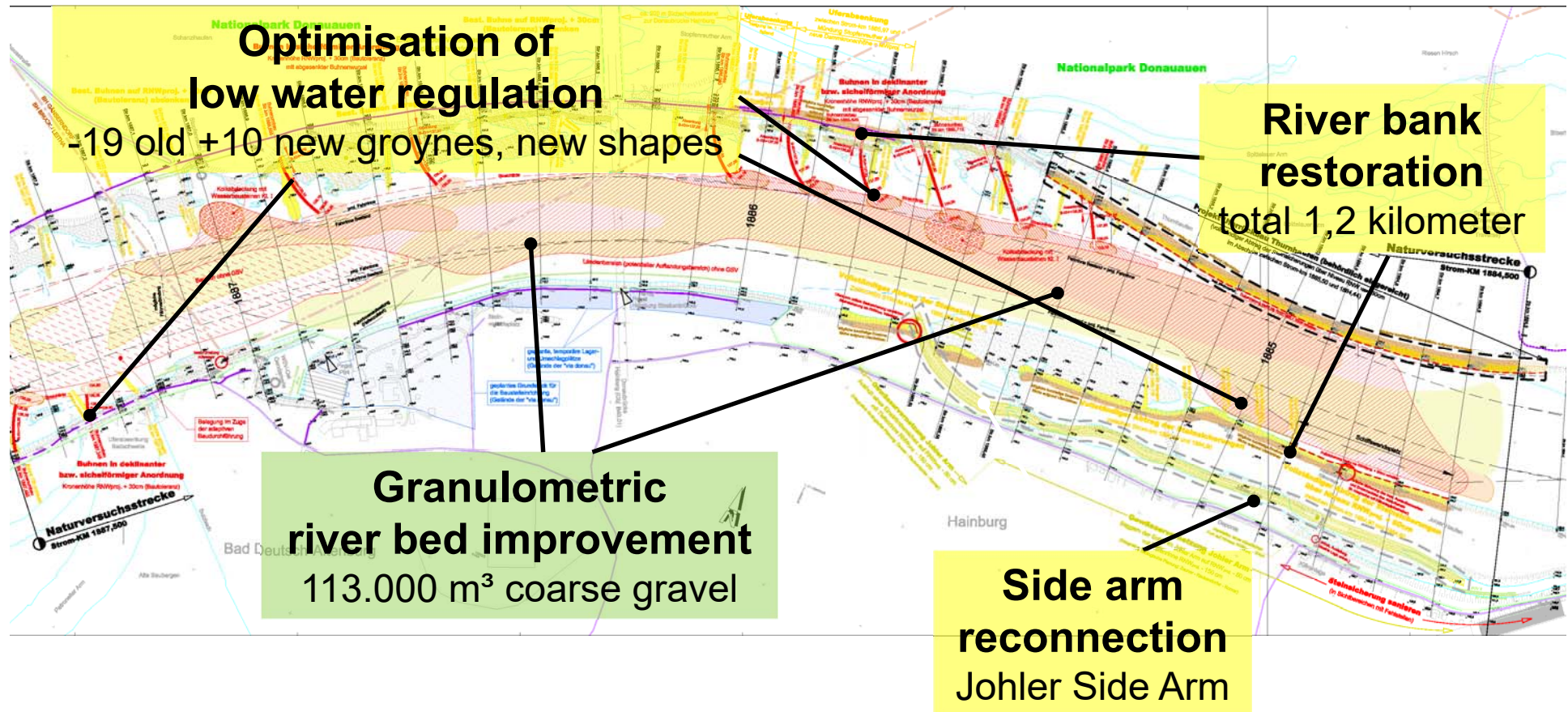


- General erosion tendency (average of 2cm/year)
- Study site Witzelsdorf: only location of the Austrian Danube River downstream of Vienna with sedimentation tendency (blue)
- Reason for sedimentation: river engineering measures

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## River reach Bad Deutsch Altenburg: measures



## Granulometric bed improvement

Original

Stage I

Stage II



- Top layer replaced by coarser material → higher resistance against incipient motion
- Original planning 40/70mm
- Stable in field test: 32/120mm

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## River bank restoration



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## Artificial island building



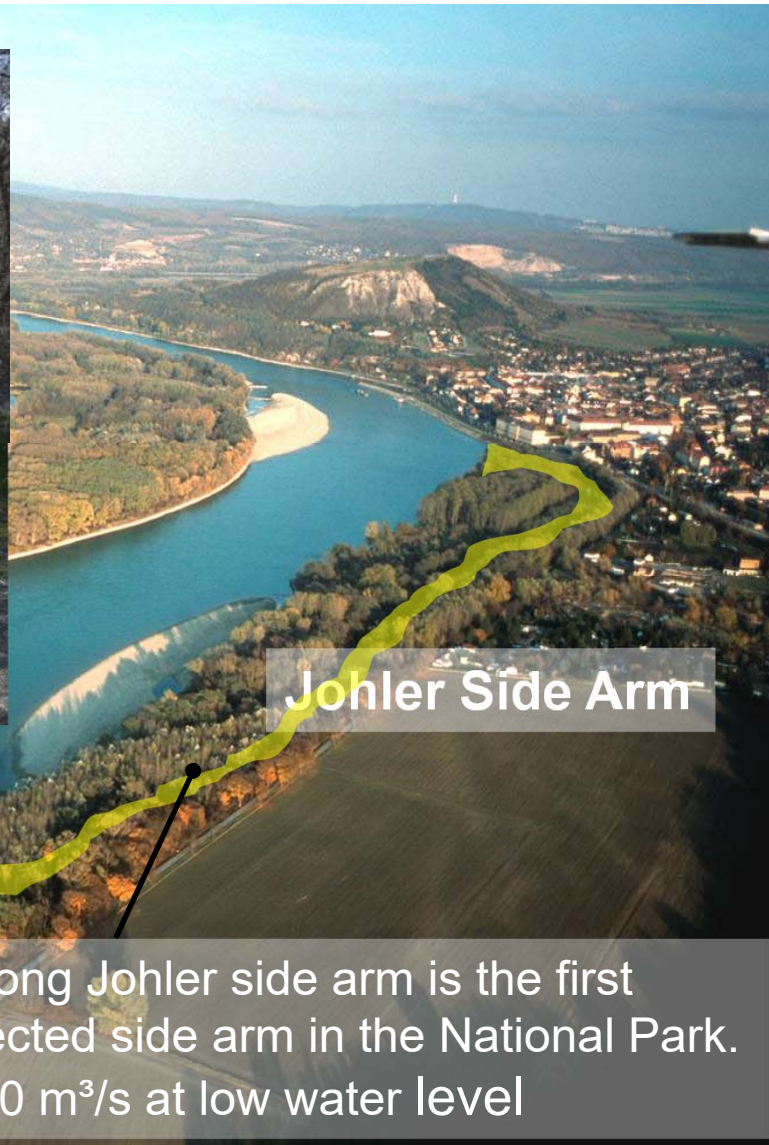
Instream gravel  
replenishment structures

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Johler side arm before reconnection



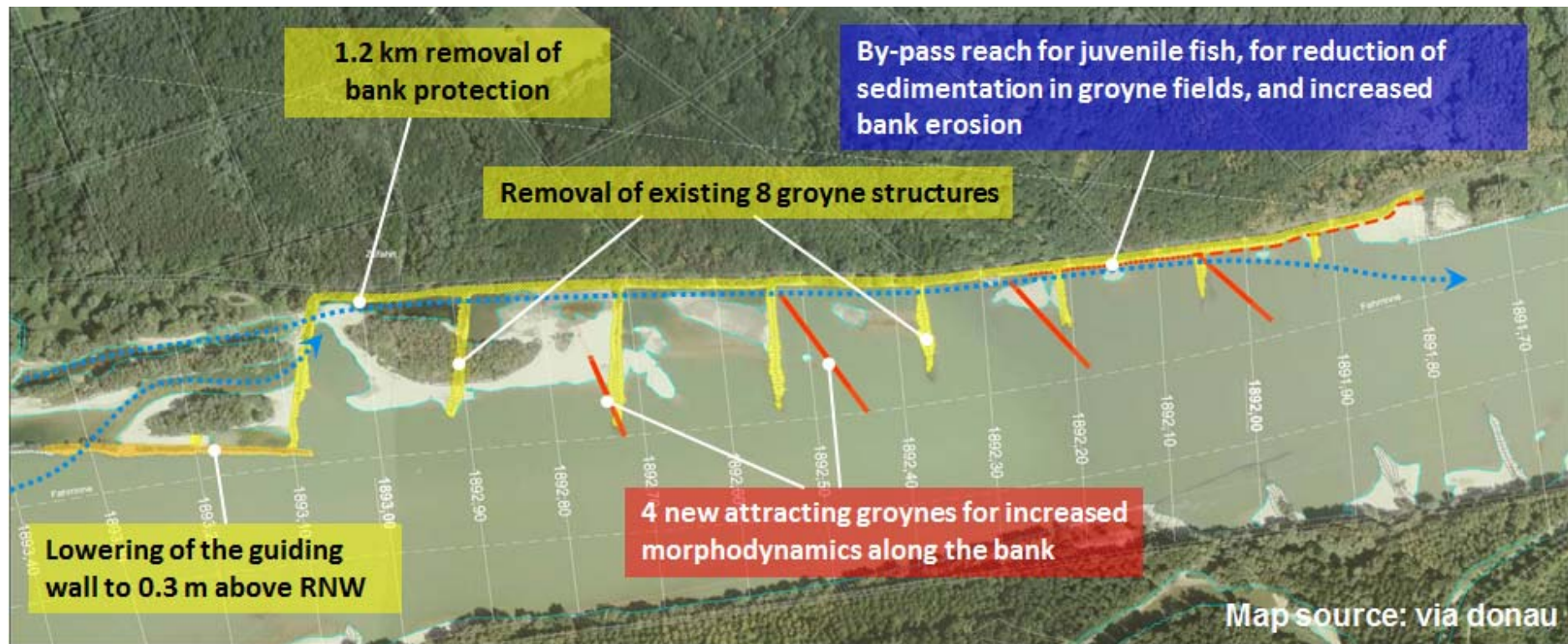
Johler Side Arm

The approx. 1.4 km long Johler side arm is the first permanently reconnected side arm in the National Park. Discharge: approx. 10 m<sup>3</sup>/s at low water level

Photo: viadonau

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## Optimization of low water regulation structures



- Removal of existing groynes and bank protection
- Construction of new groynes

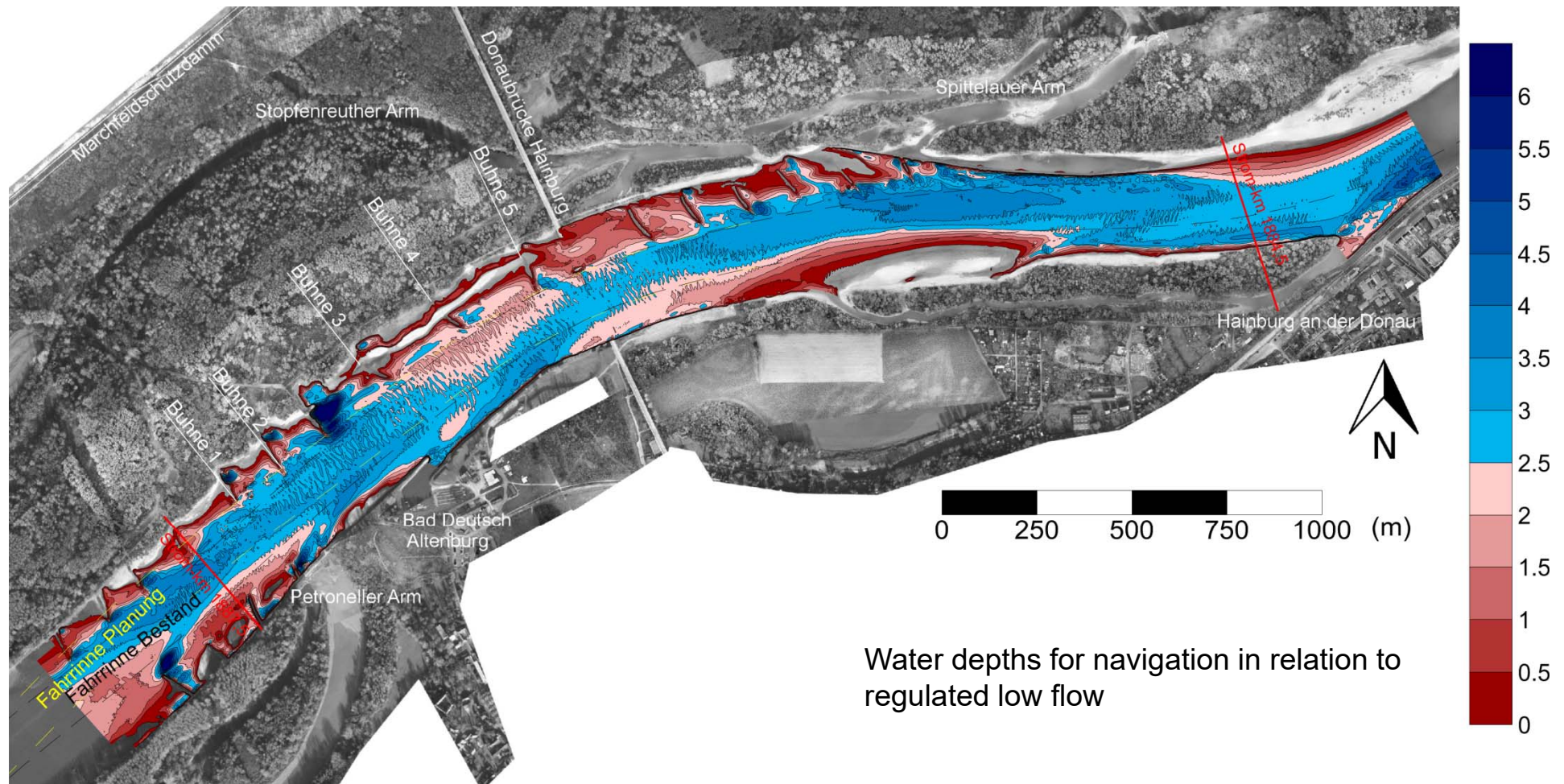
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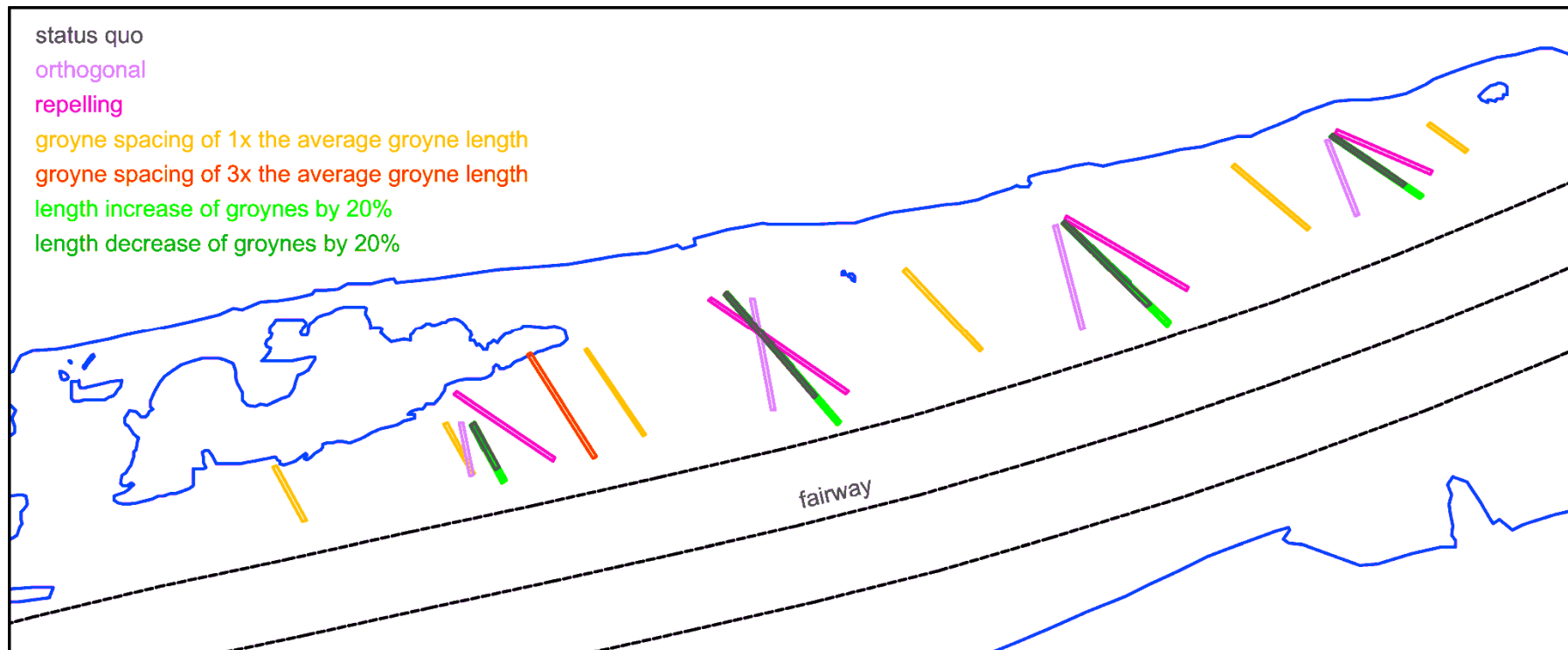
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## The problem...



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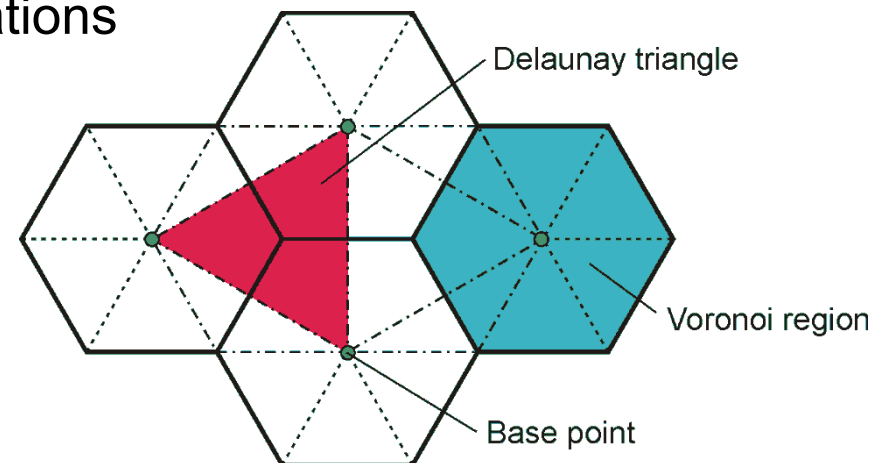
## Groyne variants



- (i) Orthogonal layout
- (ii) Repelling layout
- (iii) Groyne spacing of 1x average groyne length
- (iv) Groyne spacing of 3x average groyne length
- (v) Length increase of groynes by 20%
- (vi) Length decrease of groynes by 20%
- (vii) Increase of crest elevation

## Hydrodynamic model RSim-3D

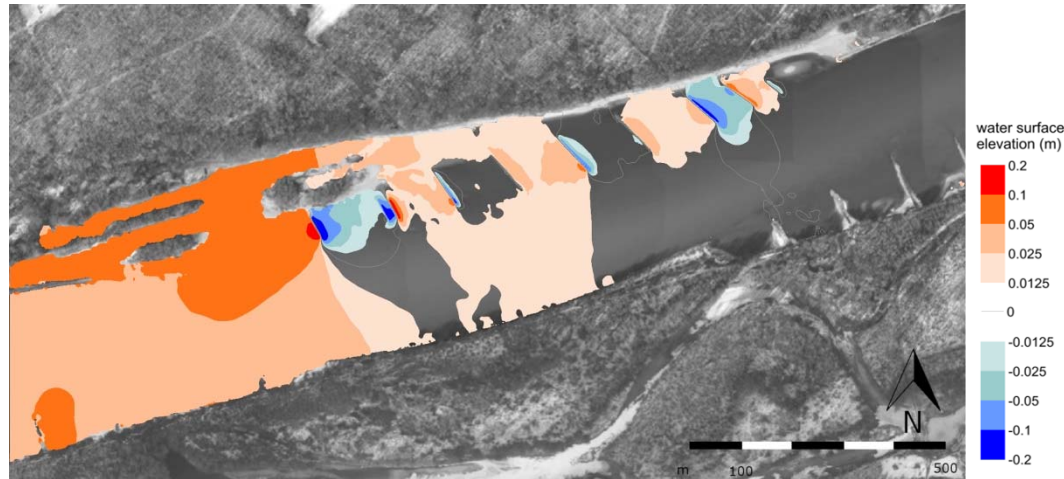
- Originally developed during the PhD thesis of Tritthart at TU Vienna
- Further development since fall 2005 at BOKU
- 3D computation model employing polyhedral grids with predominantly hexagonal base shape
- Solution of the governing flow equations using the Finite Volume Method
- Turbulence modelling using a  $k-\varepsilon$  model in standard formulation
- Steady and unsteady simulations possible



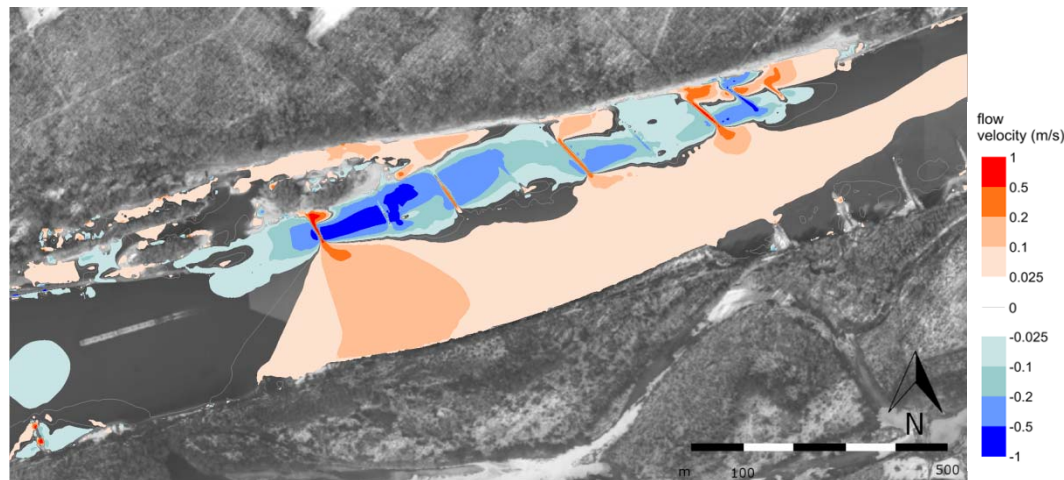
## Integrated sediment transport model iSed

- Flow field obtained by coupling with external hydrodynamic codes (2-D and 3-D)
- Capable of calculating non-uniform sediment transport with unlimited number of size fractions
- Consideration of an unlimited number of bed layers
- Computation of morphodynamics and sorting processes
- Separate implementation of suspended sediment and bedload transport

## Groyne spacing of 1x average groyne length (differences to project implementation status)



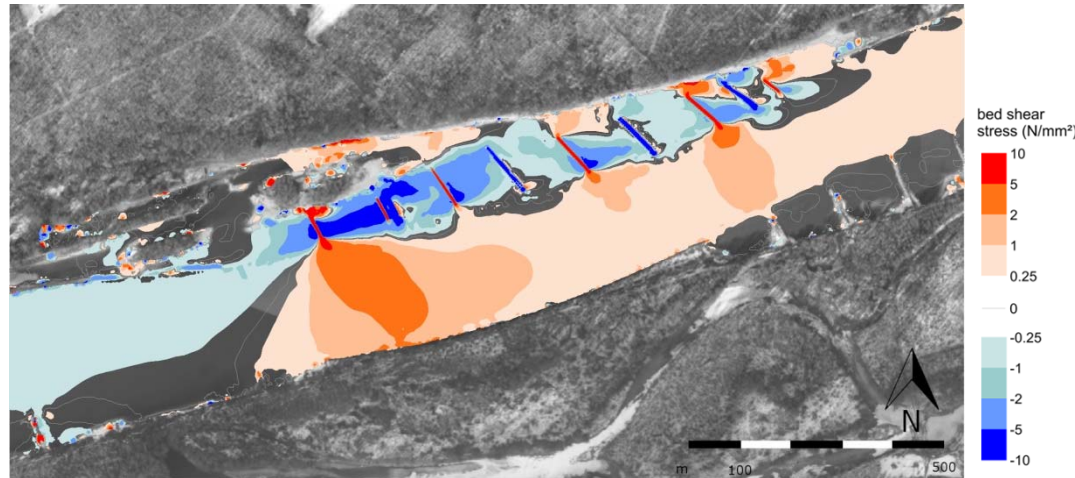
- Notable water level increase upstream
- Increase of flow velocity in main channel (fairway), decrease in groyne fields



Results for mean flow (MQ)

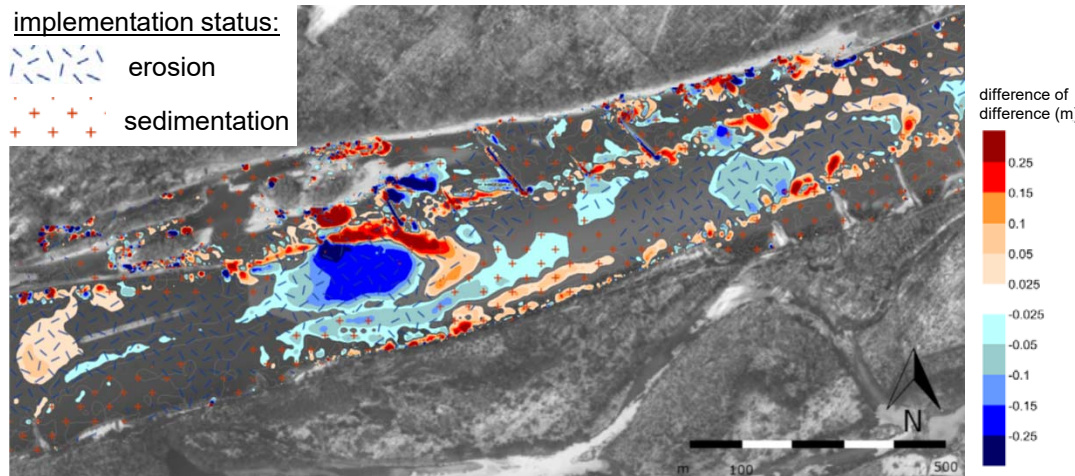
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## Groyne spacing of 1x average groyne length (differences to project implementation status)



implementation status:

 erosion  
 sedimentation

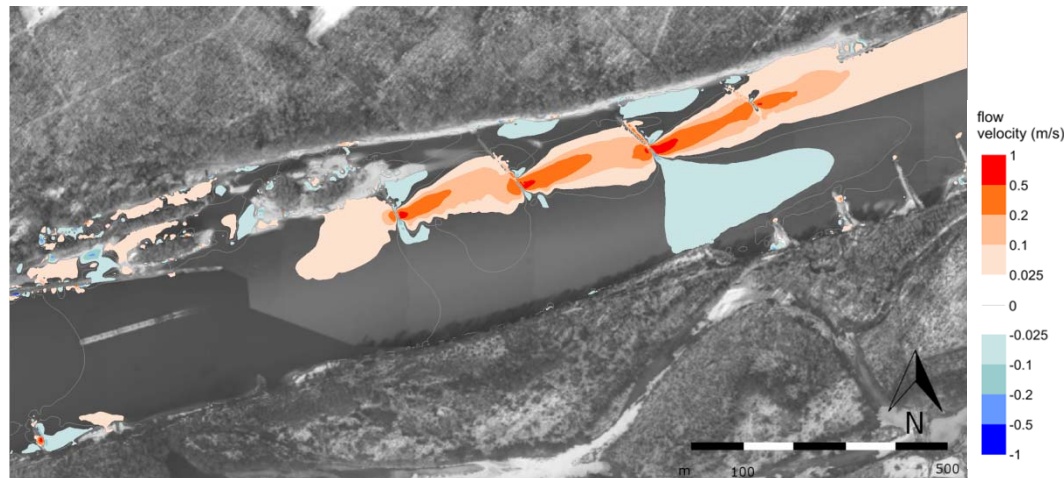
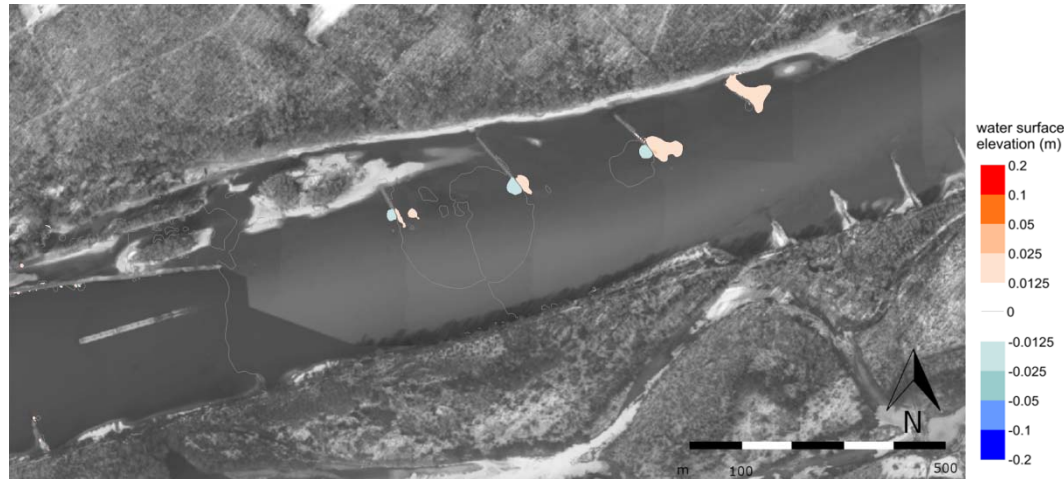


- Substantial increase of bed shear stress in main channel (fairway)
- Large scour in narrowed section of the river, followed by distinct sedimentation pattern downstream
- More erosion areas as compared to current status

Results for mean flow (MQ)

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## Length decrease of groynes by 20% (differences to project implementation status)

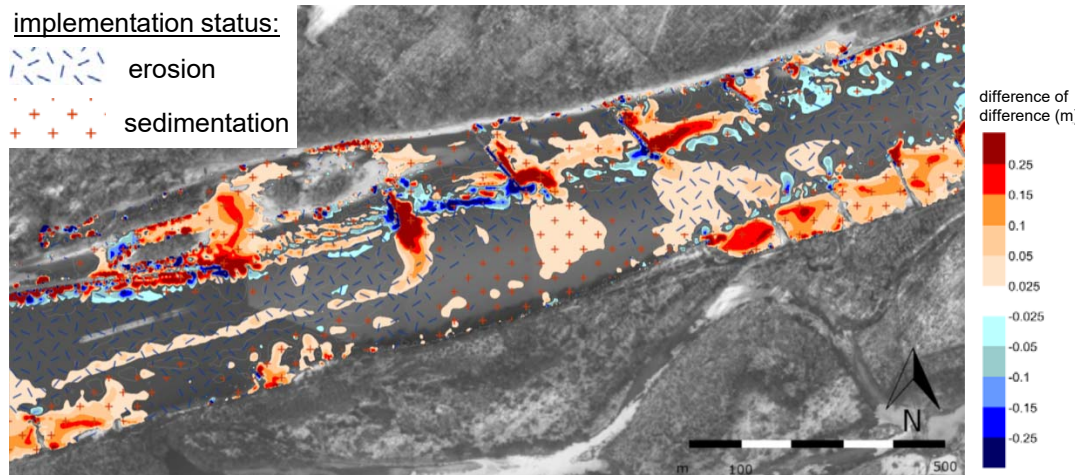
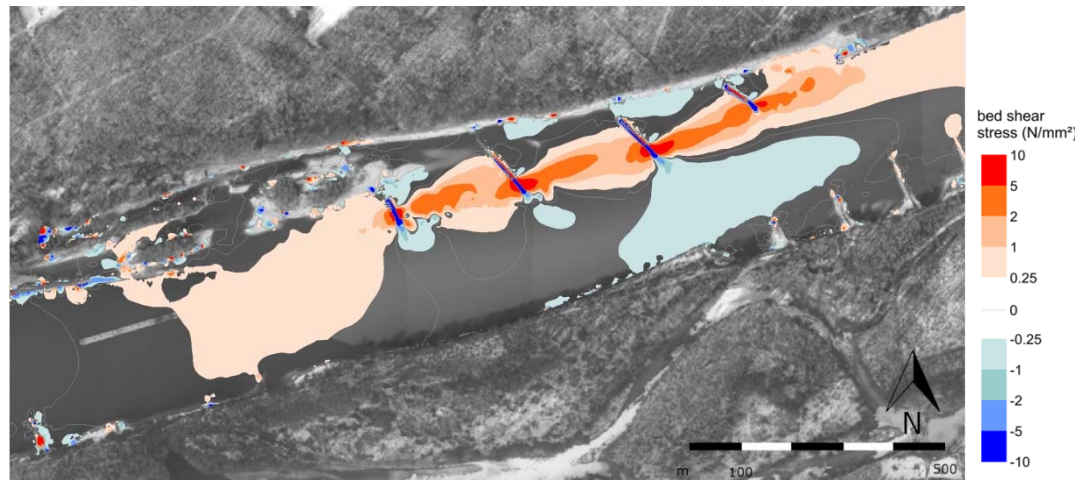


- No changes in water surface elevations
- Substantial increase of flow velocity in groyne fields, slight decrease in the main channel (fairway)

Results for mean flow (MQ)

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## Length decrease of groynes by 20% (differences to project implementation status)

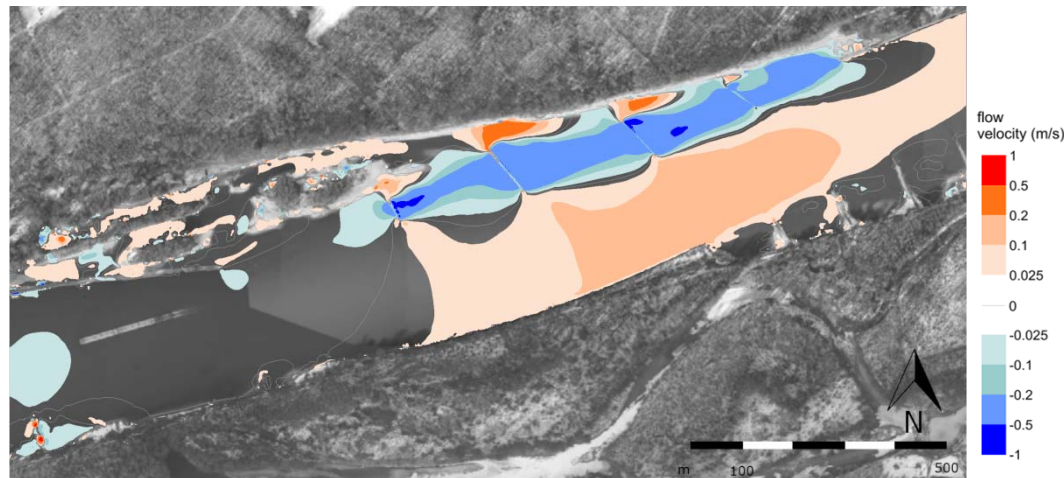
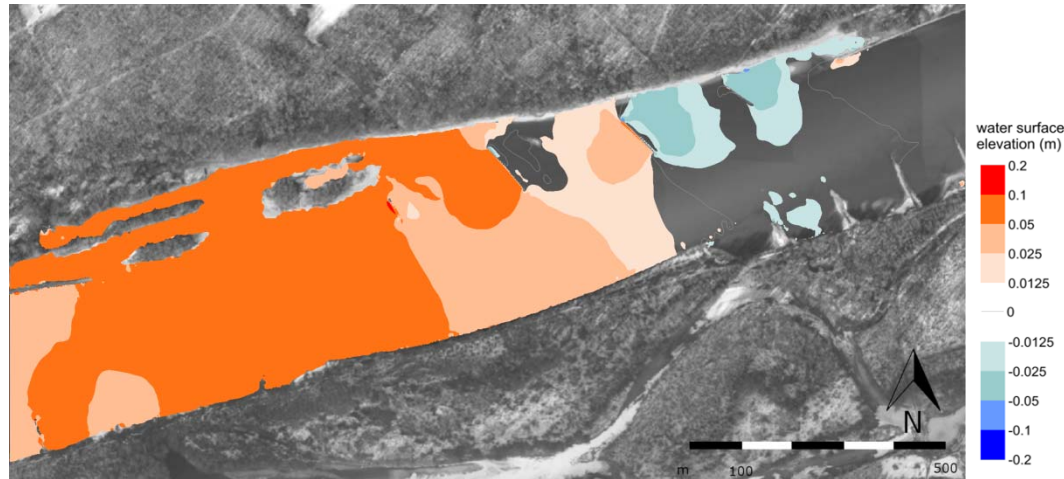


- Substantial increase of bed shear stress in groyne fields, slight decrease in main channel (fairway)
- Tendency towards more sedimentation in the main channel
- Only local erosion tendencies

Results for mean flow (MQ)

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## Increase of crest elevation (by 0.4 m) (differences to project implementation status)

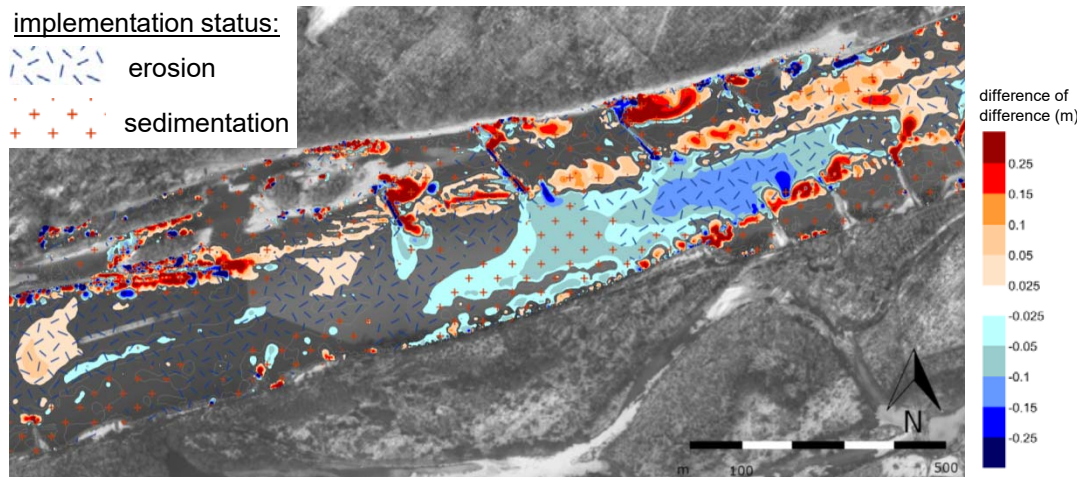
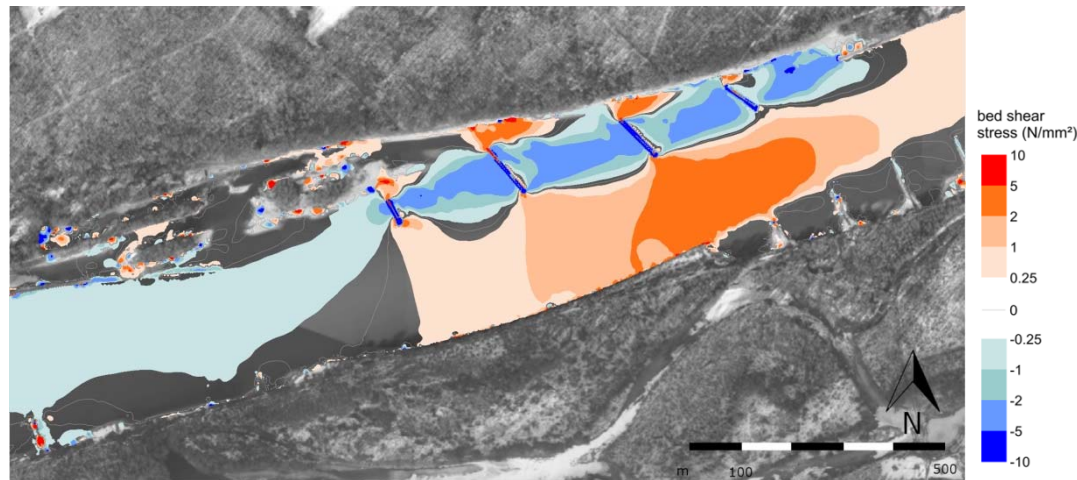


- Large increases in water surface elevations in upstream section, slight decrease in downstream groyne fields
- Substantial increase of flow velocity in main channel (fairway), notable decrease in groyne fields

Results for mean flow (MQ)

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## Increase of crest elevation (by 0.4 m) (differences to project implementation status)



- Substantial increase of bed shear stress throughout main channel (fairway) except upstream section
- Erosion tendencies in main channel where sedimentation occurred after project implementation
- Best variant for achieving the aim of a dynamic equilibrium

Results for mean flow (MQ)

## Sensitivity of parameters

| Parameter<br>Variant      | Flow velocity |      |     | Bed shear stress |      |     | Water surface elevation |      |     | Bed level changes |     |      |
|---------------------------|---------------|------|-----|------------------|------|-----|-------------------------|------|-----|-------------------|-----|------|
|                           | RNQ           | MQ   | HSQ | RNQ              | MQ   | HSQ | RNQ                     | MQ   | HSQ | RNQ               | MQ  | HSQ  |
| Orthogonal layout         | ≈             | ↑    | ≈   | ↑                | ↑    | ↑   | ≈                       | ↑↑   | ↓   | ≈                 | ≈   | ≈    |
| Repelling layout          | ≈             | ↑    | ≈   | ≈                | ↑    | ↑   | ≈                       | ↑    | ↓↓  | ≈                 | ≈   | ↕    |
| 1x Groyne spacing         | ↑↑↑           | ↑↑↑  | ↑↑  | ↑↑↑              | ↑↑↑  | ↑↑  | ↑↑                      | ↑↑↑  | ↑   | ↓↓                | ↓↓↓ | ↓↓↓↓ |
| 3x Groyne spacing         | ↕             | ↑    | ≈   | ↕                | ↑    | ↕   | ↕                       | ↑    | ↓↓  | ↑↑                | ↓↓  | ↕    |
| Length increase           | ↑↑            | ↑↑   | ≈   | ↑↑               | ↑↑   | ↑   | ↕↑                      | ↑↑   | ≈   | ↓↓                | ↓   | ↓↓   |
| Length decrease           | ↓             | ↓    | ≈   | ↓↓               | ↕    | ↓   | ↓                       | ≈    | ↓↓  | ↑                 | ↑   | ↑↑   |
| Increased crest elevation | -             | ↑↑↑↑ | ↑   | -                | ↑↑↑↑ | ↑   | -                       | ↑↑↑↑ | ≈   | -                 | ↓↓↓ | ↓↓   |

➔ Optimization of the crest elevation essential for achieving a morphodynamic equilibrium

## Outline

1. Erosion at the Danube River
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4. **Conclusions**

## Conclusions I – Sustainability of solutions

- Various solutions available for stopping river bed erosion
- Granulometric bed improvement: larger grain sizes required than expected
- Artificial island building: requires maintenance on a medium time scale
- Bank restoration: sustainable, but long-term morphodynamics of river planform potentially problematic
- Side arm reconnection: sustainable, but long-term sedimentation possible and thus potentially maintenance required
- Structural adaptations: sustainable, highly sensitive but very effective and thus preferred to achieve a morphodynamic equilibrium

## Conclusions II – Groyne adaptations

- Decrease of groyne spacing or increase of groyne length lead to rising water levels → benefit for navigation
- These variants also increase bedload transport rates → substantial erosion in fairway
- Increase of groyne spacing or reduction of groyne length initiate sedimentation (but improve ecological criteria, e.g. mass exchange)
- Orthogonal and repelling layouts in general lead to erosion in fairway, only attracting groynes cause sedimentation per se
- Crest elevation yields the strongest sensitivity of all groyne parameters
- Sedimentation patterns in equilibrium conditions achievable by optimization of crest elevation → preferred, effective and sustainable solution



# Thank you for your attention!

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