Morphodynamic modelling of complex river morphologies based on the results of the physical model of the Alpine Rhine

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BASEMENT User Meeting 2024

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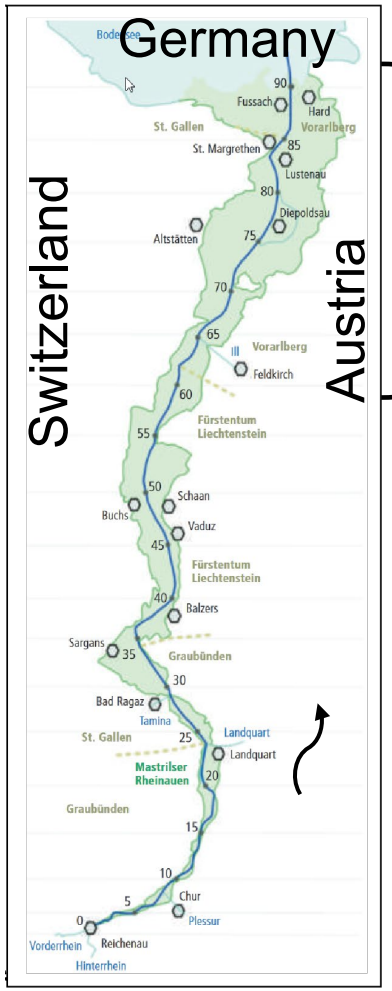
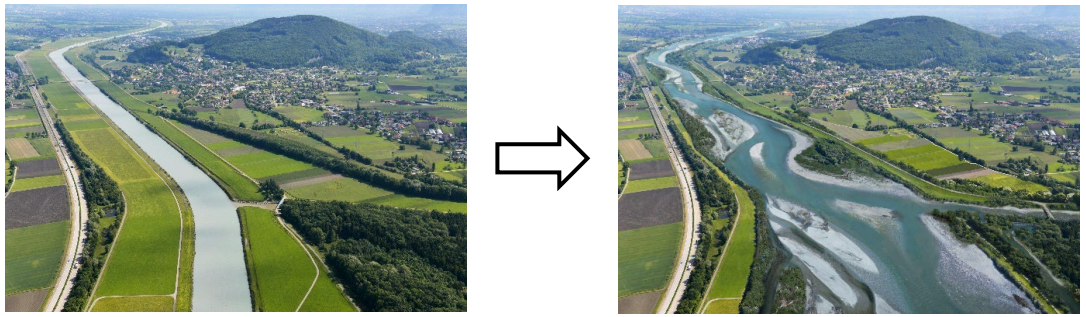
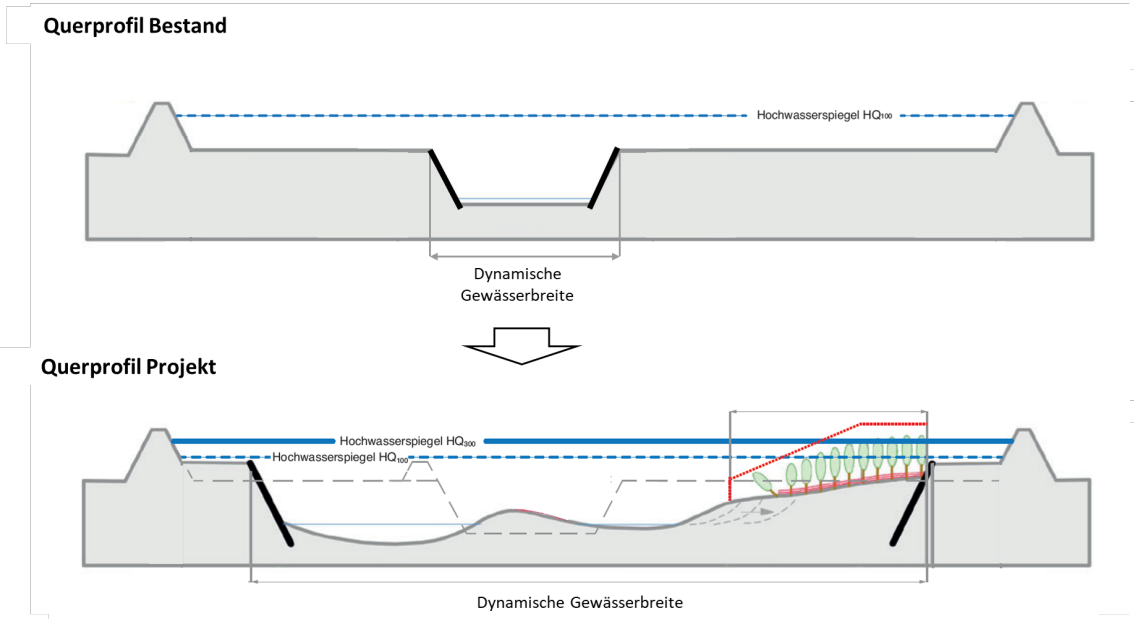
Alpine Rhine
flood protection project: International reach km 65 to km 91



«International reach»

Quelle: IRKA





Quelle: www.rhesi.org

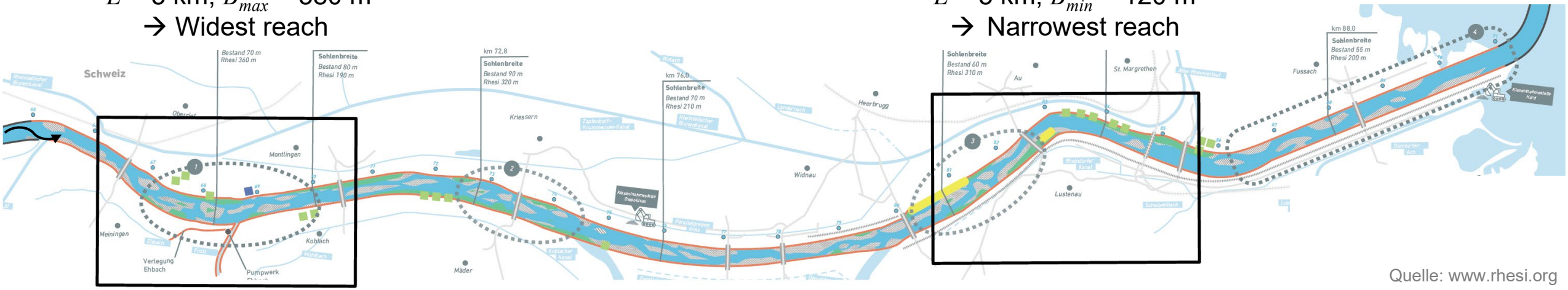
Perimeter

physical model 1:50
«Oberriet/Koblach»

L = 5 km, B_{max} = 380 m
→ Widest reach

physical model 1:50
«Widnau/Höchst»

L = 5 km, B_{min} = 120 m
→ Narrowest reach



Quelle: www.rhesi.org

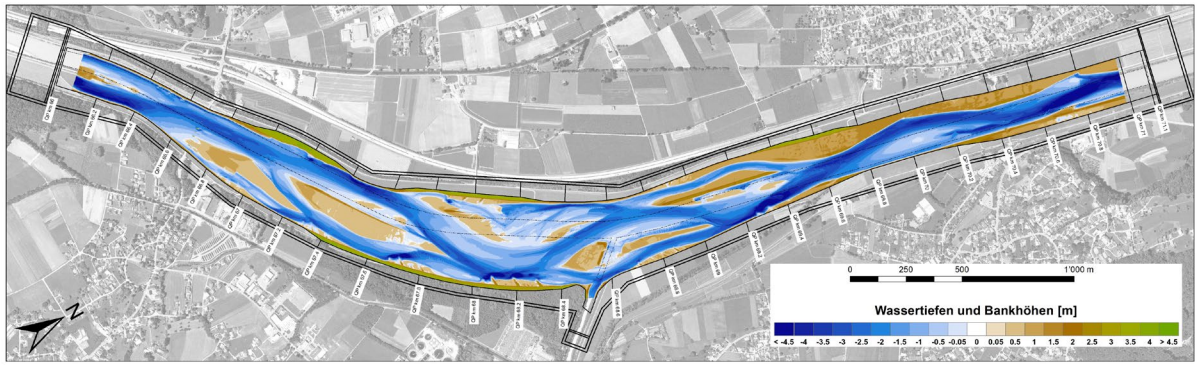
Numerical 2D simulations of the Alpine Rhine

- Hydraulic simulations of the whole reach (26 km) : definition of the boundary conditions
- Morphodynamic simulations: reproduce riverbed changes → forecast
  ! Wide range of river width and morphology !

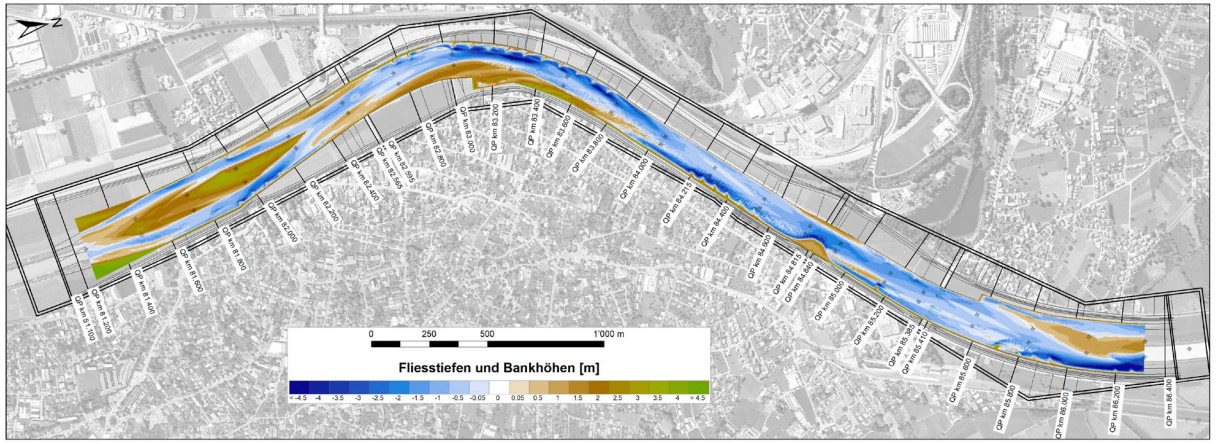
Basement v3.1

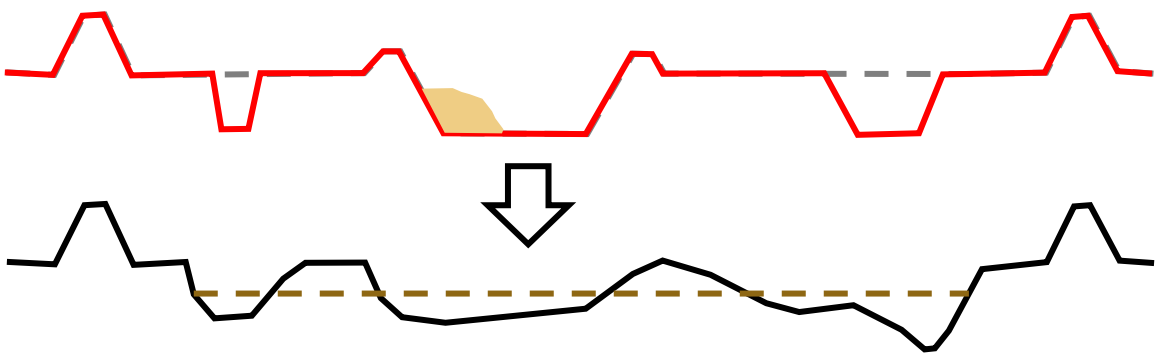
Physical model 1:50

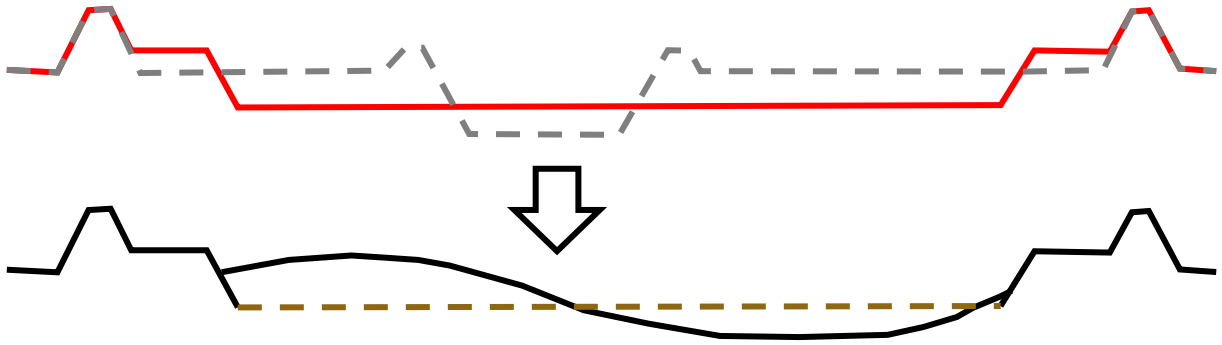
braided riverbed (b ≈ 360 m)



alternating bars (b ≈ 160 m, λ ≈ 1'400 m)





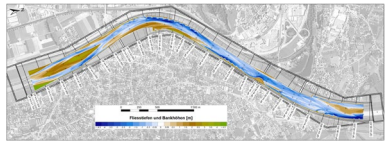


Morphodynamic Simulations

Overview of the morphodynamic simulations

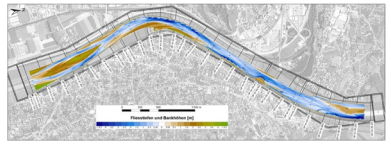
Main goal: reproduce the bed elevation changes of an experiment from the physical model

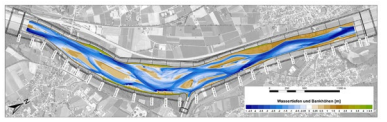
Calibration:



- 1 experiment
- bed forming discharge of HQ_5
- define all the parameters

Validation:





- 3 experiments
- HQ_{300} in the two different reaches
- annual hydrograph with $Q < HQ_2$
- validate the defined parameter

evaluation criteria:

- sediment balance
- development of the mean bed elevation
- **deposition and erosion areas** and heights

Model setup – BASEMENT v3.1

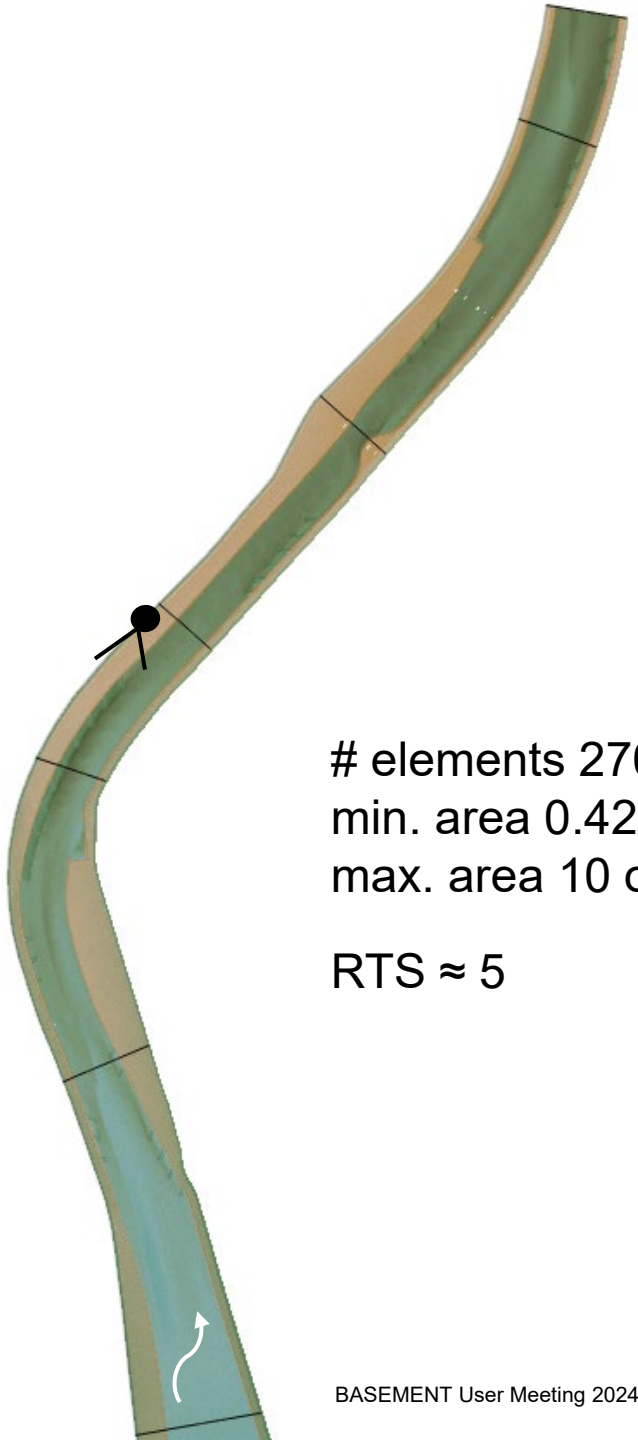
- Upstream and downstream boundaries → same as in the physical model
- Uniform bed material (d_m)
- Mobile bed: - 6 m

- Investigated Parameter
  - Curvature effect (Engelund 1974)
  - Bed load direction due to lateral bed slope (Talmon et al. 1995)
  - Gravitational bank collapse angle
  - Pre-factor of bedload formula

  - Flat initial bed vs. initial morphology
  - **Grid resolution**
  - **Downstream boundary height (IODown)**

Calibration - mesh

- Mobile bed
- Fixed groynes
- fixed bed stabilisation «Rollierung»
- Additional inflow and outflow sections



elements 270’000
min. area 0.42 m^2
max. area 10 or 100 m^2

RTS ≈ 5

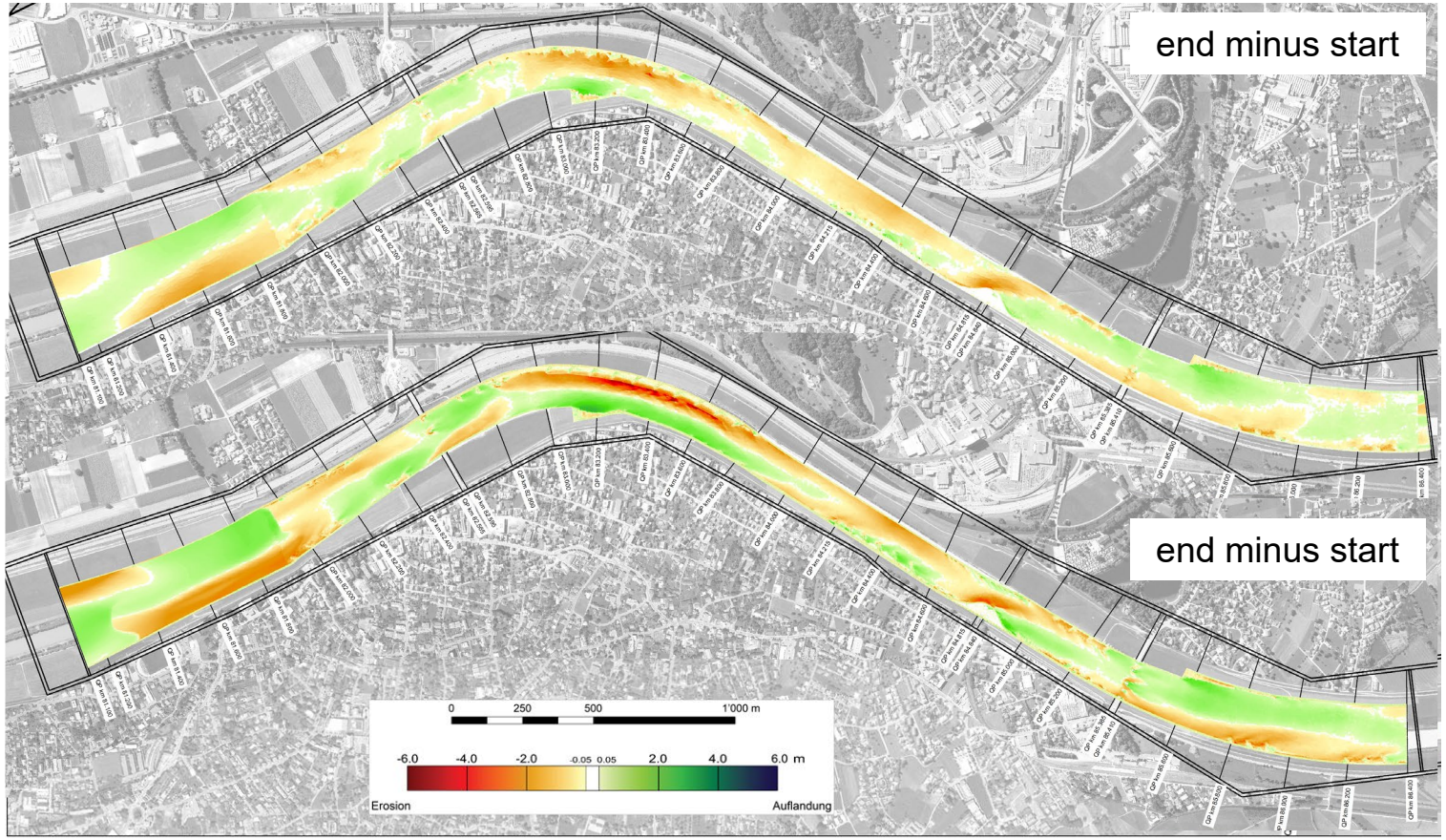
Calibration – grid resolution

≈ 20 cells per cross section

max. area 100 m^2, 120’000 elements

≈ 100 cells per cross section

max. area 10 m^2, 270’000 elements



→ General morphology is <u>independent of the gridresolution</u>

Calibration - downstream boundary

Bed elevation = initial height

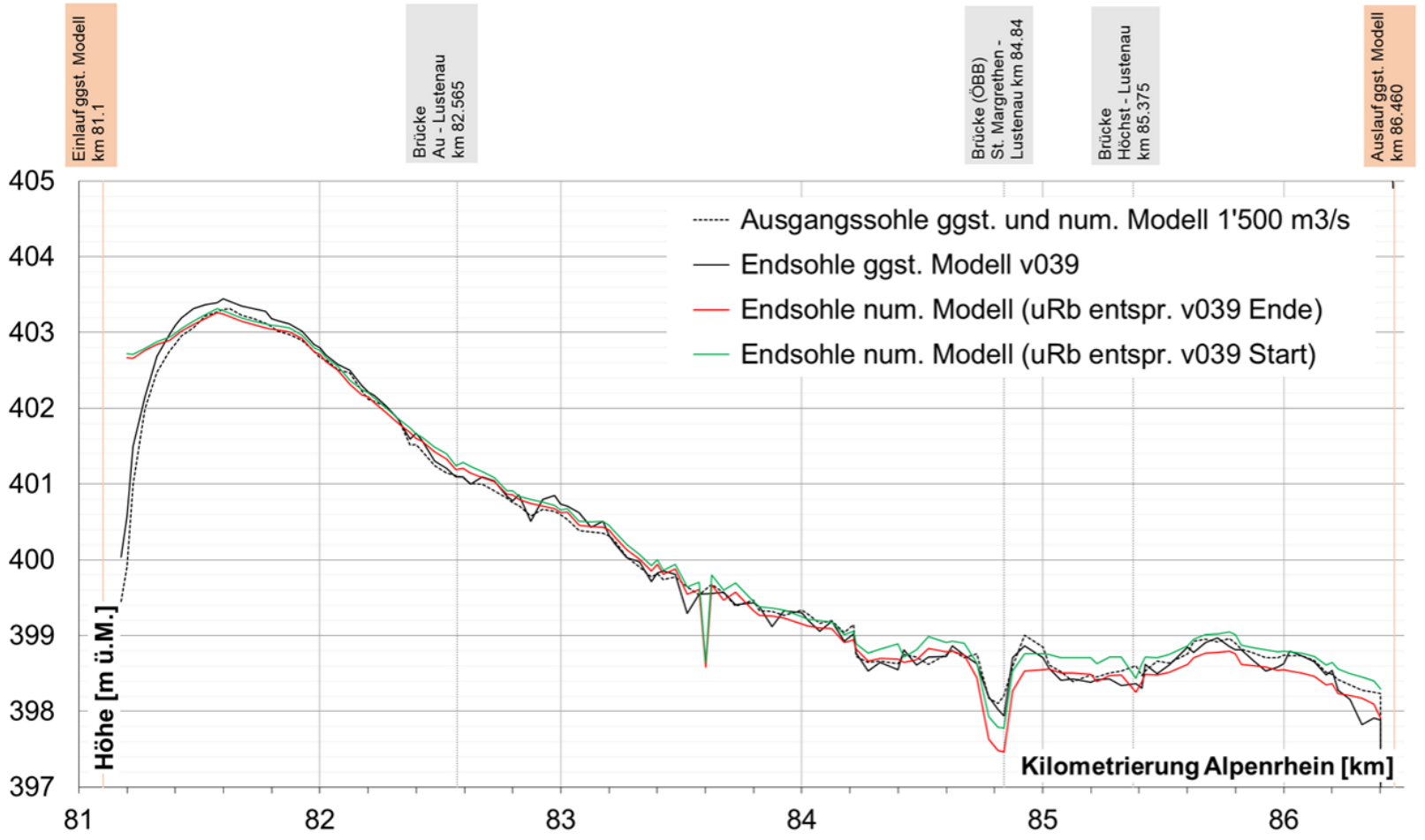
→ no change of bed elevation during simulation

Difference downstream boundary = 40 cm

→ sediment output doubled (!)

Bed elevation = height after experiment

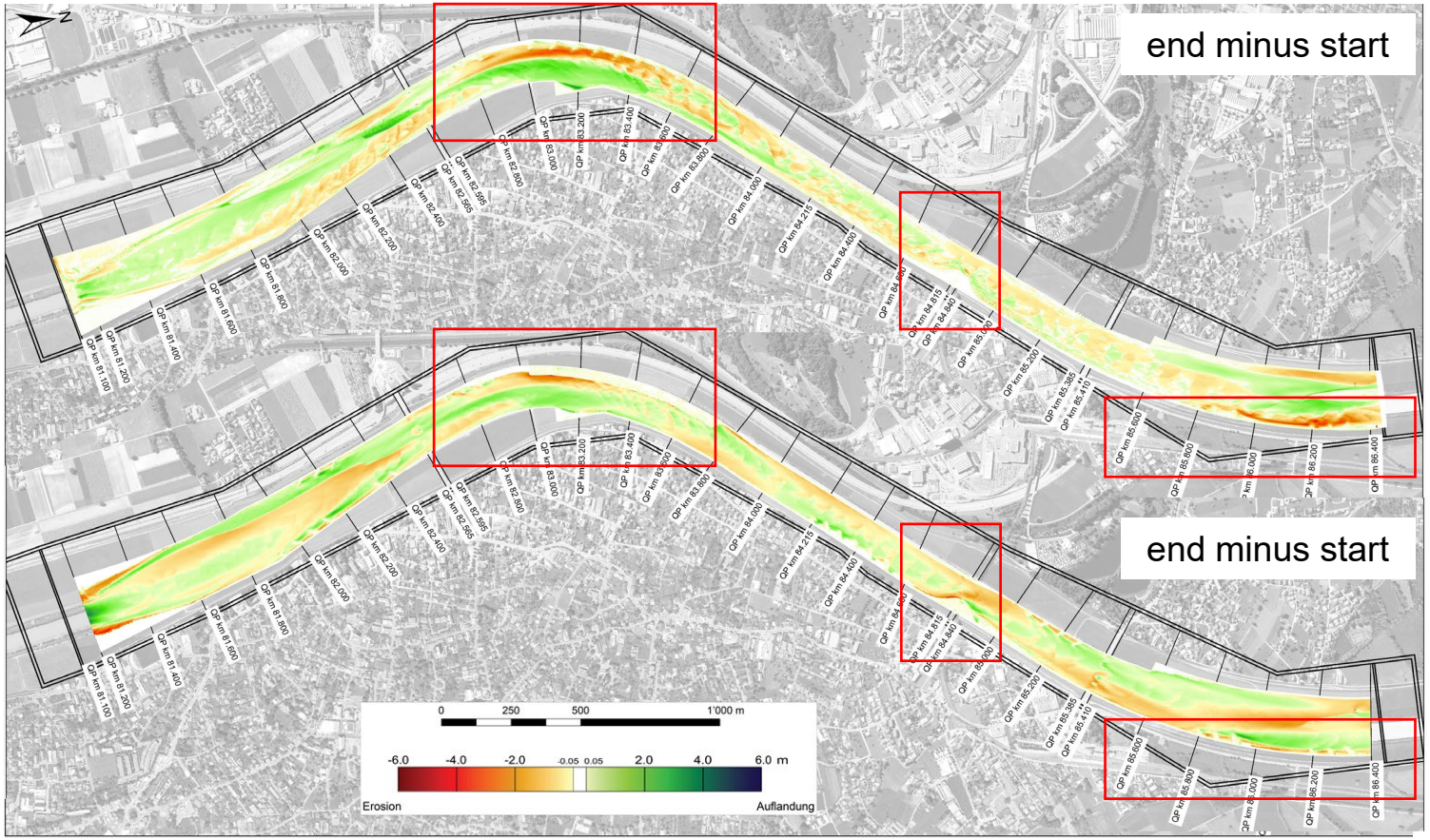
→ change of bed elevation at outlet during simulation



Calibration - final parameter set

physical model

numerical model

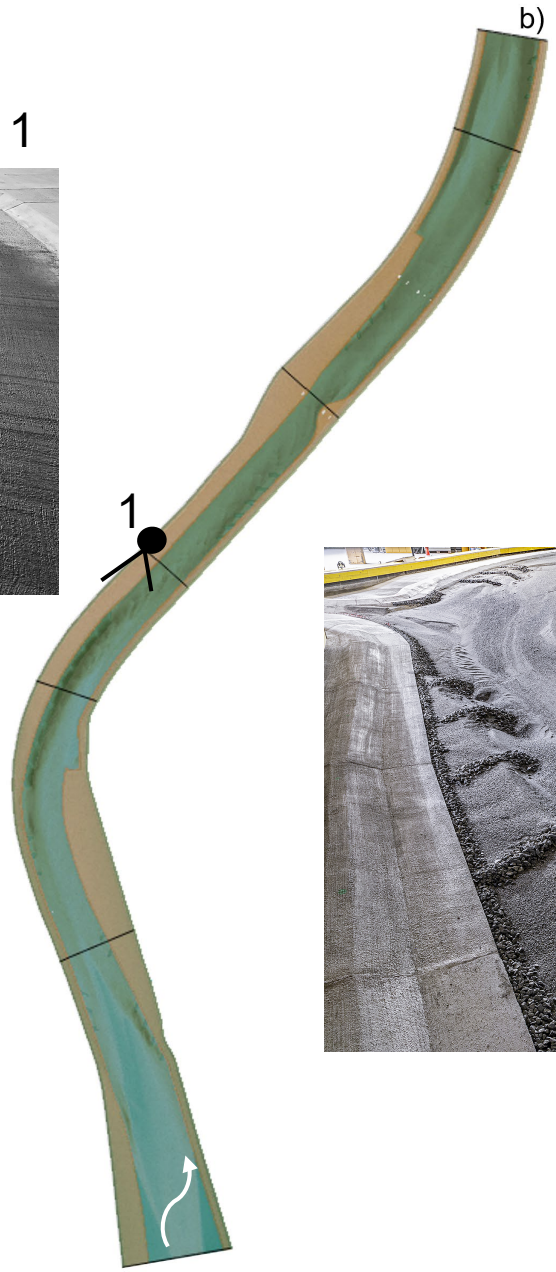


→ bedload transport volume ✓

→ development of the mean bed elevation ✓

→ deposition and erosion areas ✓ <u>but less «explicit» relief</u>

Validation - mesh



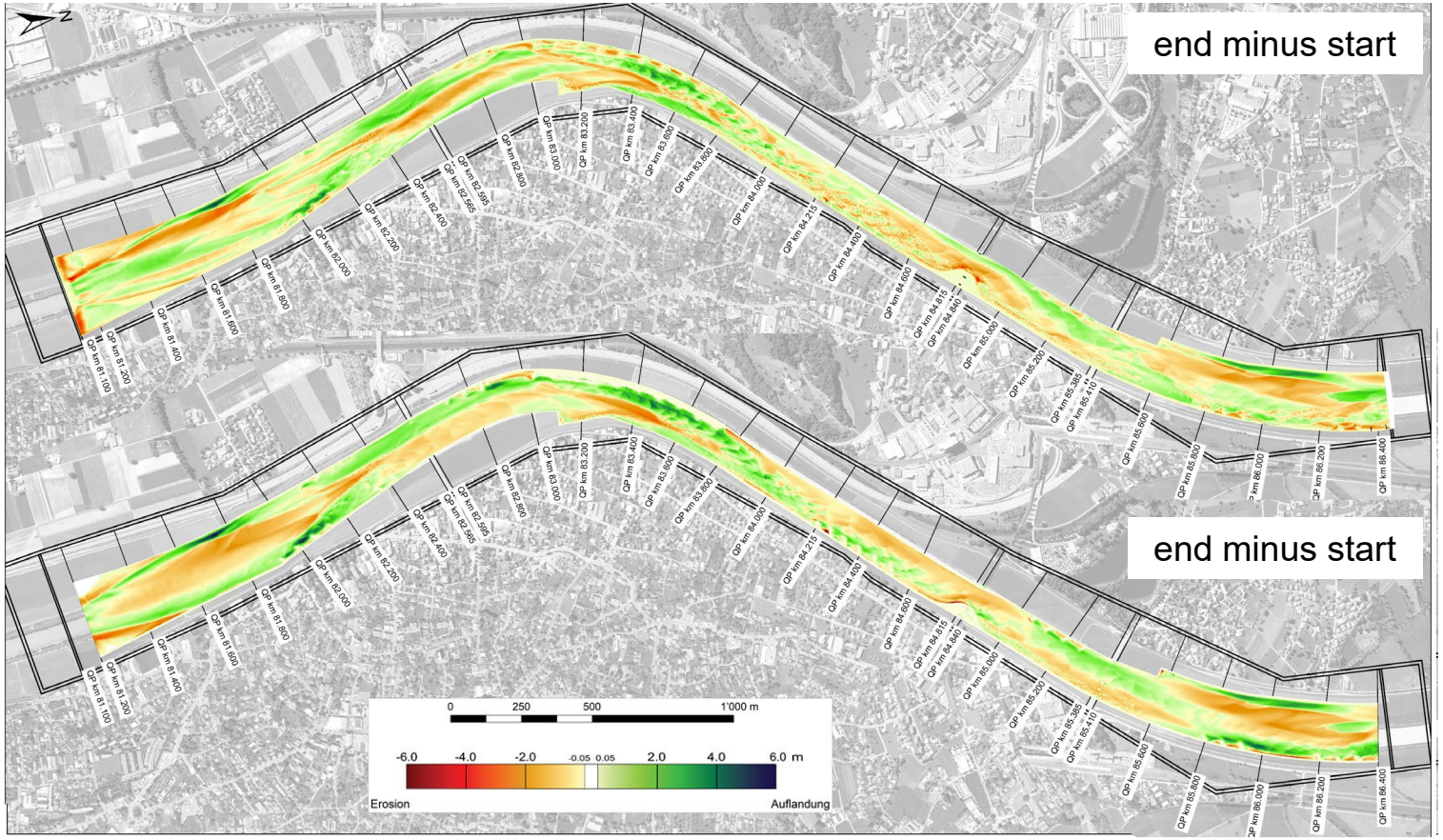
elements 270’000 / 400’000
min. area 0.42 m^2
max. area 10 m^2

RTS ≈ 5

Validation – HQ_{300}

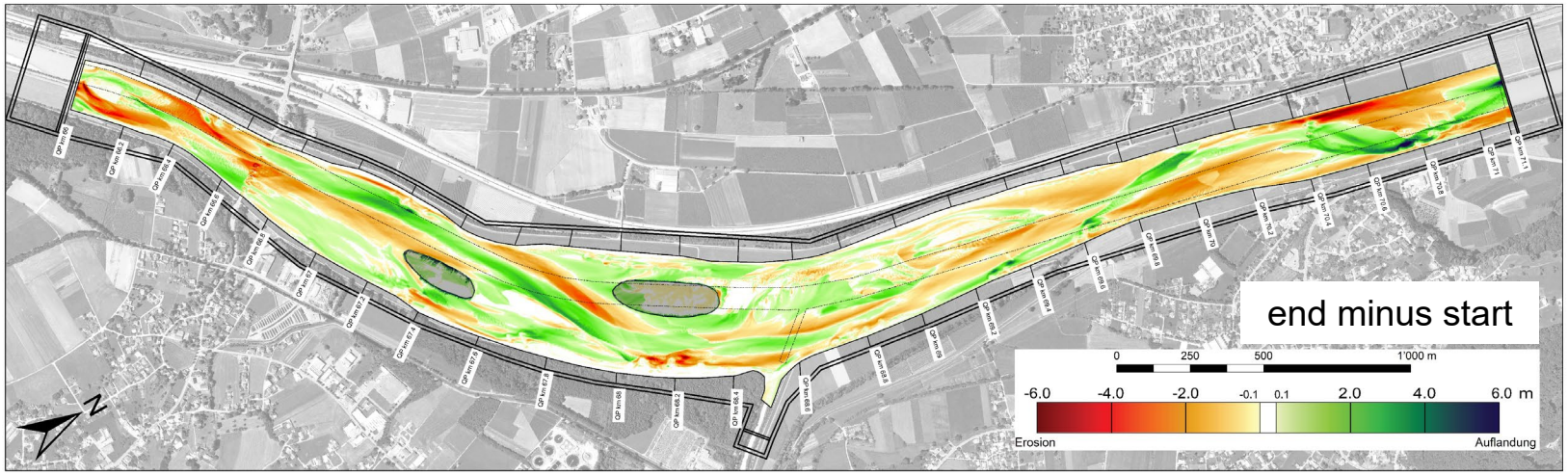
physical model

numerical model

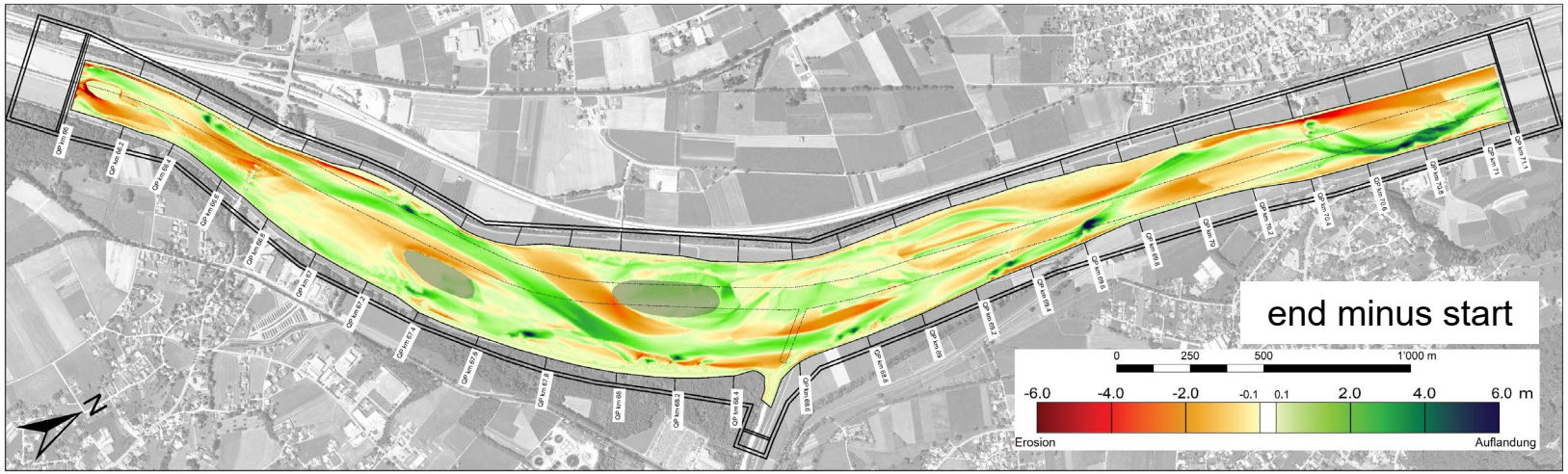


Validation – HQ_{300}

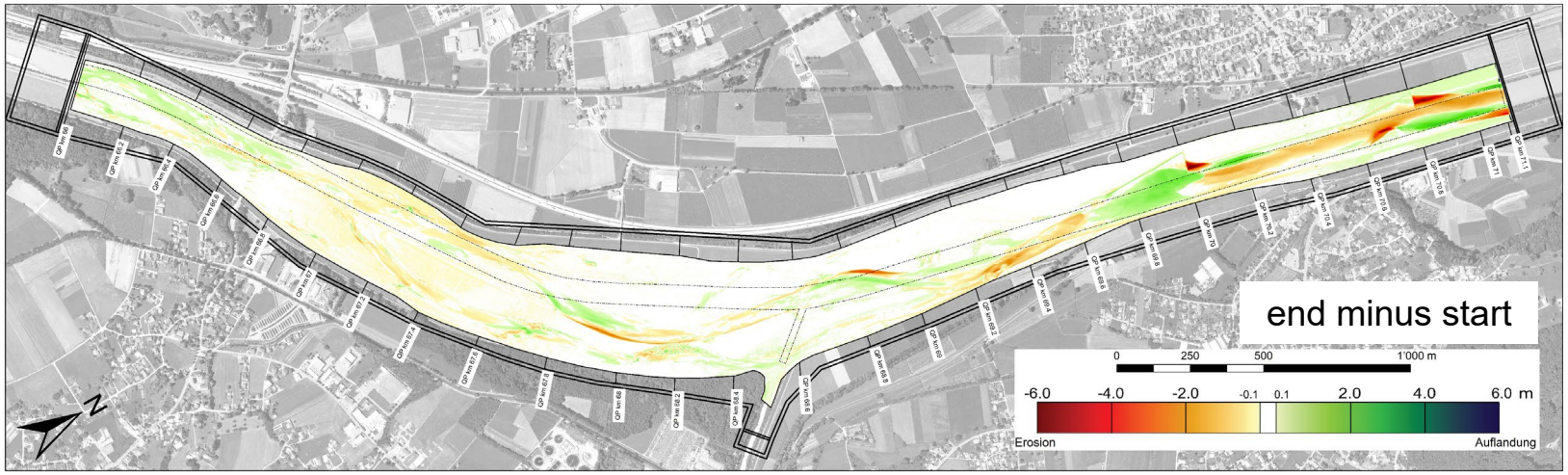
physical model

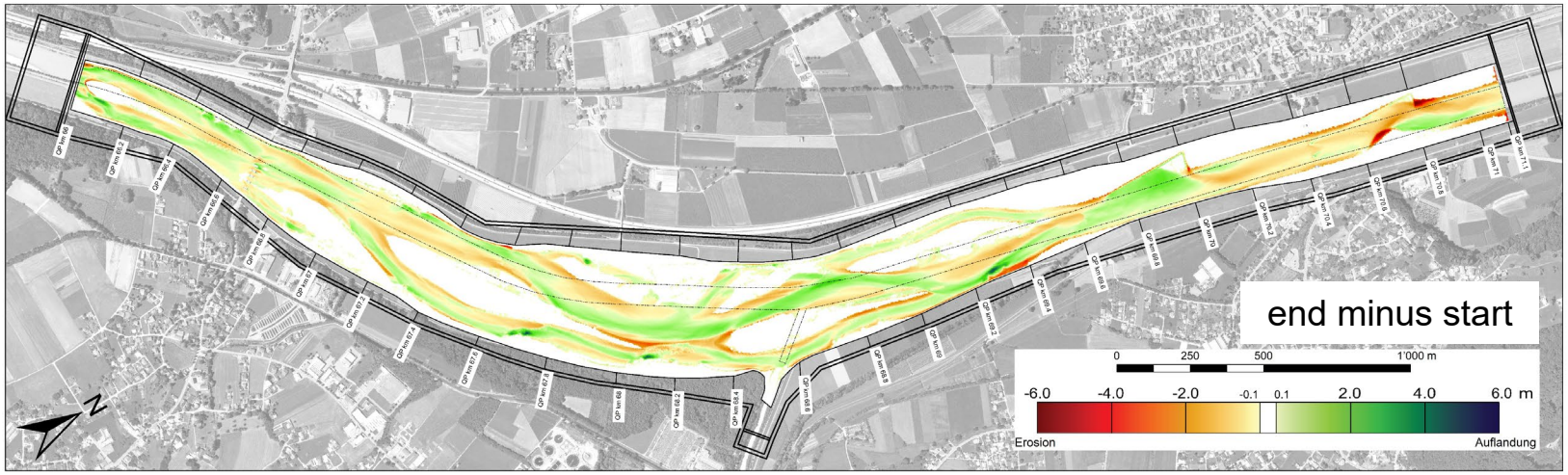


numerical model



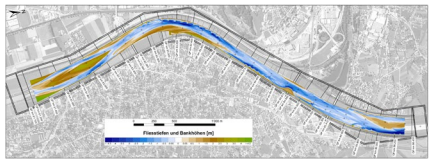
Validation – hydrograph 2011





Discussion

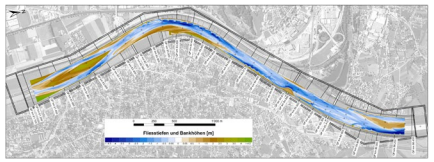
Calibration



alternating bars

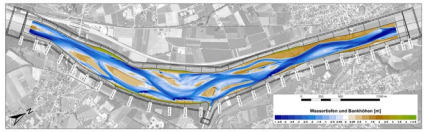
HQ5
short pre-stress

Validation



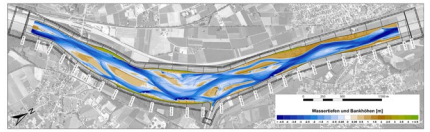
alternating bars

HQ300
long pre-stress



braided morphology

HQ300
fully developed
morphology



braided morphology

2011
partly developed
morphology

+ areas of erosion and deposition (except with low discharge)

+ good sediment balance

+ development of the mean bed elevation

- local processes and scours better resolved in physical model

Model limitations:

→ Armoring and heterogeneity in the physical model vs. uniform grainsize in the numerical model

→ Depth-averaged 2D-model

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im Auftrag

Internationale Rheinregulierung