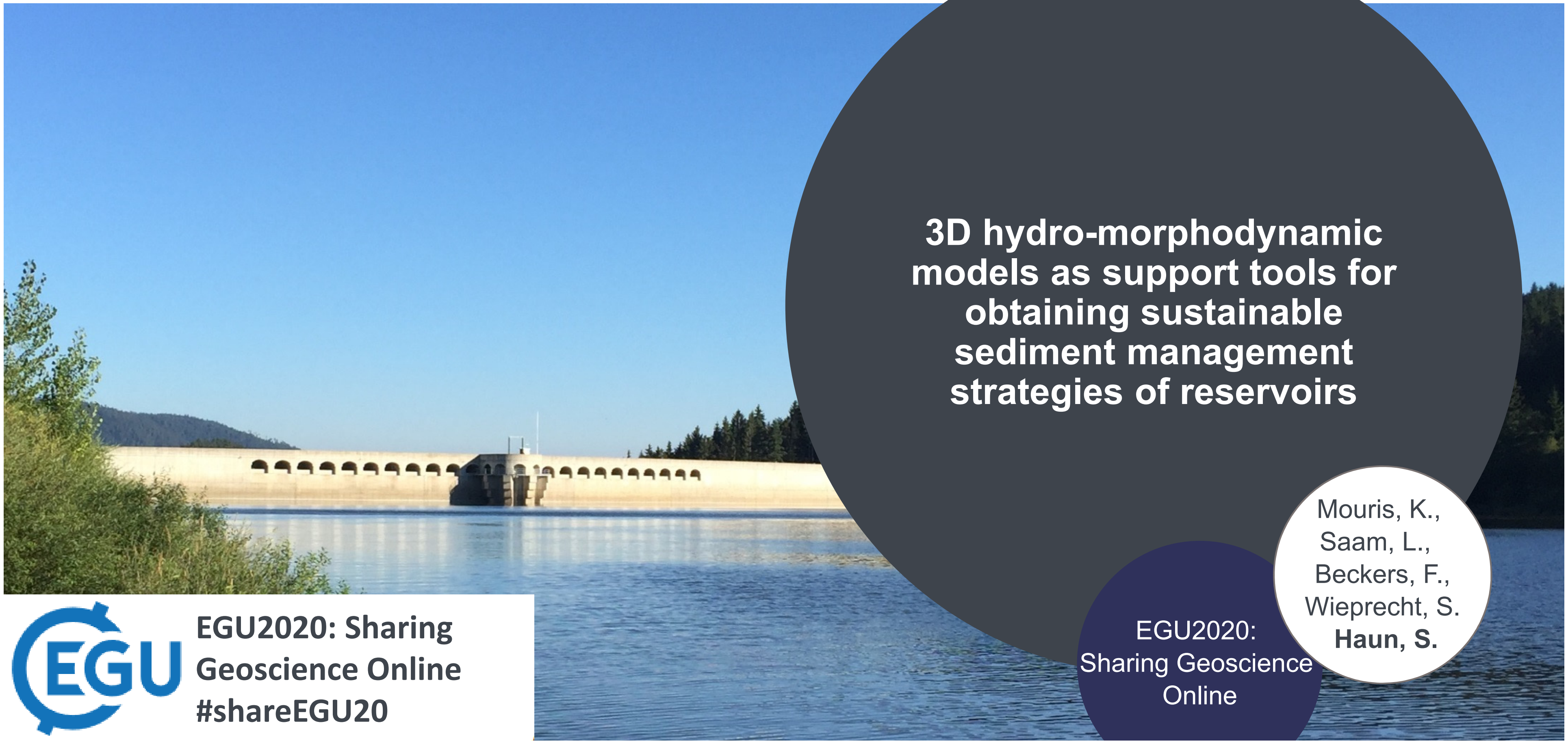
University of Stuttgart
Institute for Modelling Hydraulic and Environmental Systems

IWS
Department of Hydraulic Engineering
and Water Resources Management
Prof. Dr.-Ing. Silke Wieprecht



3D hydro-morphodynamic models as support tools for obtaining sustainable sediment management strategies of reservoirs

Mouris, K.,
Saam, L.,
Beckers, F.,
Wieprecht, S.
Haun, S.

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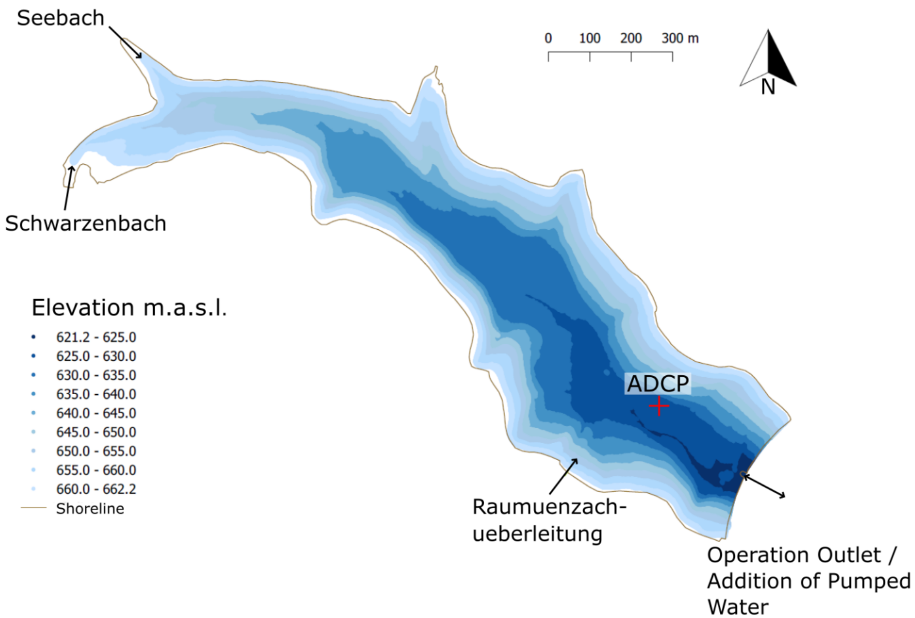
1 Background & Motivation

Study site: The Schwarzenbach reservoir

- *Length: 2.2 km*
- *Max. width: 600 m*
- *Max. depth: 47 m*
- *Storage volume: 14.4 mio. m³*

- Location: Black Forest, Germany
- Pump-storage operation



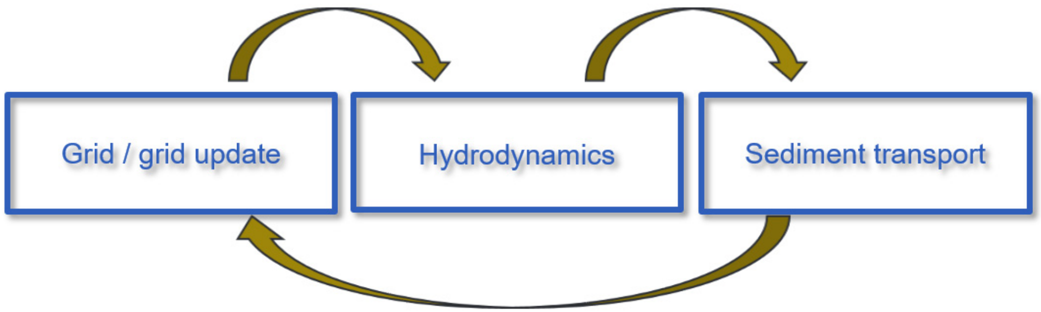
- In total 3 „natural“ inflows
- The Raumuenzachueberleitung can be controlled by the operator and carries no sediments

- The reservoir was investigated within a joint research project, but has no sedimentation problem

2 | Model setup

3D hydro-morphodynamic model SSIIM and grid

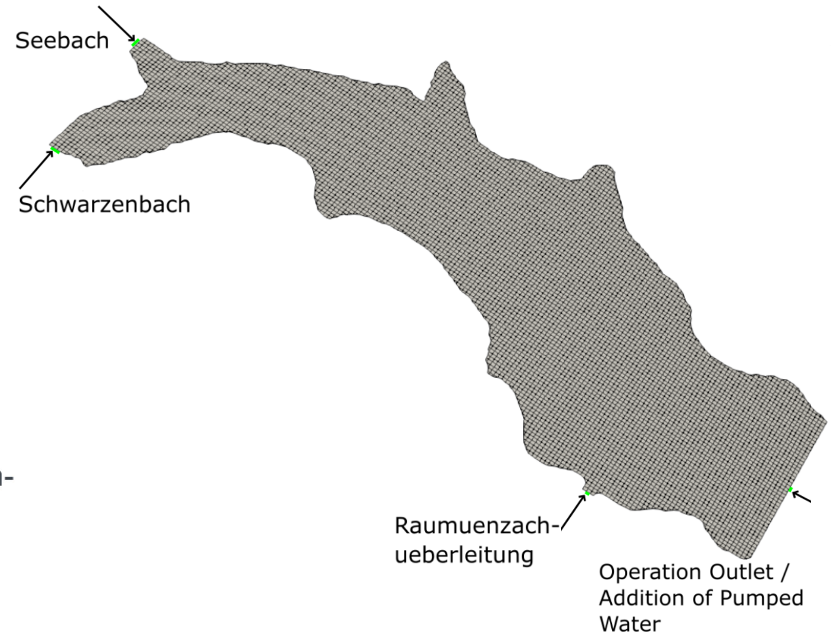
- The fully 3D hydro-morphodynamic model SSIIM is used



- Adaptive, unstructured and non-orthogonal grid
- Wetting and drying algorithm for lowering the water level

- Fully 3D RANS model
- POW and SOU is used
- k-ε turbulence model
- Implicit time discretization
- Taking wind induced shear stresses into account

- Suspended sediment transport is computed by transient convection-diffusion equation
- The bed load is calculated with an empirical formula by Van Rijn

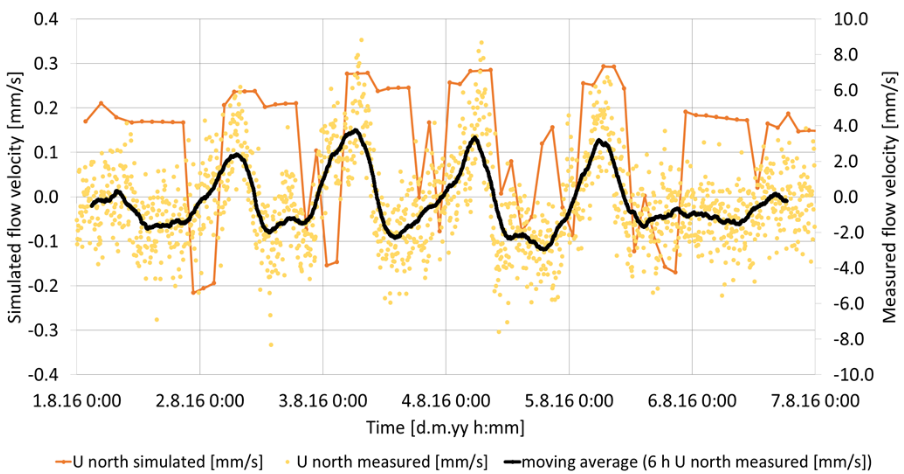


- 81.300 tetra- and hexahedral cells
- Grid resolution: 10 m x 8 m; Max. 18 cells in vertical direction

2 Model setup

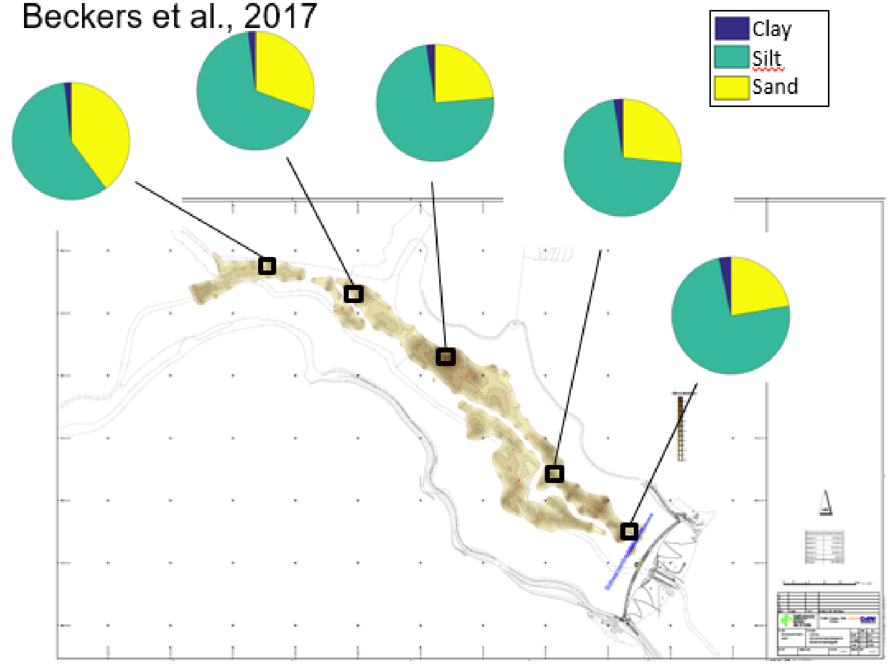
Hydrology and Sediments

Mouris et al., 2017



Instationary simulation, time step 900 sec

Beckers et al., 2017

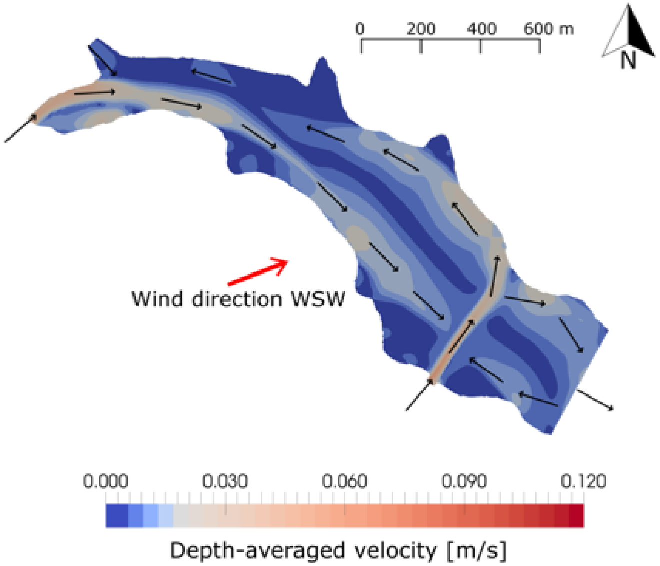


Measured spatial distribution of the sediment accumulations in the Schwarzenbach reservoir

- Plausibility check of the model against measured flow velocities (ADCP)
- Surface sediment composition in the model from bucket samples

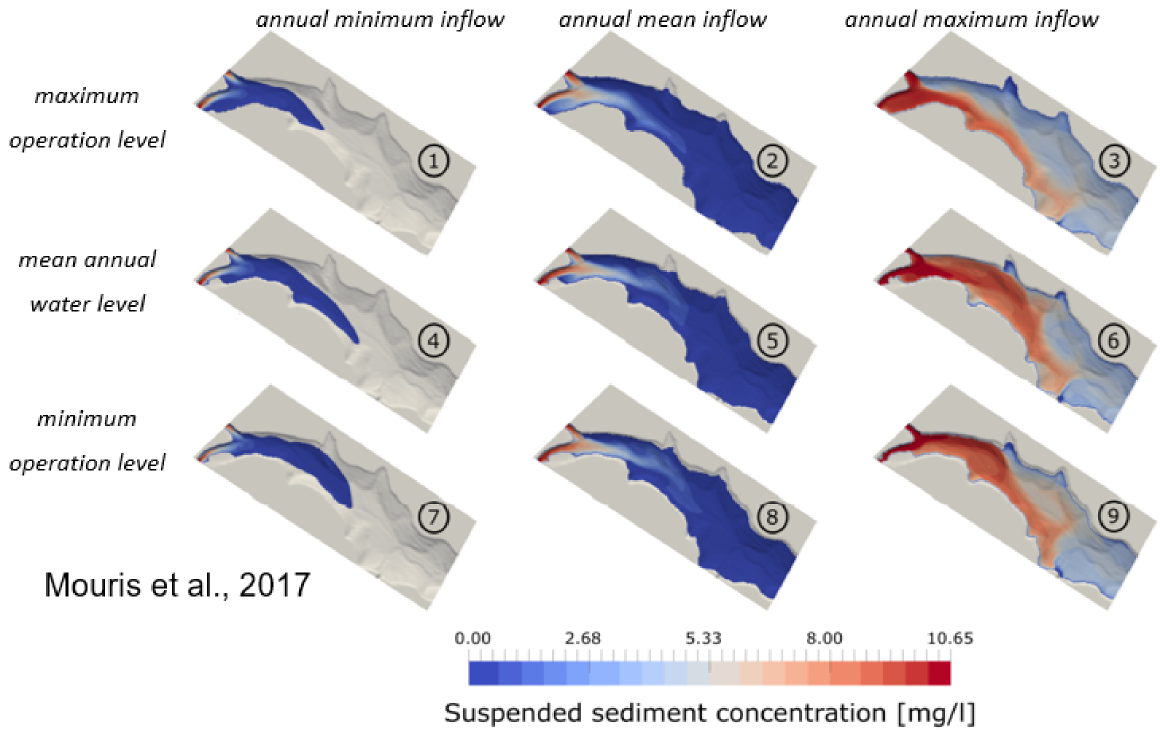
3 | Results – Hydraulics and Sediment transport

Active sediment management by means of reservoir operation



Max. operation level 668.5 m.a.s.l.

Maximum annual inflow,
turbine operation (i.e. outflow)



Mouris et al., 2017

- Suspended sediment transport simulated for different grain sizes and changing reservoir operations

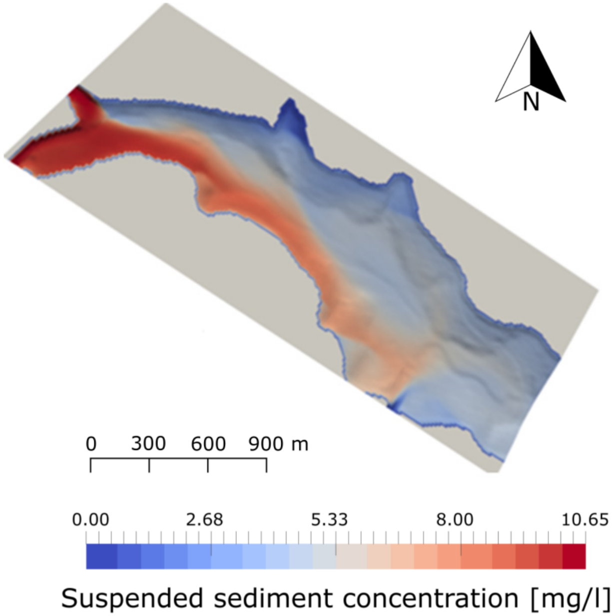
3 Results – Hydraulics and Sediment transport

Active sediment management by means of reservoir operation

Max. operation level 668.5 m.a.s.l.

Maximum annual inflow,
turbine operation (i.e. outflow)

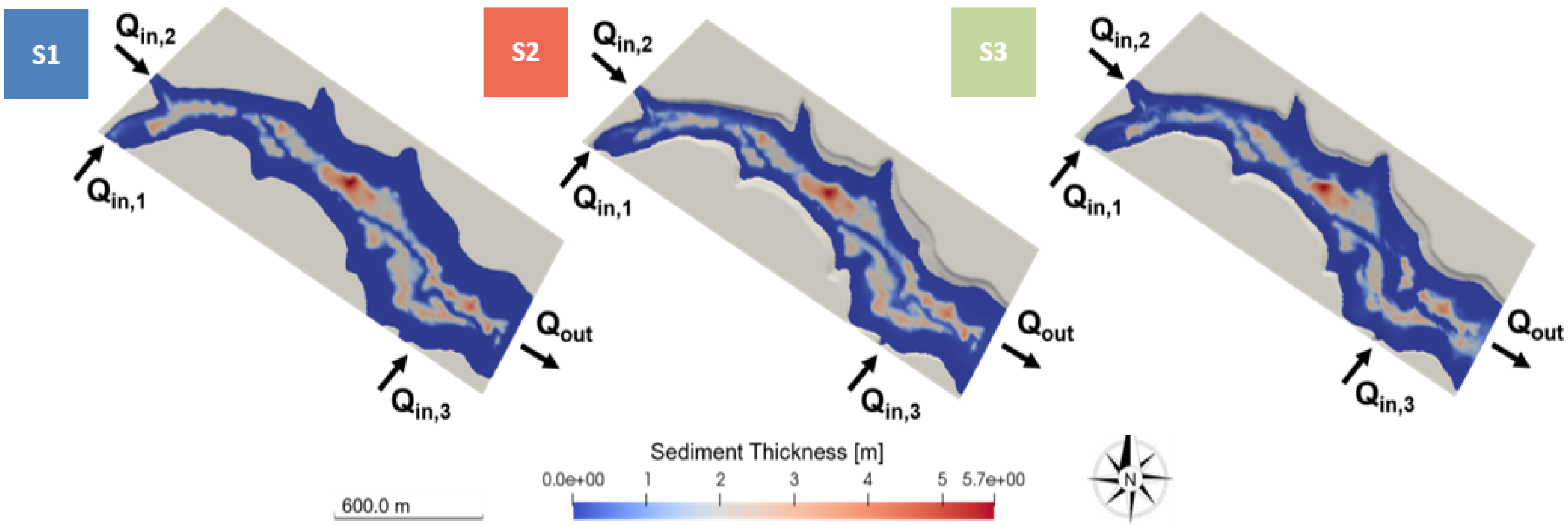
Results for grain fraction 5 (5.09 µm)



- Hydraulics and sediment transport
  - Complex flow field with two recirculation zones develops due to the lateral inflow from the Raumuenzachueberleitung (RUB)
    - In case RUB is not operated sediments may reach the dam
    - In case RUB is operated on full capacity, even fine sediments will not reach the dam
  - Active variation in the water level within the reservoir lead to changes of the suspemded sediment transport
    - Low water levels and high inflow discharges lead to a transport of sediments in direction of the dam
    - High water levels and low inflow discharges lead to depositions at the head of the reservoir

3 Results – Reservoir management

Simulation of flushing scenarios



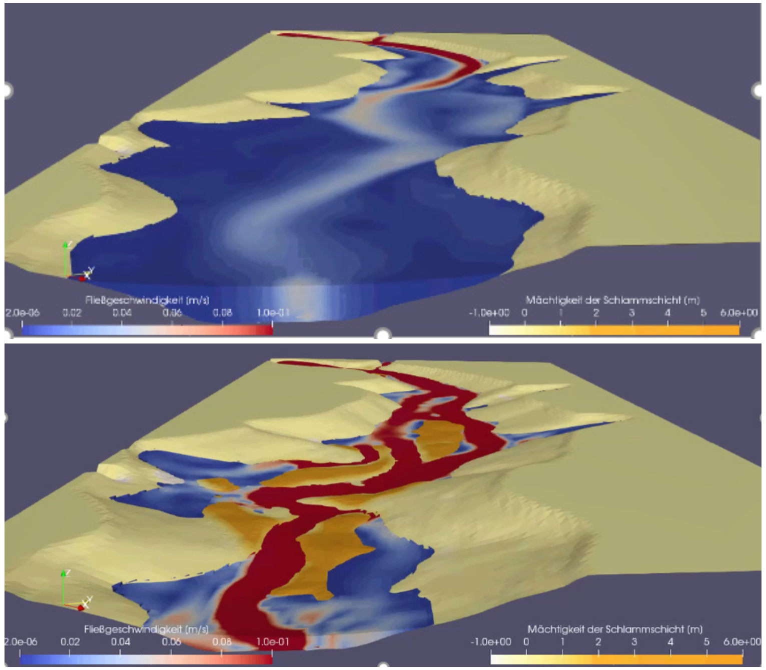
S1 Flushing without lowering of the water level (maximum operation level 668.5 masl)

S2 Flushing with partly lowering of the water level (minimum operation level 640.0 masl)

S3 Flushing with free flow conditions (628.0 masl)

- Comparison of the sediment thickness remaining after flushing indicates S3 as most successful flushing strategy

3 Results – Reservoir management
Simulation of flushing scenarios



- Sediment management by reservoir flushing
  - 80 times higher sediment outflow of flushing with full draw down compared to a flushing without draw down
  - In total 35.000 tons of sediments are flushed out within 350 hours
  - To reach equilibrium sediment conditions, a draw-down flushing must be conducted every 3.5th year

S3 Flushing with free flow conditions (628.0 masl)

4 | Conclusions

Numerical models as support tool for sediment management

- A 3D hydro-morphodynamic model was tested as a support tool for obtaining sustainable sediment management strategies of a reservoir
  - Hydraulic plausibilisation of the model and sediment transport simulations gave insight into the ongoing processes
  - The numerical model, with an adaptive grid, is able to simulate the flushing with full draw down
- Reservoir operation as possibility for an active sediment management
  - Due to the transition coming from the transition tunnel a complex flow field develops and it can be controlled if sediment deposit in front of the dam or further upstream
  - Adaption of the management strategies with respect to water level during different inflow discharges lead to changes of the sediment transport within the reservoir
- Sediment management by reservoir flushing
  - Frequently conducted flushing is the only possibility to initiate sustainable sediment conditions

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Thank you

Stefan Haun

E-Mail stefan.haun@iws.uni-stuttgart.de
Phone +49 (0) 711 685-64691
Fax +49 (0) 711 685-64746

University of Stuttgart
Institute for Modelling Hydraulic and Environmental Systems
Pfaffenwaldring 61, 70569 Stuttgart
Germany

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