



RESTORATION OF THE MARITIME NATURE OF MONT-SAINT-MICHEL

DESIGN AND USE OF A NUMERICAL HYDROSEDIMENTARY MODEL

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Context

Numerical model

- Software
- Mesh and forcings
- Sedimentary model

Model calibration

- Measurement campaign
- Hydraulic calibration
- Sedimentary calibration

Model operation



Mont-Saint-Michel bay is subject to siltation

(approximately 1 million m³/year)

-> gradually destroying the maritime nature of the bay.



On-going works:

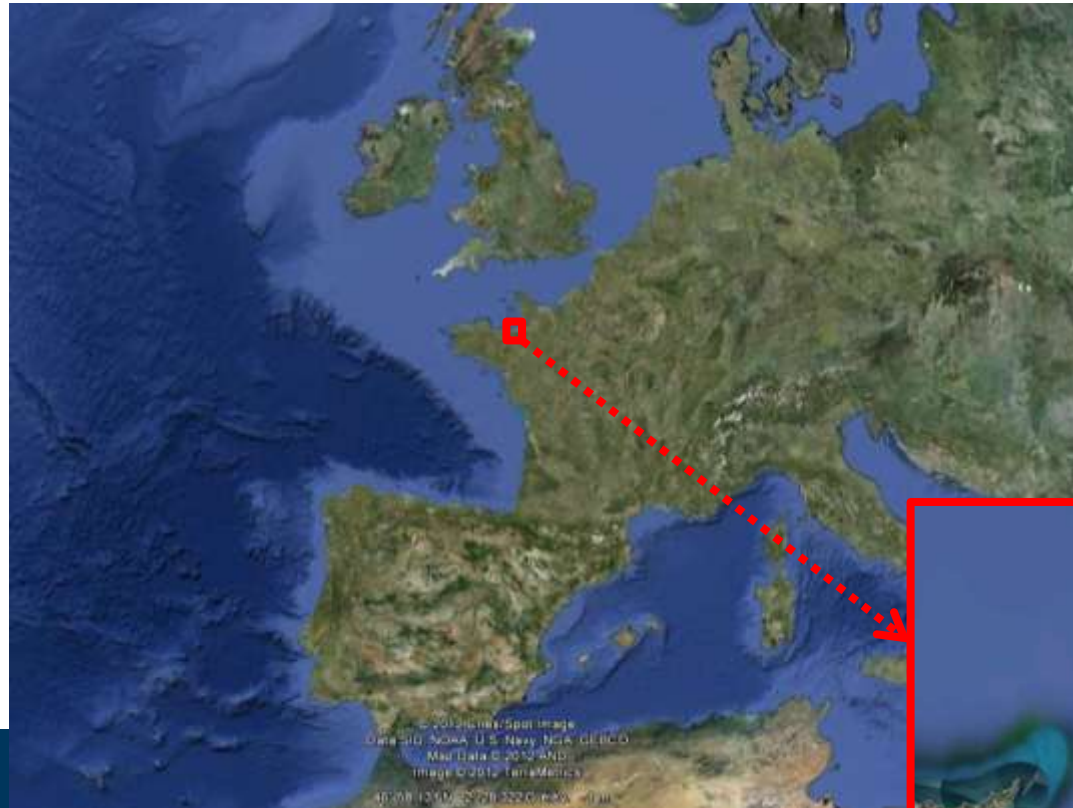
- re-construction of a dam on the river Couesnon for sediment flushing,
- increase of the storage capacity upstream of the dam,
- Creation of channels downstream of the dam,
- replacement of the causeway leading to Mont-Saint Michel by a pile bridge.

Aim of the numerical study:

- obtaining a decision-aid tool for dam management optimisation

Context

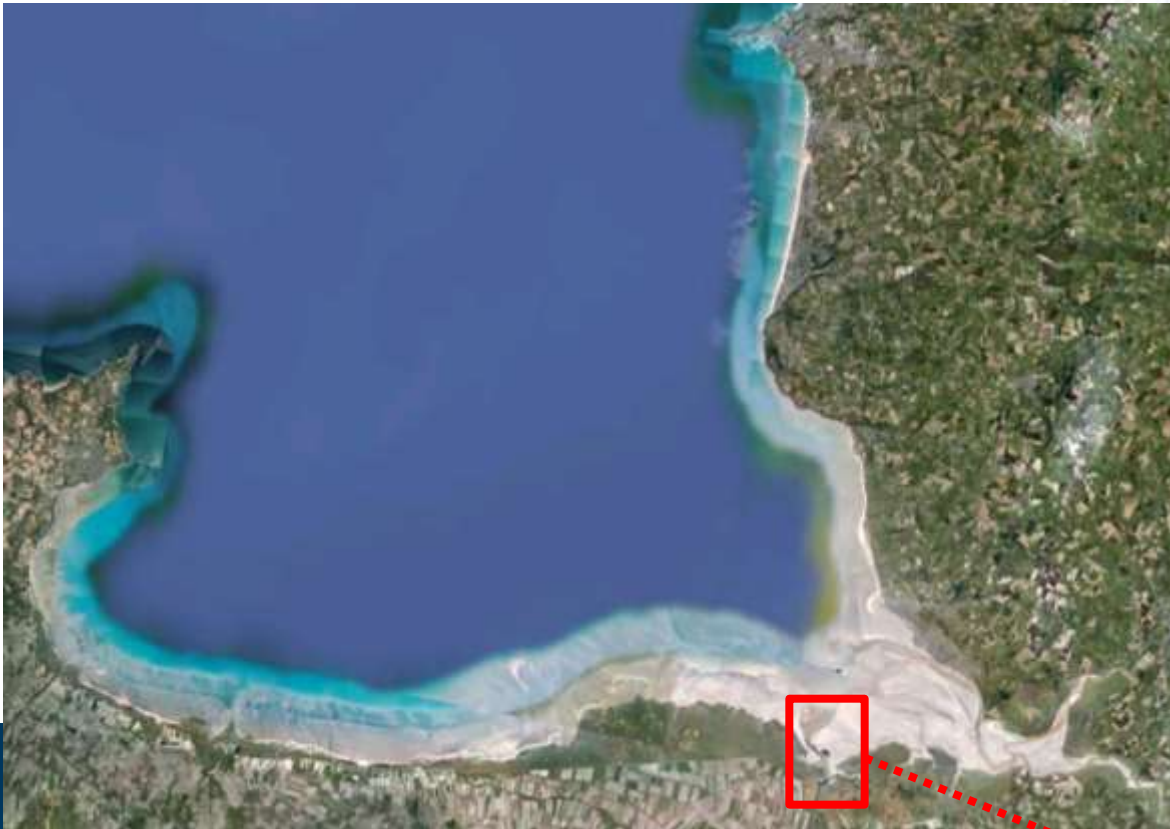
Location of project site :
Mont-Saint- Michel Bay (France)



Context

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Mont-Saint- Michel Bay (France)

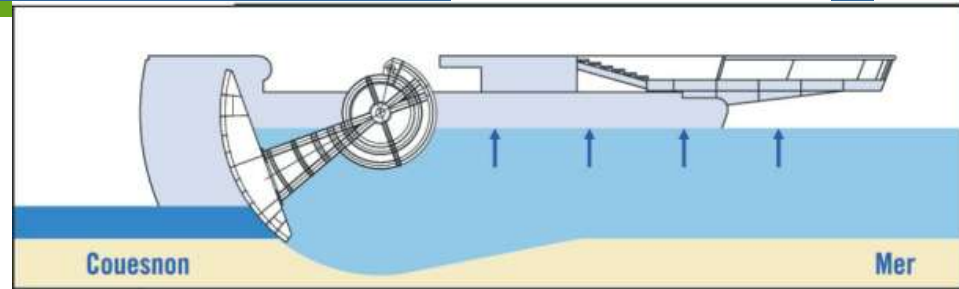
UG. 27-31, 2012



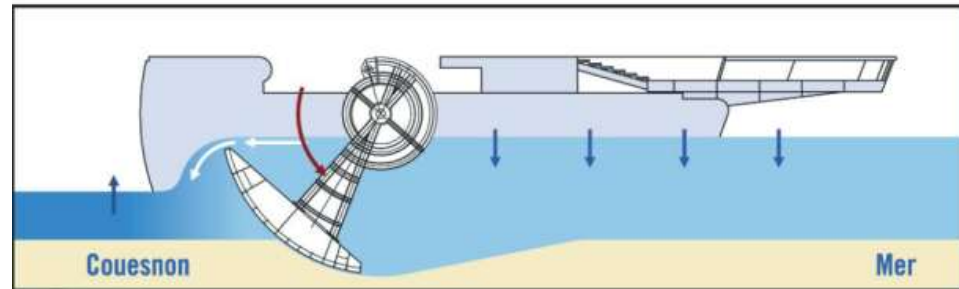
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Dam operating

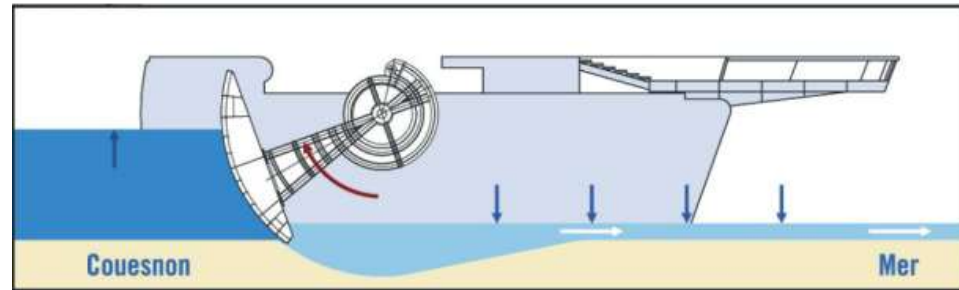
Waiting for filling



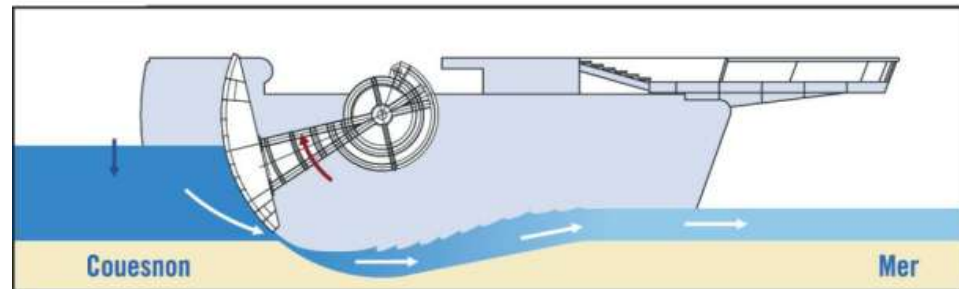
Filling by overtopping



Waiting for flushing



Flushing



Model description

TELEMAC system (EDF R&D) :

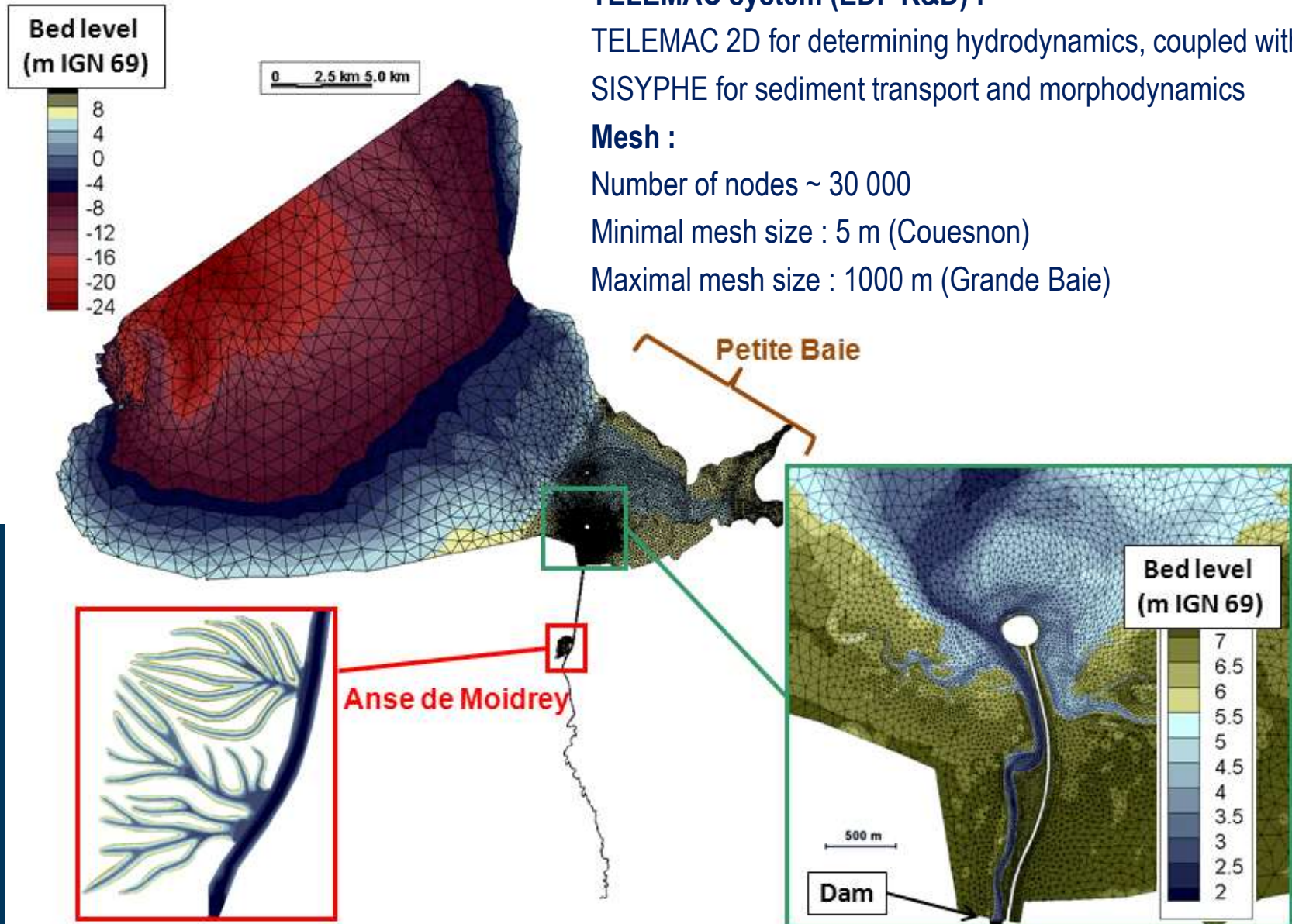
TELEMAC 2D for determining hydrodynamics, coupled with SISYPHE for sediment transport and morphodynamics

Mesh :

Number of nodes ~ 30 000

Minimal mesh size : 5 m (Coesnon)

Maximal mesh size : 1000 m (Grande Baie)



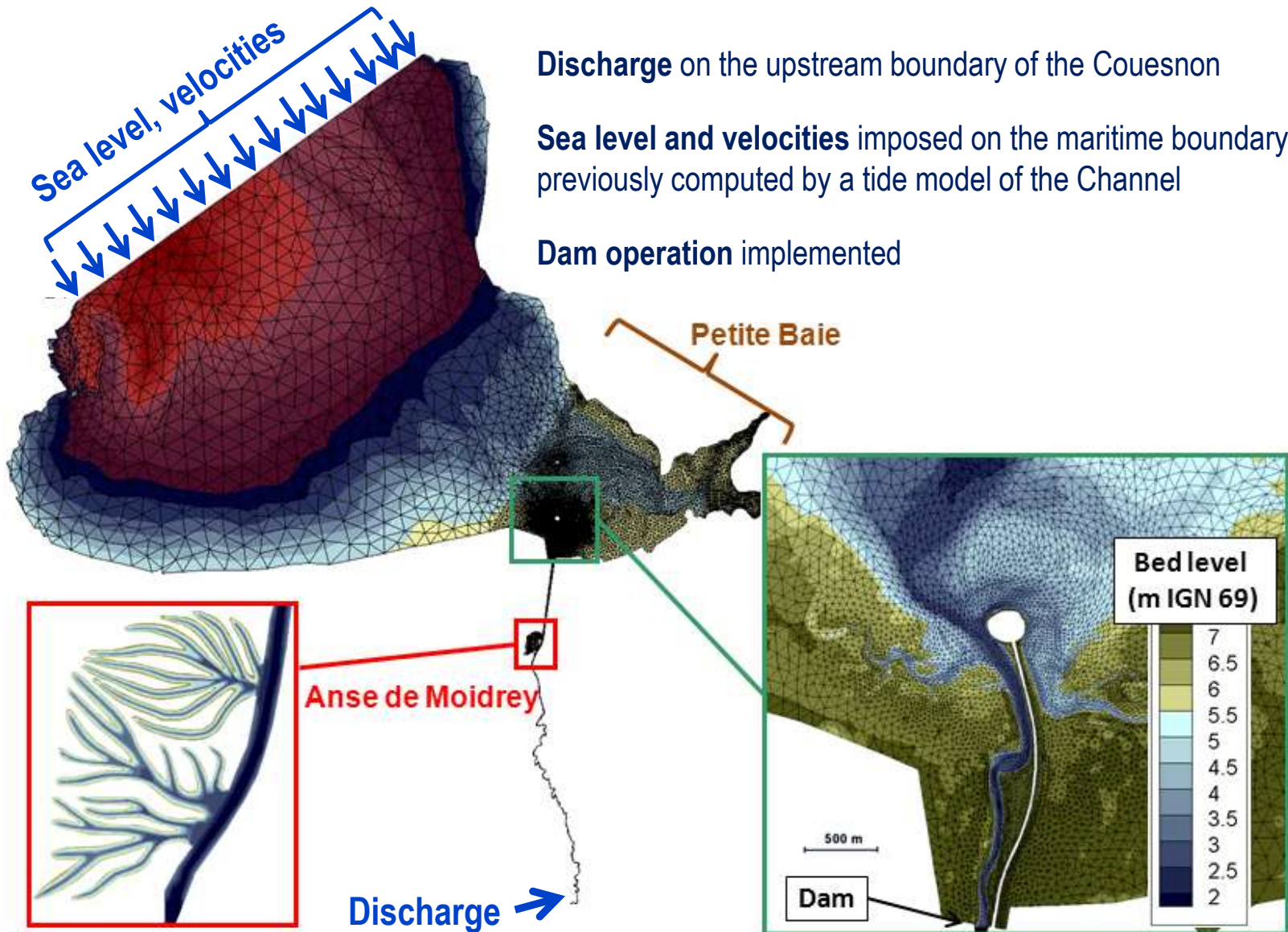
Model description

Forcing:

Discharge on the upstream boundary of the Couesnon

Sea level and velocities imposed on the maritime boundary, previously computed by a tide model of the Channel

Dam operation implemented



Sedimentary model

Transport model implemented for this case :

- **Partially based on Waeles (2007)** « *Modelling sand/mud transport and morphodynamics in the Seine river mouth (France)* »
- **Two classes : sand (~0.1 mm) and mud**
- **Water column** : transport and deposition computed independently

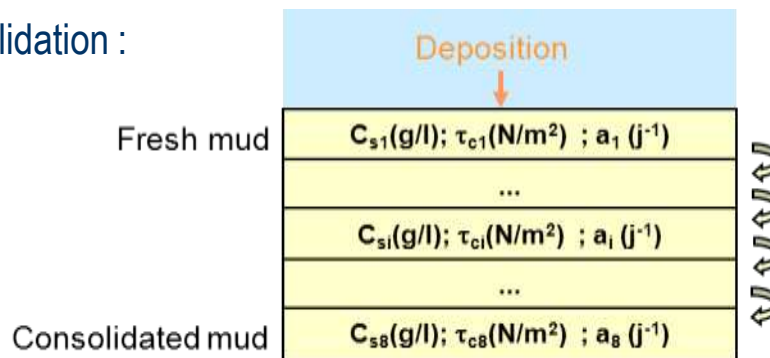
- Deposition rate :

$$\text{Sand : } \frac{dD}{dt} = W_c C_{a,e} \quad C_{a,e} \text{ equilibrium bottom concentration by Van Rijn (1993)}$$

$$\text{Mud : } \frac{dD}{dt} = W_c P C \quad P = \left[1 - \left(\frac{u^*}{u_d^*} \right)^2 \right] \quad \text{Krone (1962)}$$

- **Sediment bed** : mixture of variable composition (in space and time)

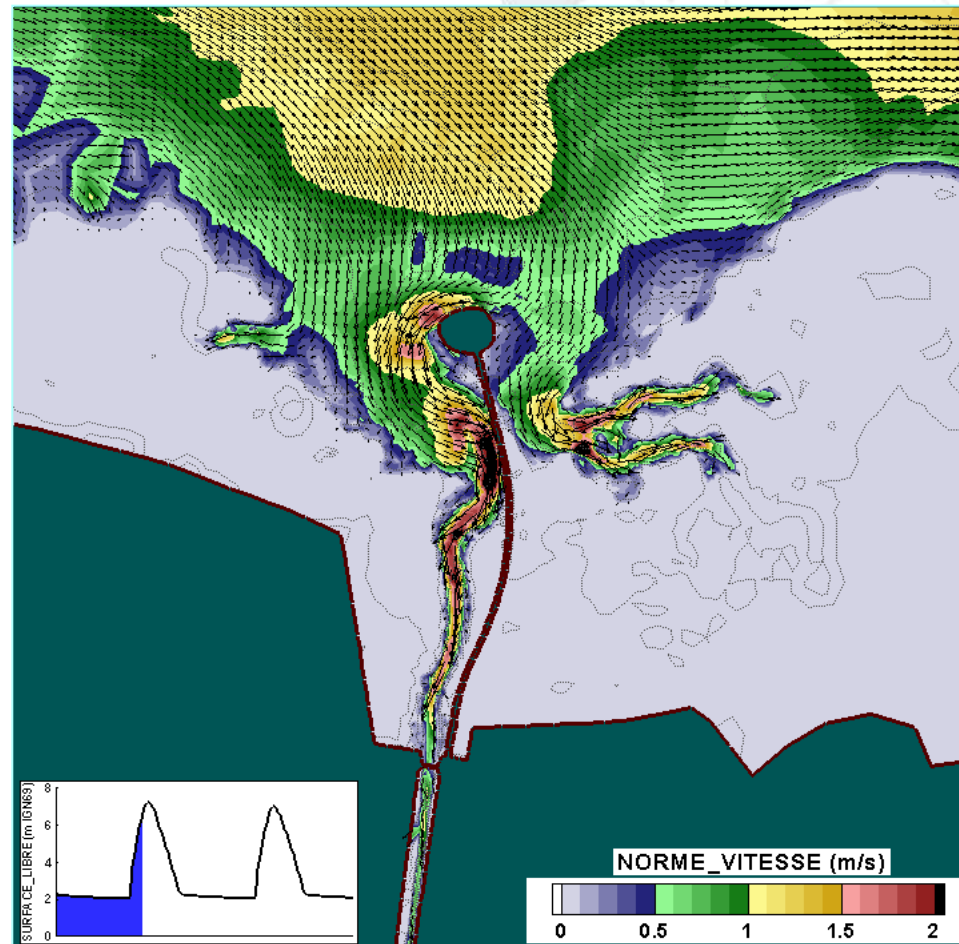
- Mud consolidation :



- Critical shear stress and erosion rate are computed depending on mud fraction using a composition between the relationships for pure mud and pure sand

Hydraulic calibration

The model was initially calibrated hydraulically to make sure that tidal flow propagation in the Bay is properly represented.



Measurement campaign

July 2009 : commissioning of the dam

15-days continuous measurement of :
Water level, flow velocity, turbidity

The subcontractor doing the measurements encountered lots of troubles because of tidal range, strong currents and turbidity range

-> some data was not usable



Hydraulic & Sedimentary calibration

Operation of the new dam (with fillings and flushings) was then programmed.

Calibration based on level&velocity measurements in the Couesnon river.

Measured and computed current speed and water level 300 m downstream of the dam.

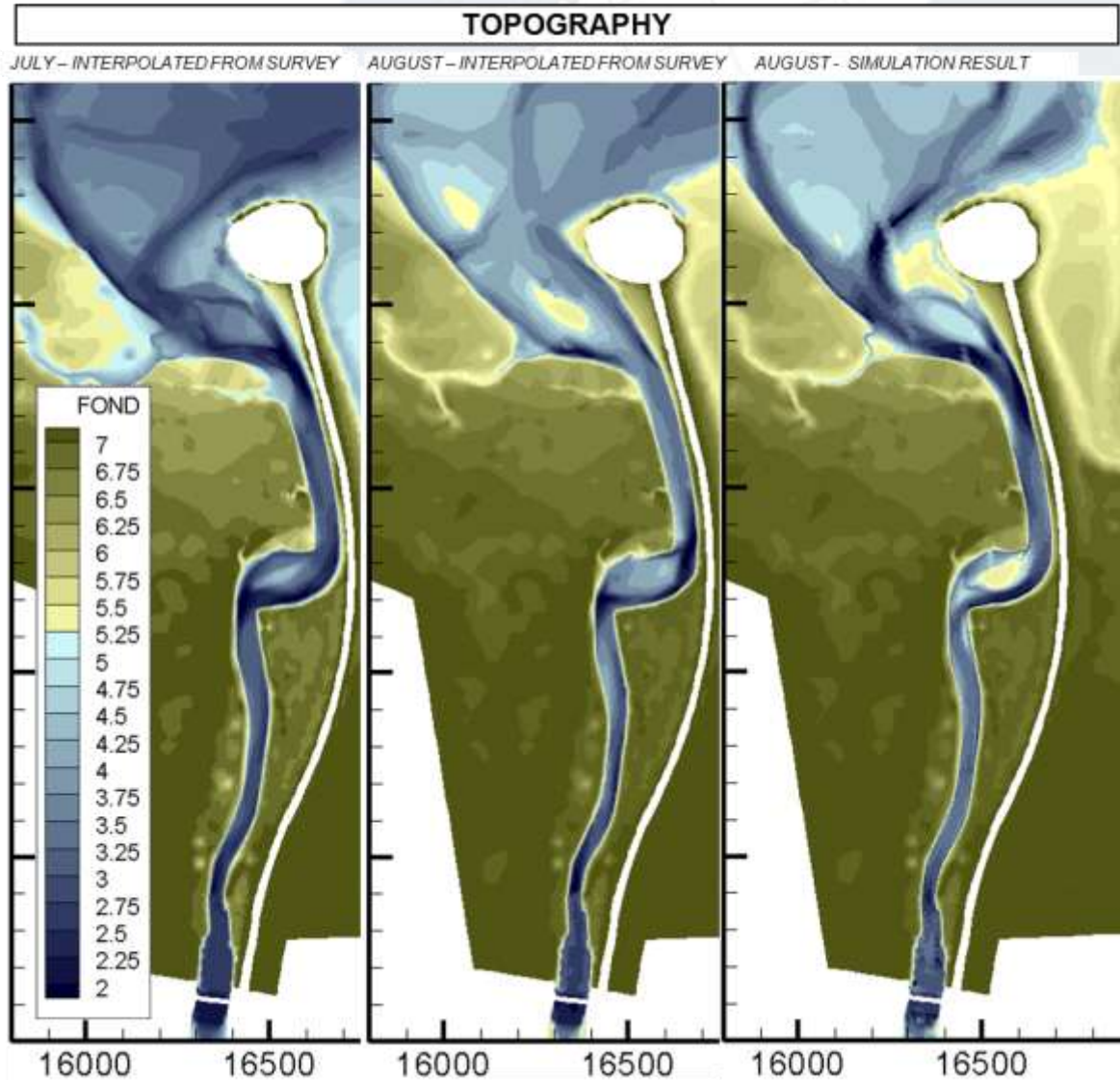
Calibration based on turbidity measurements in the Couesnon river.

Measured and computed sediment concentration 300 m and 1200 m downstream of the dam.

Model calibration

Morphodynamic calibration

Using 2009 bathymetric survey
(commissioning of the new dam)



Model operation

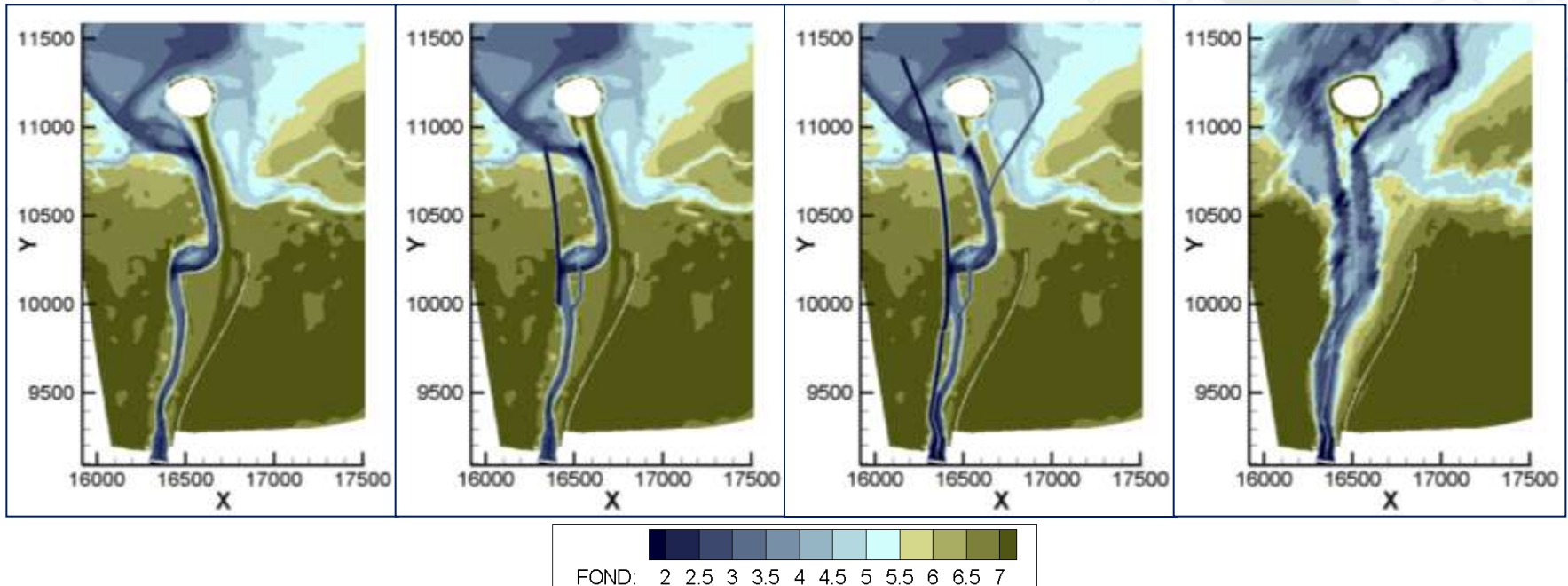
Methodology

Model used to assess the impact of :

- Changes to the new dam's operating instructions
timing
flushing discharge

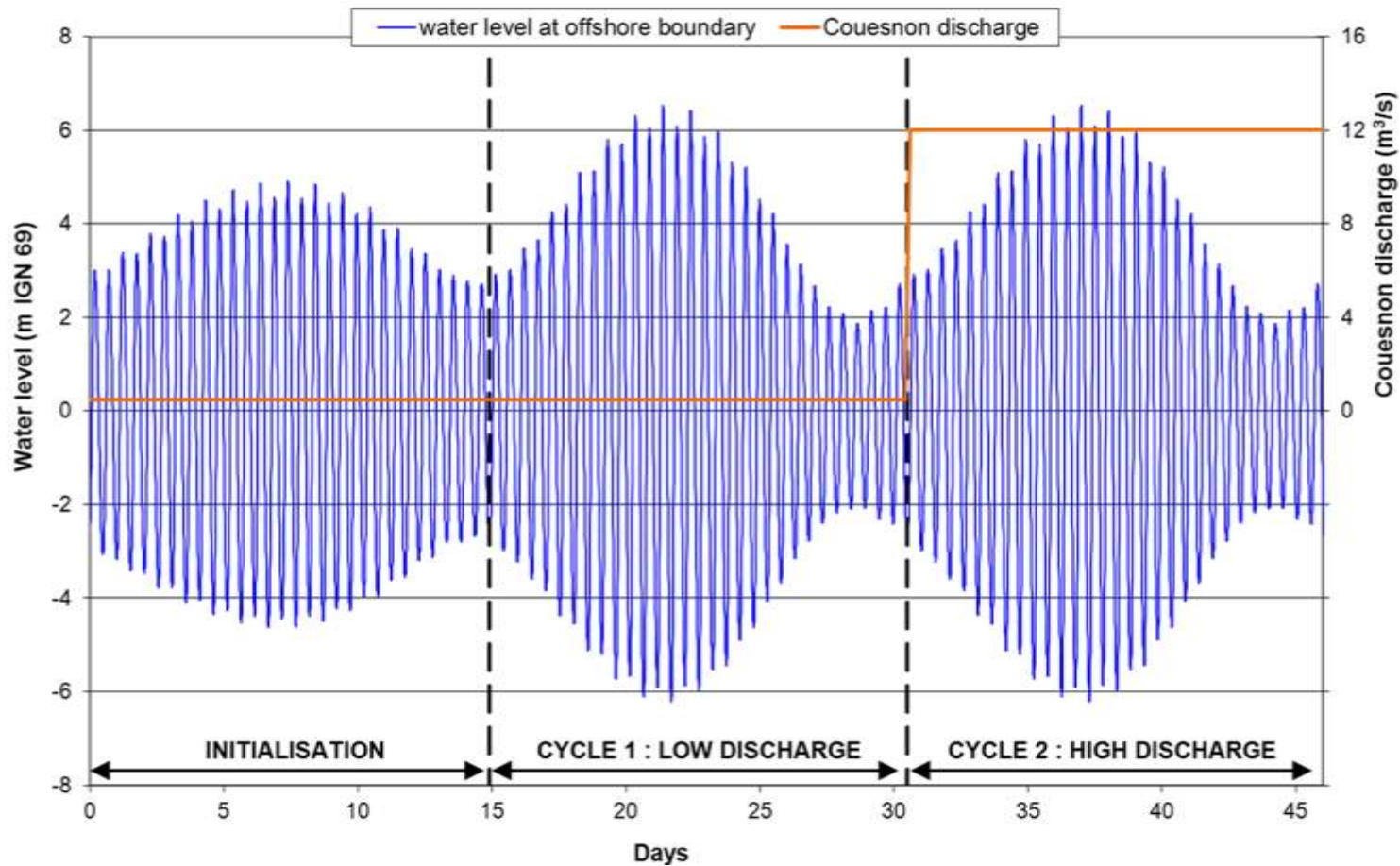
...

- Different bathymetric configurations of the Couesnon river bed :



Methodology

30-days hydrologic scenario used to **evaluate the impact of the test** on hydrodynamics and sediment budgets



Hydrodynamics well simulated

-> numerical model can be used to evaluate hydrodynamic efficiency of different dam management scenarios

Sedimentology :

- Usable to compare scenarios
- Some limitations (lateral erosion, meandering, long term) are inherent to modelling
- Also limited by :
 - the state of the knowledge of the behaviour of sand/mud mixtures (lack of well-validated behavioural laws for this kind of sediment)
 - the difficulties of in-situ measurements

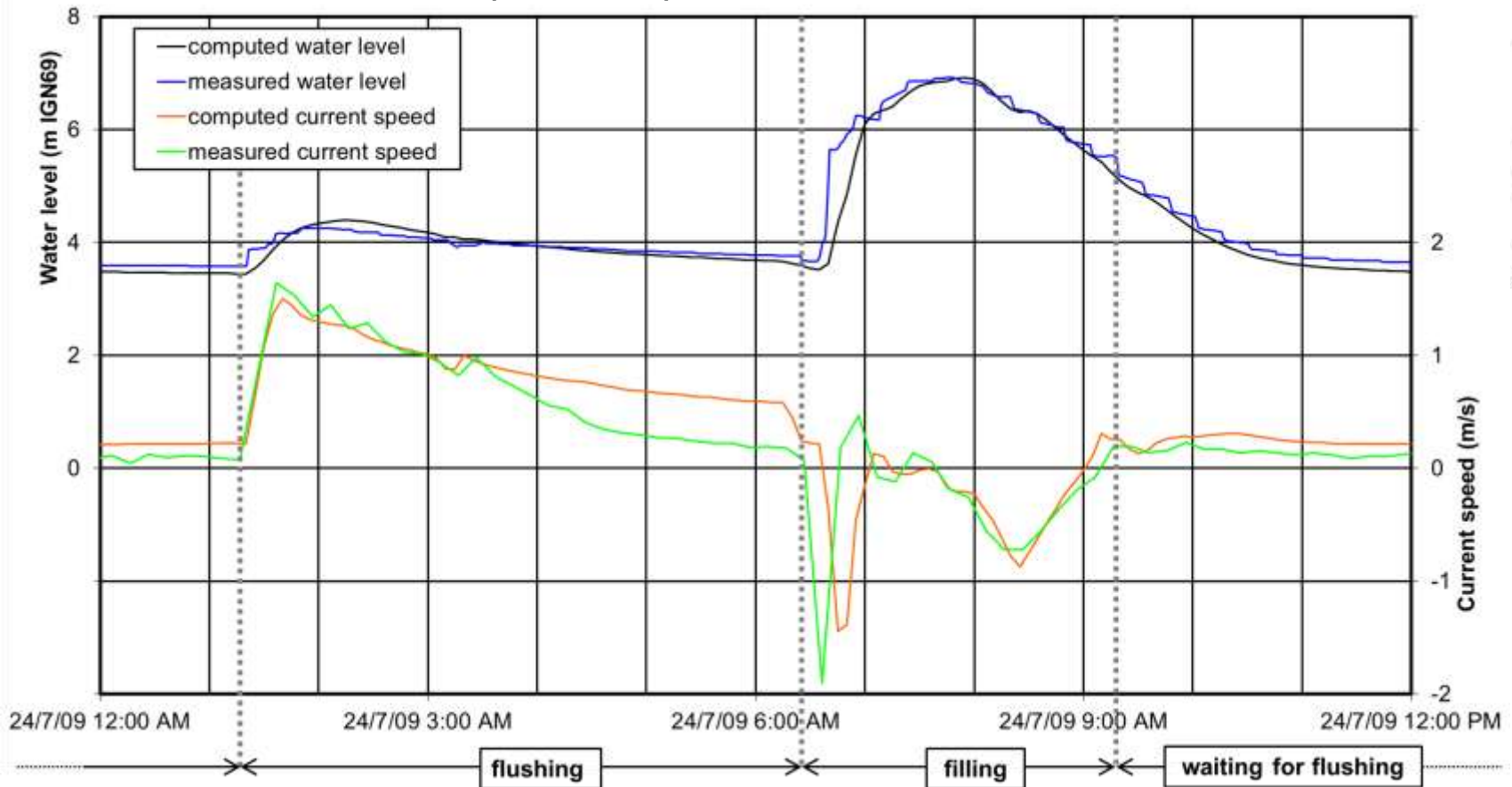
Thus we appreciate that both themes are well active in the research community as shown by the presentations in this conference !

Hydraulic calibration

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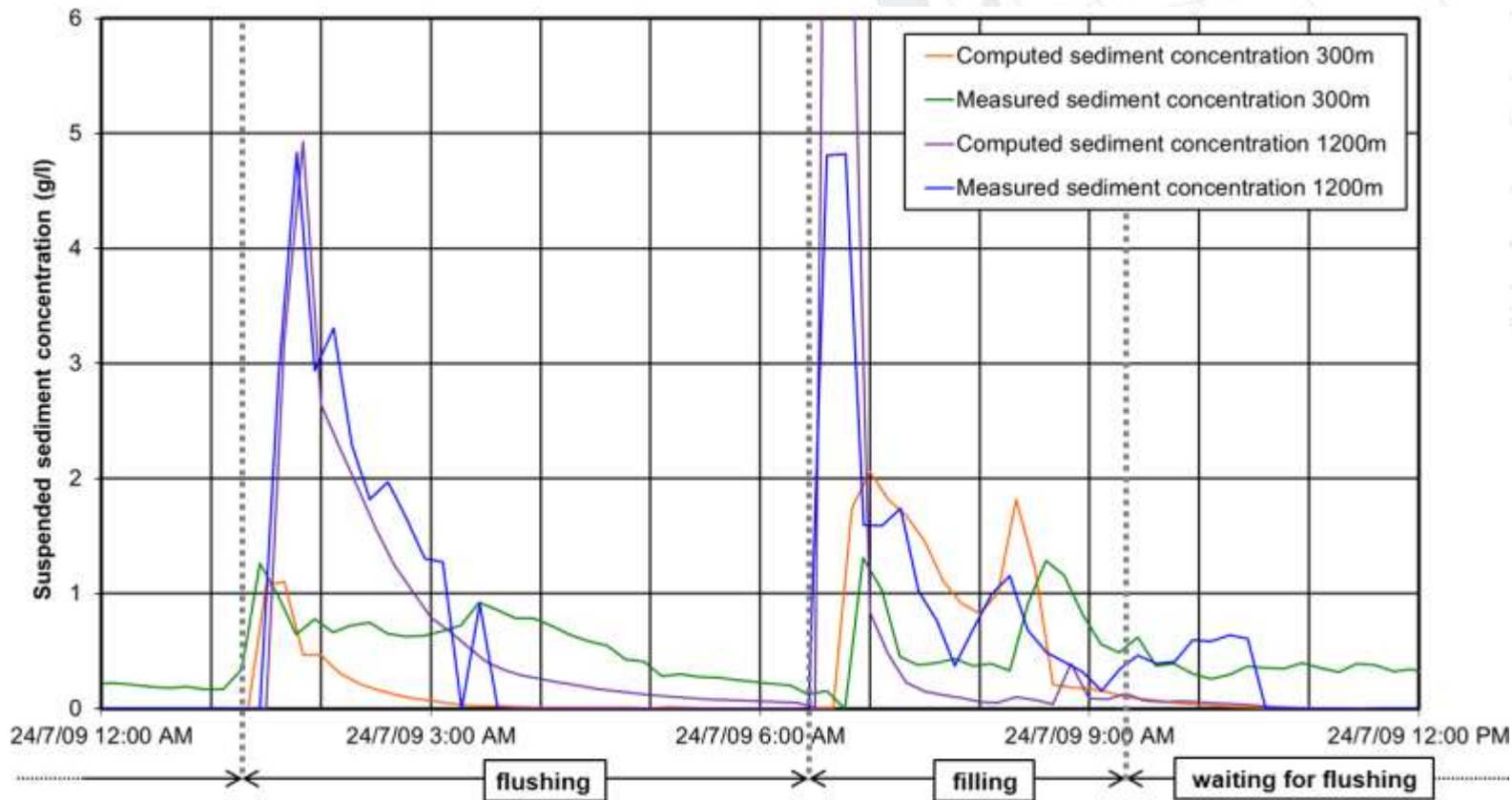
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Sedimentary calibration

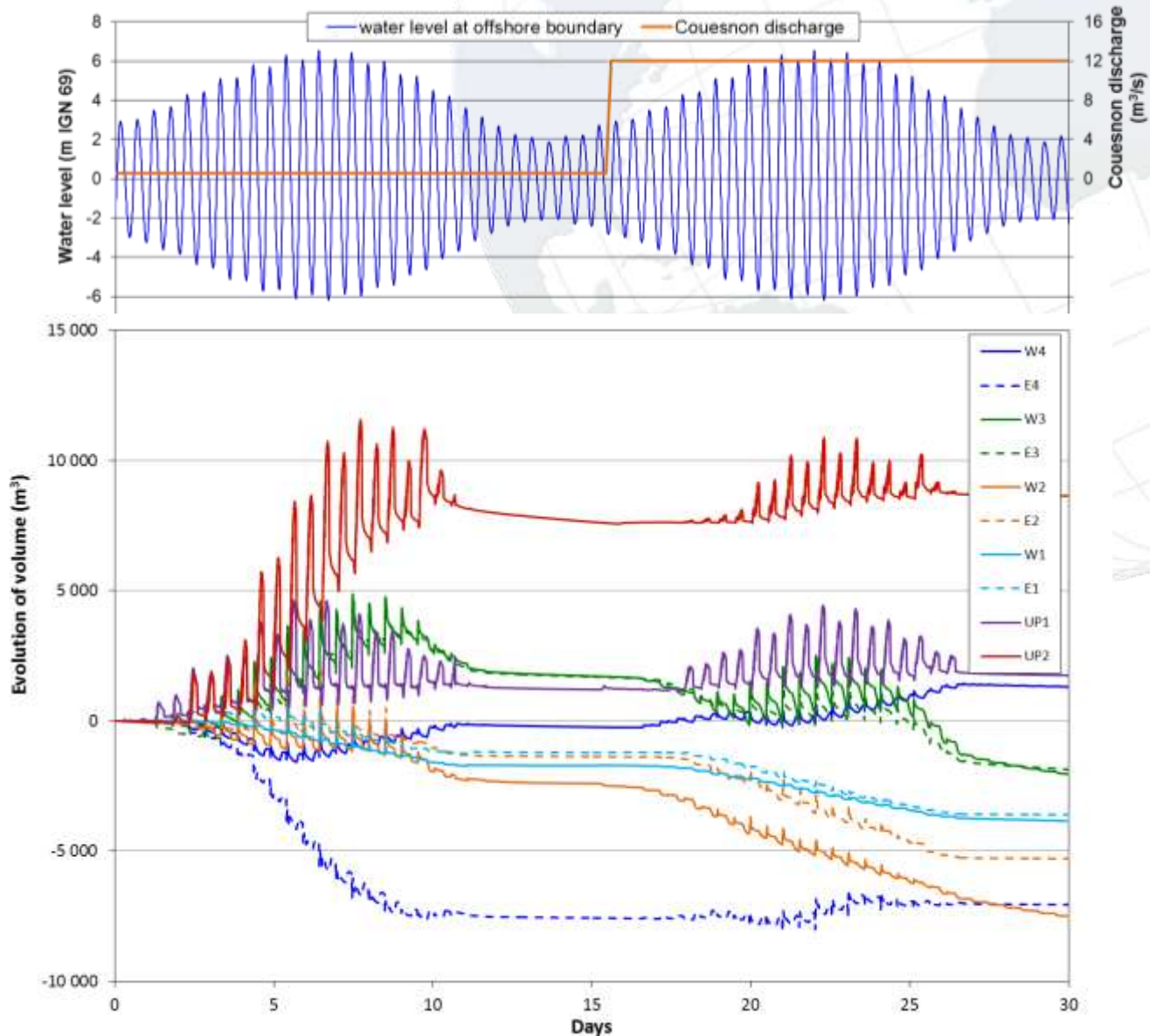
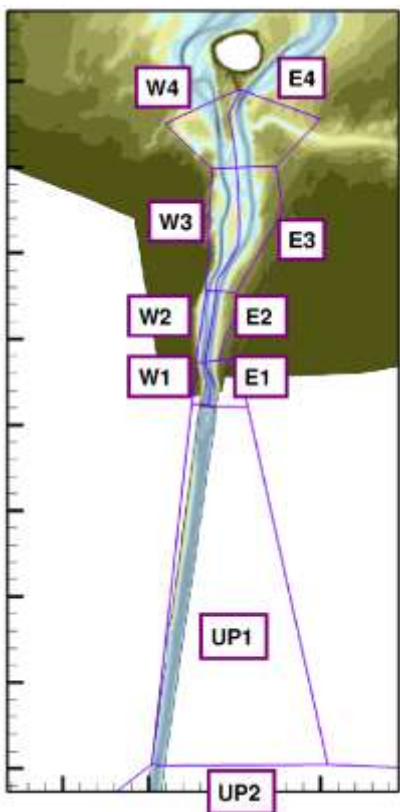
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Model operation

Example of results :
sediment budgets



Volume deposited and eroded in predefined areas