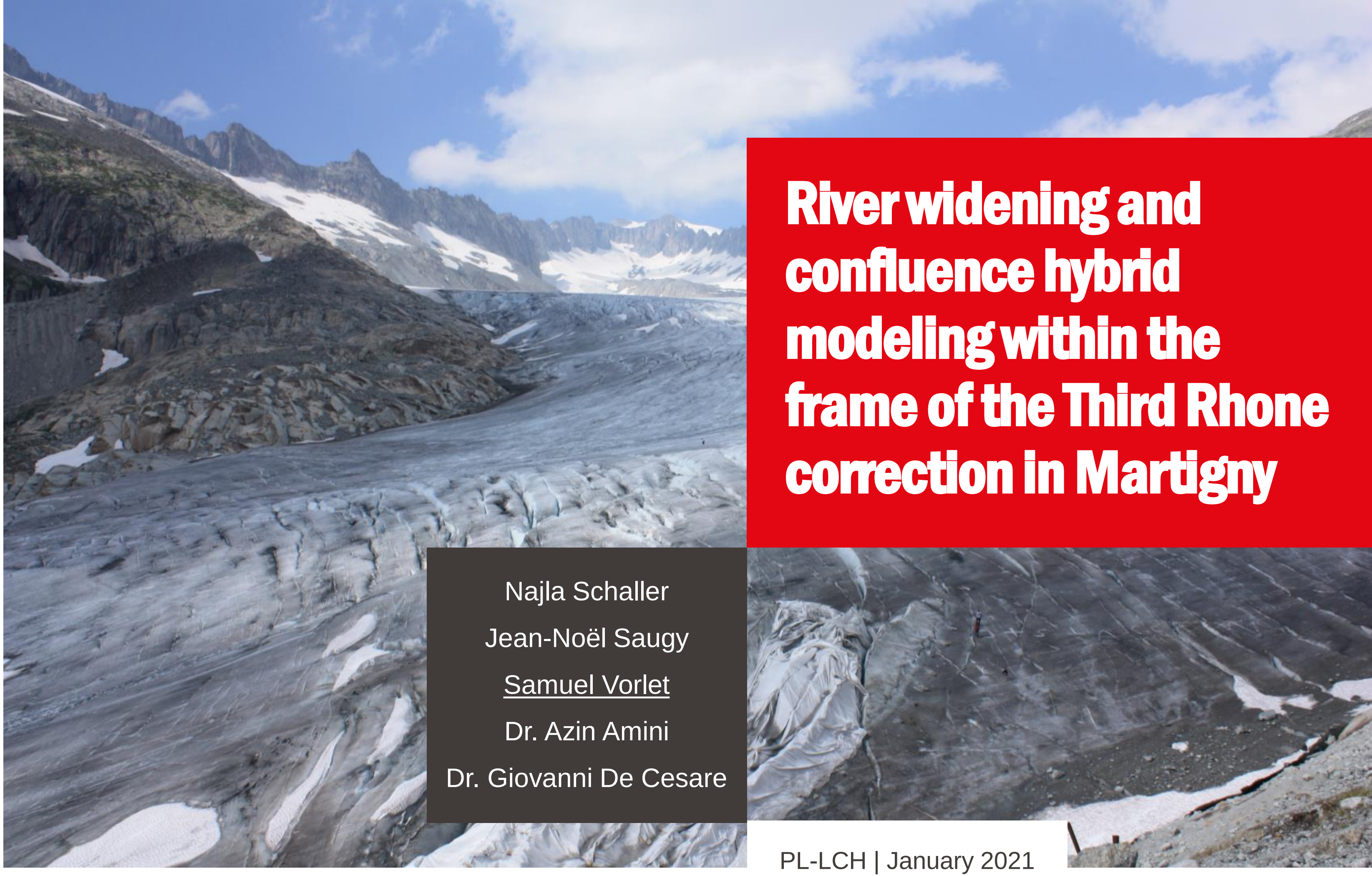


EPFL

River widening and confluence hybrid modeling within the frame of the Third Rhone correction in Martigny

Najla Schaller

Jean-Noël Saugy

Samuel Vorlet

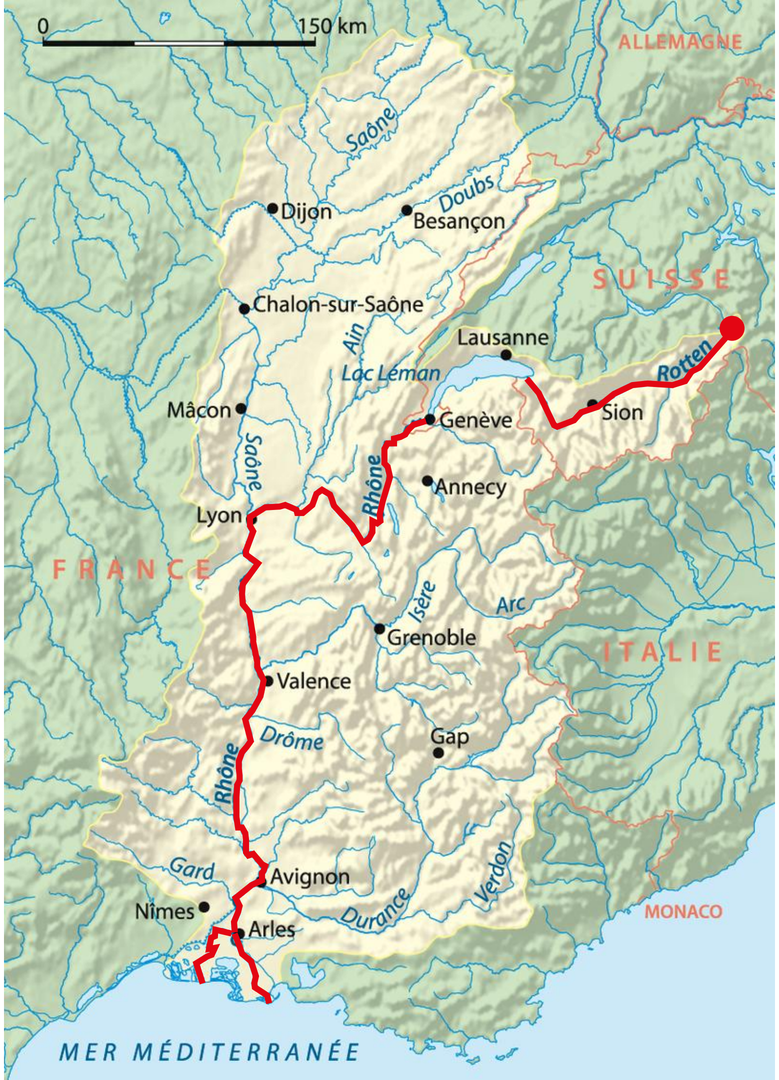
Dr. Azin Amini

Dr. Giovanni De Cesare

PL-LCH | January 2021

Rhone river

- One of the major rivers of Europe
  - 812 km
  - Rhone Glacier in the Swiss Alps
  - Passing through Lake Geneva
  - Mediterranean Sea
- 1/3 in Switzerland
- 2/3 in France

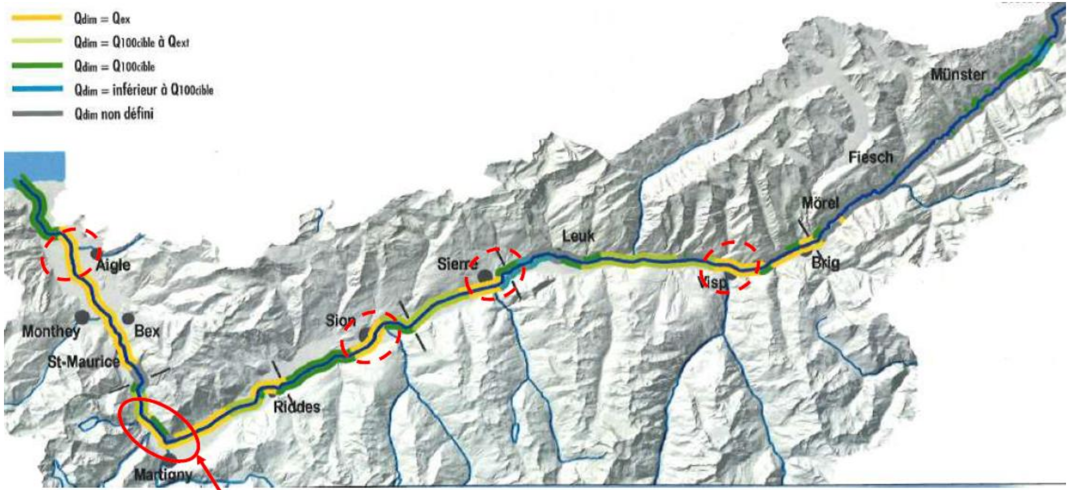


Rhone river

- First correction (1863 – 1894)
  - Constrained river and drainage of the river plain
- Second correction (1936 – 1960)
  - Increase sediment transport

3rd Rhone river correction

- Project over the next decades
- Divided into several steps (priority measures, 20-30 years)
- Objectives: safety, environmental, socio-economical concerns



GCR

Martigny bend

Martigny Bend Priority Measure

- Complexity:
  - Bend
  - Confluence of the Drance river
- Objectives
  - Flood protection
  - Sediment transport capacity
- Measures:
  - Widening and lowering of the riverbed

Background of the project

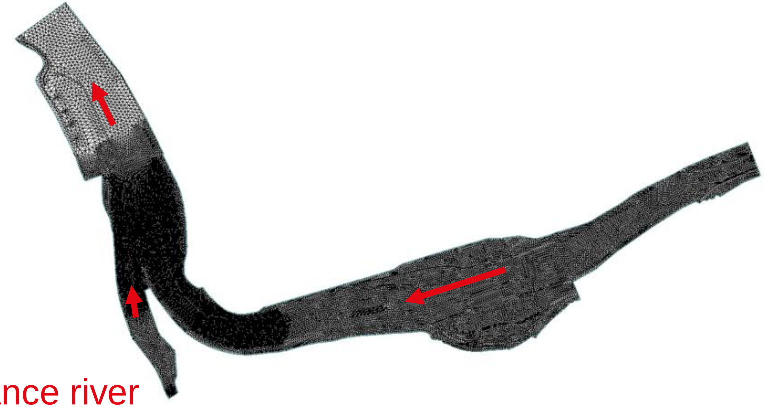
- Hydraulic study of the first phase: 1D model (HEC-RAS)
  - Adequate to compute water lines
  - Inadequate to understand and evaluate precisely the hydro-morphological dynamics
- Necessity of hybrid study:
  - Physical model
  - 2D numerical model
    - Calibration with the results of the physical model
    - Downstream extension
    - What are we able to predict?

Phyisical model

- 2017-2020
- Scale: 1/52
- Study the Rhone river’s behavior in its new geometry
- Main focus:
  - Water lines
  - Morphodynamics
  - Erosion / deposition phenomena
  - Sediment transport and budget

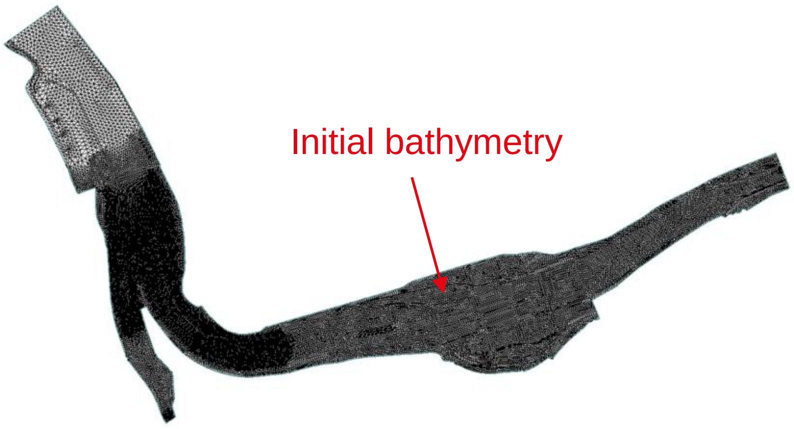
Numerical model

- BASEMENT v2.8 (SMS for pre and post-processing)
- Computational domain:
  - Model calibration and validation: physical model area
  - Final domain: whole area of the Priority Measure
- Objectives
  - Complement and extend the results obtained with the physical model



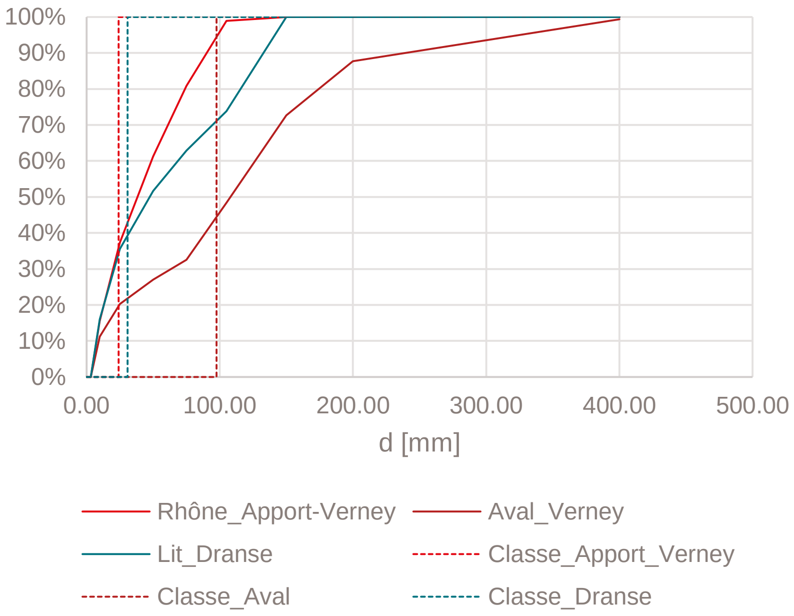
Boundary and initial conditions

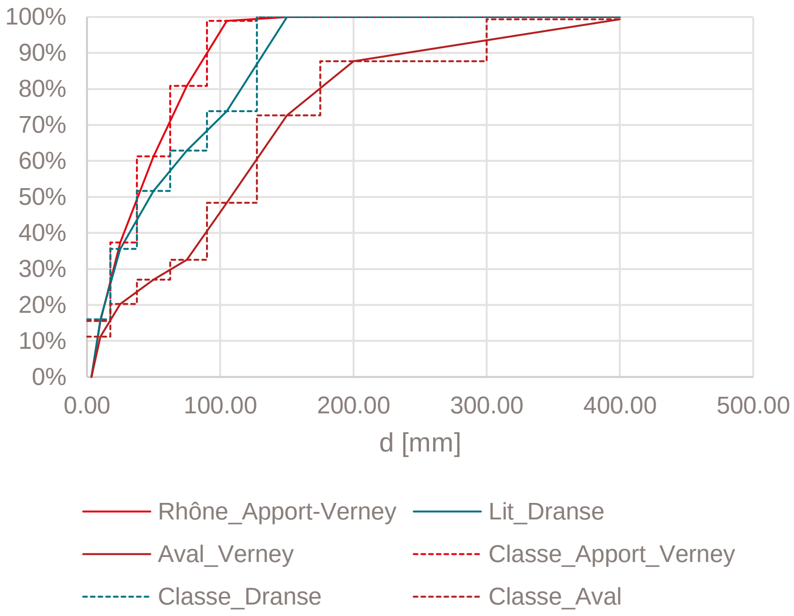
- Depend on the tested scenario
  - Solid/liquid inflows (upstream boundaries)
  - Water depth – Discharge relationship (downstream boundary)
  - Initial bathymetry
- Hydraulic simulations
  - Q_{in}: liquid
  - No water in the domain
- Morphodynamic simulations
  - Q_{in}: liquid/solid
  - Water in the domain



Sediment transport characteristics

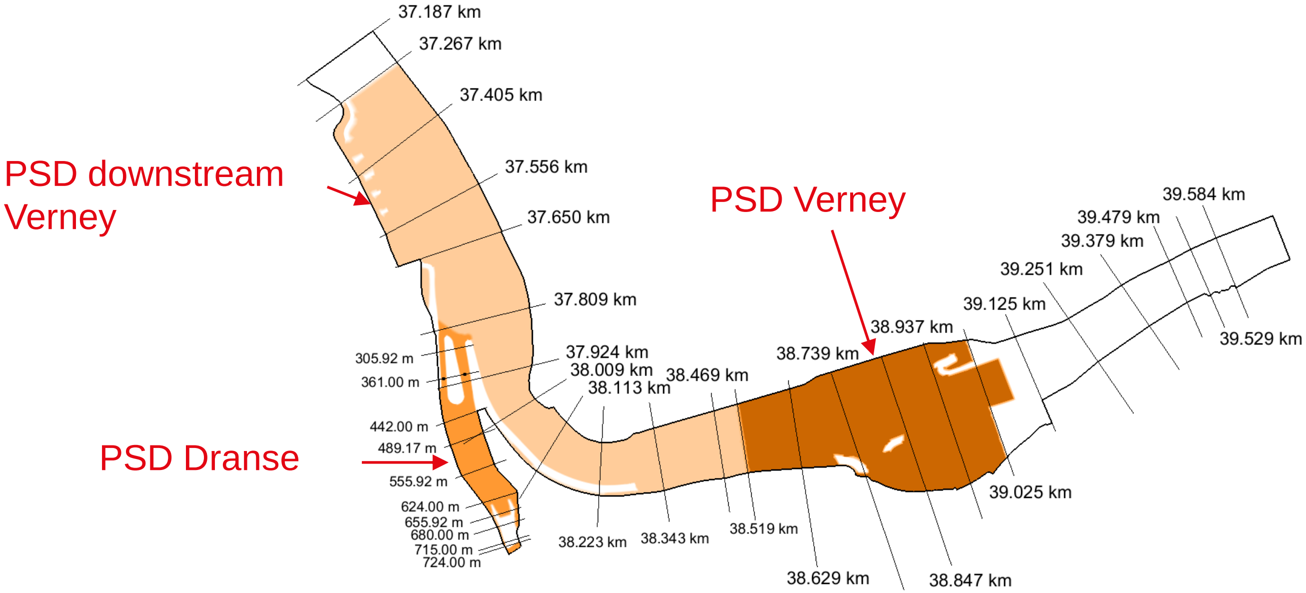
- Three particle-size distributions (PSD)
- 1 class / 8 classes





Sediment transport characteristics

- Initial PSD of the bed
- Bedload: Hunziker (MPM-H)

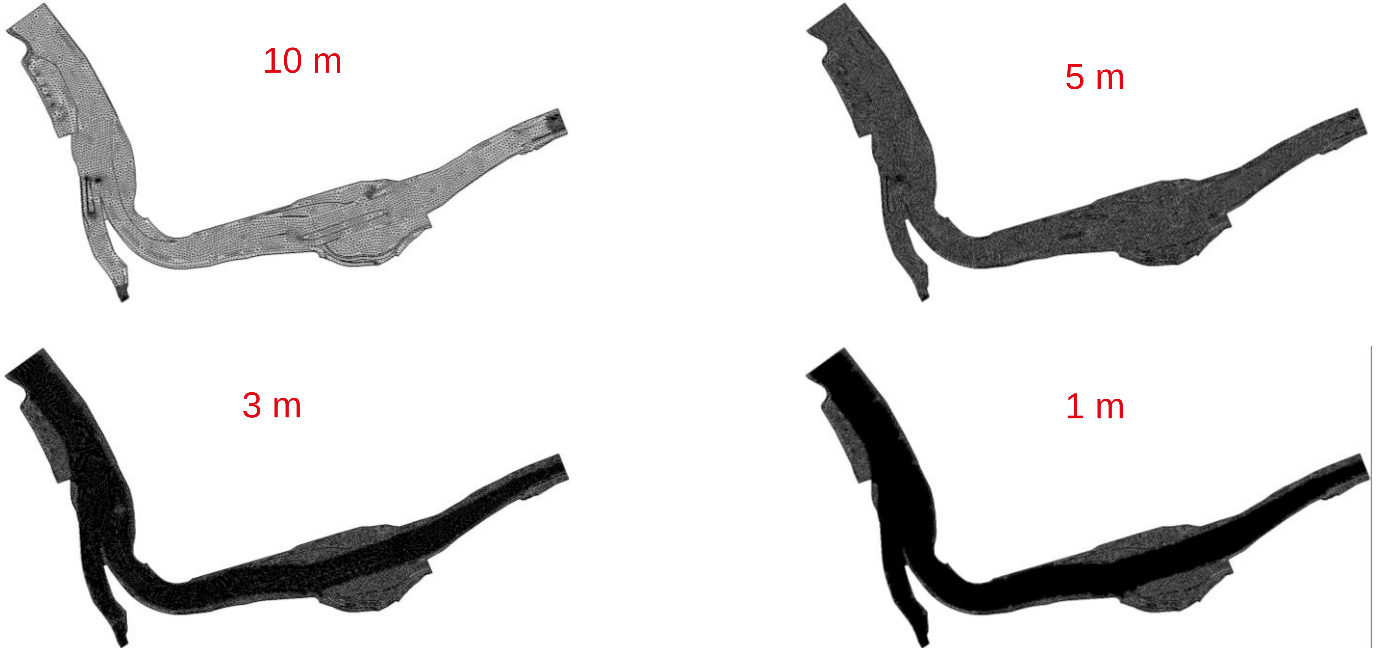


Calibration of the numerical model

- Calibration with **R10** scenario (14.7 days)
  - Return period 10 years in the Rhone river (downstream)
  - Rhone river: 669 m^3/s
  - Drance river: 95 m^3/s
- Hydraulic / morphodynamic simulations
- Steps:
  - Mesh sensitivity analysis
  - Roughness
  - Class number (PSD)
  - Critical shear stress

Mesh sensitivity analysis

- Hydraulic simulations (steady state)

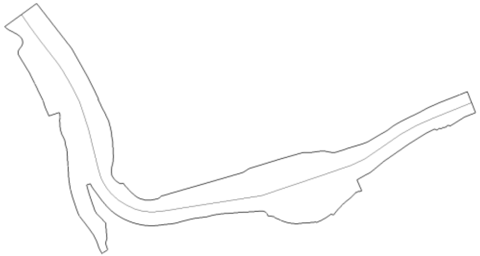


Mesh sensitivity analysis

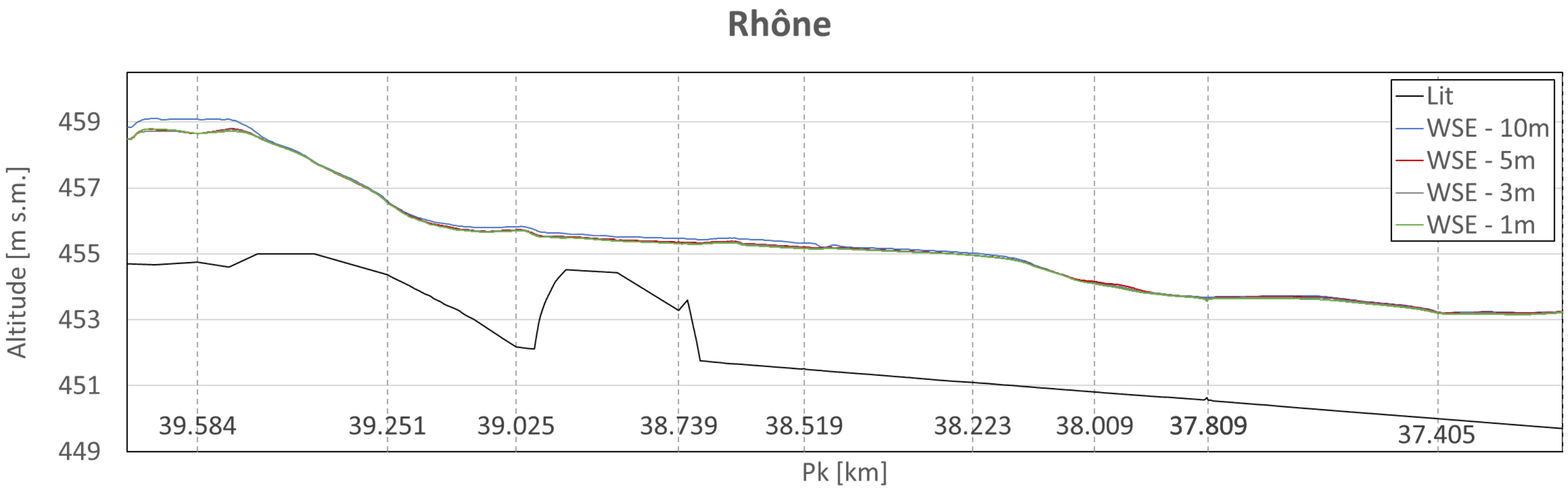
- Hydraulic simulations (steady state)

Mesh size	Elements	Nodes	Time	RTS
10 m	15’137	7’910	0h17	17
5 m	41’782	21’518	2h27	2.04
3 m	84’870	43’083	5h29	0.91
1 m	642’946	322’269	209h (8.7j)	0.0245

Mesh sensitivity analysis



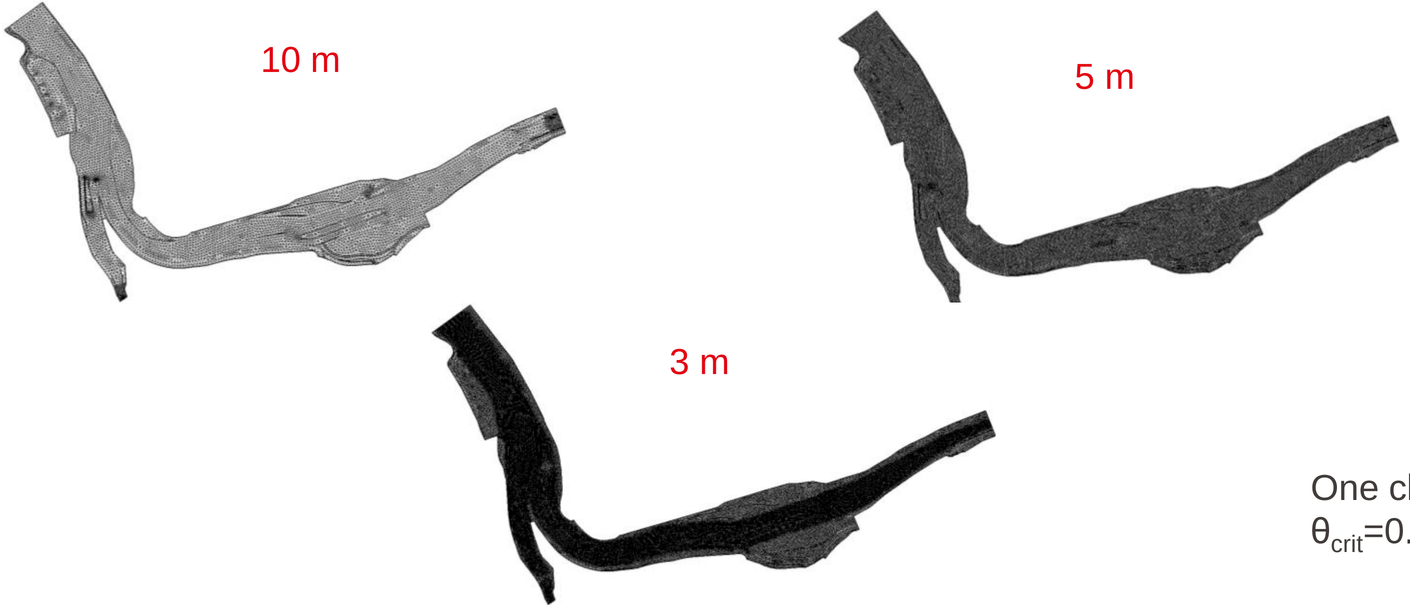
- Hydraulic simulations (steady state)



→ Adequate mesh size: 5 m

Mesh sensitivity analysis

- Morphodynamic simulations (14.7 days)



One class
θ_{crit}=0.055

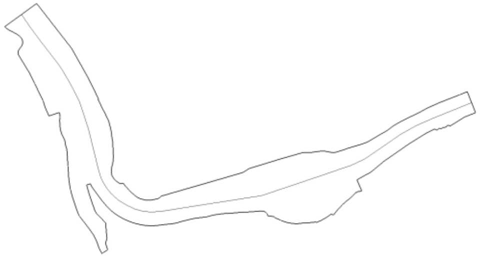
Mesh sensitivity analysis

- Morphodynamic simulations (14.7 days)

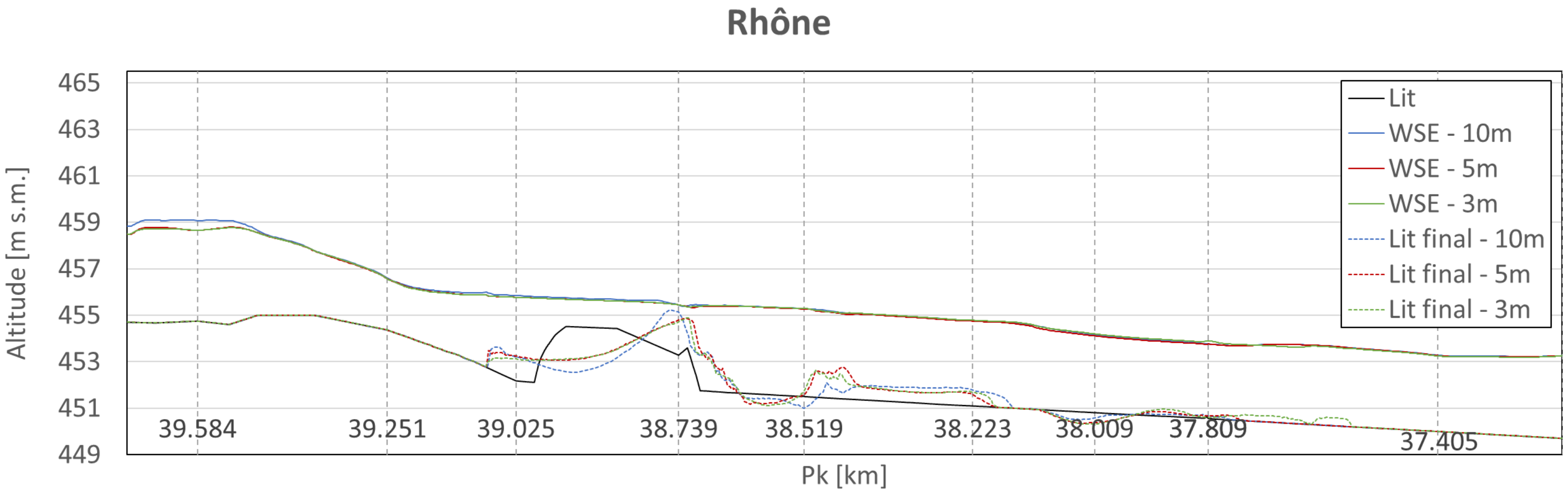
Mesh	Elements	Nodes	Time	RTS
10 m	15’137	7’910	29h34 (1.2d)	12
5 m	41’782	21’518	154h47 (6.5d)	2.29
3 m	84’870	43’083	436h52 (18.2d)	0.813

One class
θ_{crit}=0.055

Mesh sensitivity analysis

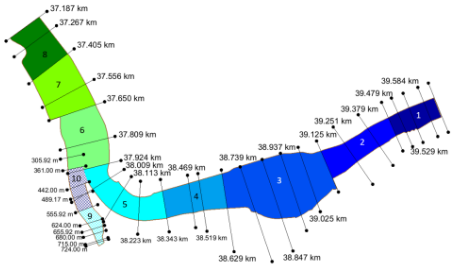


- Morphodynamic simulations (14.7 days)



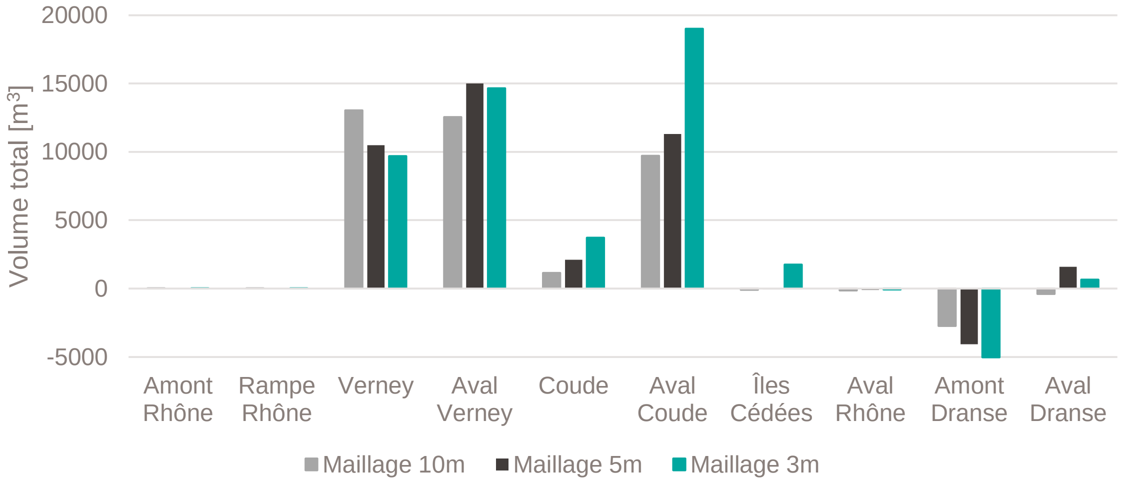
One class
θ_{crit}=0.055

Mesh sensitivity analysis



- Morphodynamic simulations (14.7 days)

$$V_{tot} = V_{deposited} - V_{eroded}$$



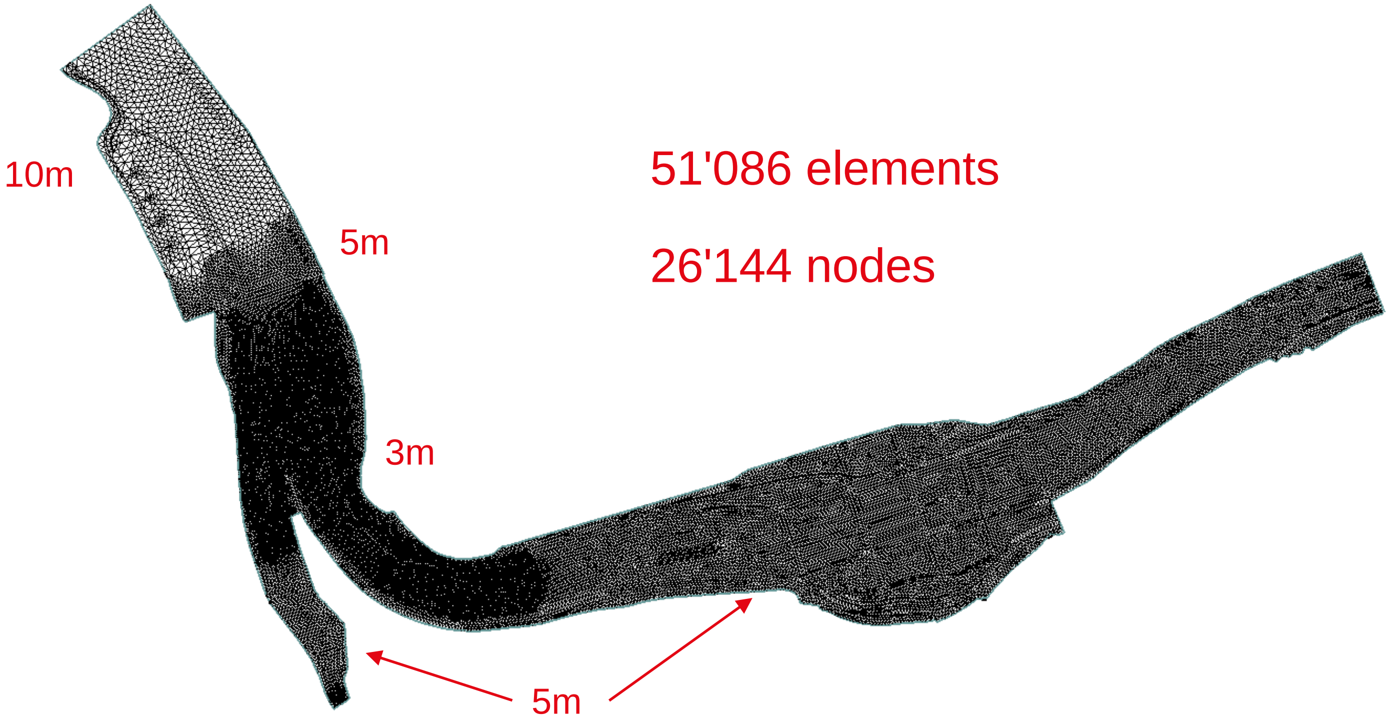
One class

$\theta_{crit}=0.055$

→ Adequate mesh size: 5 m

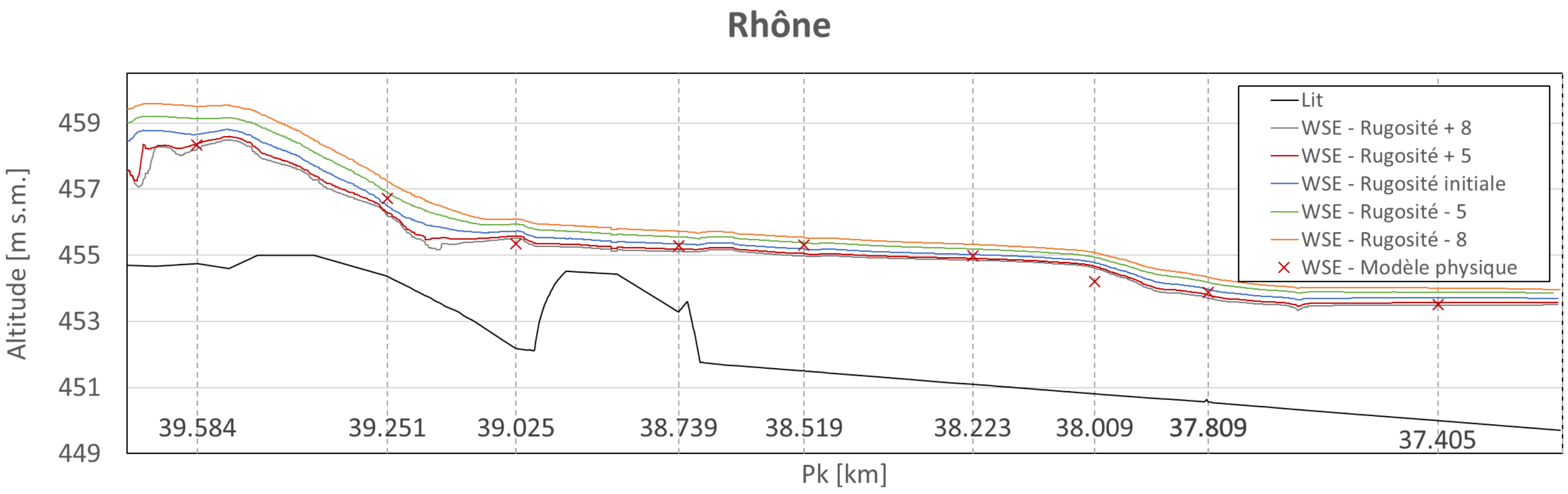
Mesh sensitivity analysis

- Final mesh



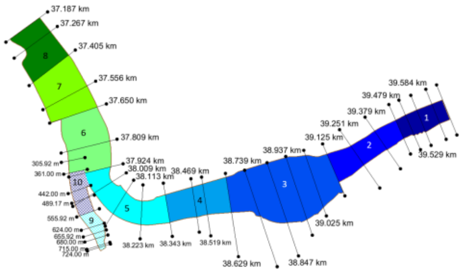
Roughness

- Hydraulic simulations (steady state)

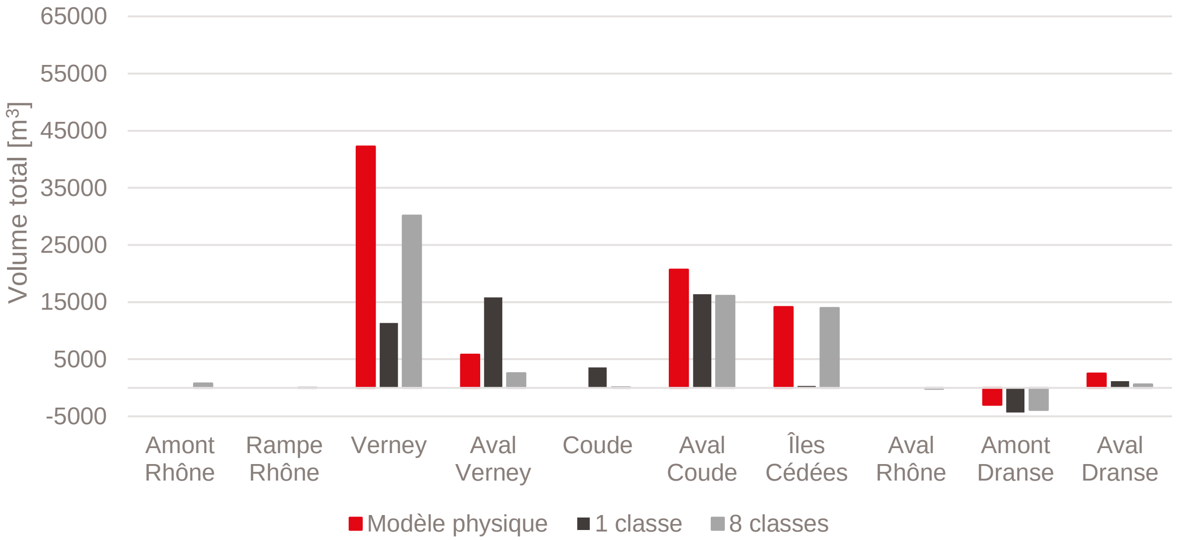


→ Initial roughness recommended

Classes (PSD)

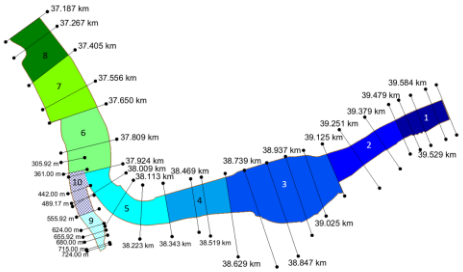


- Morphodynamic simulations (14.7 days)
  - 1 class / 8 classes

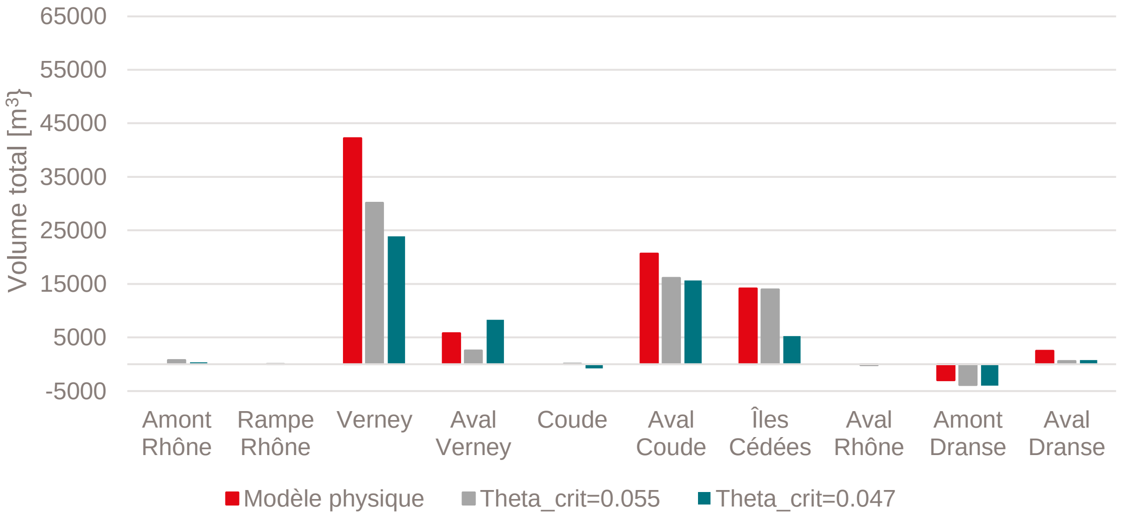


→ 8 classes recommended

Critical shear stress



- Morphodynamic simulations (14.7 days)
  - θ_{crit}: 0.047 / 0.055

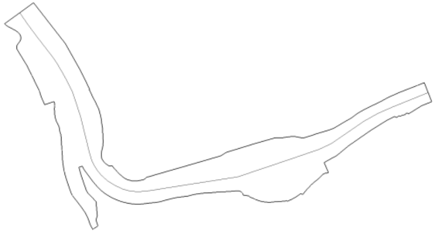


→ θ_{crit} = 0.055 recommended

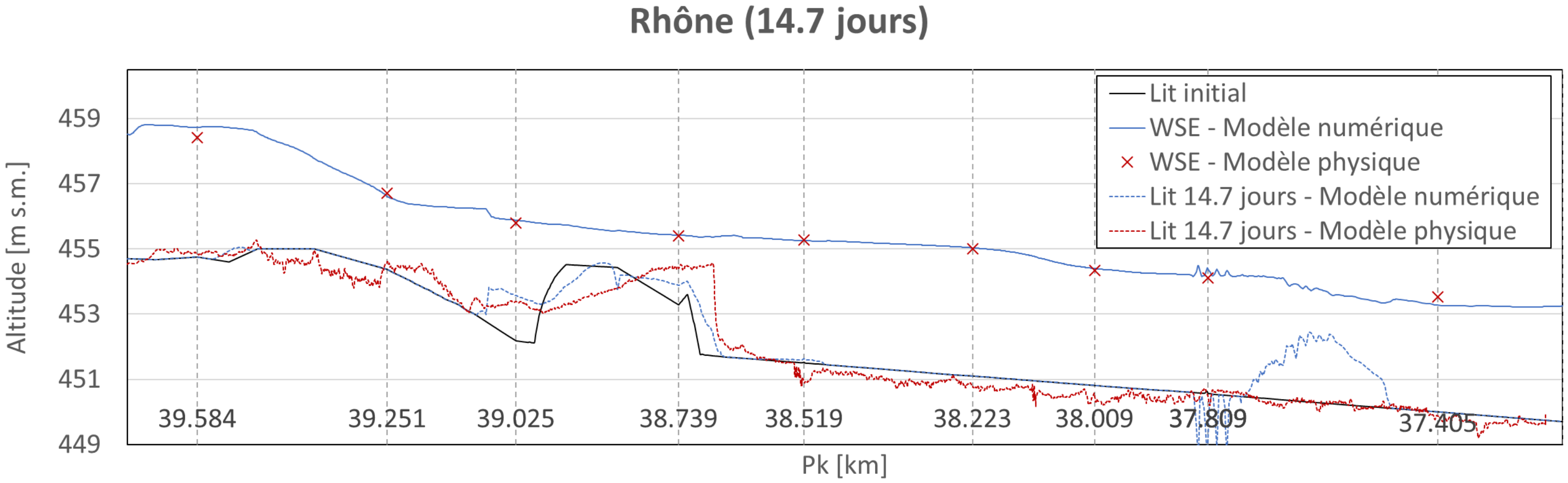
Recommendations

Parameter	Tested		Recommended
Mesh size	1, 3, 5, 10 m		Adapted mesh
Roughness	Berge renforcée en dur	20, 23, 25, 28	20
	Lit pré-rampe	34, 37, 39, 42	34
	Lit Verney	34, 37, 39, 42	34
	Lit aval Verney	34, 37, 39, 42	34
	Lit Dranse	31, 34, 36, 39	31
	Rampe	21, 24, 26, 29	21
	Secteur aval	34, 37, 39, 42	34
Classes (PSD)	1, 8		8
θ_{crit}	0.047, 0.055		0.055

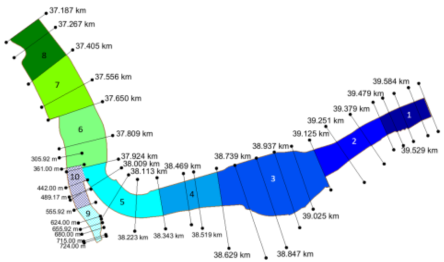
Validation of the numerical model



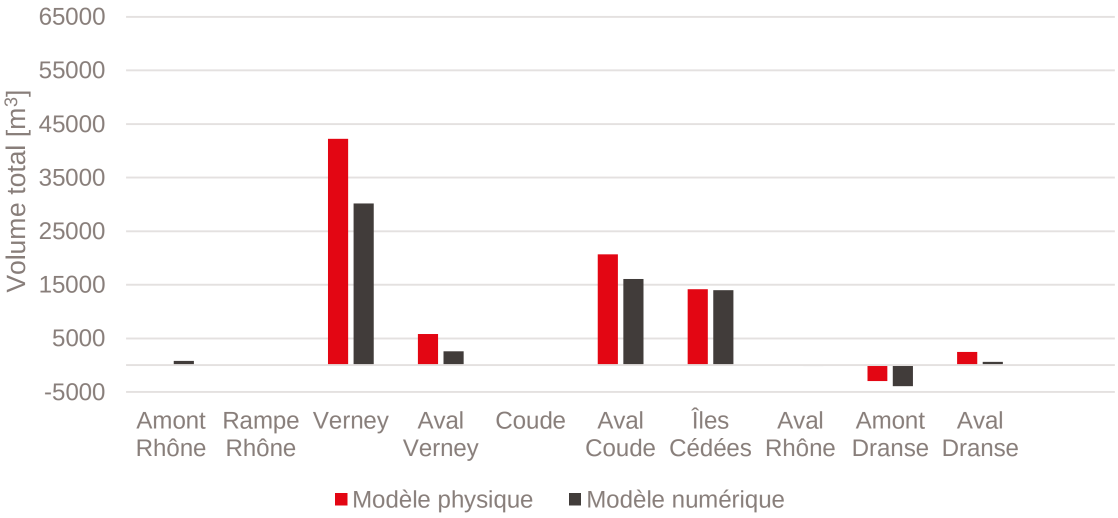
- **R10** (14.7 days)
  - WSE / morphology



Validation of the numerical model

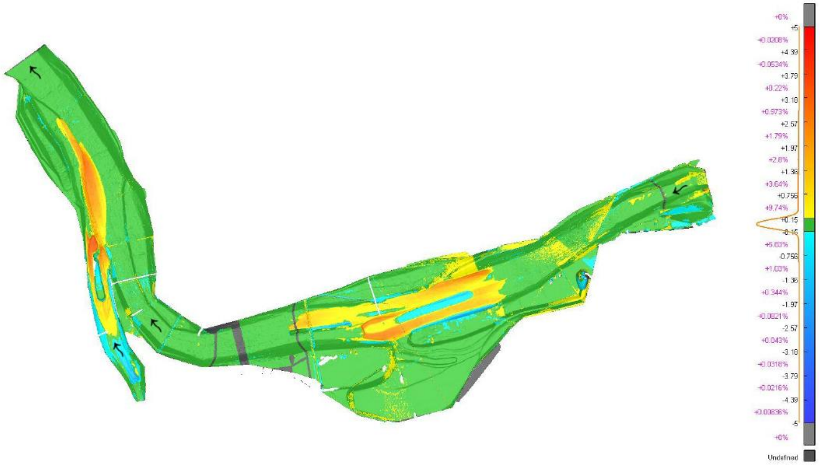


- **R10** (14.7 days)
  - Volume balance

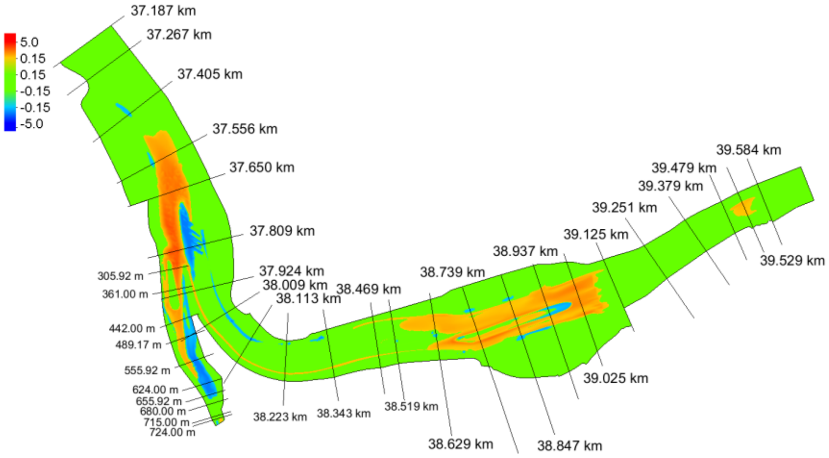


Validation of the numerical model

- **R10** (14.7 days)
  - Morphology

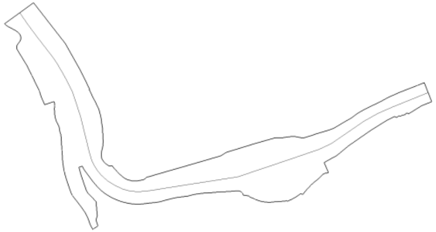


Physical model

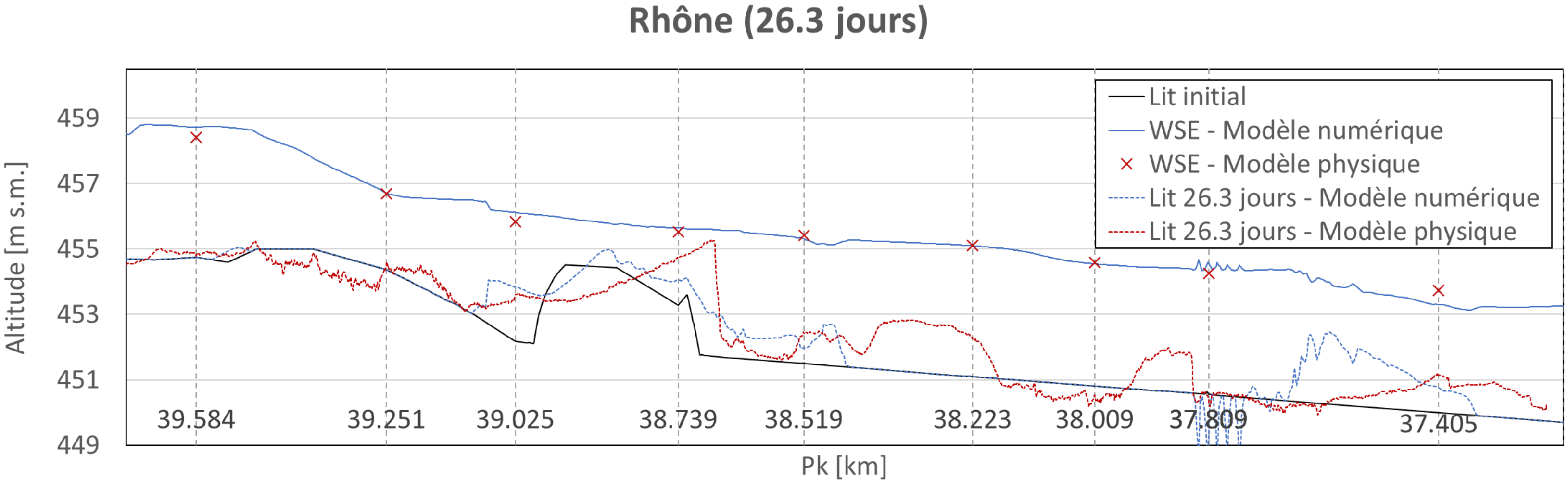


Numerical model

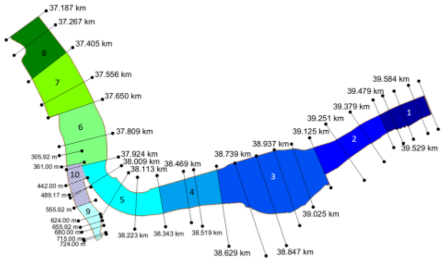
Validation of the numerical model



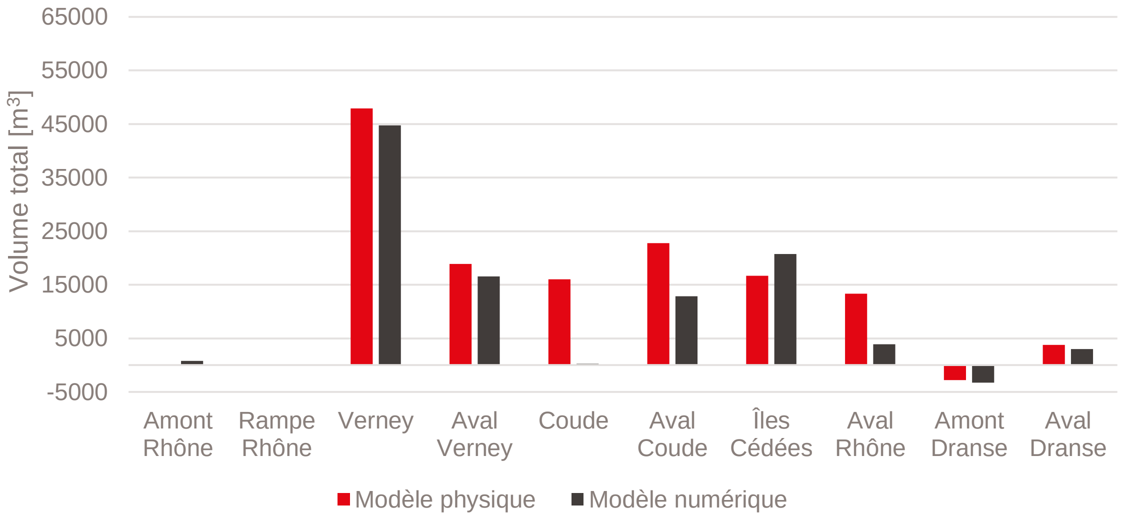
- **R10** (26.3 days)
  - WSE / morphology



Validation of the numerical model

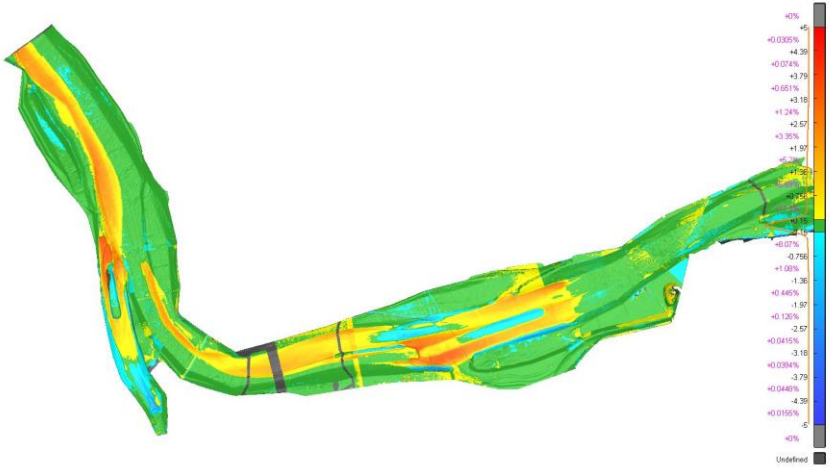


- **R10** (26.3 days)
  - Volume balance

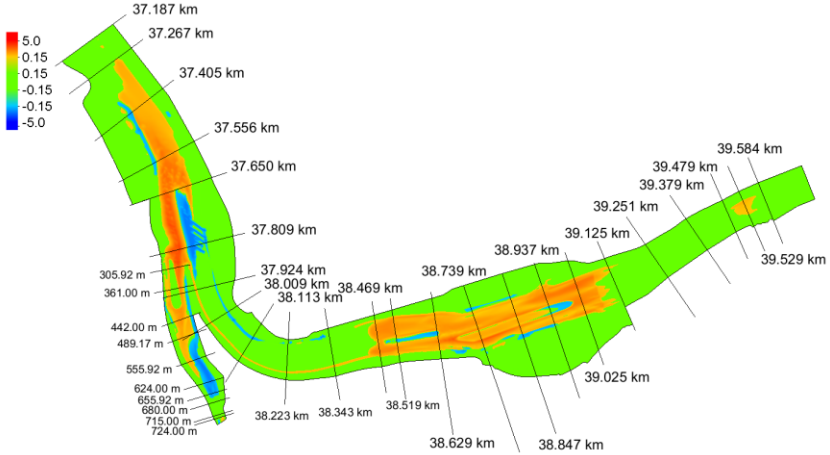


Validation of the numerical model

- **R10** (26.3 days)
  - Morphology

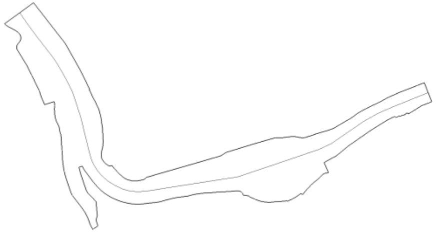


Physical model

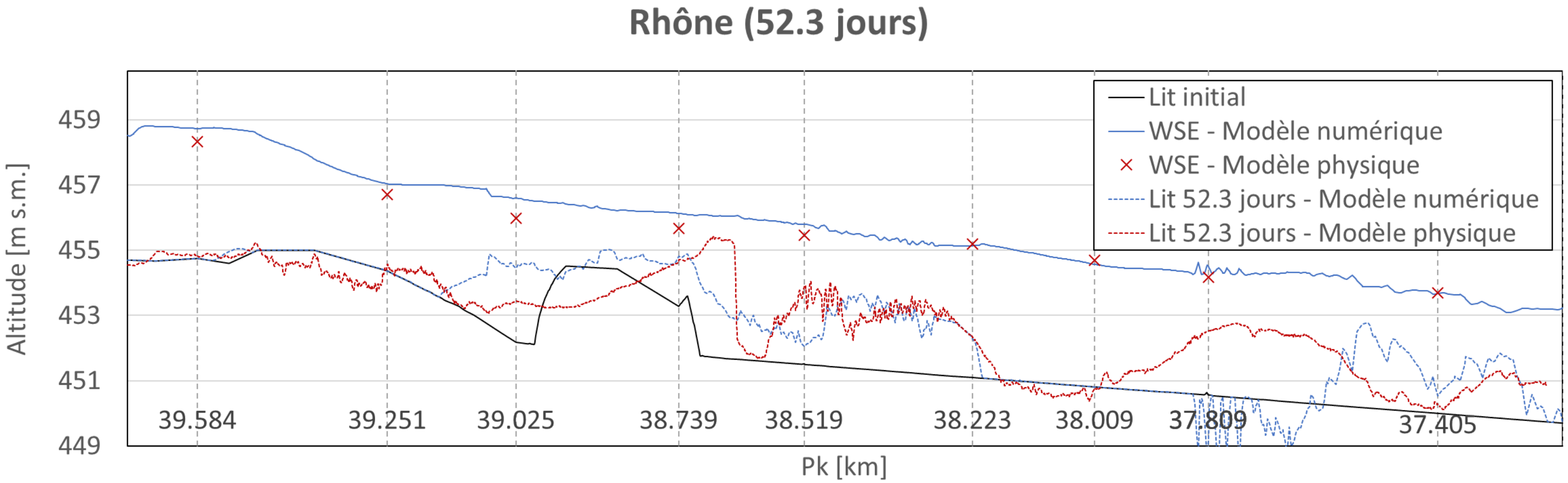


Numerical model

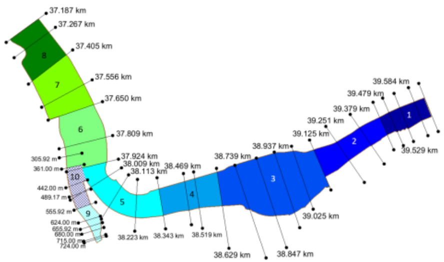
Validation of the numerical model



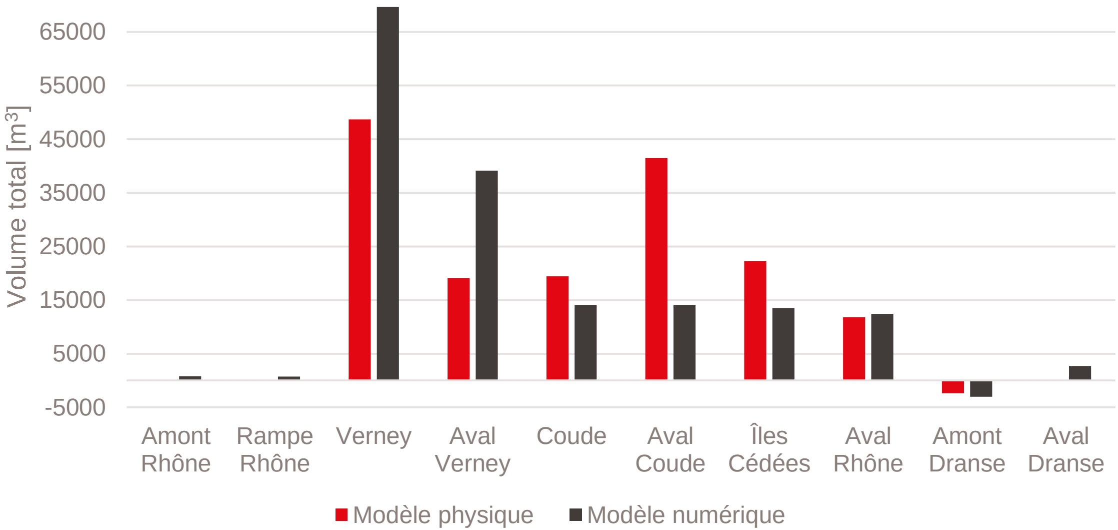
- **R10** (52.3 days)
  - WSE / morphology



Validation of the numerical model

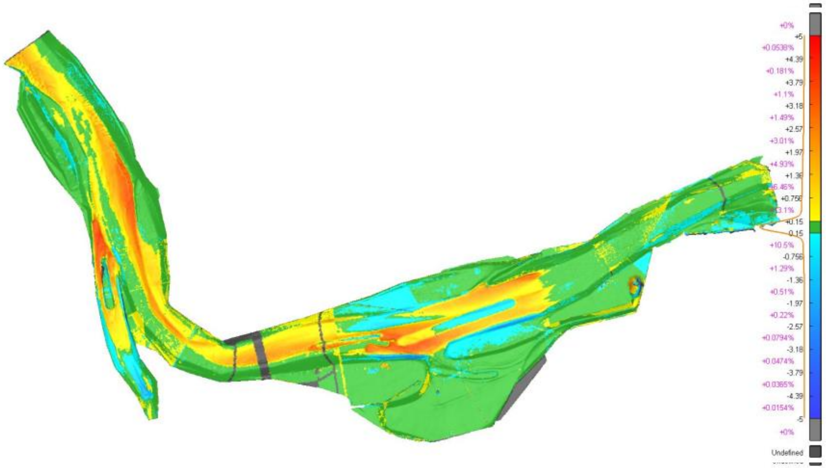


- **R10** (52.3 days)
  - Volume balance

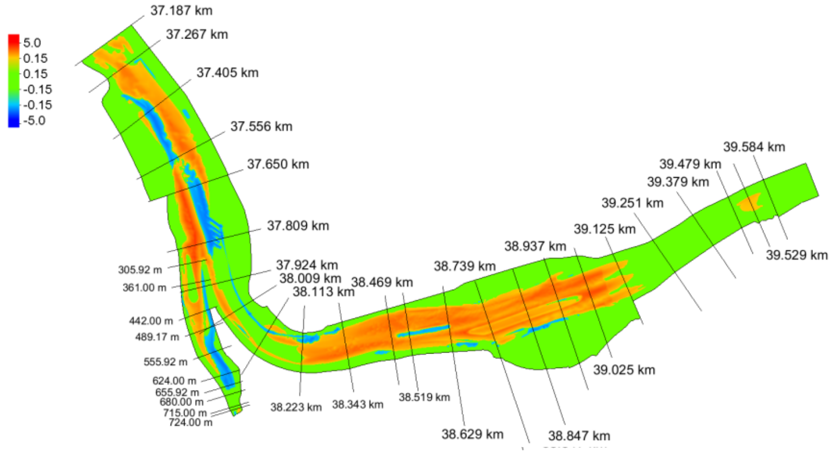


Validation of the numerical model

- **R10** (52.3 days)
  - Morphology

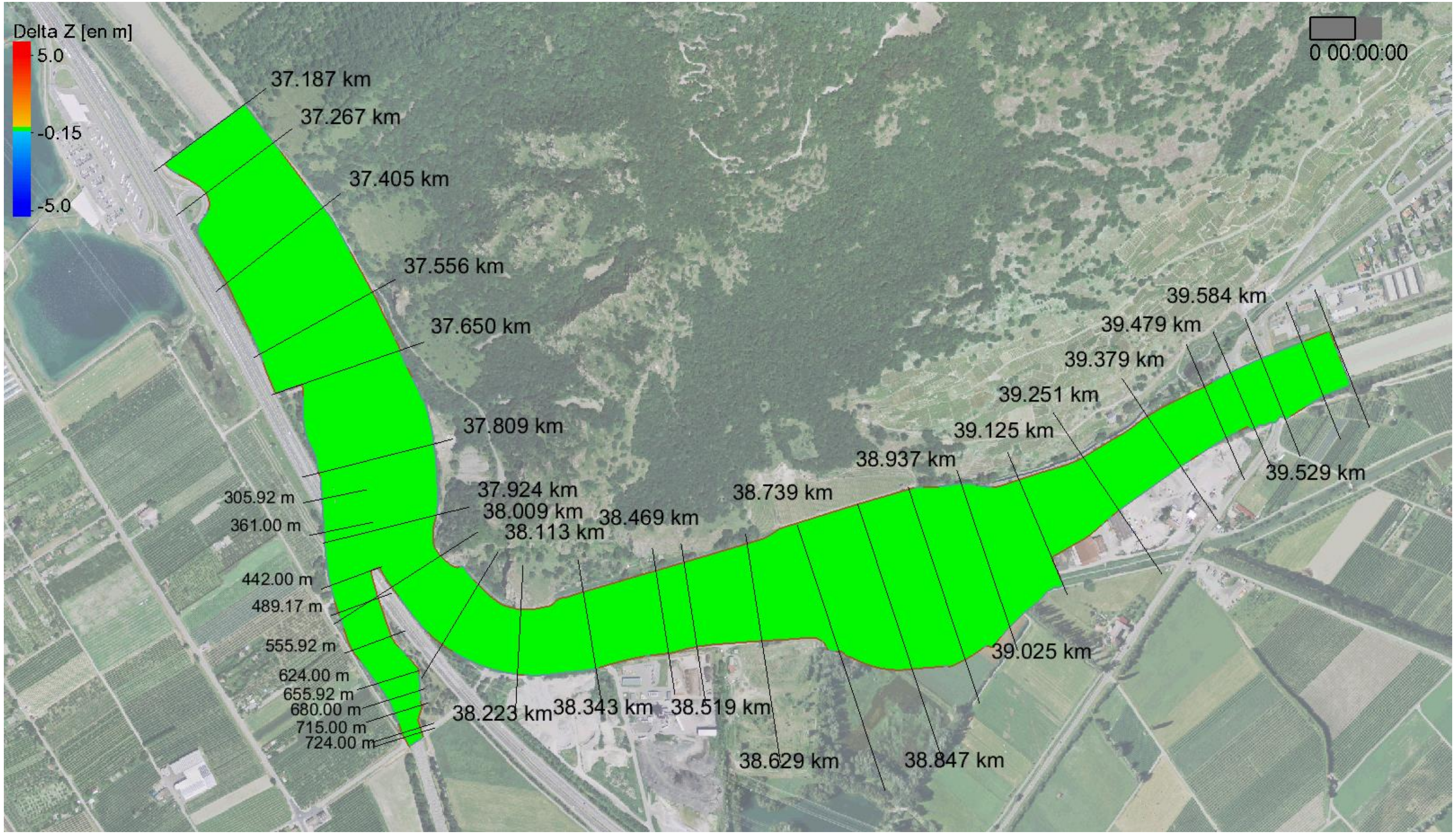


Physical model



Numerical model

Validation of the numerical model



Validation of the numerical model

Conclusion

- Numerical model was able to correctly reproduce the results observed on the physical model for the R10 scenario.
- Slight differences, increasing with time.
- Given the complexity, results are satisfactory for this scenario
- Accuracy to model the extended downstream part

→ Accuracy of the numerical for other scenarios

→ Set of parameters for each discharge