Modelling in applied hydraulics
More accurate in decision making than in science? (PPT)

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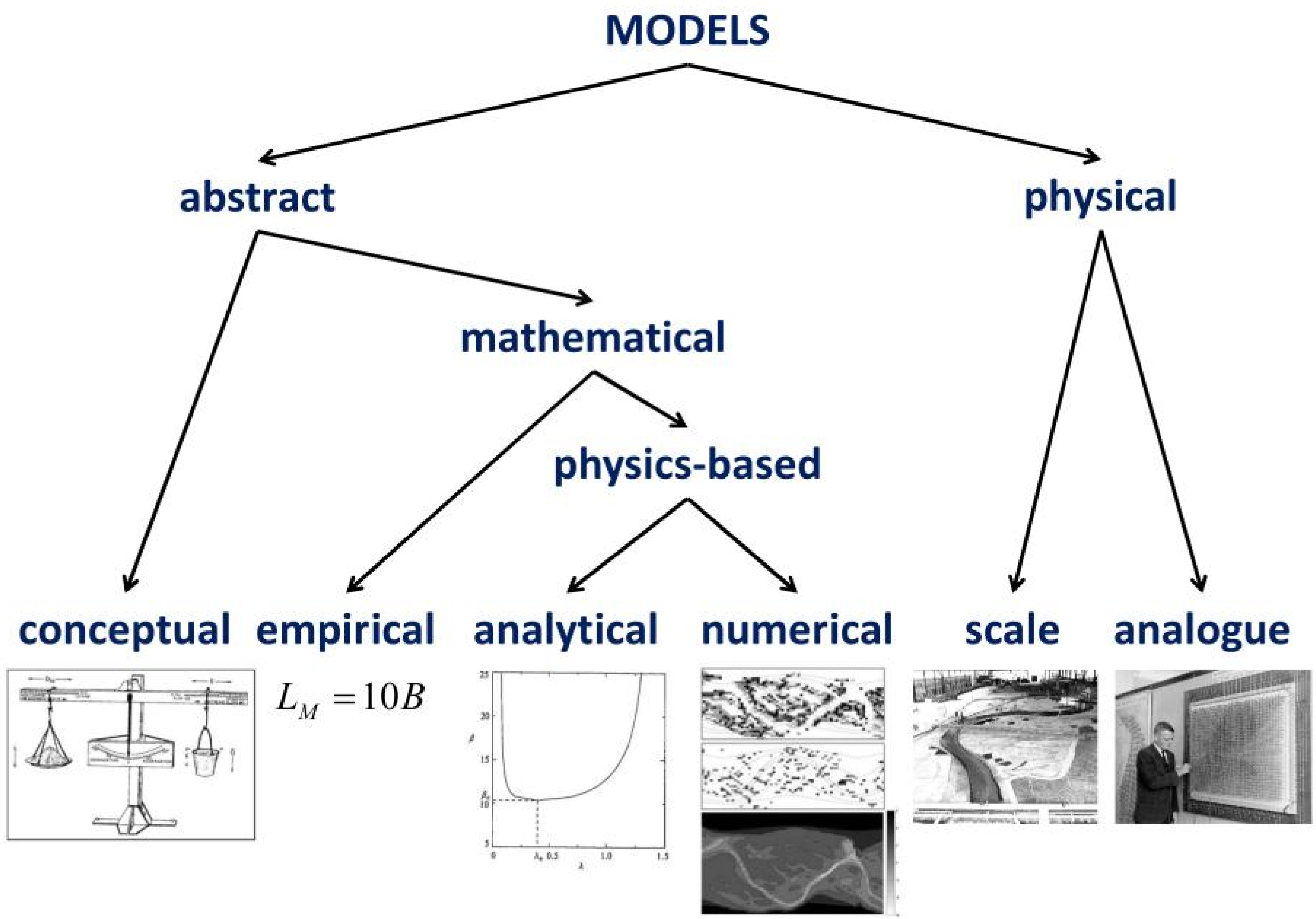
Modelling in applied hydraulics: more accurate in decision making than in science?

Erik Mosselman

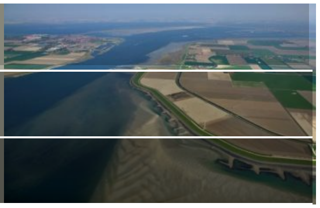
SimHydro*2017*

Sophia-Antipolis, France, 14 June 2017

Modelling in applied hydraulics



Modelling in applied hydraulics



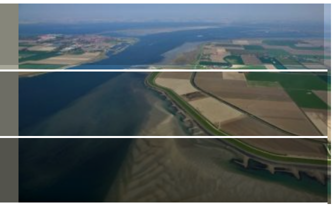
Modelling of hydrodynamics and morphodynamics:

- Physical scale models
- Numerical models

Choice of type of model and required accuracy depends on context of application:

- Scientific hydraulic research
- Hydraulic engineering
- Public decision making

Physical scale models



Context of scientific research

- Generic experimental set-ups
- Relatively simple geometries
- Controlled conditions

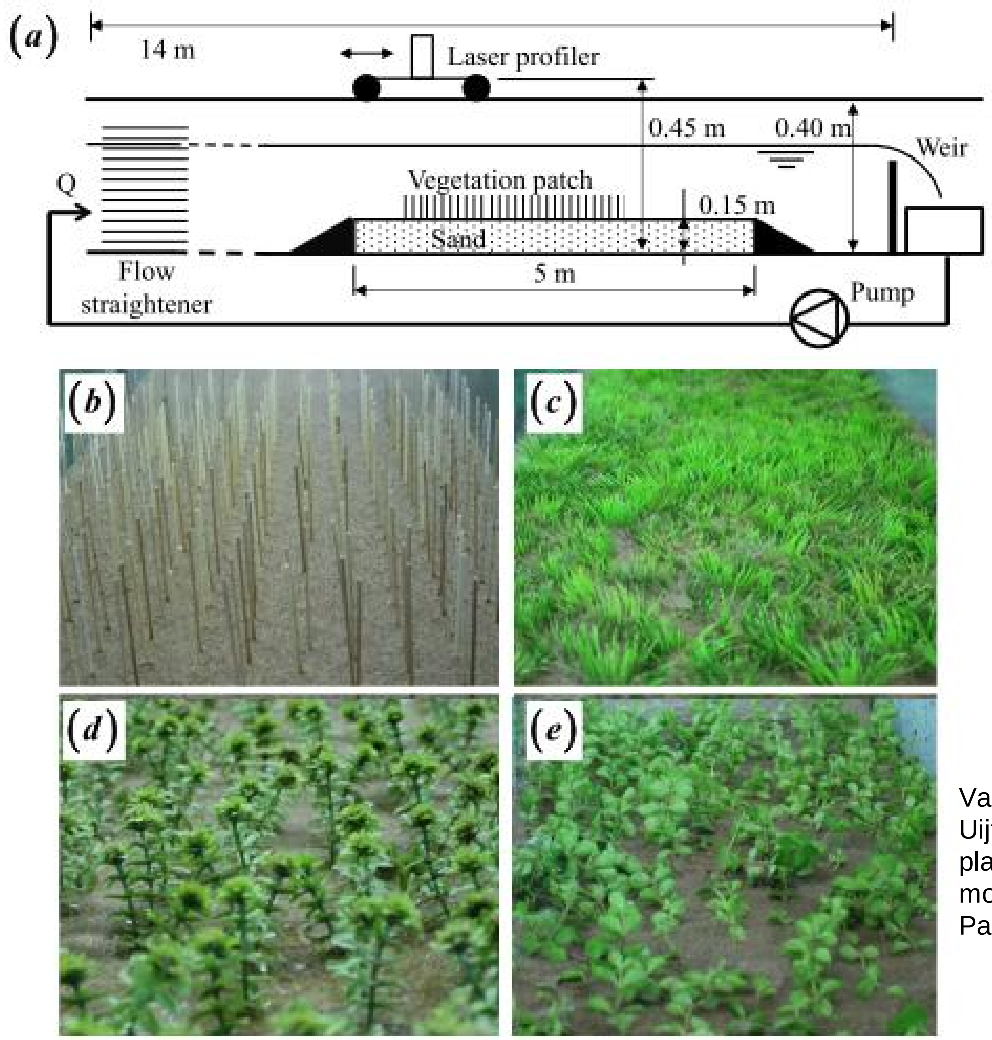
- Study of elementary processes and their interactions
- Interpretation of mathematical findings

Context of scientific research

Blom, A., J.S. Ribberink & H.. de Vriend (2003), Vertical sorting in bed forms. Flume experiments with a natural and a tri-modal sediment mixture. *Water Resources Res.*, AGU, Vol.39, No.2, p.1025 (13 pp.).

Physical scale models

Context of scientific research



Vargas-Luna, A., Crosato, A., Calvani, G., and Uijttewaal, W. S. J. (2016). Representing plants as rigid cylinders in experiments and models. *Advances in Water Resources*, **93**, Part B, 205–222.

Physical scale models

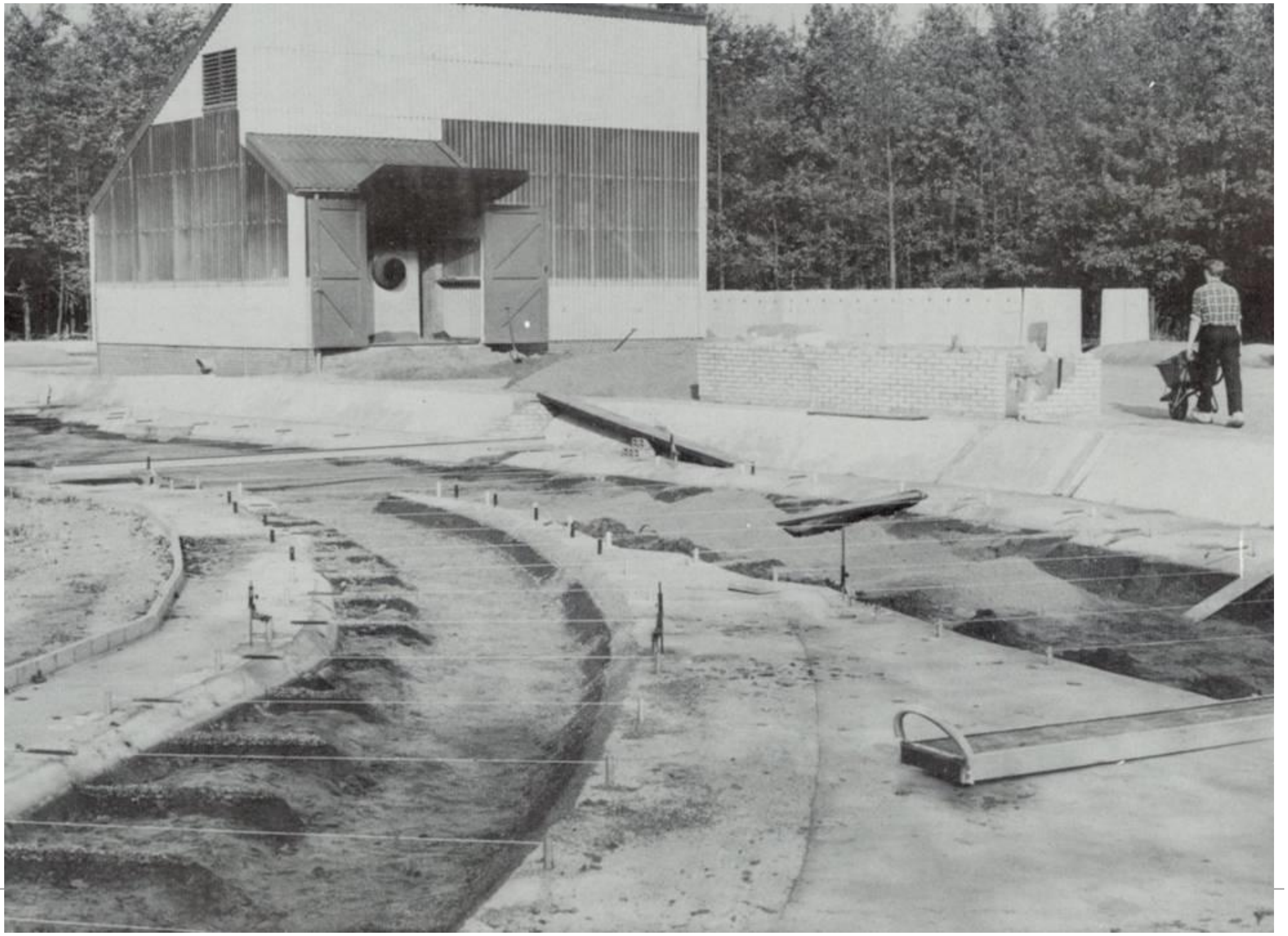
Context of hydraulic engineering practice

- Tool for design

- Compared to numerical models:
  > Superior for local 3D flows (because of imprecise empirical turbulence closure)
  > Inferior for areas where horizontal dimensions are much larger than vertical dimensions (because of scale effects)
  > *provided that mathematical descriptions and computer codes are available for relevant processes*

Physical scale models

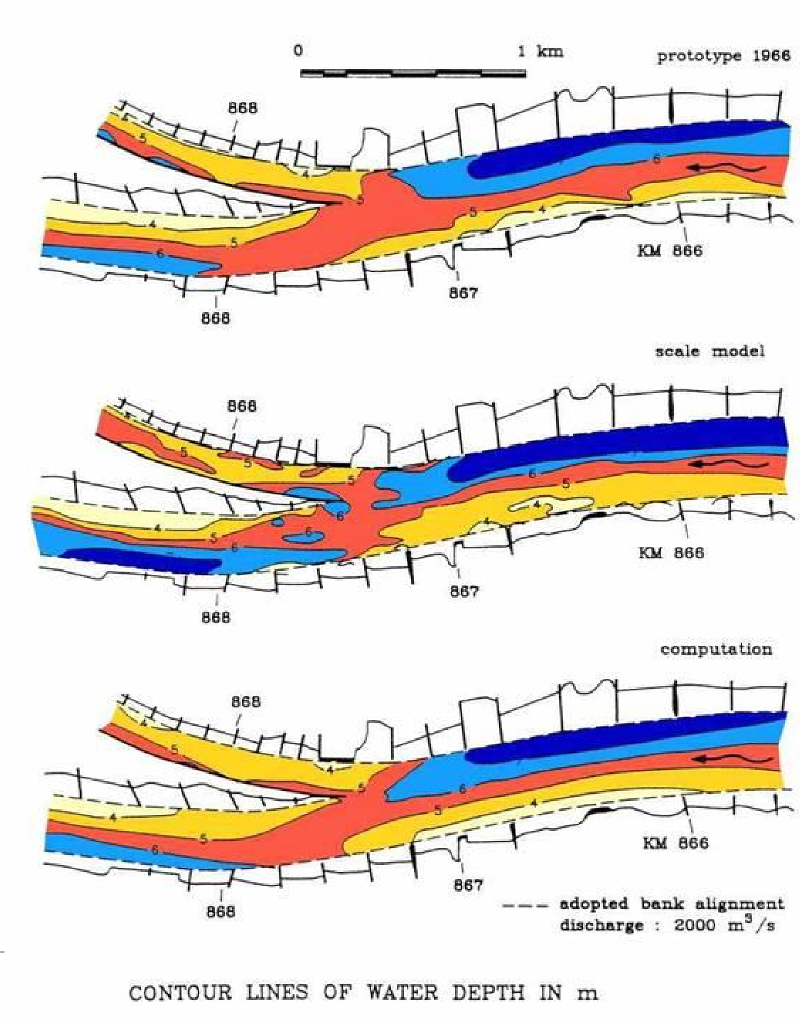
Context of hydraulic engineering practice



Deltares

Physical scale models

Context of hydraulic engineering practice



prototype

scale model

2DH numerical morphodynamic model in 1980s

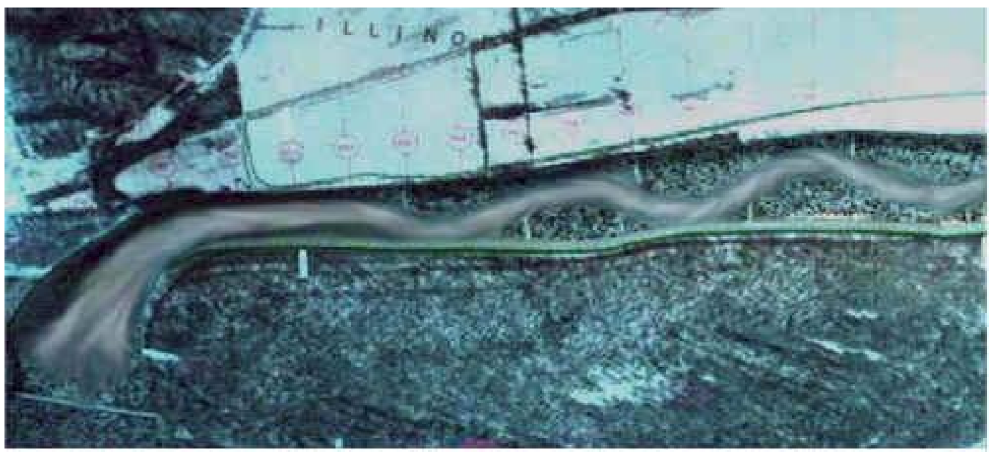
Deltares

Context of hydraulic engineering practice

Die Moran, A, K. El Kadi Abderrazzak, E. Mosselman, H. Habersack, F. Lebert, D. Aelbrecht & E. Laperrousaz (2013), Physical model experiments for sediment supply to the old Rhine through induced bank erosion. *International Journal of Sediment Research*, Vol.28, No.4, pp.431-447.

Context of decision making with stakeholders

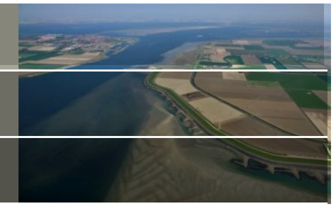
- Communication: explication and demonstration



3. Alternating Flow Patterns and Fish Habitat Created by the Design

4. Model Design Plan Implemented in the Actual Mississippi River

US Army Corps of Engineers,
St. Louis District



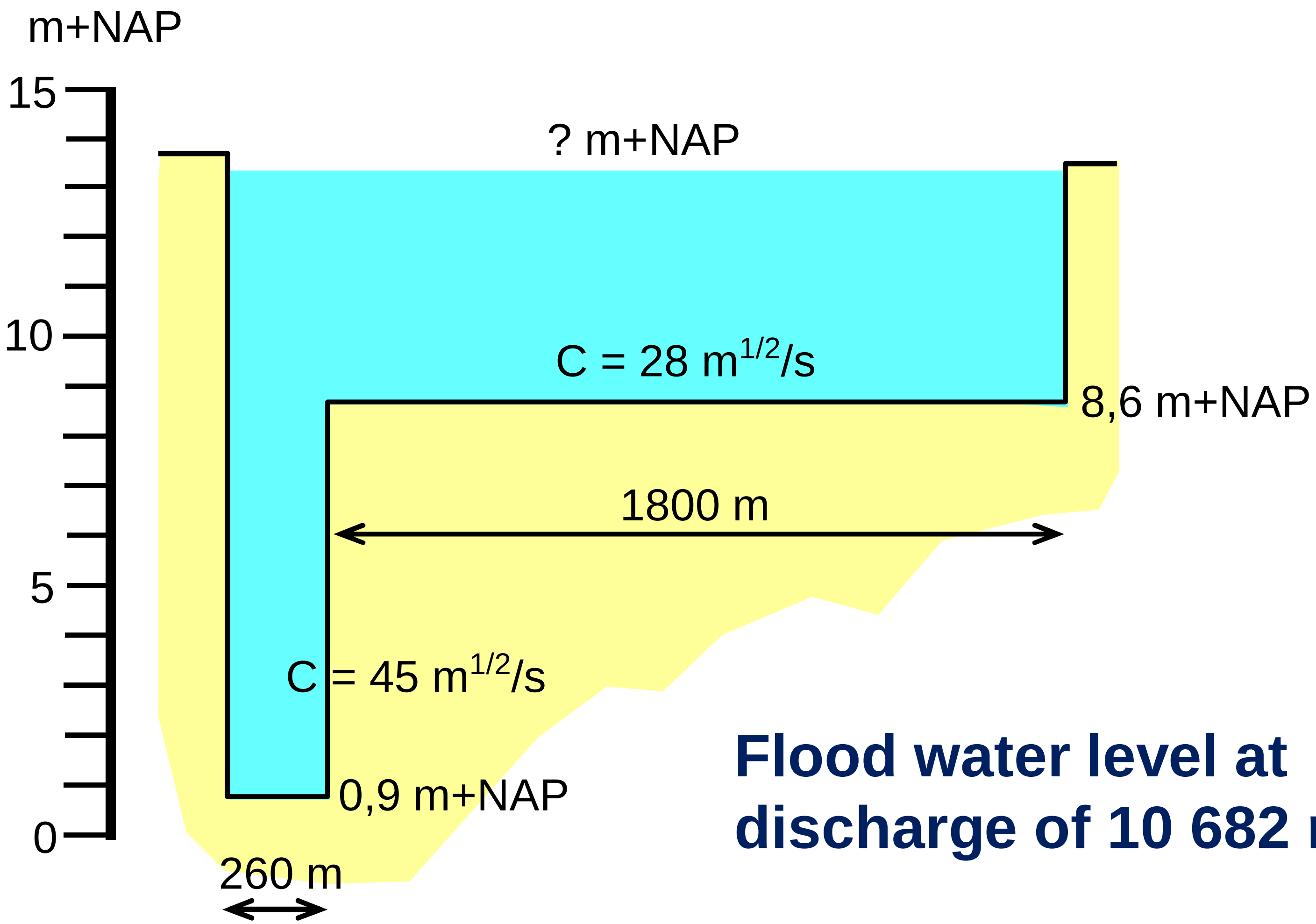
Context of scientific research

- Tool to test hypotheses
- Tool to identify requirements for field measurements
- Object of scientific research

- No basis for scientific evidence, at most “confirmation” (because of truncation errors and underdetermination)
- Oreskes et al (1994): “*Verification and validation of numerical models of natural systems is impossible*”

Oreskes, N., K. Shrader-Frechette & K. Belitz (1994), Verification, validation and confirmation of numerical models in the earth sciences. Science, Vol.263, pp.641-646.

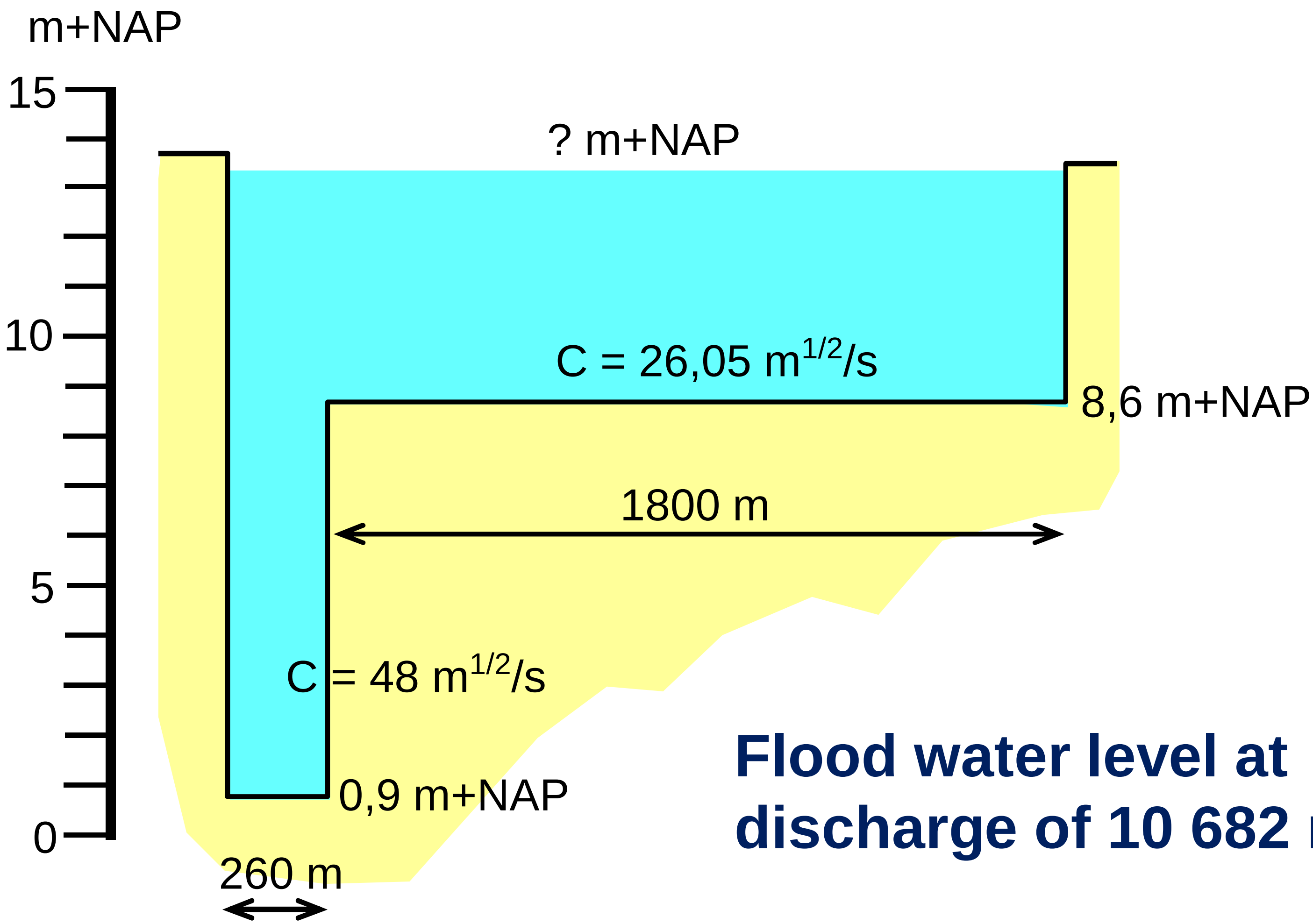
Numerical models



Flood water level at discharge of 10 682 m^3/s ?

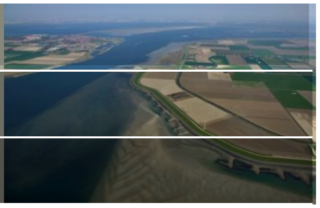
Cross-section representative for Waal at Dodewaard

Numerical models



Flood water level at discharge of 10 682 m^3/s ?

Cross-section representative for Waal at Dodewaard

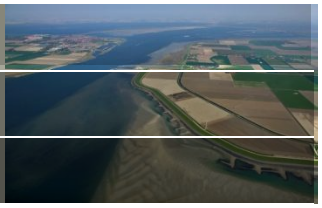


Calculated flood water levels

- Roughness: main channel 45 $m^{1/2}/s$ and floodplain 28 $m^{1/2}/s$:
  - > Flood water level = 13,08 m + NAP
- Roughness: main channel 48 $m^{1/2}/s$ and floodplain 26,05 $m^{1/2}/s$:
  - > Flood water level = 13,08 m + NAP

What is the effect of lowering the floodplain by 1 m?

Numerical models



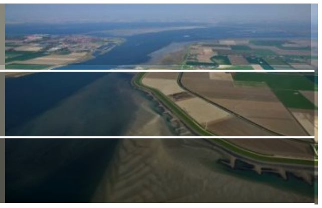
Effect of 1 m floodplain lowering

- Roughness: main channel 45 $m^{1/2}/s$ and floodplain 28 $m^{1/2}/s$:
  - > Flood water level = 12,35 m + NAP
  - > Effect = -0,73 m

- Roughness: main channel 48 $m^{1/2}/s$ and floodplain 26,05 $m^{1/2}/s$:
  - > Flood water level = 12,38 m + NAP
  - > Effect = -0,70 m

Uncertainty due to underdetermination

Numerical models



Context of hydraulic engineering practice

- Integration of knowledge in a structured database
- Enhancing of data through “intelligent” interpolation
- Identification of requirements for measurements and monitoring
- Diagnosis of problems
- Assessment of effects of interventions and scenarios
- Quantification of design conditions

Dealing with uncertainty

- Safety factors
- Sensitivity analysis (assessment of robustness)
- Probabilistic approaches
- ***How to communicate this to stakeholders?***

Numerical models

Context of decision making with stakeholders

Room for the River programme: 2.2 billion euro

Context of decision making with stakeholders

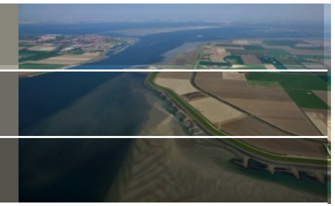
Nijmegen flood channel: 0.3 billion euro

Numerical models

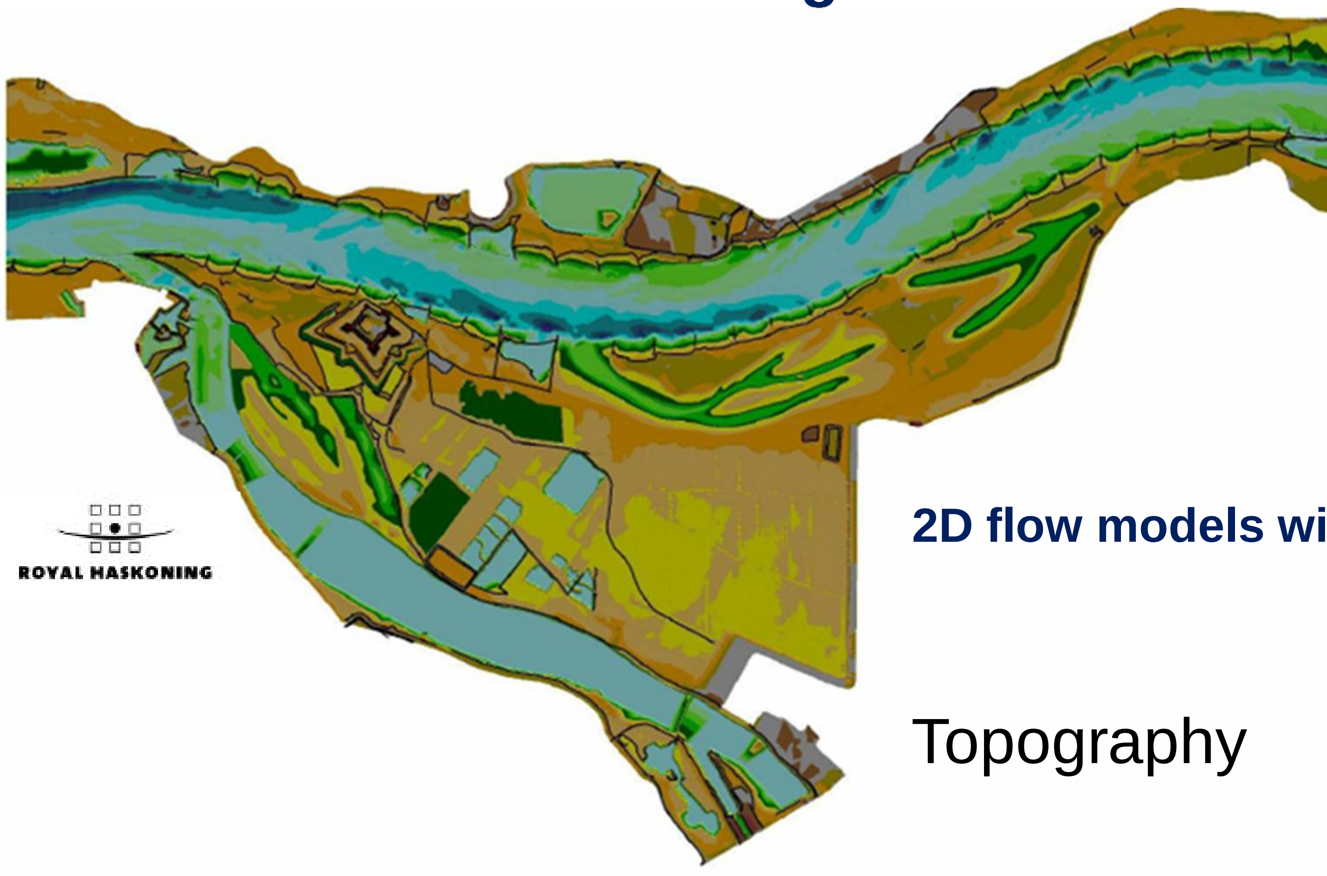
Context of decision making with stakeholders

Deltares

Numerical models



Context of decision making with stakeholders

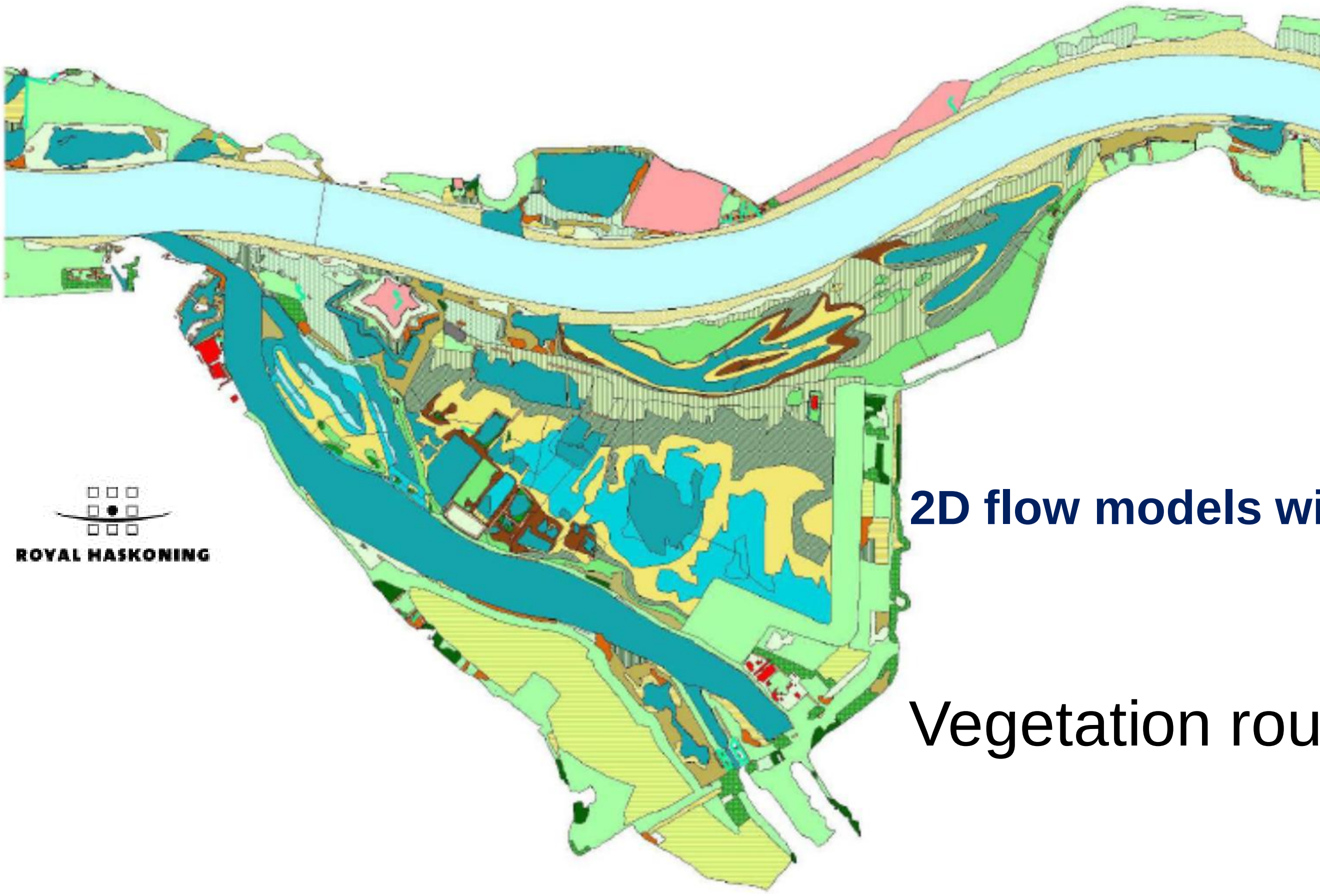


2D flow models with great detail

Topography

Numerical models

Context of decision making with stakeholders

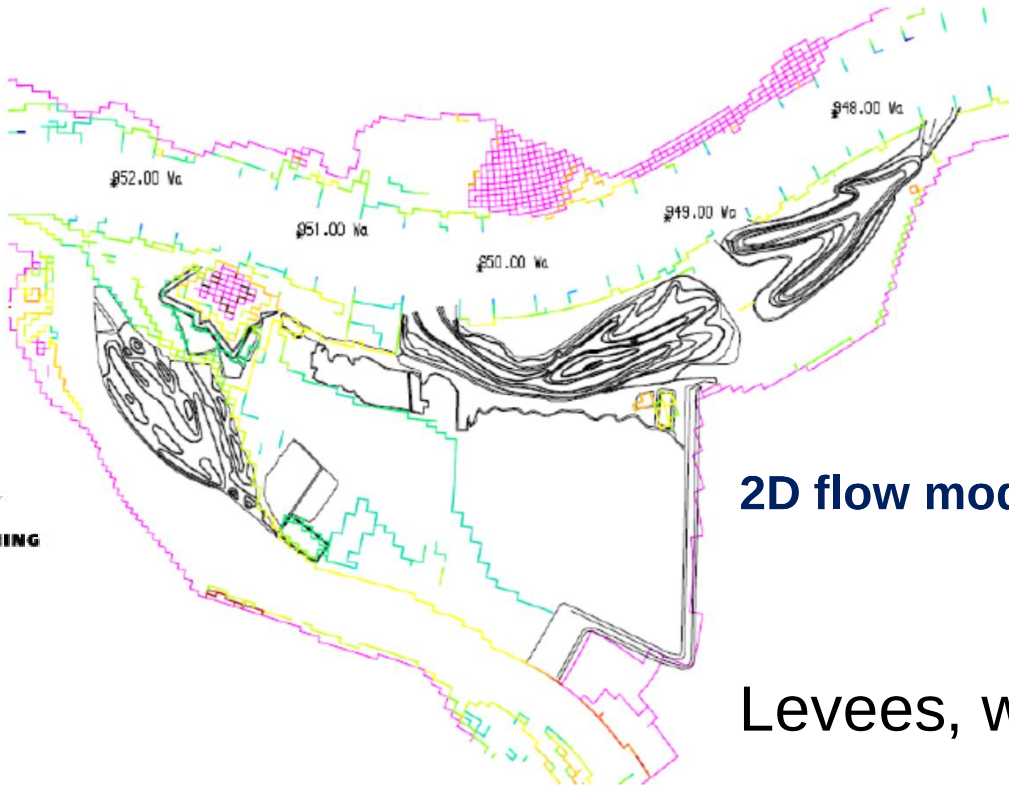


ROYAL HASKONING

2D flow models with great detail

Vegetation roughness

Context of decision making with stakeholders

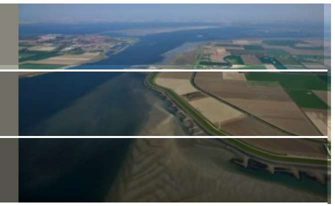


ROYAL HASKONING

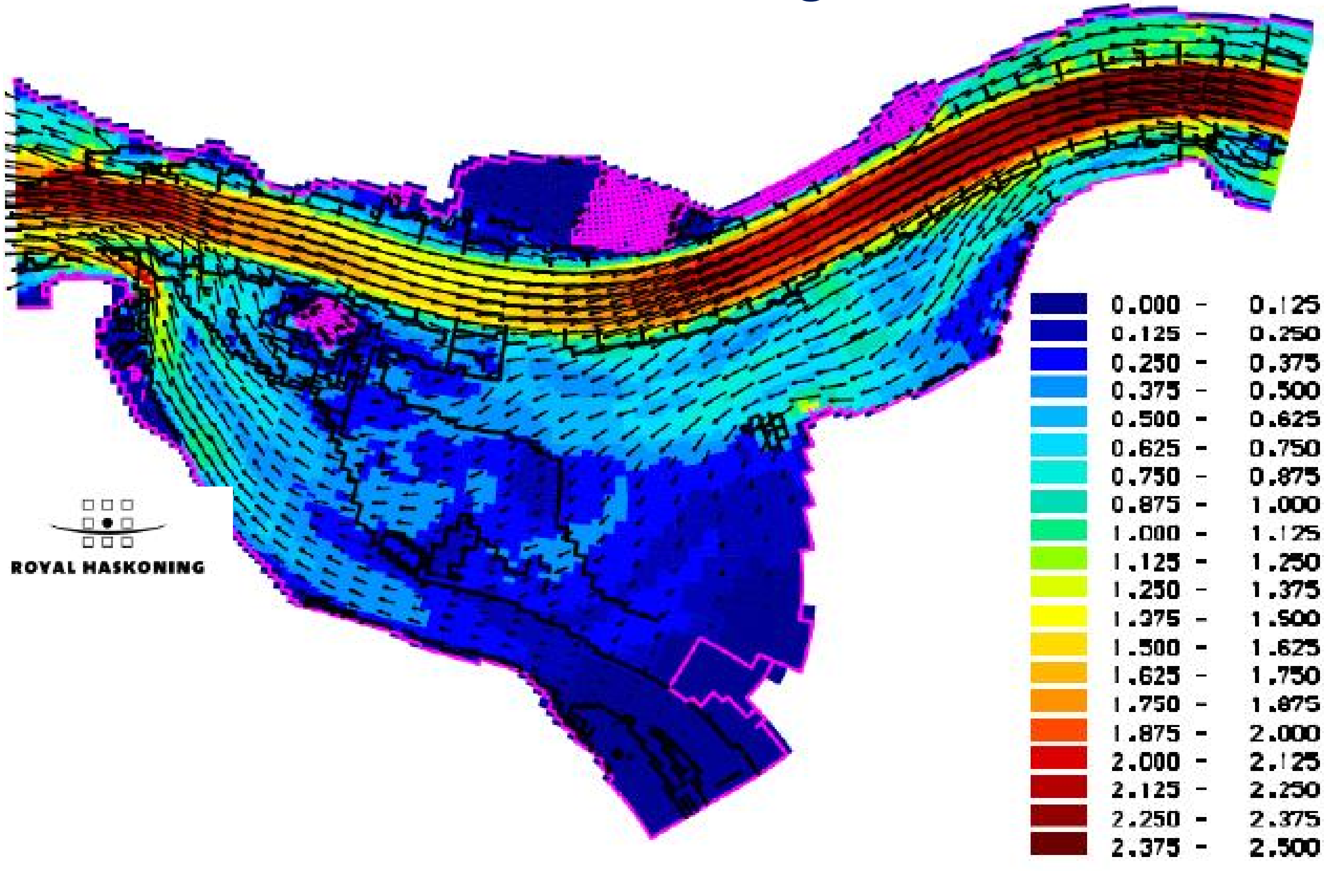
2D flow models with great detail

Levees, weirs, groynes

Numerical models

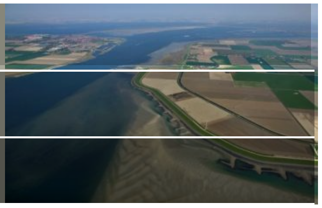


Context of decision making with stakeholders



Flow velocities

Numerical models



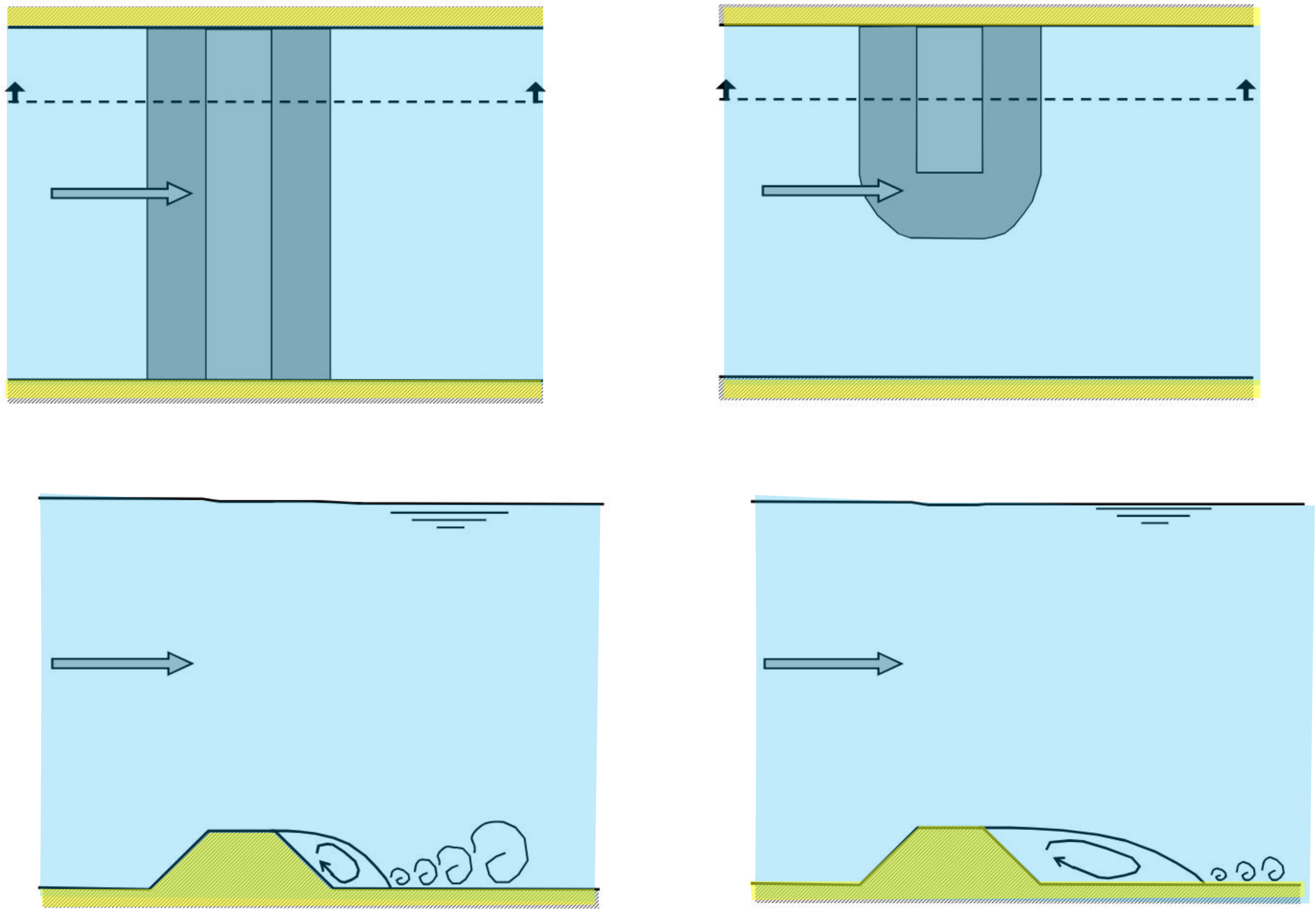
Context of decision making with stakeholders

- Accuracy of design flood levels:
  - > According to assessment: ±0.5 to ±1 m
  - > Suggestion in stakeholder communication: ±1 mm to ±1 cm

- Rationality of communicating values in centimetres:
  - > Differences of centimetres involve significant costs of interventions (flood defences, room for the river)
  - > Permission to construct in case of small flood level rises sets precedents towards larger cumulative effects

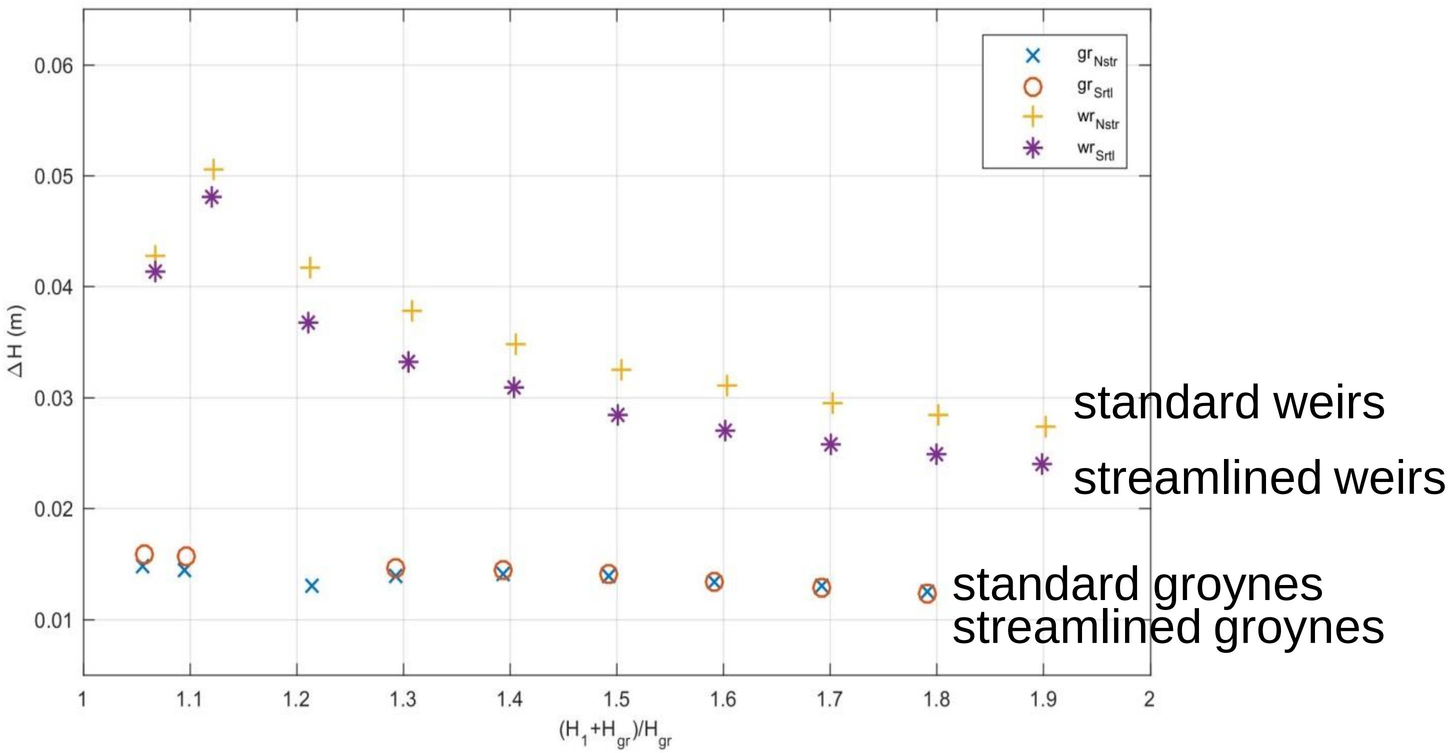
- ***Paradox: higher accuracy demands than in science***

Lack of knowledge: groyne streamlining



Lack of knowledge: groyne streamlining

Insight from 3D computations




Thanks!