



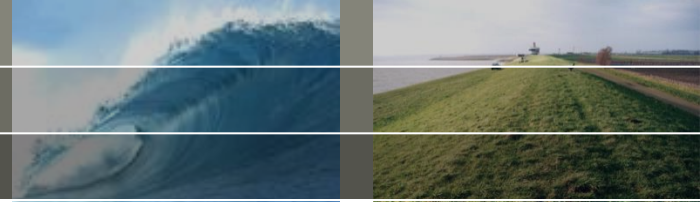
Numerical model to predict the erosion of a dike using time dependent boundary conditions

Dorothea Kaste - Deltares

Mark Klein Breteler - Deltares

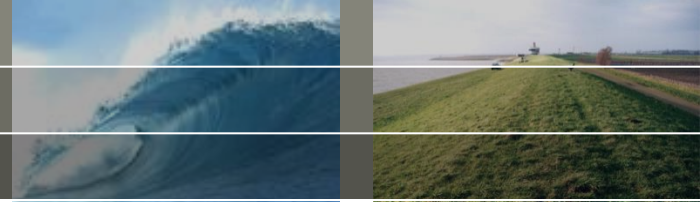
Yvo Provoost - Projectbureau Zeeweringen

IAHR Congress - The Hague - July 2nd 2015



- **Introduction**
- Derivation of the numerical model
- Adaption for time dependant boundary conditions
- Example

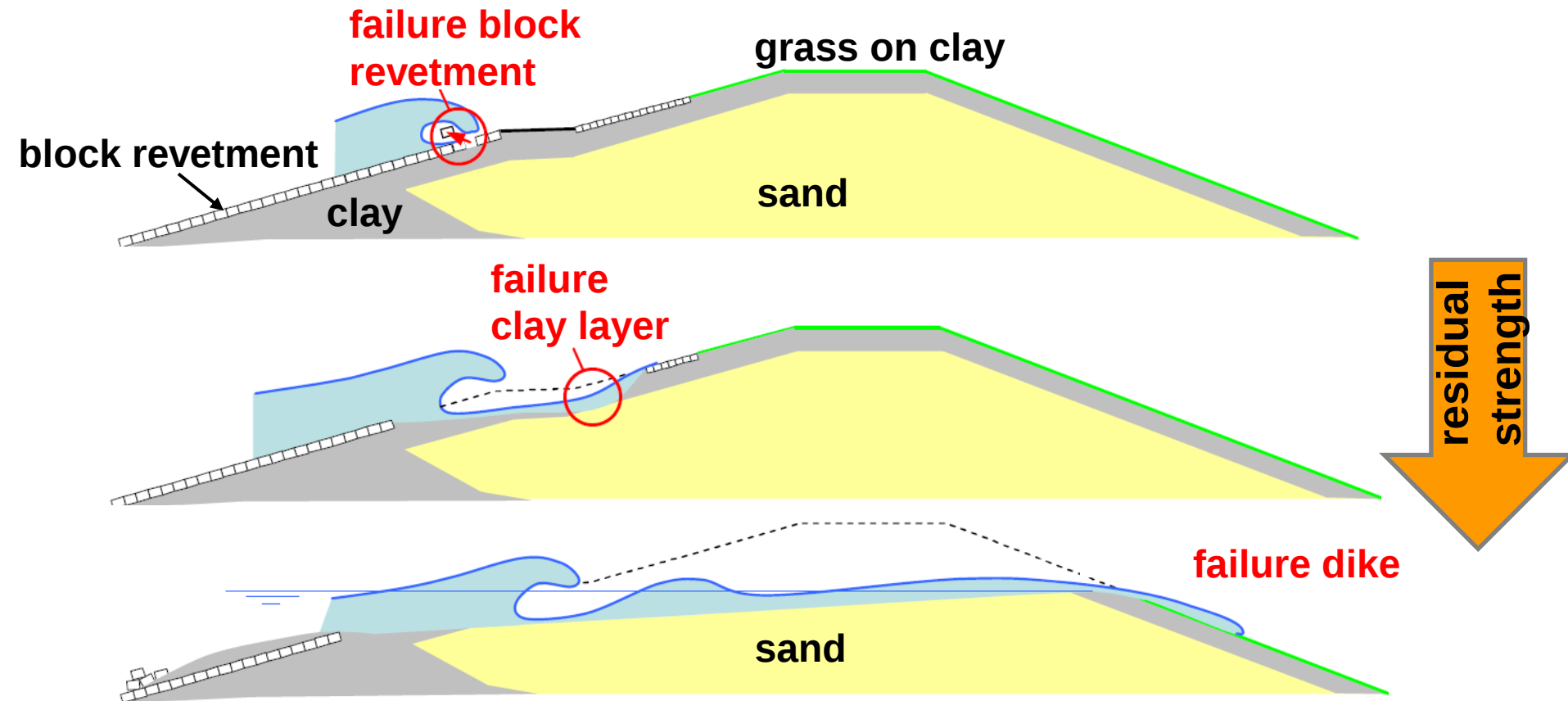
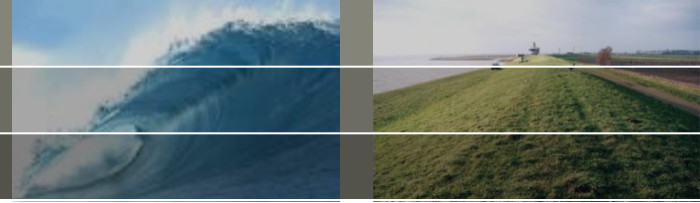
Why do we need this model?



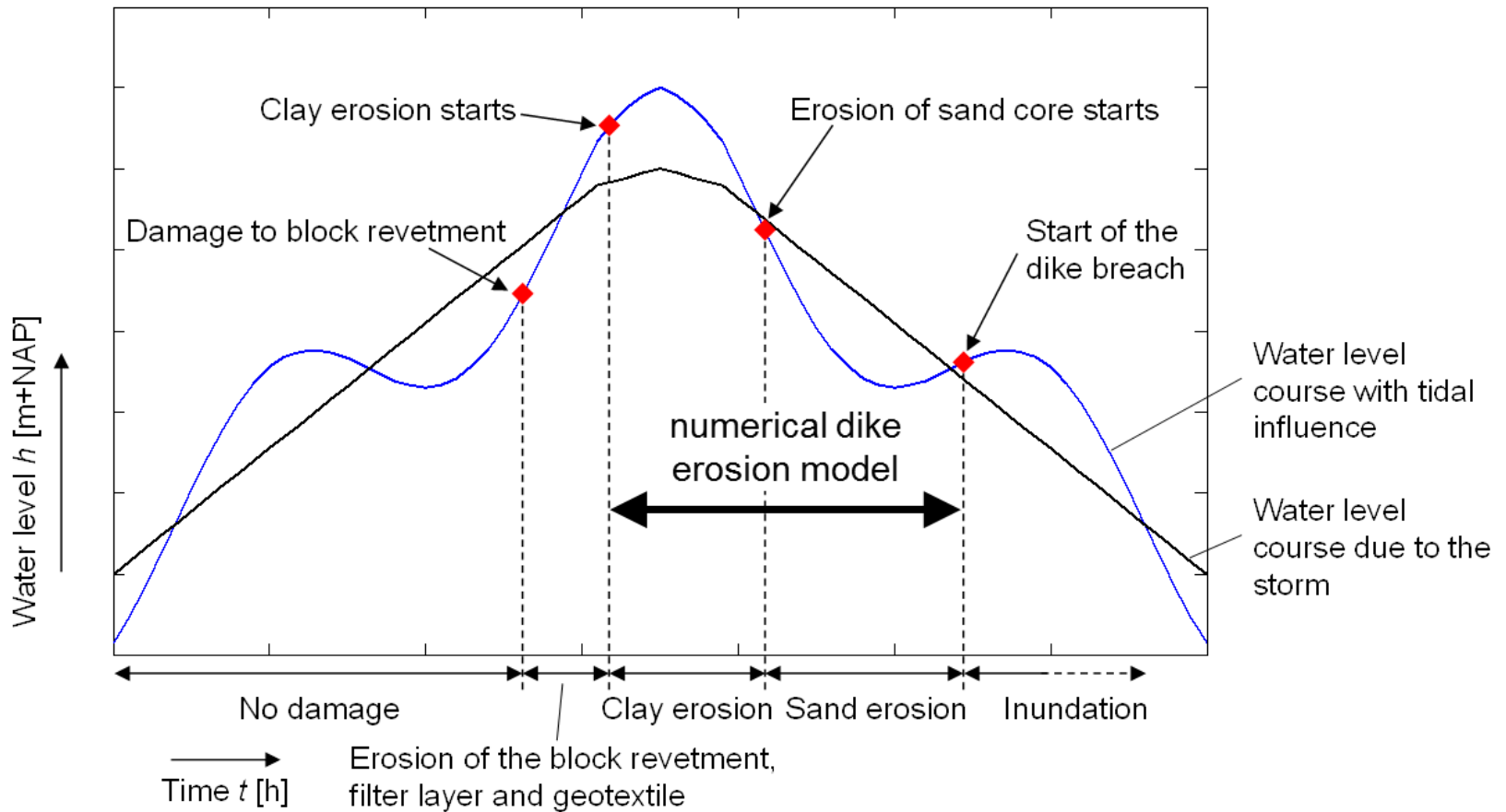
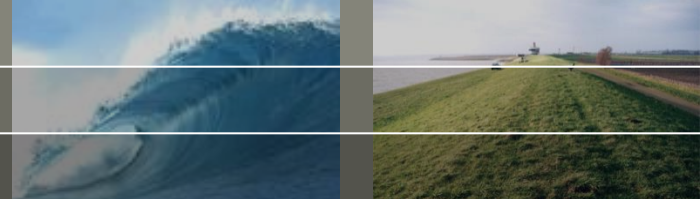
Typical dike in the Netherlands with a block revetment

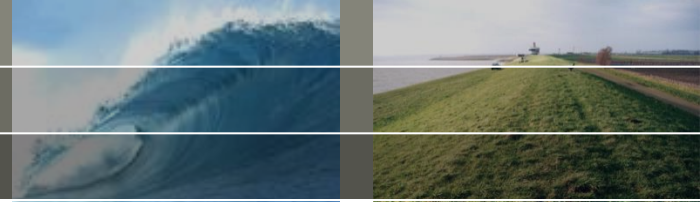


Residual strength of a dike



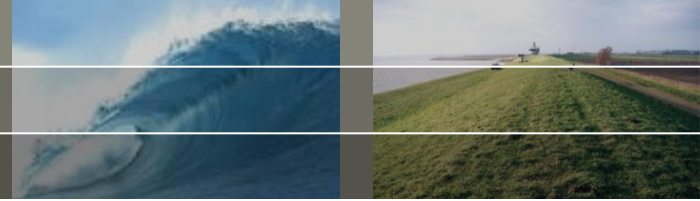
Simulating a whole storm





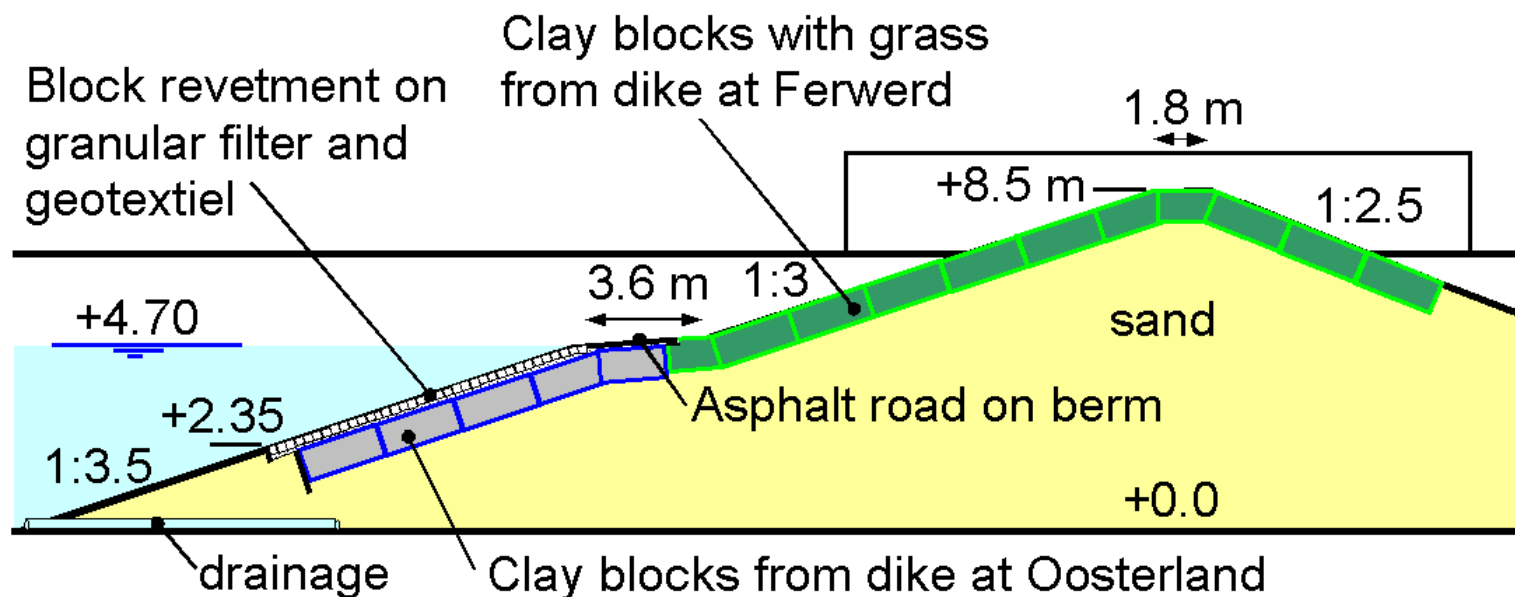
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Large scale model tests

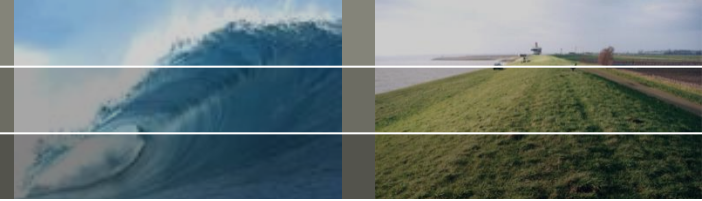


Large scale experiments in the Deltaflume (Wolters & Klein Breteler, 2011)

- Scale 1:1
- Dike is built with a sand core and a clay layer made from clay blocks (2 x 2 m, 80 cm thick)
- Block revetment below the berm and grass on the upper slope



Large scale model tests

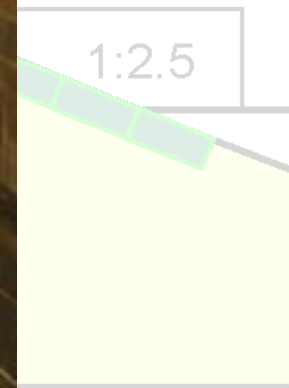
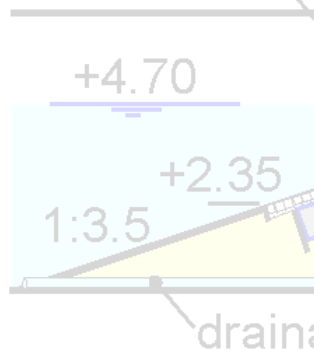


Large scale ex

- Scale 1:1
- Dike is built from clay blocks (80 cm)
- Block revetment

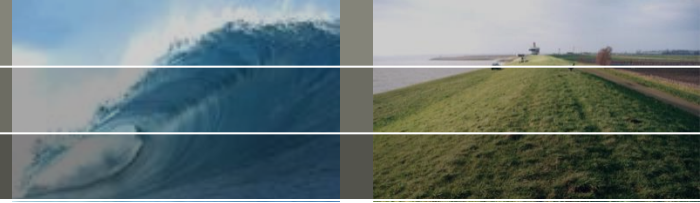
from clay

Block revetment
granular filter
geotextiel



Deltares

Large scale model tests

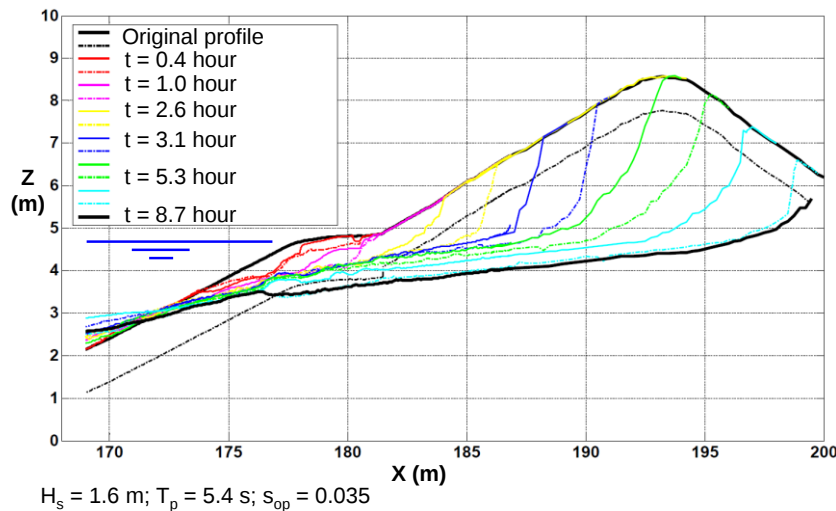


Large scale experiments in the Deltaflume



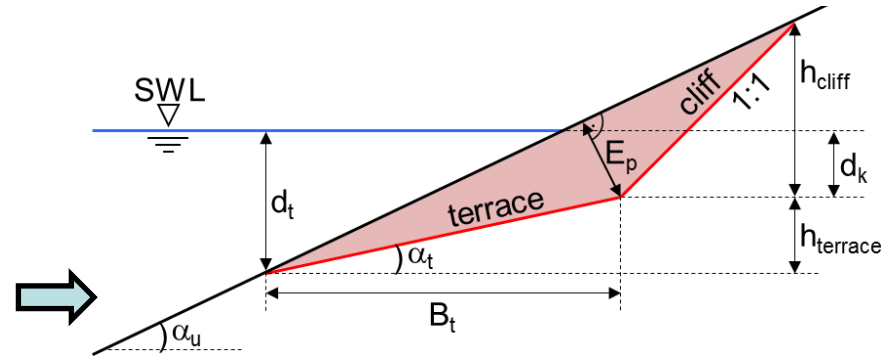
Erosion of the clay layer and the sand core by waves

Analysis of the physical model tests



Measurements of the erosion

(Klein Breteler et al., 2012)



schematized erosion profile

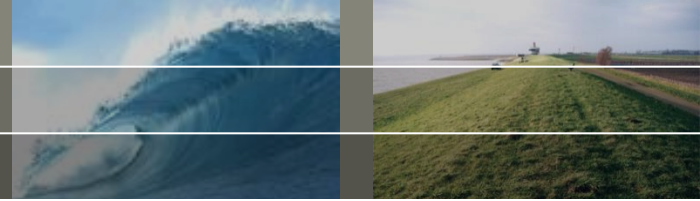
$$\frac{\partial V_e}{\partial t} = c_{m,1} \cdot 0.063 \frac{H_s^2 \cdot \tan \alpha}{s_{op}}$$

$$\frac{\partial V_e}{\partial t} = c_{m,2} \cdot \frac{H_s^2}{T_p} \left(\frac{0.15}{s_{op}^{1.3}} + (\tan \alpha)^{0.8} \cdot (135 - 1500 \cdot s_{op}) \cdot \exp \left(-0.0091 \cdot \left(\frac{B_t}{H_s} \right)^2 \right) \right)$$

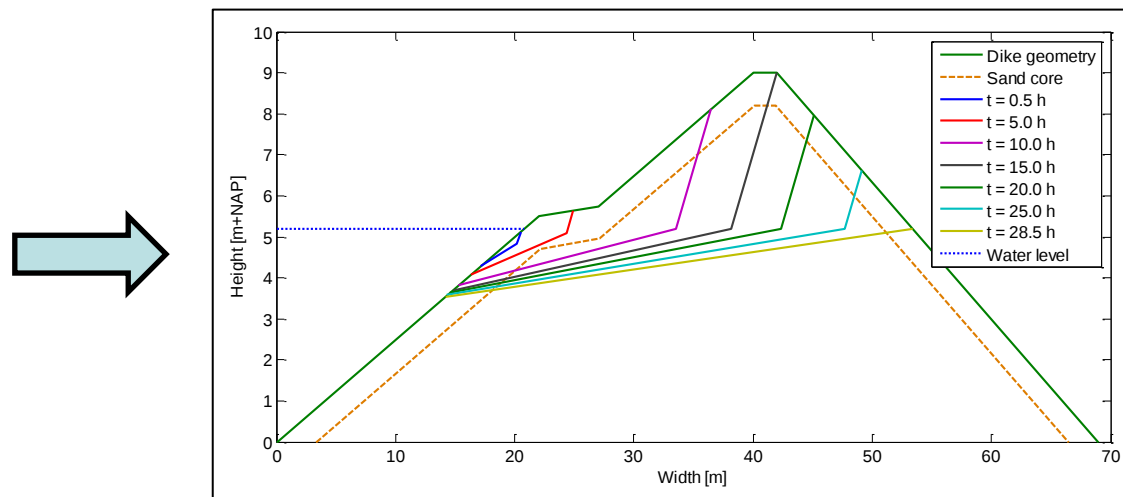
$$d_t = c_{m,3} \cdot \min \left\{ 0.4 \frac{V_e^{0.25}}{\sqrt{H_s}} + 0.7; 2H_s \right\}$$

formulas to calculate the erosion rate in clay and sand

Numerical model

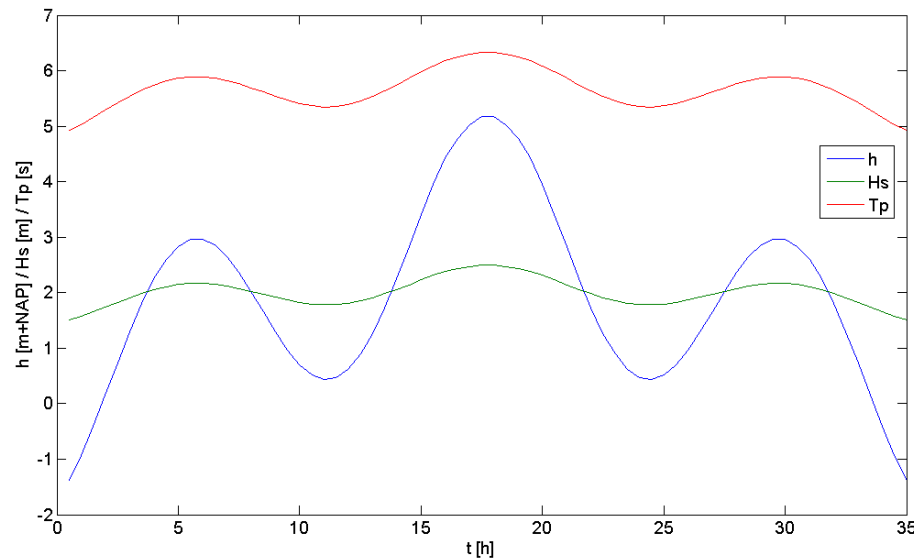
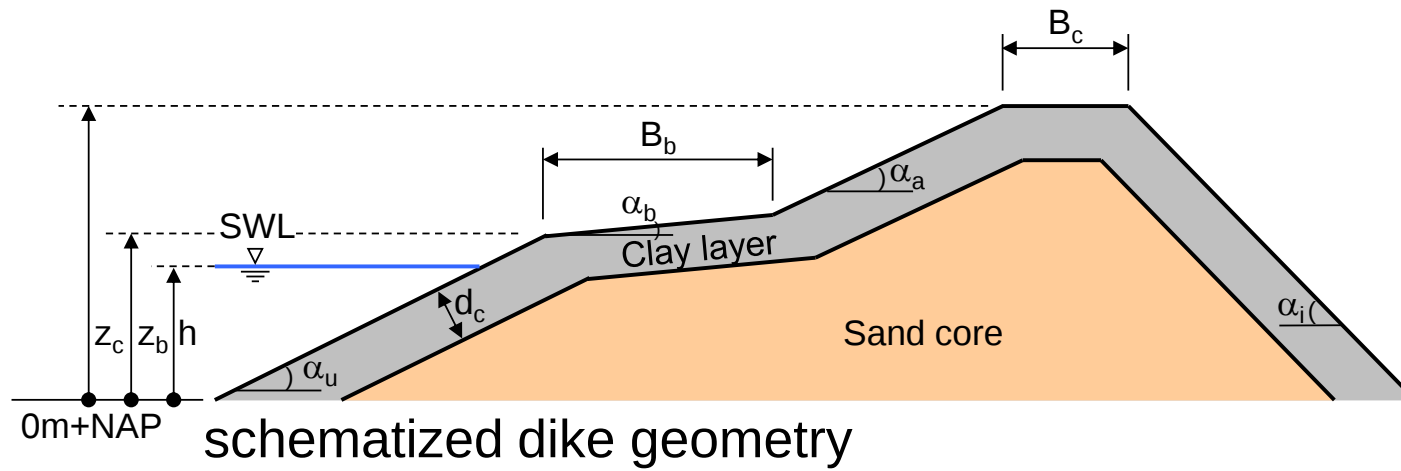


- Calculation of the erosion volume over the duration of the storm divided in time steps
- Determination of the erosion profile in each time step
→ erosion depth, progress of erosion

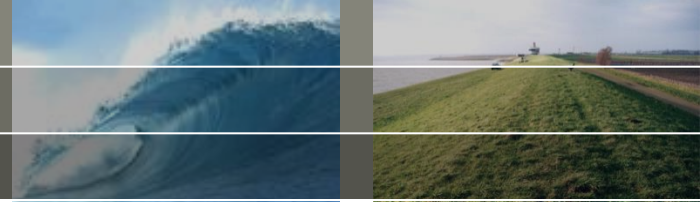


(Kaste & Klein Breteler, 2014)

Input



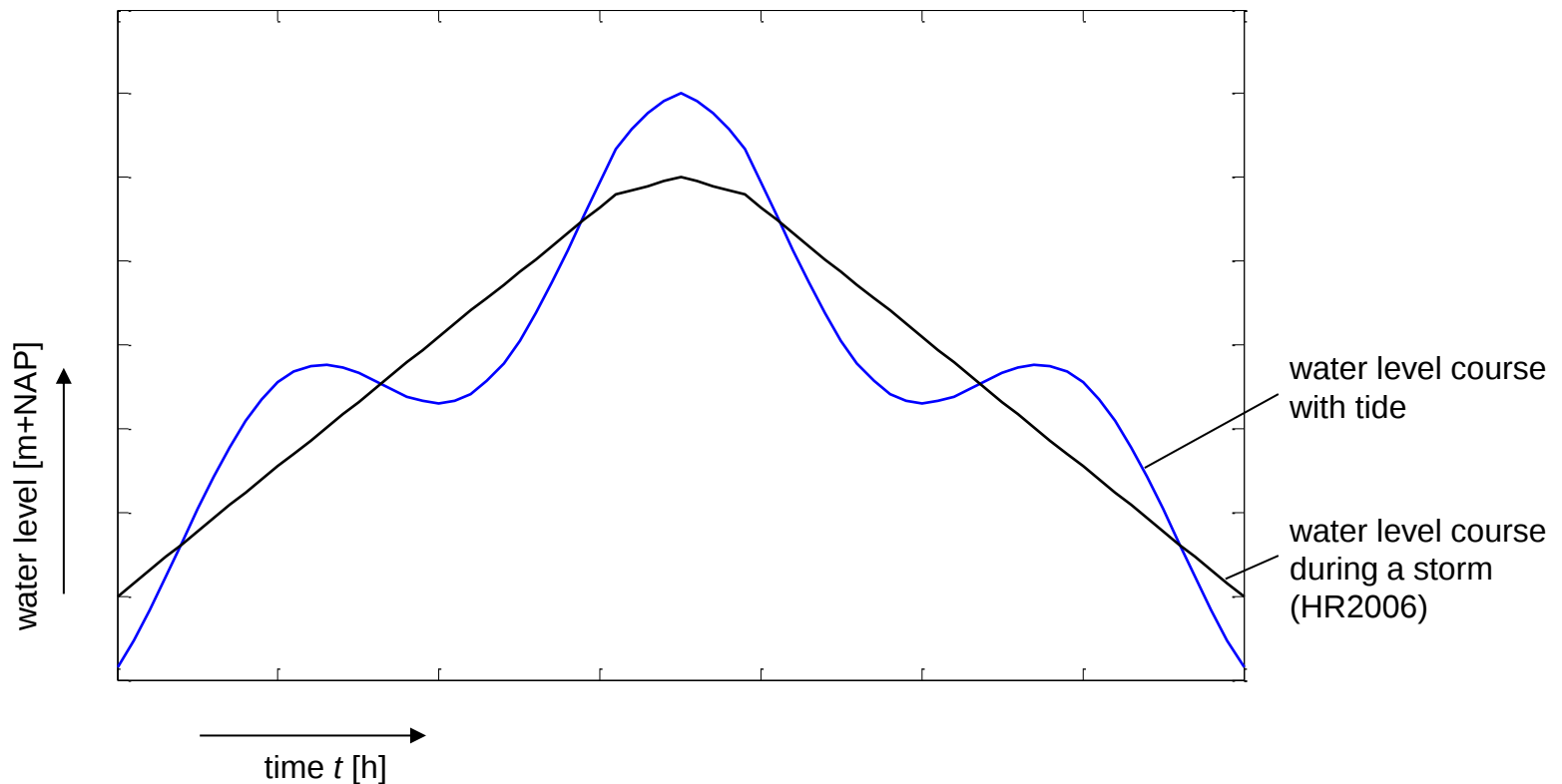
hydraulic boundary conditions



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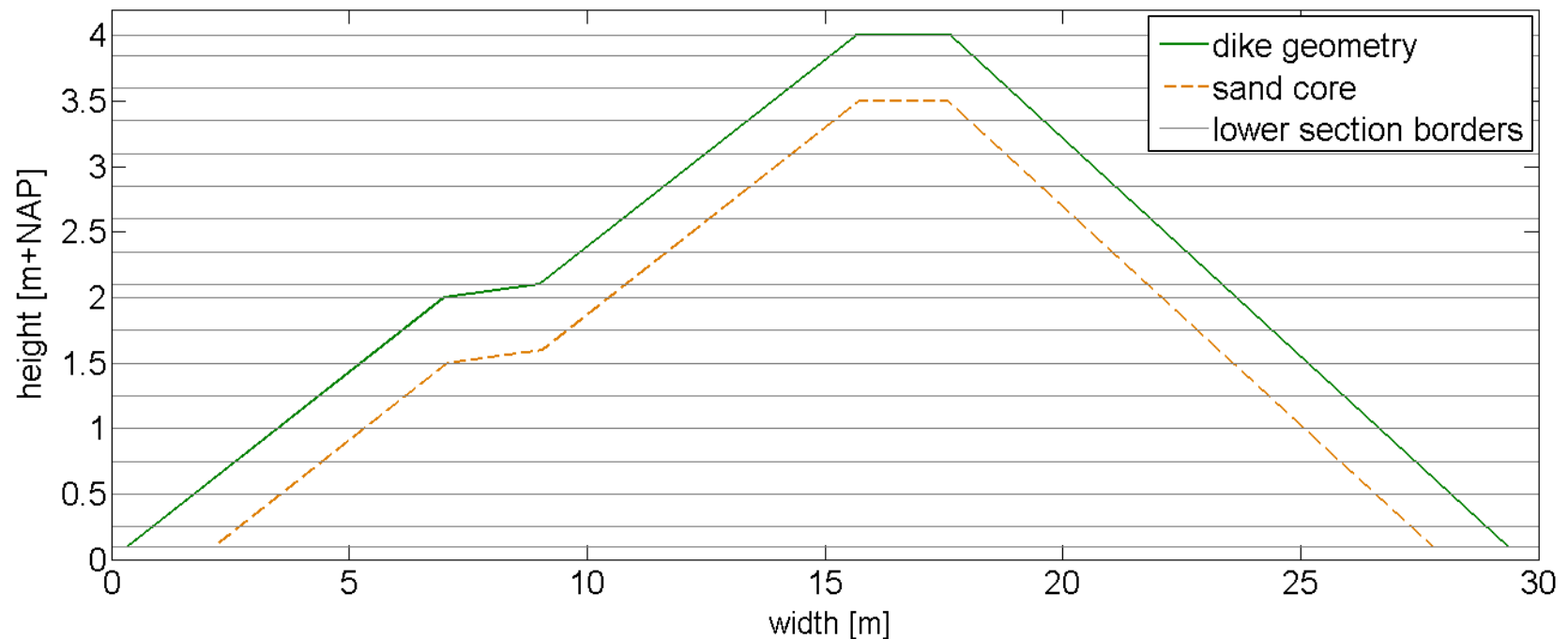
Adaption numerical model

- Recent enhancement with PBZ: adaptation for varying boundary conditions
- Replacing erosion rate formula for clay with new formula (Mourik, 2015)



Approach for a varying water level

- Split the dike into horizontal sections
- Distribute erosion volume of the current time step over the sections
- Store erosion volume and erosion depth per section

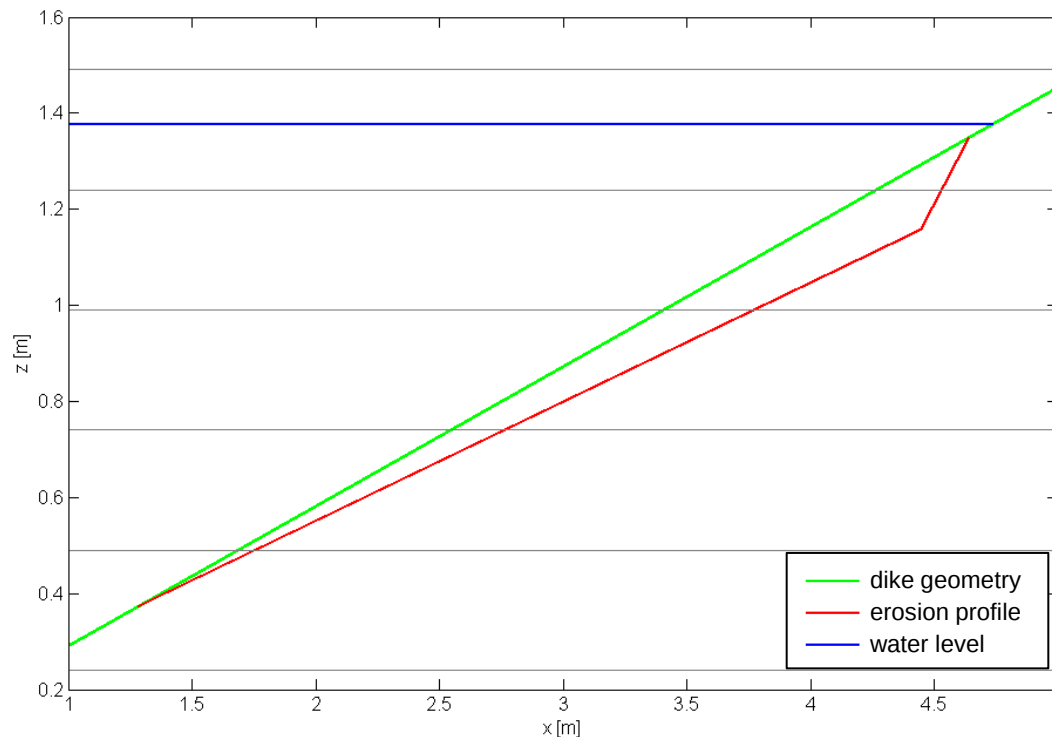


(Kaste & Klein Breteler, 2015)

Deltares

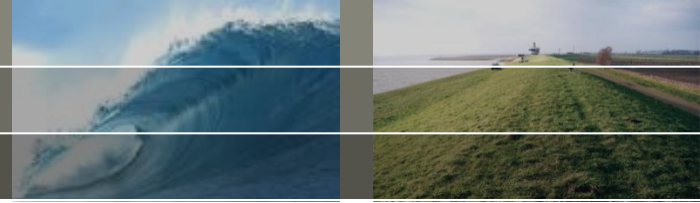
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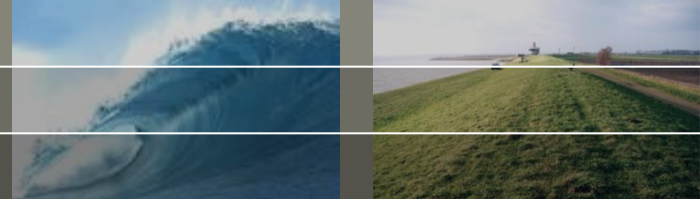
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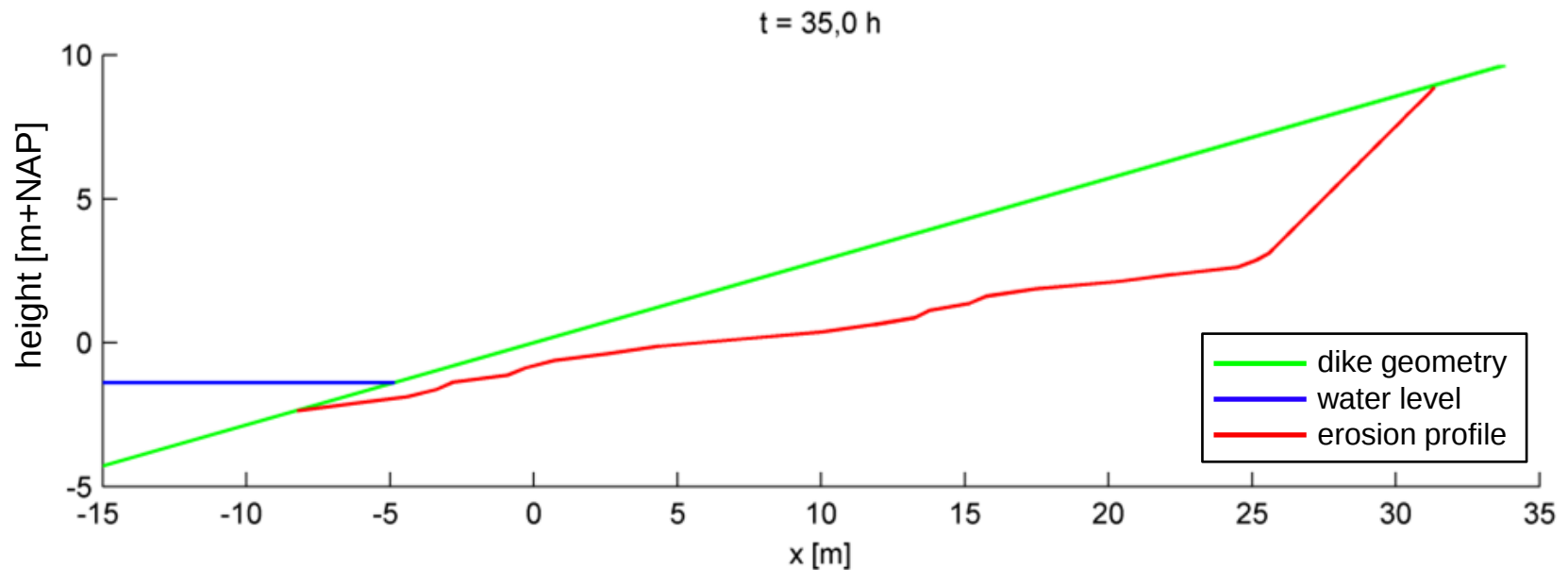


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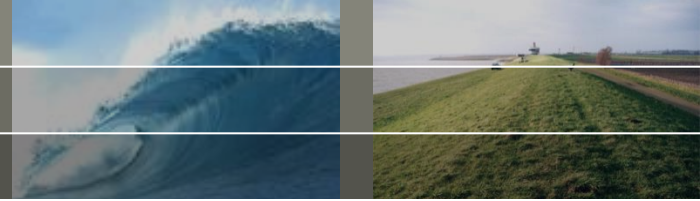
Example



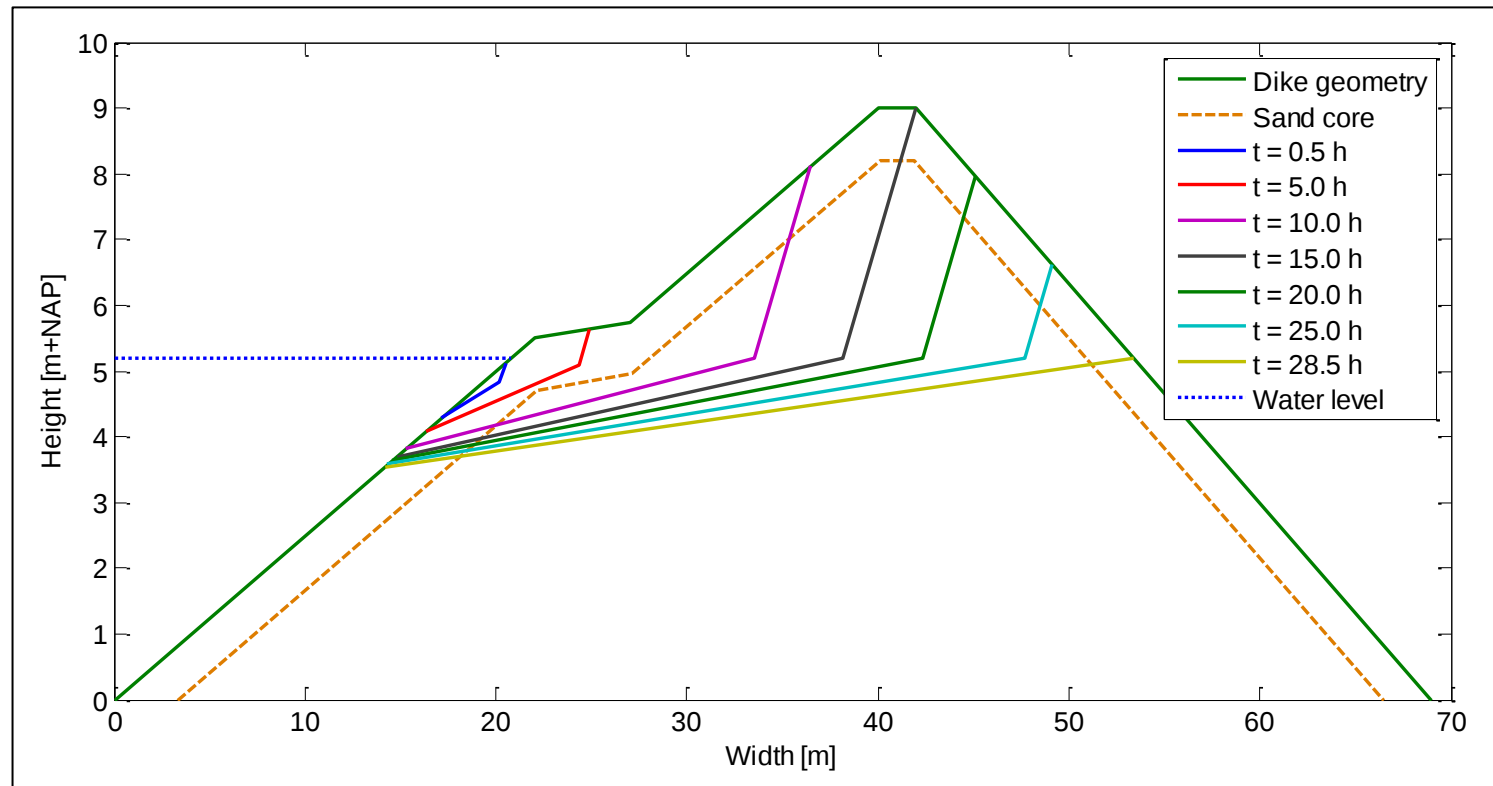
Example of the erosion of clay with a varying water level and varying wave conditions



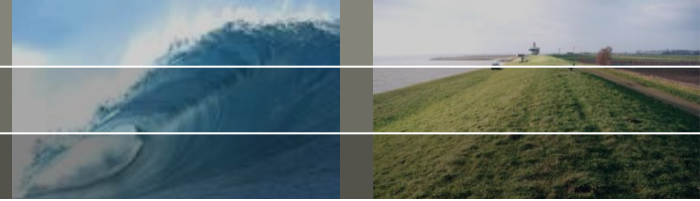
Questions?



Thank you for attending my presentation!



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- Kaste & Klein Breteler, 2014: Sensitivity study into residual strength of dikes after block revetment failure, given as preliminary safety factor – WTI 2017. Deltares, rapport 1207811-010.
- Kaste & Klein Breteler, 2015: Rekenmodel voor kleierosie bij variërende waterstand. Deltares, report 1209832-010.
- Klein Breteler et al., 2012: Erosie van een dijk na bezwijken van de steenzetting door golven - SBW reststerkte; analyse Deltagootproeven. Deltares, report 1204200-008.
- Mourik, 2015: Prediction of the erosion velocity of a slope of clay due to wave attack – WTI2017. Deltares, report 1209437-017.
- Wolters & Klein Breteler, 2011: Reststerkte van een dijk met steenzetting op een kleilaag - Meetverslag Deltagootproeven SBW-Reststerkte. Deltares, report 1202122.002.