



Joint-Industry-Project

Handbook Scour and cable Protection Methods



Tim Raaijmakers, Deltares
13 June 2018



*Balance of plant & integration of wind turbine
and support structures (15h30-17h00)*

JIP HaSPro – Handbook Scour and Cable Protection Methods



The topic

Scour and cable protection methods for offshore wind support structures and cable crossings

The objective

to develop:

- a clear, generic and science-based comparison between different scour and cable protection methods (*both optimizing existing methods and validating new methods*)
- recommendations/guidelines when and where to apply which method

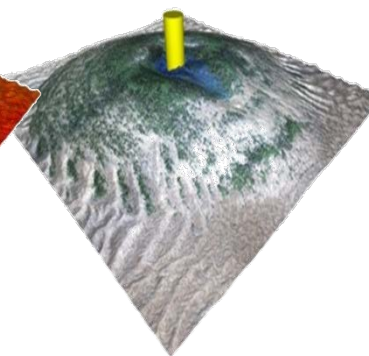
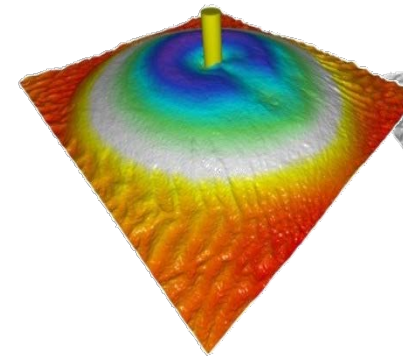
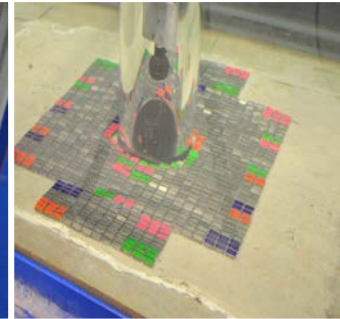
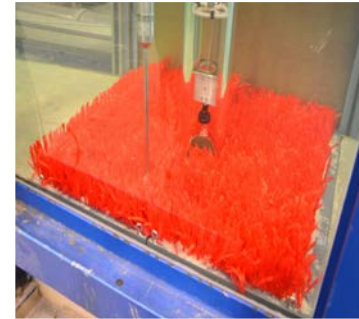
No protection method exists that works for all situations:
room for alternative solutions!

Project details

Partners: 21 partners (at present)

Duration: 1 September 2016 – 1 September 2019

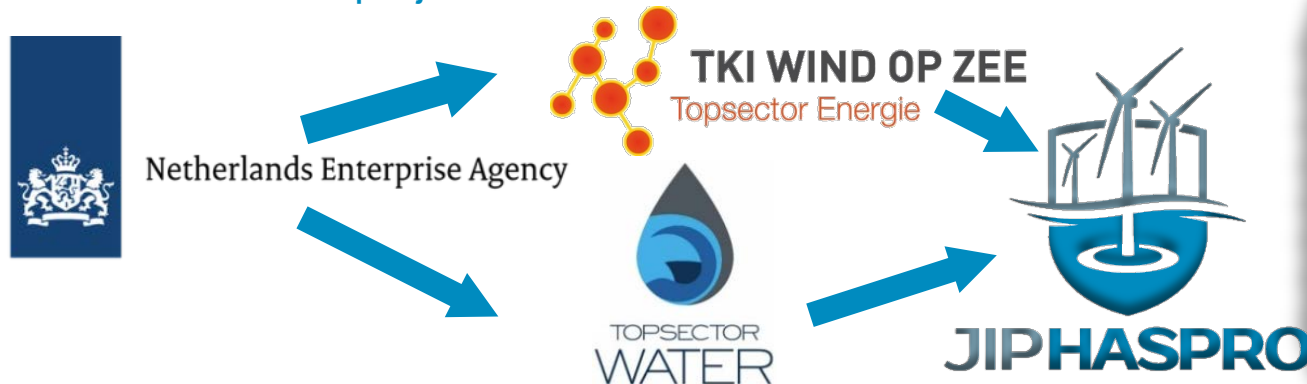
Budget: 2.3 M€



Project partners in JIP HaSPro



Cross-over project between two TKI's



Research (2)



Contractors (5)



Utilities (7)



Suppliers (6)



Engineering **COWI**

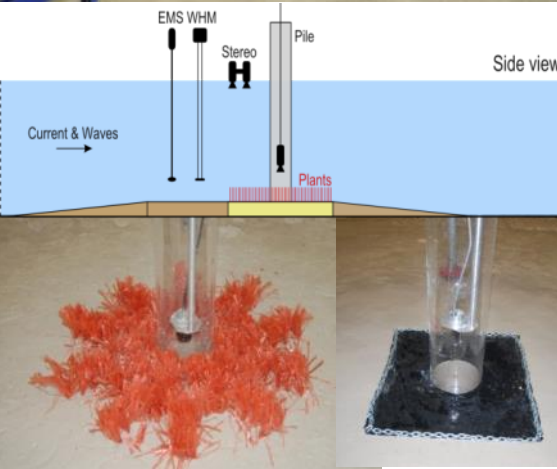
Systematic scale model testing on three scales



Scheldt Flume

- Model scale 1:30 to 1:50
- Tidal currents + waves
- Fast cycle times: many exploratory tests

completed



Atlantic Basin

- Model scale 1:20 to 1:40
- Tidal currents + waves
- Wave section with mobile bed
- All governing processes are included

1st phase completed
2nd phase Q3-2018



Delta Flume

- Model scale 1:1 to 1:10
- World's largest wave flume
- No scale effects
- Validation of smaller scale tests

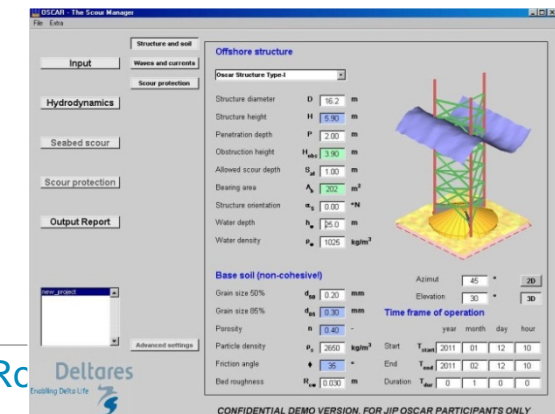
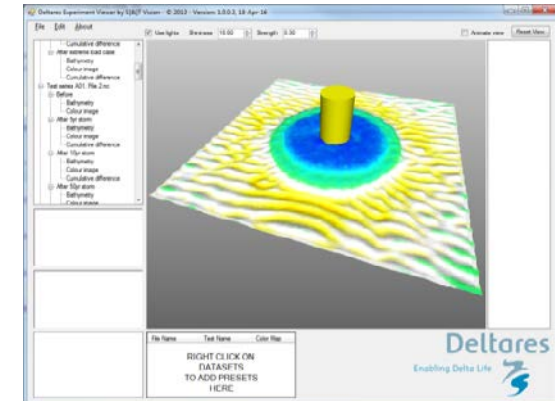
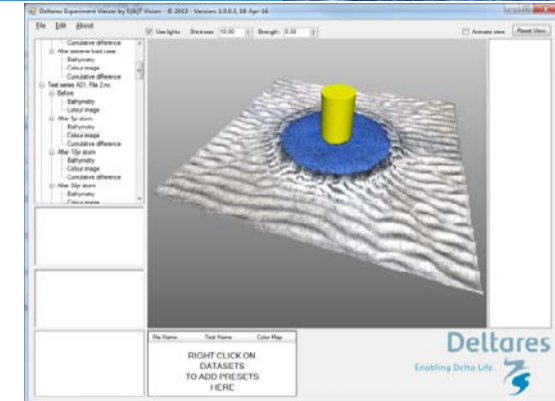
completed



Deliverables of JIP HaSPro



- **Database with hundreds of test results**, made accessible through the generic **3D Experiment Viewer**
- **Scour protection design formulae**, implemented in a **Scour Protection Design Tool**, which will guide designers through all relevant steps in design of a scour protection
- **Digital Handbook Offshore Scour Protection Methods**, which describes methodologies to compare different scour mitigation methods and how to design them
- **Recommended Practice** by DNV GL
- **Ecological Evaluation Framework** for scour protections
- Guidelines for **Nature-inclusive Design**

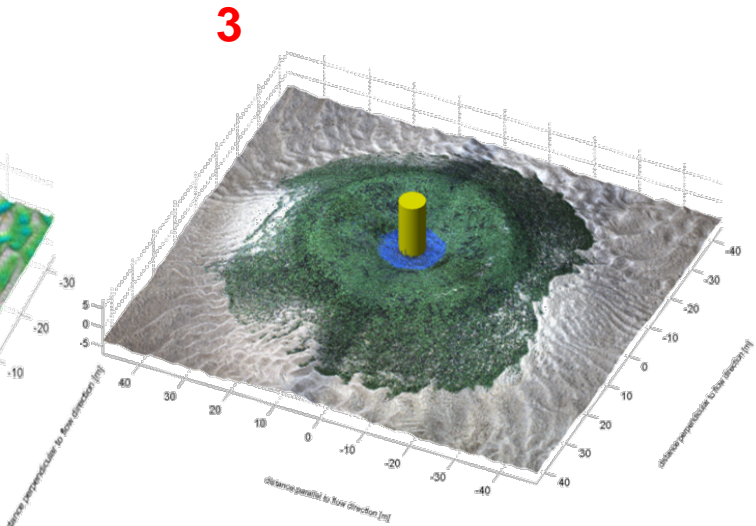
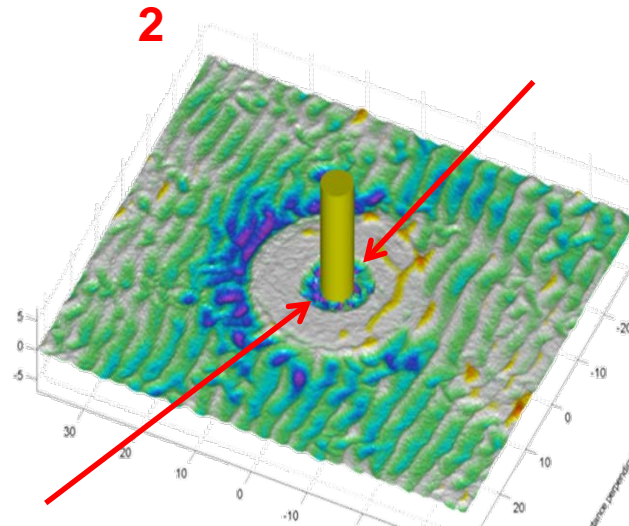
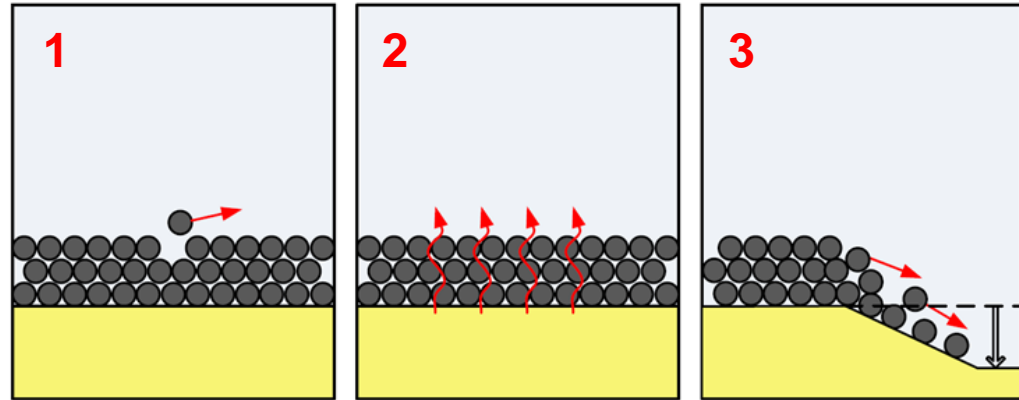


Requirements for a scour protection

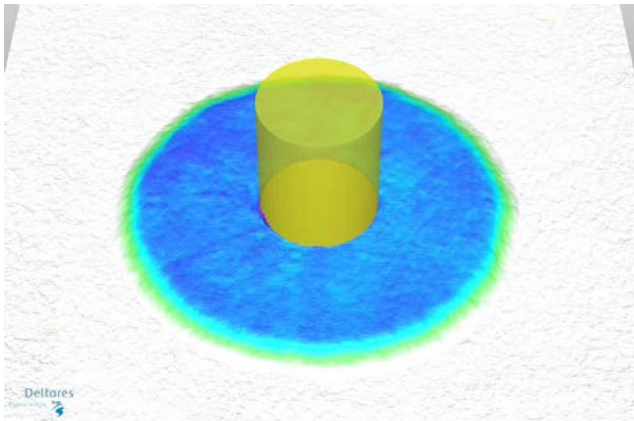


Main design requirements:

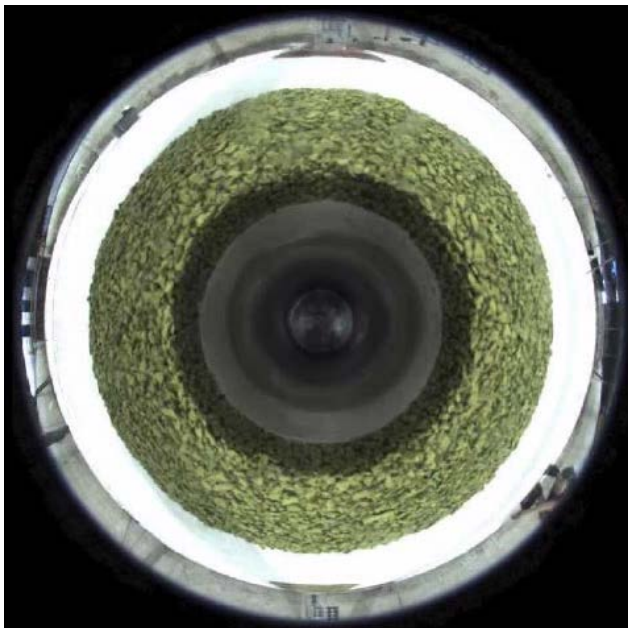
1. External stability
2. Internal stability (filter function)
3. Flexibility (performance around edge scour and in morphodynamic areas)
4. Ecological impact



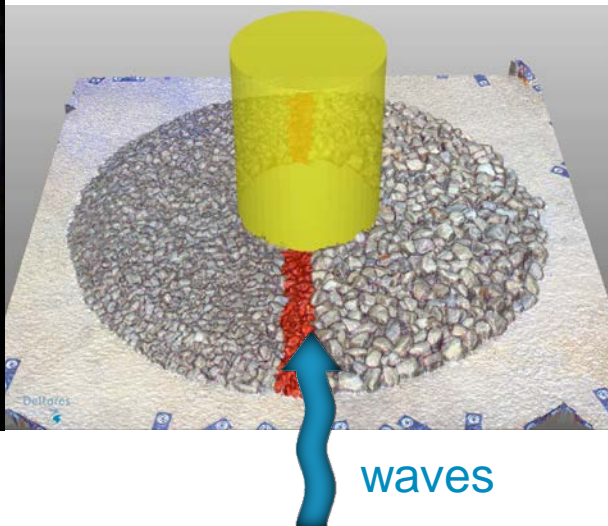
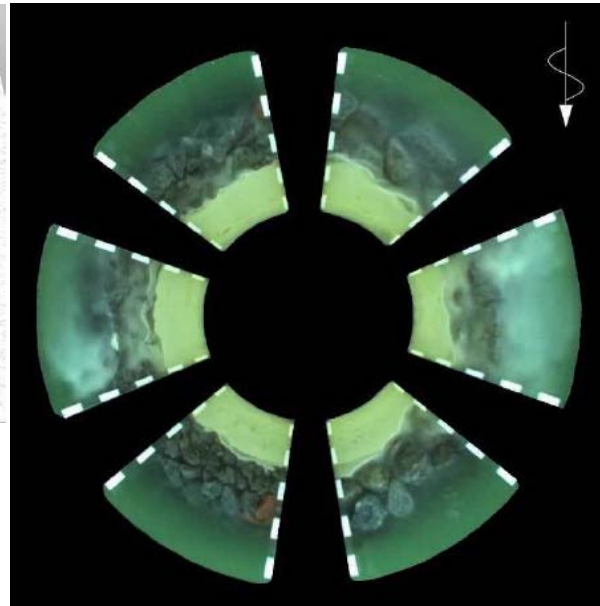
External stability



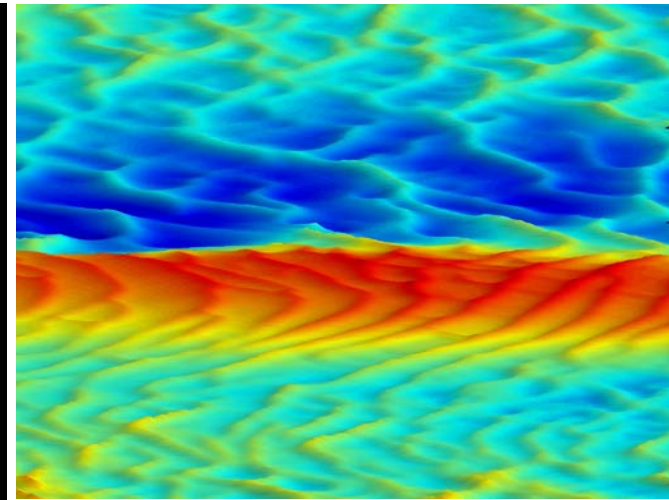
→ waves



Internal stability (winnowing)



Flexibility



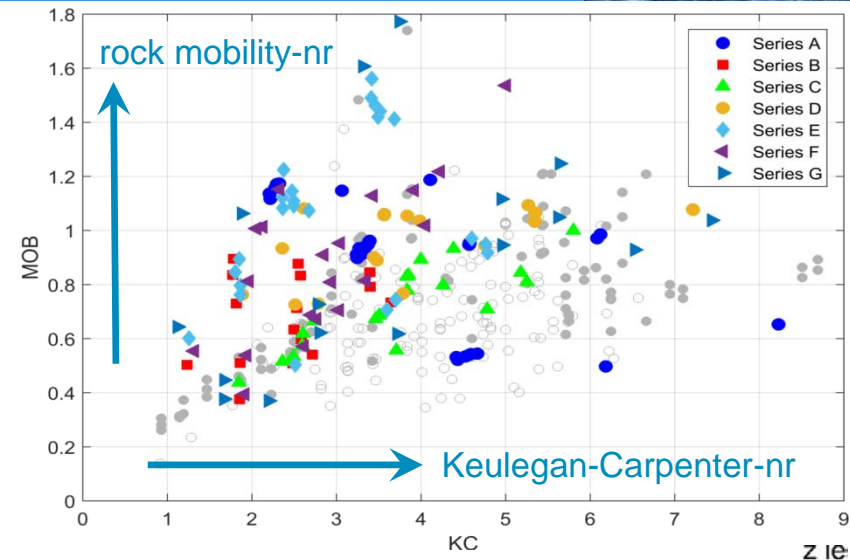
↔ tidal current



Test programme for rock protections

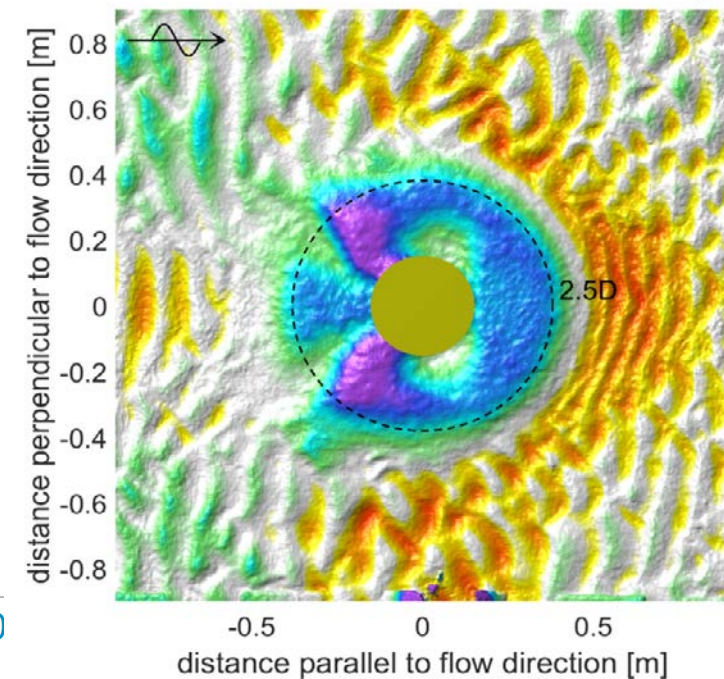


- Filling database for a multivariate space: (varying wave conditions, current conditions, water depth, pile diameter, rock size and grading width, rock density, protection layout, seabed lowering etc.)
- >148 (and counting) unique medium-scale tests and 11 unique large-scale results
- For every test we record the 3D-deformation patterns to derive quantitative deformation numbers
- 3D-deformation formula is being developed



test setup in
Delta Flume

3D-deformation
pattern



Innovative scour protection methods

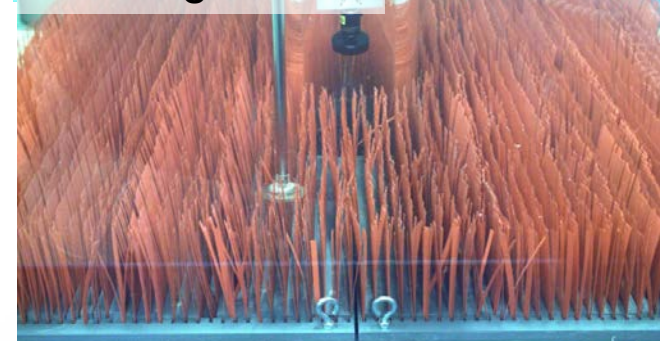


- First proof-of-concept tests on the smallest scale (fast cycle times, quick optimization), focusing on failure mechanisms and hydraulic stability
- Stepwise increase in hydraulic load.....until failure
- Selected concepts were optimized and tested on medium scale, also including interaction with mobile seabed: winnowing, edge scour, morphological seabed changes
- A further narrowed down selection of concepts was validated in large-scale tests in waves-only conditions, focusing on potential scale effects

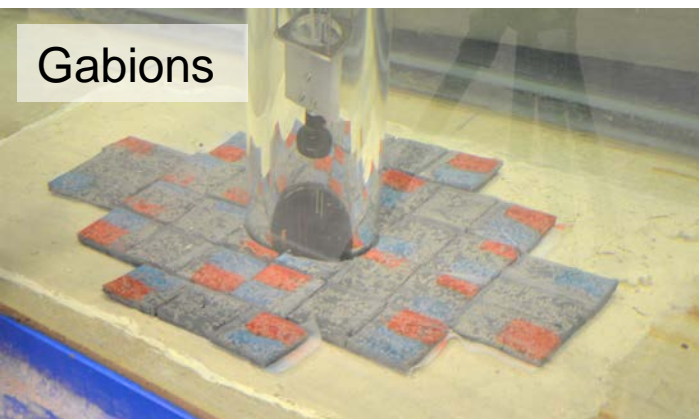
Flexible vegetation



Stiff vegetation



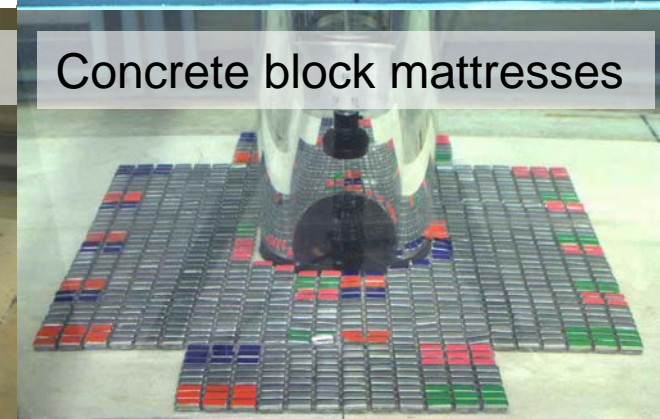
Gabions



Ballast-filled mattresses



Concrete block mattresses



Towards eco-friendly design of wind farms



- With increasing use of marine space by offshore wind farms and reducing LCoE, interest is increasing to enhance ecological value of wind farms and scour + cable protections in particular
- Rock protections (hard substrates) are already rich in ecology and show a great biodiversity (compared to the surrounding sandy seabed)
- Recently, research was conducted on potential ways to further enhance the ecological quality of scour protections
- Two umbrella species were selected:
 1. Atlantic cod (*Godus morhua*)
 2. European flat oyster (*Ostrella edulis*)
- Nature-inclusive design of scour protections attempts to target these umbrella species



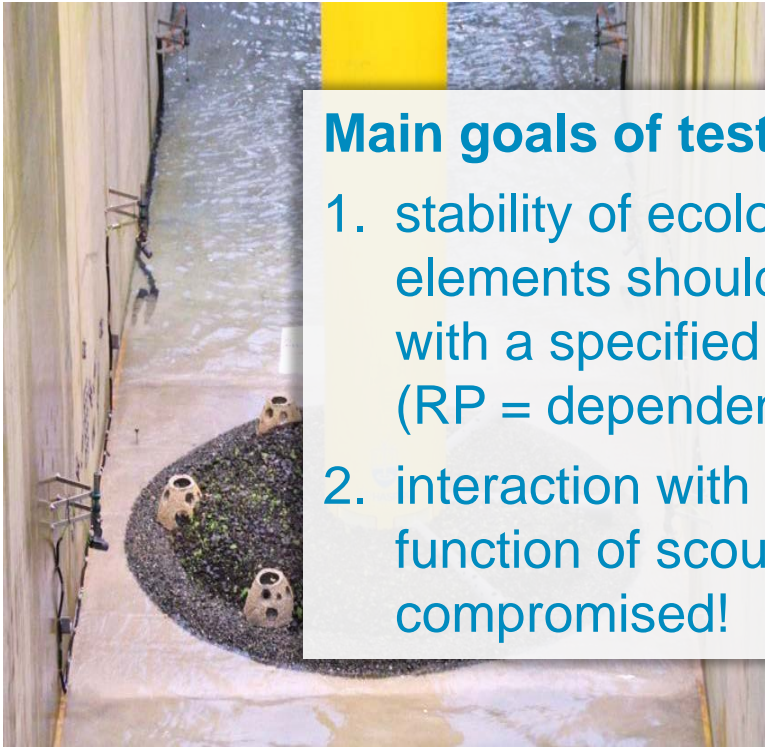
Lengkeek, Wouter; Didderen, K.; Teunis, M.; Driessen, F.; Coolen, J.W.P.; Bos, O.G.; Vergouwen, S.A.; Raaijmakers, T.; Vries, M.B. de; Koningsveld, M. van (2017)

Nature-inclusive designs tested in JIP HaSPro



Monopile scour protection:

Rock scour protection with integrated reef balls and perforated concrete tubes



Cable (crossing) protection:

Rock berms with loose oysters and with integrated reef balls

Gabion mattresses with top layer of rock replaced by oyster shells



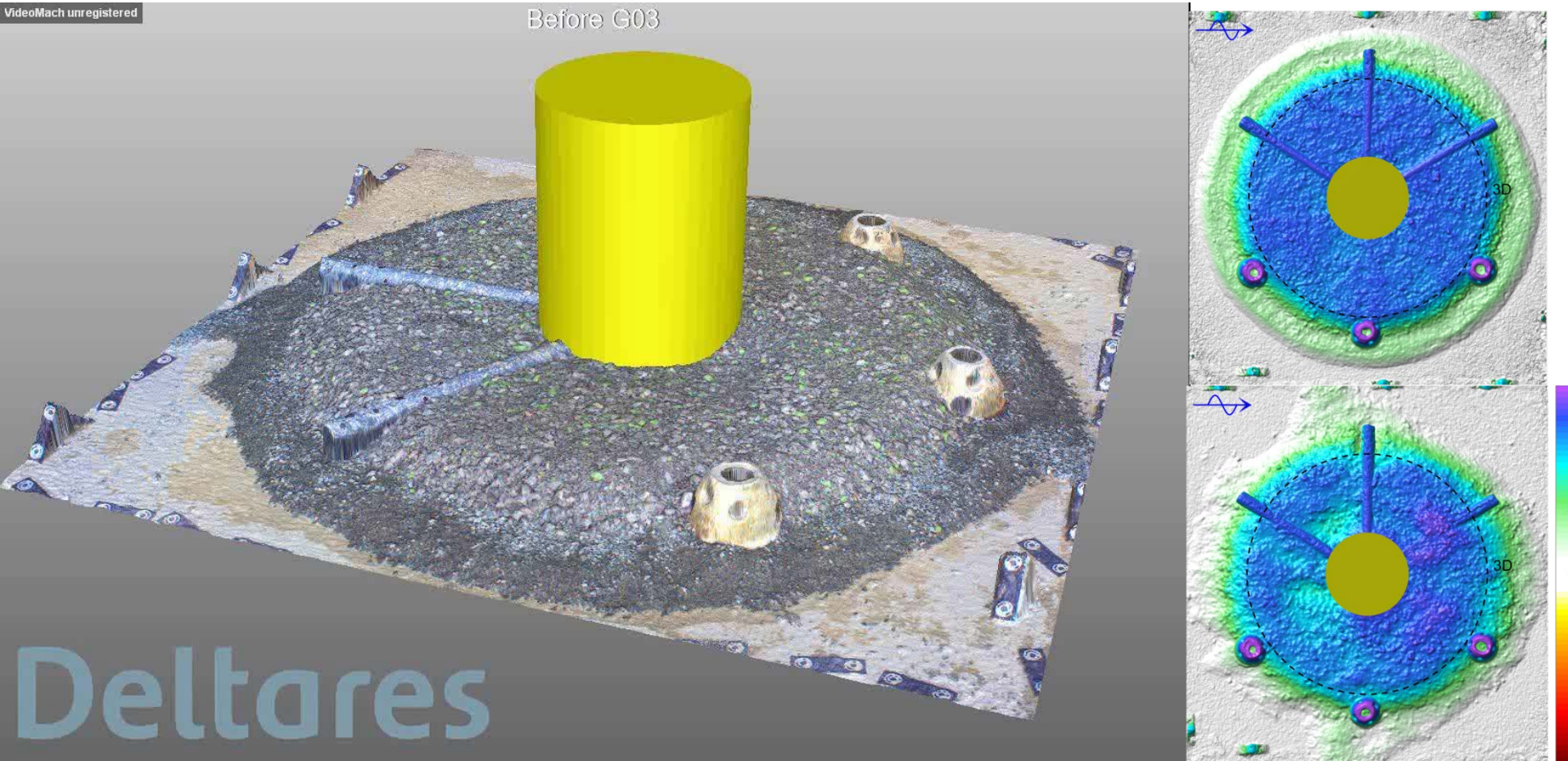
Main goals of test programme in JIP HaSPro:

1. stability of ecological concepts: the eco-elements should be able to survive a storm with a specified return period (RP = dependent on size of elements)
2. interaction with surrounding protection: function of scour/cable protection may not be compromised!

Deformation of scour protection during storm tests



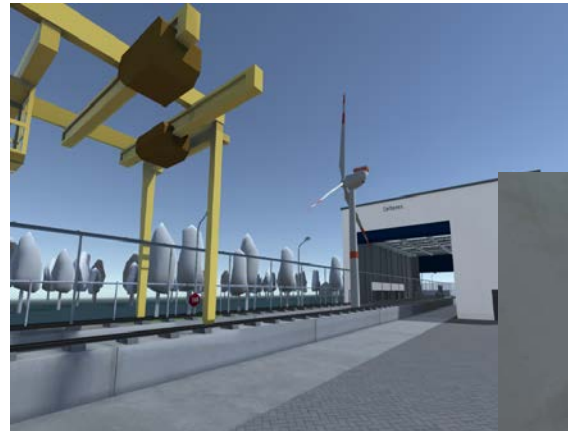
3D-animation switching between height maps and colour images of nature-inclusive scour protection (obtained with 3D-stereophotography)



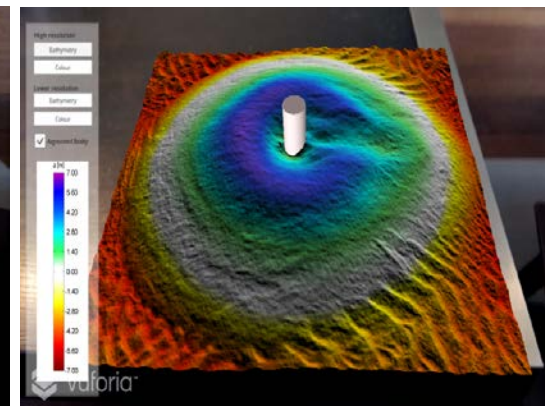
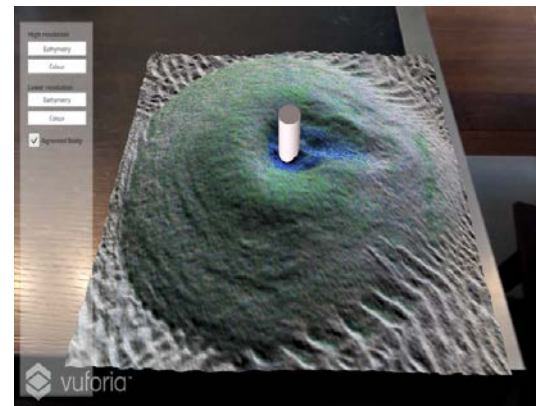
JIP HaSPro: innovative techniques



- JIP HaSPro is not just about some engineers playing in a large sandbox with water, sand and rocks
- Serious Game of Test Setup (to help design of experiments for non-experimentalists)
- Virtual Reality of Delta Flume
- Augmented Reality of 3D measurements
- Big Data (many Tb's)
- Automated motion detection to observe deformation of protection systems
- Pattern recognition of deformation patterns and classification by AI
- Machine Learning techniques on database of test results to develop/improve formulae



Serious Game incl. VR of model setup in Delta Flume



Augmented Reality: 3D-model results visualized on meeting table

Key take-aways

KEY TAKE AWAY

Together with **21 leading partners** in the offshore wind industry new knowledge is being developed on **scour and cable protection methods** in JIP HaSPro

KEY TAKE AWAY

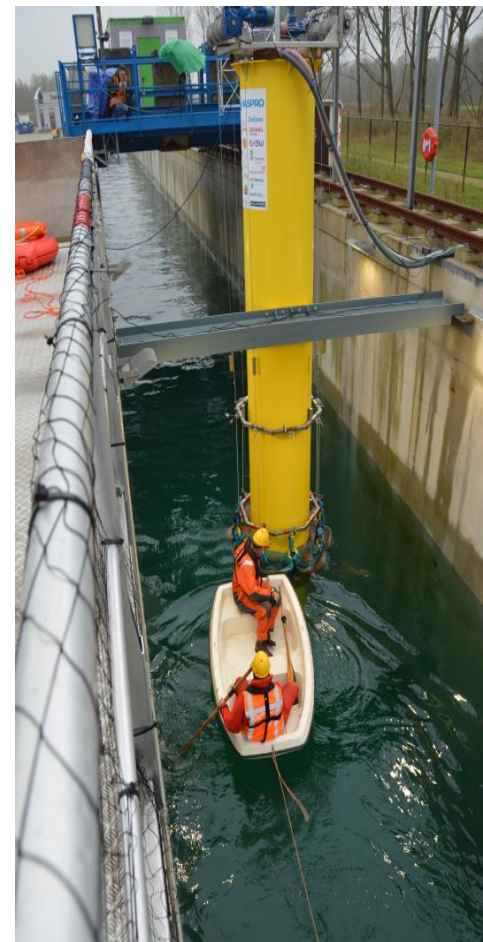
The most common method consisting of **loose rock** is being **optimized**, resulting in improved **design formulae** and engineering software (also for morphodynamic seabeds)

KEY TAKE AWAY

Several **innovative/alternative methods** were first tested conceptually on small-scale and then optimized in medium- and large-scale tests

KEY TAKE AWAY

Very promising **nature-inclusive scour protections** were tested on their hydraulic and morphological performance, but ecological functioning can only be tested in the field (in offshore pilots)



more information?



tim.raaijmakers@deltares.nl



Deltares