Rijkswaterstaat
Ministerie van Infrastructuur en Waterstaat

piLot Survey Services

Verification of rock dumped slopes

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Rockworks for coastal protection

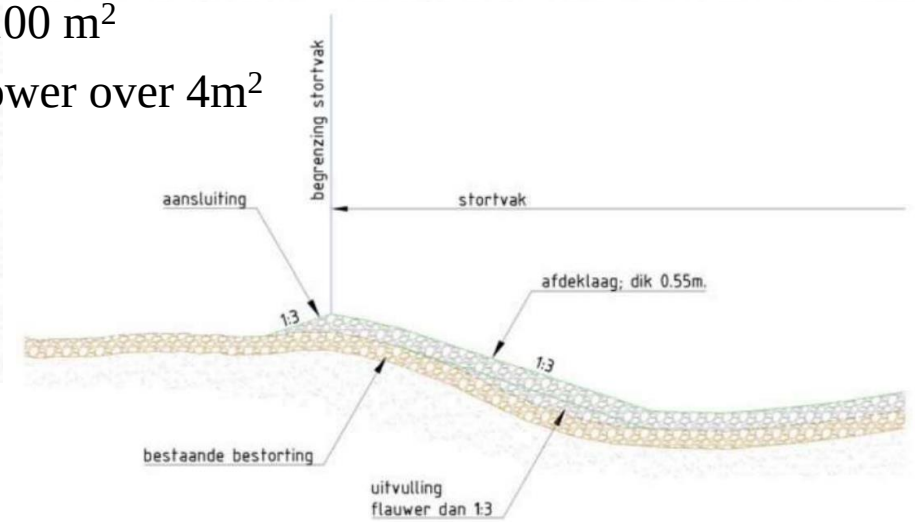
- Coastal protection
- Construction built from rock layers of variying gradations
- Rocks are dumped or placed
  - Shallow: placement
  - Deep water: dumping
- Volumes, slopes, gradations and layer thickness are engineered

Contract specification and verification

PFT-01 De taludhelling in het Microgrid dient te voldoen aan de minimale geëiste taludhelling 1:3 of flauwer.

- Design & Construct
  - Contract has main specifications
  - Contractor works these into a design
- Main specifications for example:
  - Minimum layer thickness e.g x m over 4 m^2
  - Average layer thickness e.g. y m over 100 m^2
  - Maximum slope angle e.g. 1:3 or shallower over 4m^2

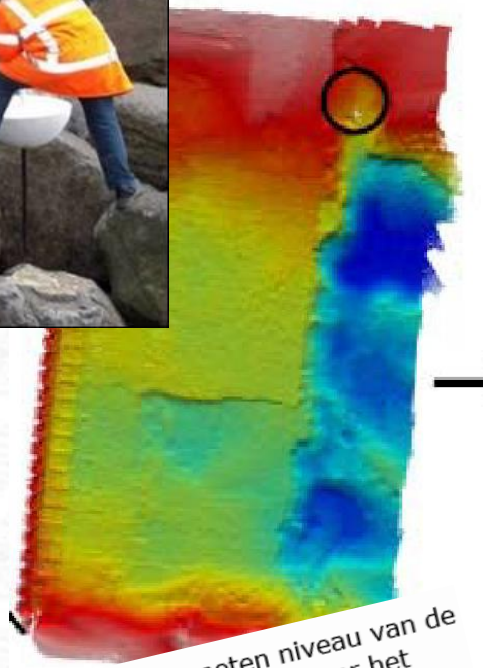
    -> steeper slopes may lead to instability



Survey and verification methods

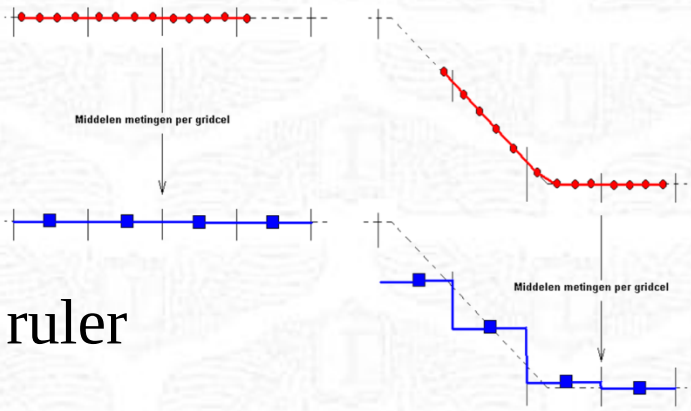
- Formal method: 1x1 semi-sphere grid
- Multibeam surveys are the standard
  - Results are ‘binned’ in e.g. 1x1 grid
  - Requirements for accuracy & coverage
- Minimum, average layer:

  SBRCURnet: Construction and survey accuracies for rockworks (2014)
- Slopes: no standard (2018)



VVL-01 Voor elke gridcel in het Basis-grid dient het gemeten niveau van de bovenkant van elke gerealiseerde laag te zijn vertaald naar het referentieniveau volgens de systematiek uit paragraaf 3.4.3.1 van [SBRCURnet, 2014], op de volgende wijze:

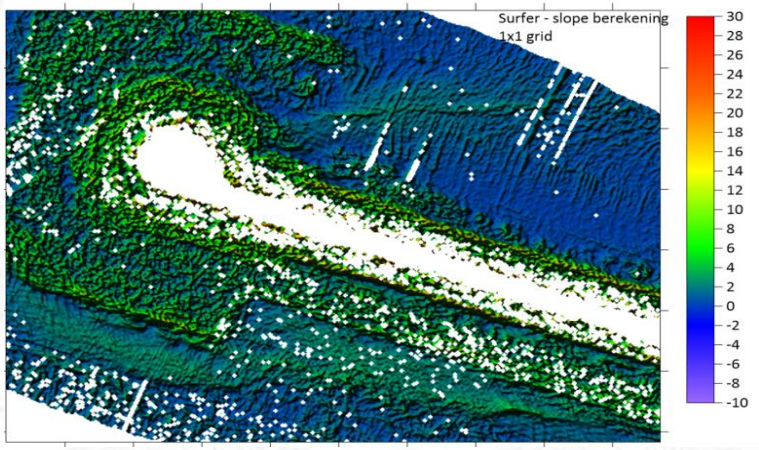
Slope verification



- Traditional:
  - Plot profiles and take best ‘fit’ using ruler
- Issues detected:
  - Subjective, discussions
  - Profile direction determines slope
  - MBES grid are averages, not a true profile
  - Layer thickness is perpendicular to slope, not vertical
  - Sub-optimal use of available data

Alternative: GIS methods

- Objective?!
- Uses MBES data gridded
- Requires comparable data
  - Design & survey must be gridded
- Same input = same output?
  - Many different formulas
    - Horn is often used
  - Software implementation?



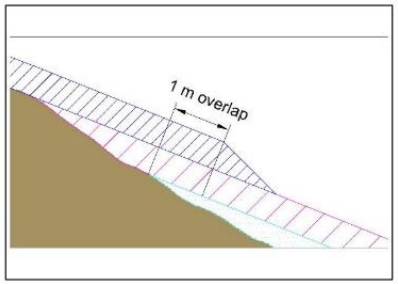
$$S_T \approx \frac{360}{2\pi} \cdot \arctan\left[\sqrt{\left(\frac{Z_E - Z_W}{2\Delta x}\right)^2 + \left(\frac{Z_N - Z_S}{2\Delta y}\right)^2}\right]$$

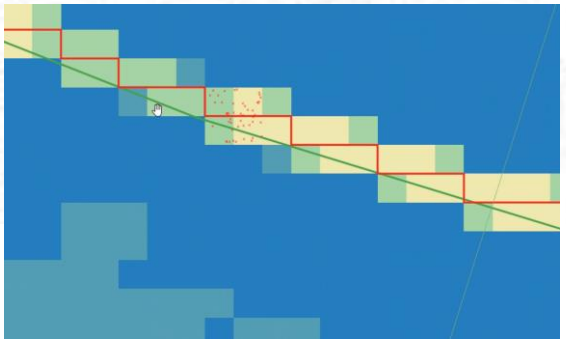
Approach 1 (2018 – 2021)

- Grid design from profiles / 3D model into 1x1
  - Create very small bins (0.1 x 0.1) and average
- Contratror: verify slope computation using Rijkswaterstaat reference software (Surfhelling)
- Grid survey into 1x1
  - Compute layer thickness (SBRCURNet, 2014)
  - Compute slope using verified method

Results: Approach 1

- Method generally works, but:
  - Surfhelling software difficult to operate
  - Slope from Surfhelling has artefacts
  - Layer thickness essentially defines slope
    - If design is correctly translated into grid model
  - ‘Transition’ effects where construction meets original bottom

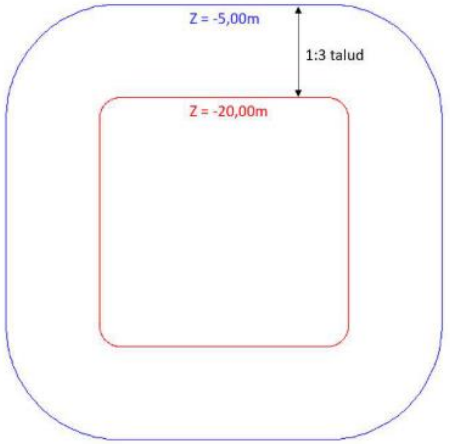




Approach 2 (2022 -)

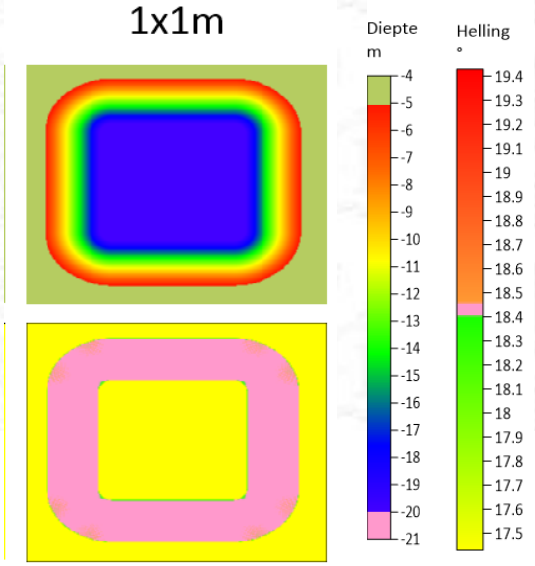
- Verify slope computation against theoretical model (computation <= theoretical slope)
- Verify design model for slope and layer thickness
- Verify layer thickness against design from surveys

Theoretical 1:3 model



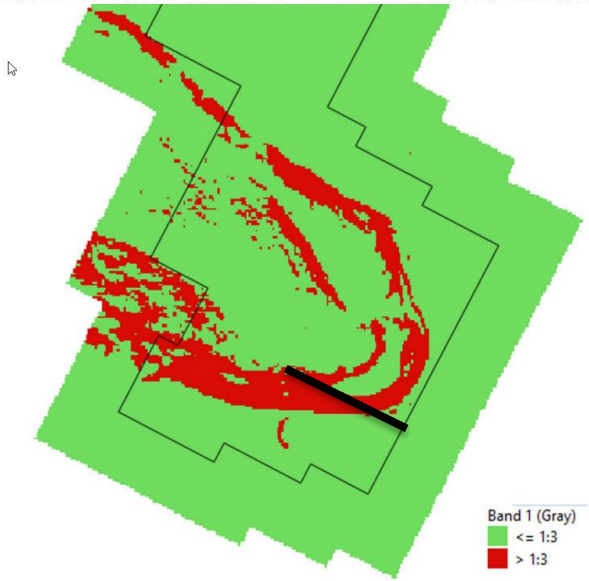
Depth

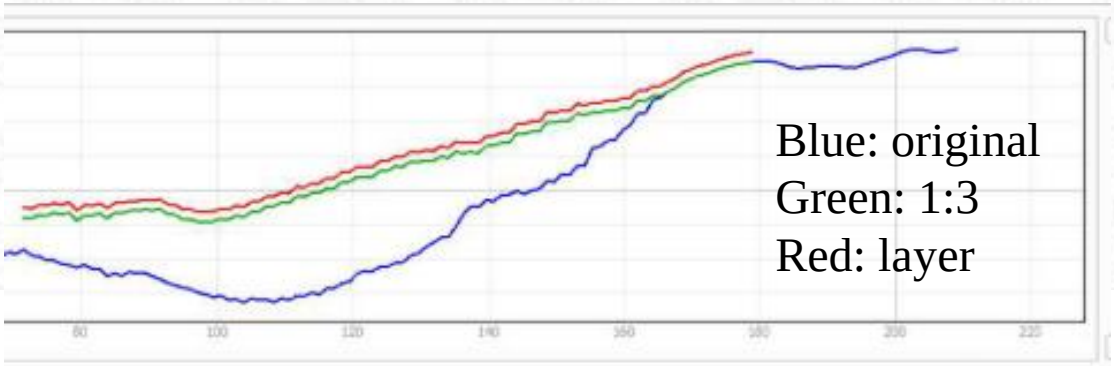
Slope (Horn)



Initial results

- New methods, requires new thinking
- Shift towards 3D designs
- Shift towards automatic computation of designs in GIS
  - Automatically compute maximum slope from bathymetry





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Thank you for your attention!