



CoDES: AN INTEGRATED AND INTERACTIVE TOOLBOX FOR THE DESIGN OF COASTAL INFRASTRUCTURE

Freek Scheel

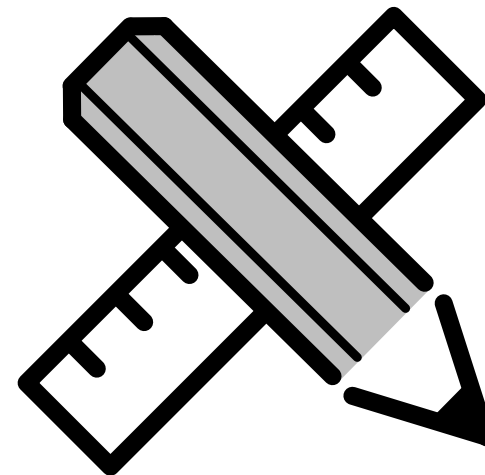
Wiebe de Boer, Arjen Luijendijk, Ronald Stive & Ruud Bouw

Deltares

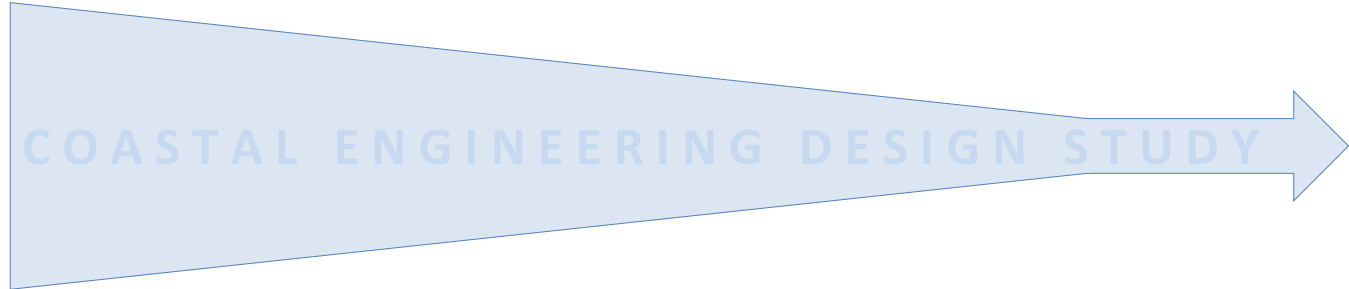
Enabling Delta Life



- Motivation
- Introduction to CoDeS
- Overview of functionality
- Impression of key functionalities
 - Generic data
 - CoDeS tools
- Highlights & conclusions
- Future developments



1. Motivation



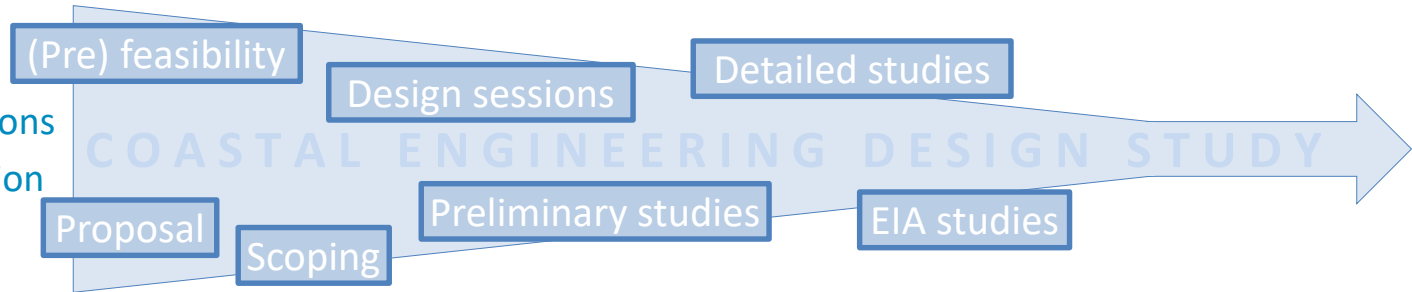
- Research questions
- Problem definition

- Answers
- Solutions



1. Motivation

- Research questions
- Problem definition



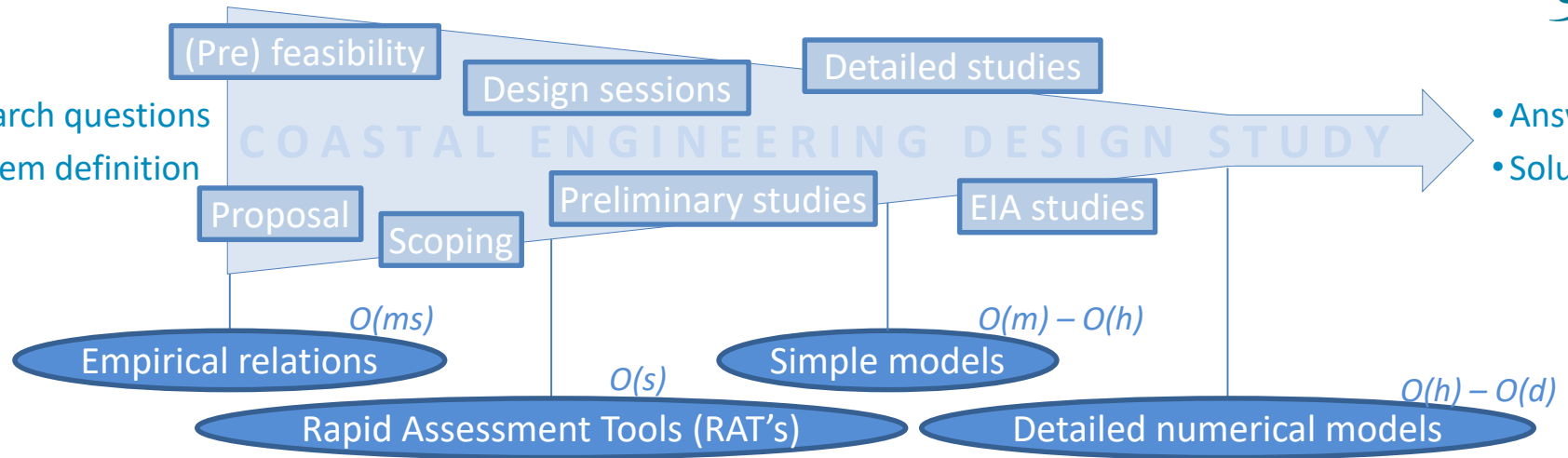
- Answers
- Solutions



1. Motivation

- Research questions
- Problem definition

- Answers
- Solutions

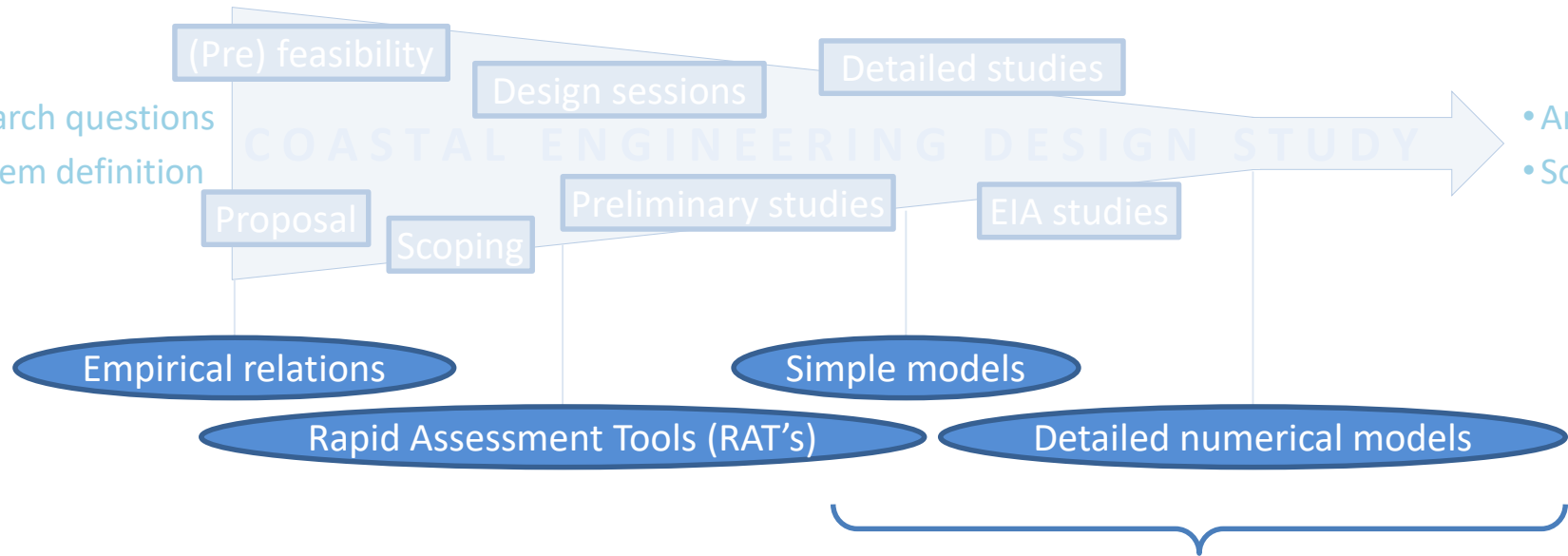




1. Motivation

- Research questions
- Problem definition

- Answers
- Solutions



Increasingly complex physics, therefore

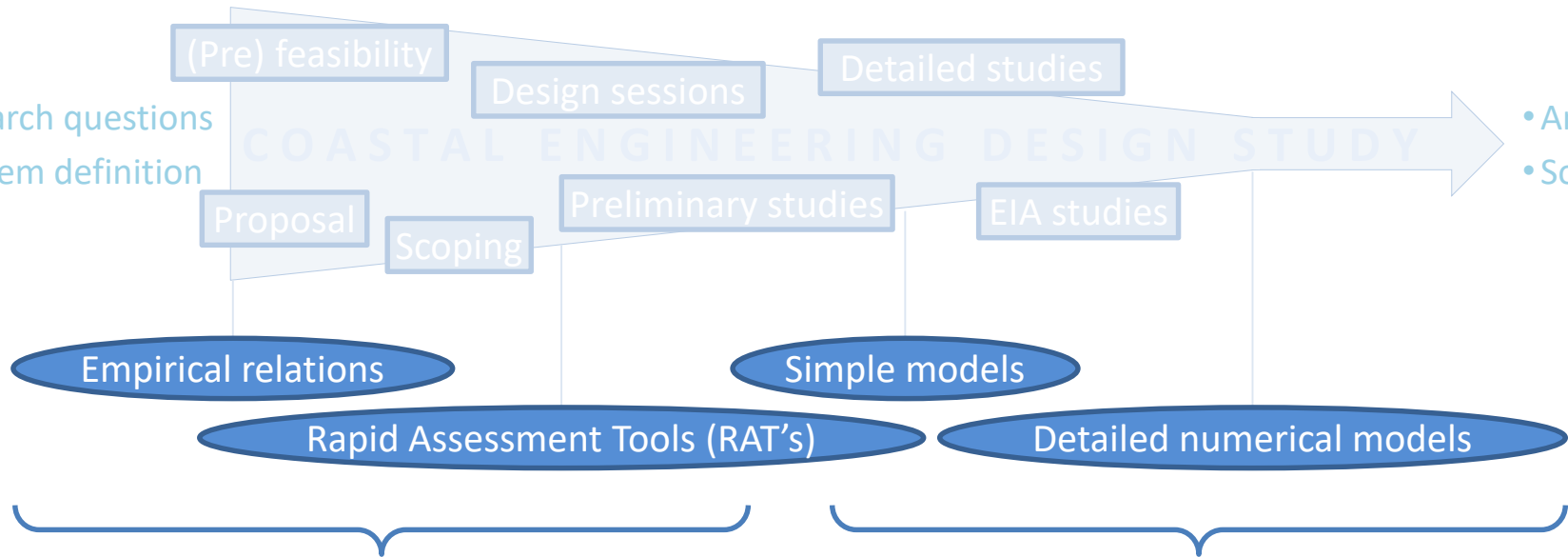
- Computationally demanding
- Hardly interactive
- Hard to integrate disciplines
- Professionally developed & validated



1. Motivation

- Research questions
- Problem definition

- Answers
- Solutions



Not consistently developed, potential for:

- Discipline integration
- Uniform and clear visualizations
- Validation and robustness
- Interactivity

Increasingly complex physics, therefore

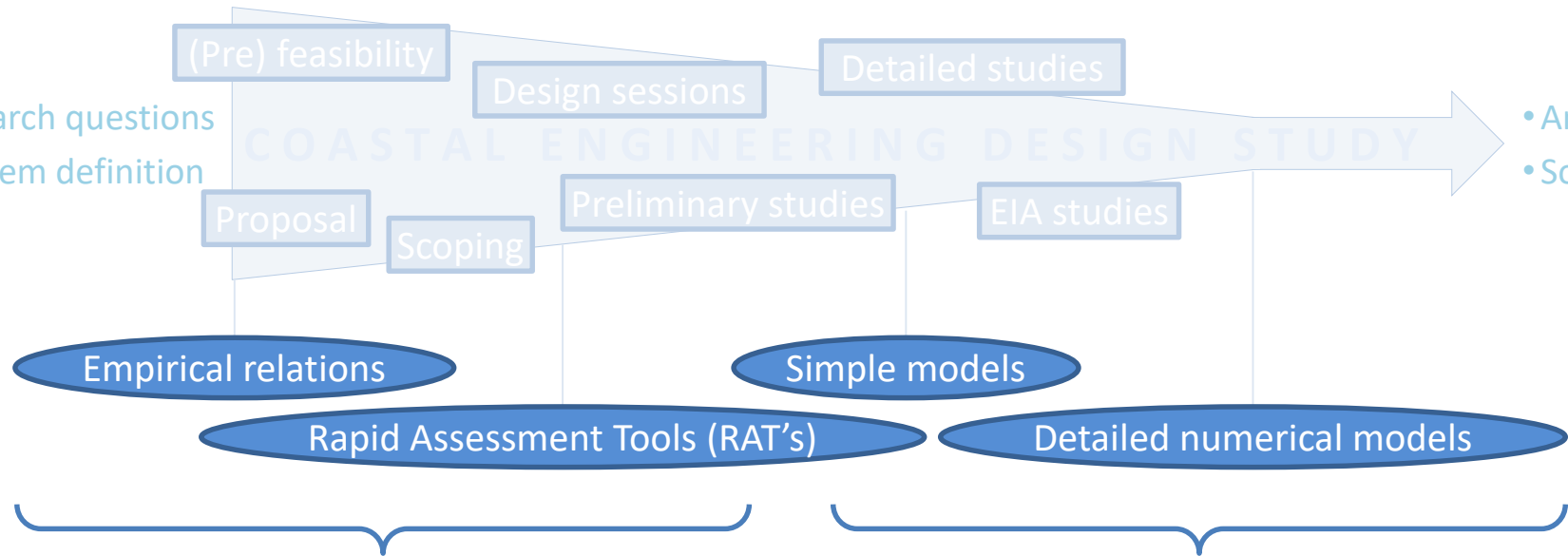
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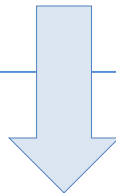


Not consistently developed, potential for:

- Discipline integration
- Uniform and clear visualizations
- Validation and robustness
- Interactivity

Increasingly complex physics, therefore

- Computationally demanding
- Hardly interactive
- Hard to integrate disciplines
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CoDeS Tools (Coastal Design & Support Tools) are aimed at harvesting this potential

What is CoDeS ⁽¹⁾

- A framework in which tools from different disciplines are implemented, with focus on:
 - Validation
 - Consistency
 - Robustness
 - Discipline integration
 - Interactivity (fast tools)

} Gain confidence in basic tools

→ Optimizing designs

→ Communication with clients & stakeholders (design sessions)
- Supporting clients & stakeholders in early design phases of interventions in coastal systems
- Developed in a consortium formed by:



- Developing an open community in which engineers can contribute to the framework


⁽¹⁾ CoDeS tools → Coastal Design & Support Tools

3. CoDeS – Overview

 Generic data

 Settings

 Coastline


 Bathymetry


 Structures


 Waves

 Tide

 Sediment


CoDeS Tools 

Coastline dynamics 


Breakwater design 

Wave penetration 

Channel sedimentation 

Harbour basin siltation 

eCoDeS 

Interactive flow fields 

3. CoDeS – Overview



Generic data

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Bathymetry

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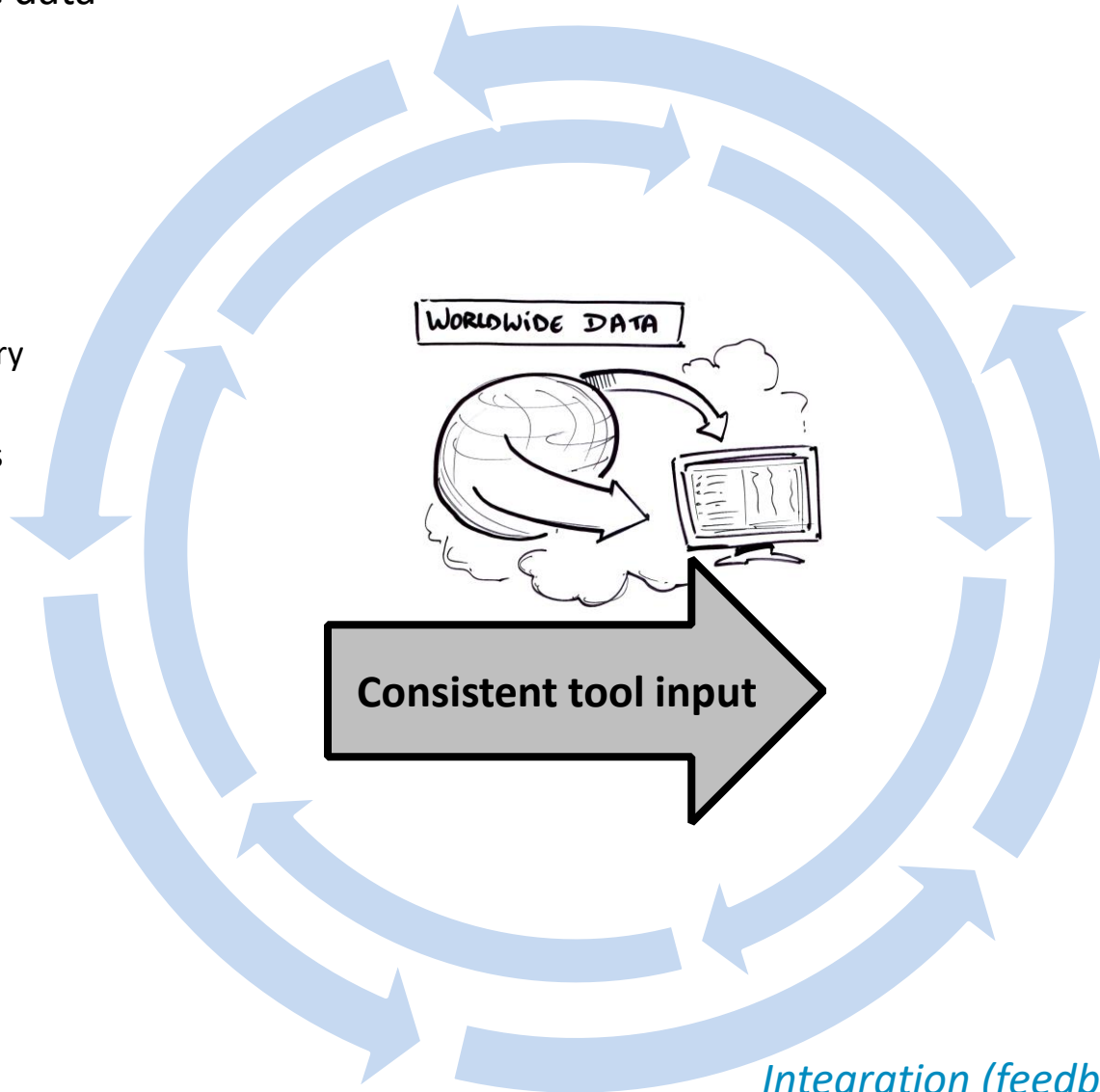
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Integration (feedback) between all tools

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4. CoDeS – Generic data – Bathymetry



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4. CoDeS – Generic data – Bathymetry



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Generic data



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Coastline



Bathymetry



Structures



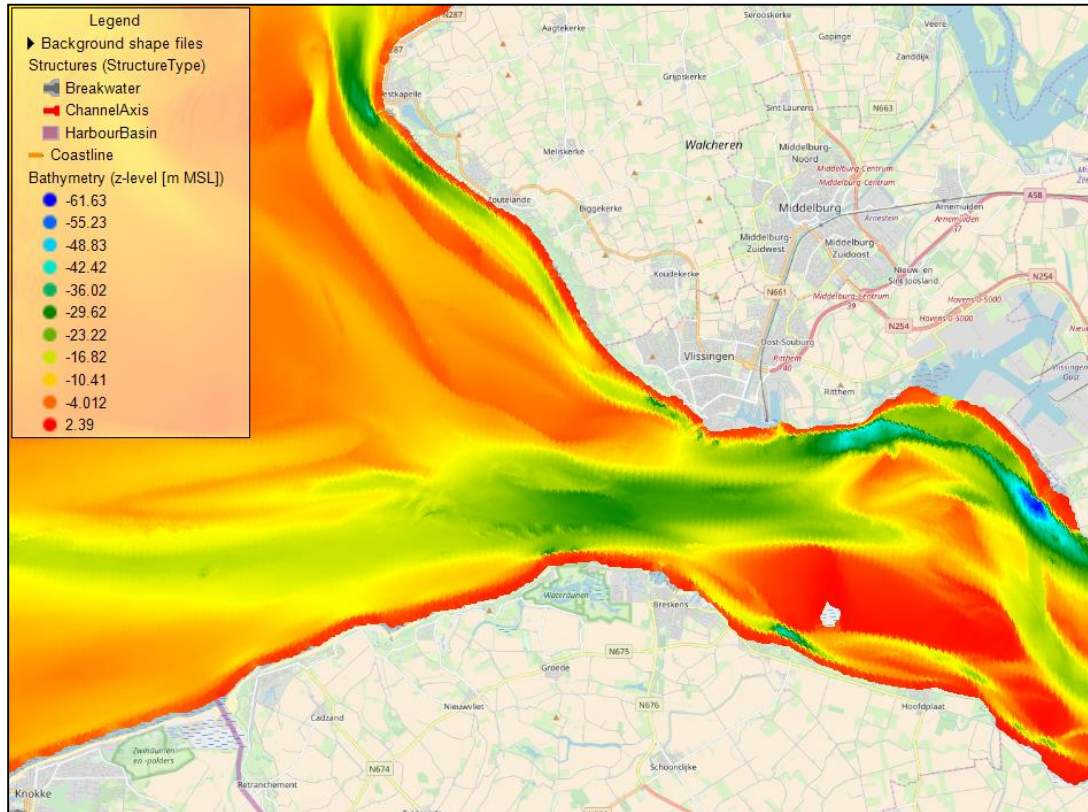
Waves



Tide



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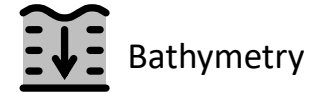


- Define cross-shore profiles and/or load spatial fields
- Work with different coordinate systems
- Create and modify bathymetry data:





4. CoDeS – Generic data – Bathymetry



Choose coordinate system

WGS 84 / UTM zone

- Geographic Coordinate Systems
- Projected Coordinate Systems
 - WGS 84 / UTM zone 1N [EPSG:32601]
 - WGS 84 / UTM zone 2N [EPSG:32602]
 - WGS 84 / UTM zone 3N [EPSG:32603]
 - WGS 84 / UTM zone 4N [EPSG:32604]
 - WGS 84 / UTM zone 5N [EPSG:32605]
 - WGS 84 / UTM zone 6N [EPSG:32606]
 - WGS 84 / UTM zone 7N [EPSG:32607]
 - WGS 84 / UTM zone 8N [EPSG:32608]
 - WGS 84 / UTM zone 9N [EPSG:32609]
 - WGS 84 / UTM zone 10N [EPSG:32610]
 - WGS 84 / UTM zone 11N [EPSG:32611]
 - WGS 84 / UTM zone 12N [EPSG:32612]
 - WGS 84 / UTM zone 13N [EPSG:32613]
 - WGS 84 / UTM zone 14N [EPSG:32614]
 - WGS 84 / UTM zone 15N [EPSG:32615]
 - WGS 84 / UTM zone 16N [EPSG:32616]
 - WGS 84 / UTM zone 17N [EPSG:32617]
 - WGS 84 / UTM zone 18N [EPSG:32618]**
 - WGS 84 / UTM zone 19N [EPSG:32619]
 - WGS 84 / UTM zone 20N [EPSG:32620]
 - WGS 84 / UTM zone 21N [EPSG:32621]
 - WGS 84 / UTM zone 22N [EPSG:32622]
 - WGS 84 / UTM zone 23N [EPSG:32623]

PROJ.4: +proj=utm +zone=18 +datum=WGS84 +units=m +no_defs

WKT:
 PROJCS["WGS 84 / UTM zone 18N",
 GEOGCS["WGS 84",
 DATUM["WGS_1984",
 SPHEROID["WGS 84", 6378137.298, 257223563,
 AUTHORITY["EPSG", "7030"]],
 AUTHORITY["EPSG", "6326"]],
 PRIME["Greenwich", 0],
 AUTHORITY["EPSG", "8901"]],
 UNIT["degree", 0.0174532925199433,
 AUTHORITY["EPSG", "9122"]],
 AUTHORITY["EPSG", "4326"]],
 PROJECTION["Transverse_Mercator"],
 PARAMETER["latitude_of_origin", 0],
 PARAMETER["central_meridian", -75],
 PARAMETER["scale_factor", 0.9996],
 PARAMETER["false_easting", 500000],
 PARAMETER["false_northing", 0],
 UNIT["metre", 1],
 AUTHORITY["EPSG", "9001"]],
 AXIS["Easting", EAST],
 AXIS["Northing", NORTH],
 AUTHORITY["EPSG", "32618"]]

OK Cancel

CoDeS Tools

Coastline dynamics

Breakwater design

Wave penetration

Channel sedimentation

Harbour basin siltation

eCoDeS

Interactive flow fields

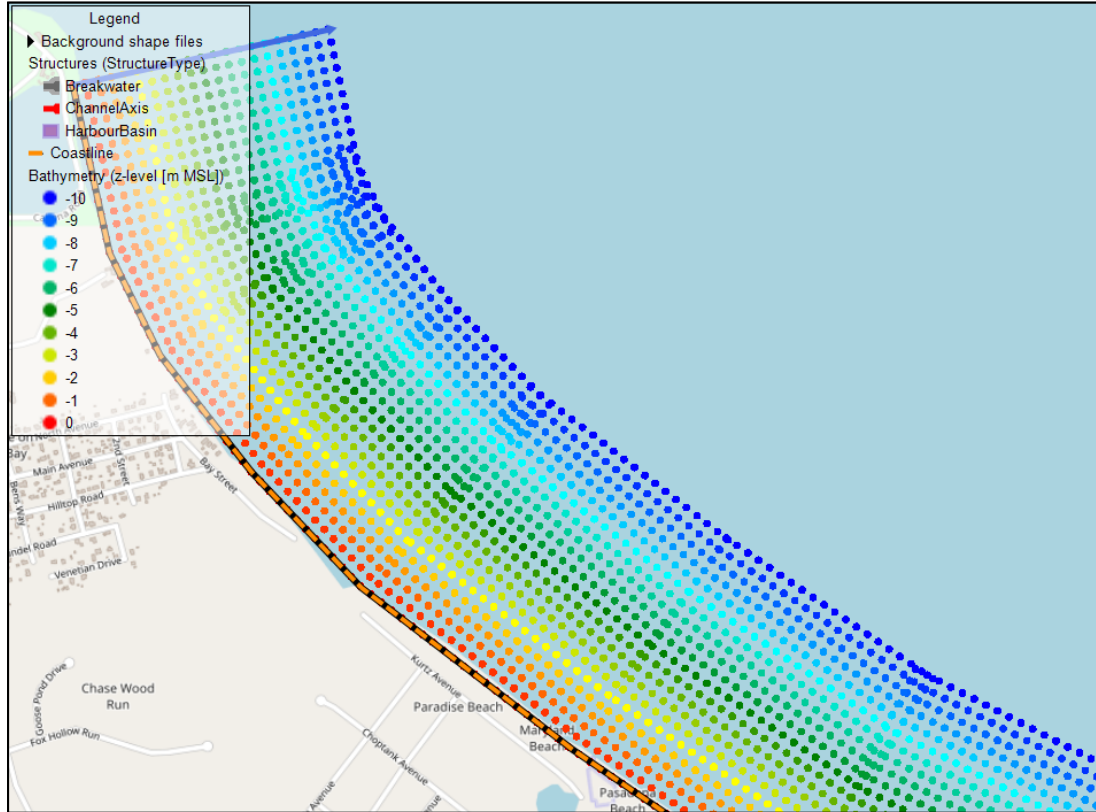
- Define cross-shore profiles and/or load spatial fields
- Work with different coordinate systems
- Create and modify bathymetry data:



4. CoDeS – Generic data – Bathymetry

Generic data

- Settings
- Coastline
- Bathymetry
- Structures
- Waves
- Tide
- Sediment



- CoDeS Tools
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- eCoDeS
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4. CoDeS – Generic data – Bathymetry



Generic data



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Coastline



Bathymetry



Structures



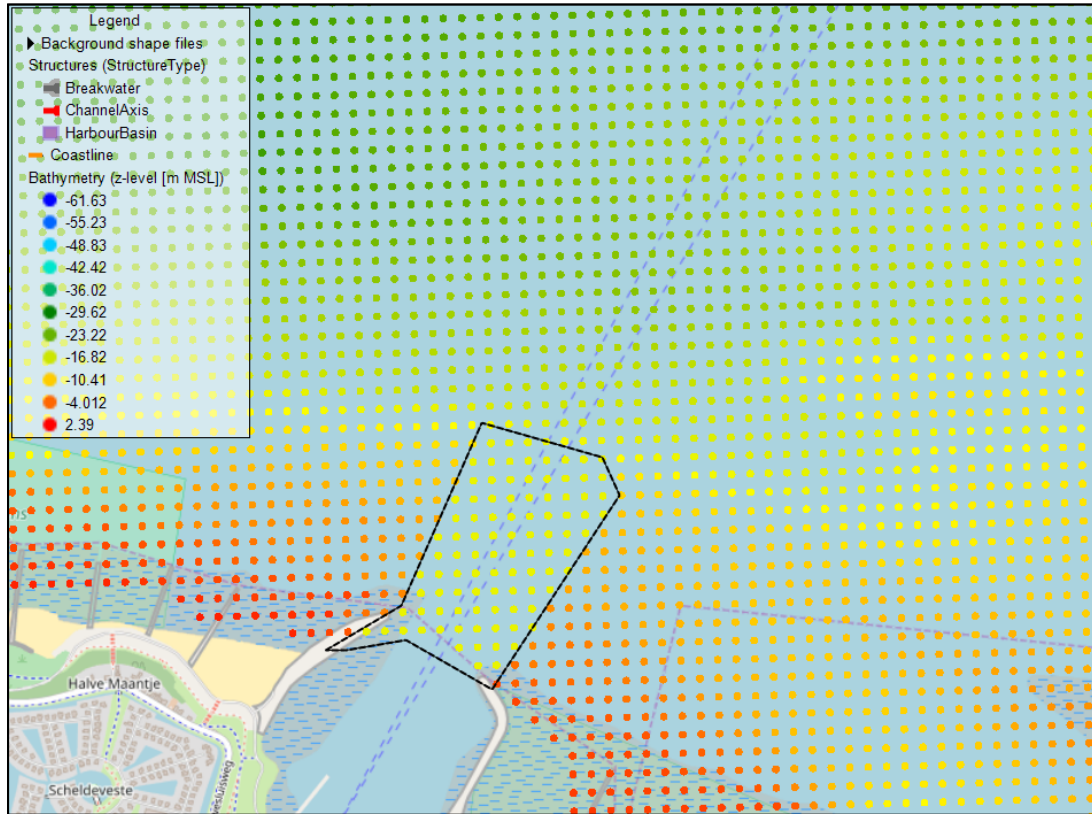
Waves



Tide



Sediment



CoDeS Tools



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eCoDeS



Interactive flow fields



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4. CoDeS – Generic data – Bathymetry

 Generic data

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4. CoDeS – Generic data – Structures

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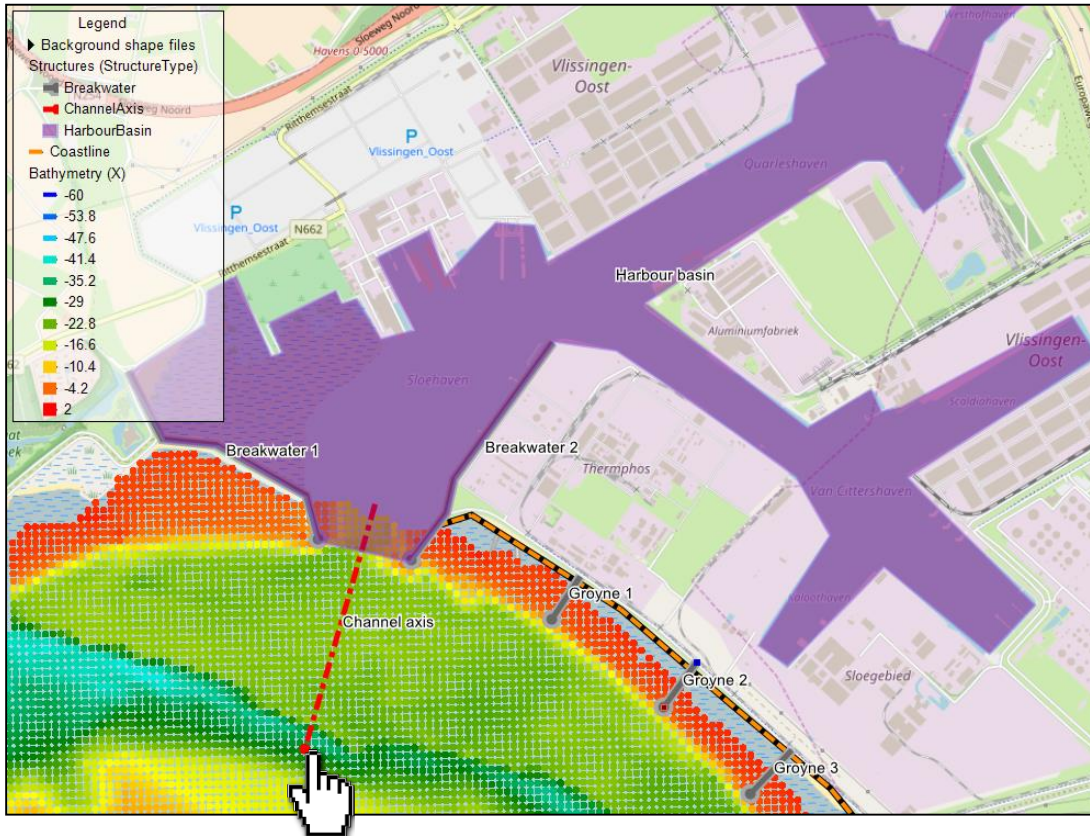
Waves



Tide



Sediment



- Design & manage structures, harbour basin, channel axis, etc.

CoDeS Tools



Coastline dynamics



Breakwater design



Wave penetration



Channel sedimentation



Harbour basin siltation



eCoDeS



Interactive flow fields




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4. CoDeS – Generic data – Waves



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Generic data



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Bathymetry



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Sediment

The screenshot shows the CoDeS software interface. On the left, there is a sidebar with a tree view containing: Bathymetry, Structures, Waves, Wave climate, Extreme wave climate (optional), and Information. The 'Wave climate' section is expanded, showing a table with columns: Hs [m], Tp [s], Dir [deg N], and Occurrence [-]. Below the table are controls for 'Wave location' (Nearshore/Offshore) and 'Offshore depth' [m]. The 'Extreme wave climate (optional)' section also has a table with columns: Hs [m], Tp [s], and Dir [deg N]. On the right, a map shows a coastal area with labels like 'Boschplaat', 'Terschellinger Wad', and 'Ameland Airport Bolkum'. A 'Classify wave climate' dialog box is open over the map, with fields for ΔH_s [m], ΔT_p [s], and ΔDir [deg]. A 'Compress wave climate into bins' button is also visible.

Hs [m]	Tp [s]	Dir [deg N]	Occurrence [-]
1.037	7.557	328.3	0.0006823
1.043	7.556	347.3	0.002957
1.062	8.364	10.02	0.000796
1.035	8.152	333.6	0.0005686
1.048	8.399	345.1	0.002729
1.046	9.435	2.21	0.0002274

Hs [m]	Tp [s]	Dir [deg N]
3.54	9.78	246.3
4.05	11.04	238.4

- Load wave data (time series, climates, extreme waves)
- Instantly create joint occurrence tables & wave roses:
- Wave climate input reduction (bin compression)
- Offshore → nearshore wave transformation in all tools (linear wave theory)




4. CoDeS – Generic data – Waves

 Generic data

 Settings

 Coastline

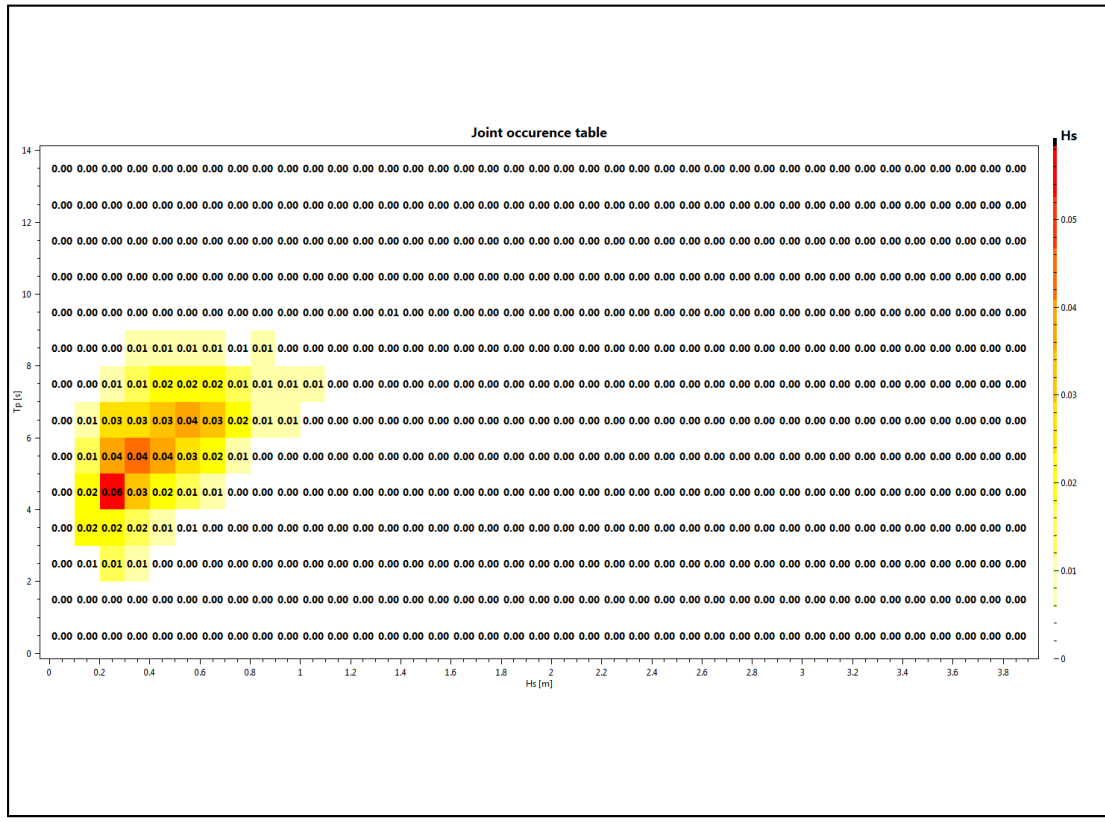
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Breakwater design 



Wave penetration 

Channel sedimentation 

Harbour basin siltation 

eCoDeS 

Interactive flow fields 

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4. CoDeS – Generic data – Waves



Generic data



Settings



Coastline



Bathymetry



Structures



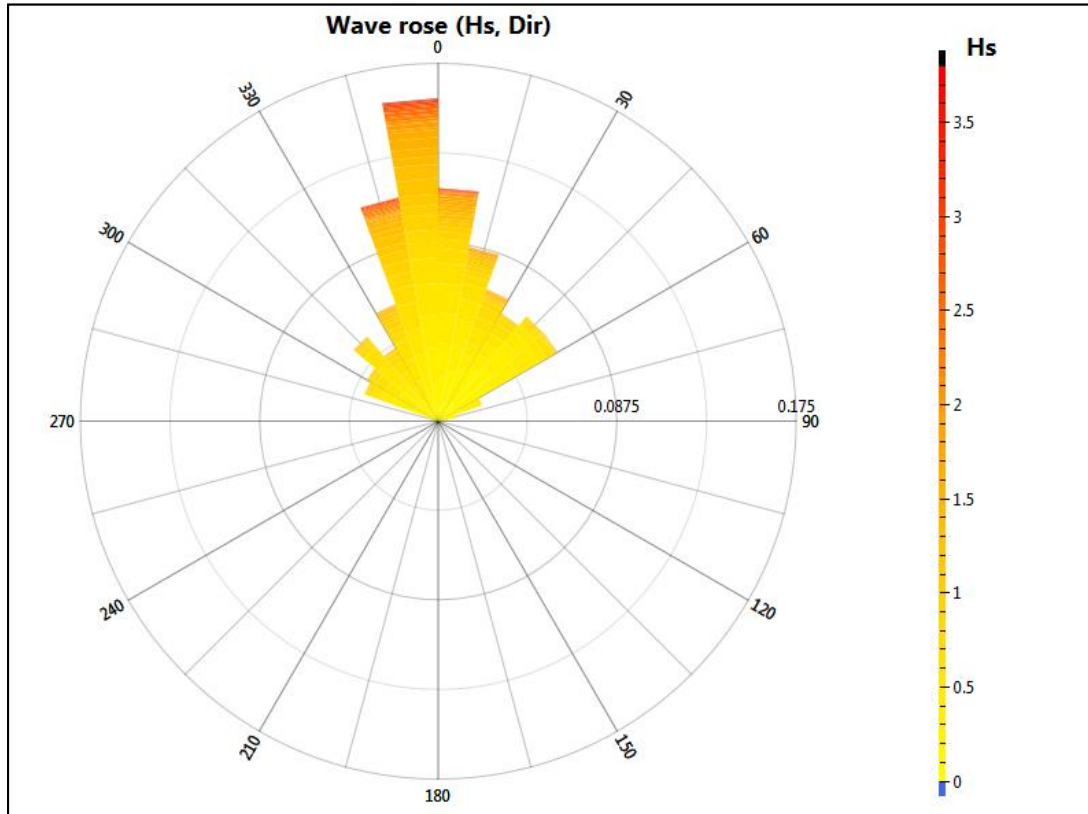
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eCoDeS



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4. CoDeS – Generic data – Waves



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4. CoDeS – Generic data – Tide



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Generic data



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Sediment

The screenshot shows the CoDeS software interface. On the left is a sidebar with a menu: Bathymetry, Structures, Waves, Tide, Vertical tide, Horizontal tide, and Information. The 'Vertical tide' section is active, displaying a table of tidal components and a table of tidal classifications. The 'Horizontal tide' section has input fields for maximum ebb and flood flow, and radio buttons for 'Along-shore tide' and 'Cross-shore tide'. On the right is a map of the Atlantic coast from North America to the Caribbean, with a mouse cursor pointing to the Florida peninsula.

Name	Amp. [m]	Phase [deg]
O1	0.01402	-25.37
P1	0.002	-90
Q1	0.004472	-26.57

Name	Level [m]
HAT	0.687
MHWS	0.593
MHW	0.505
MHWN	0.394
MSL	4.73E-05
MLWN	-0.444
MLW	-0.506
MLWS	-0.578
LAT	-0.694

- Obtain tidal components anywhere on earth (TPXO 8.0)
- Instantly create water level time series
- Classify to vertical tidal levels (LAT – MSL - HAT, etc.)

4. CoDeS – Generic data – Tide



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The screenshot shows the 'Vertical tide' settings panel on the left and a map of the Caribbean region in the center. Below the map is a graph titled 'Tidal waterlevel from components' showing a blue line representing water level over time. The y-axis is 'Water level wr.t. MSL [m]' ranging from -0.2 to 0.4. The x-axis is 'Hours' ranging from 550 to 850. The graph shows a regular oscillating pattern with a period of approximately 12 hours.

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4. CoDeS – Generic data – Tide

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4. CoDeS – Generic data – Consistent tool input

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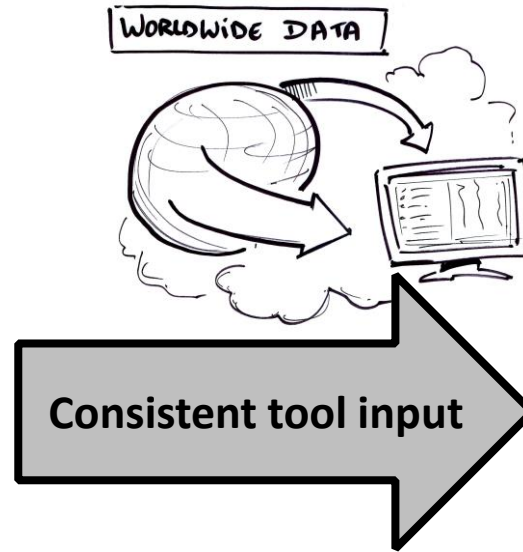
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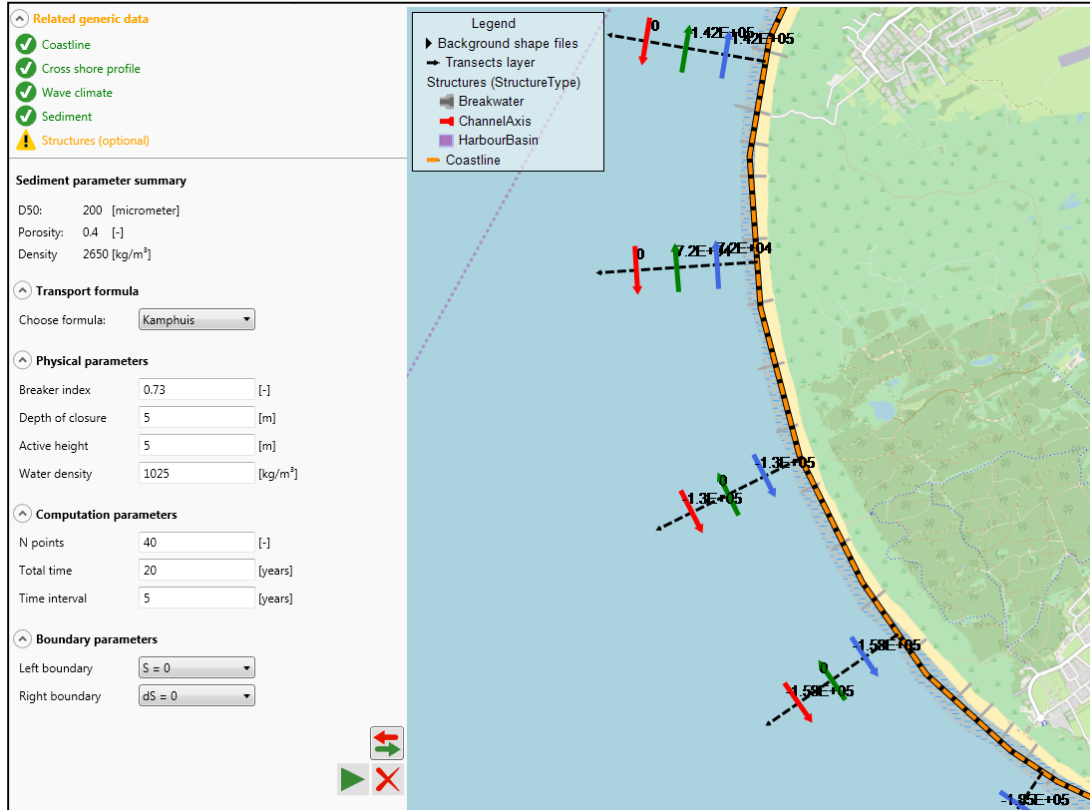
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Interactive flow fields


- Inspect $S-\phi$ curves
- Gross/net alongshore transports (CERC & Kamphuis)
- Coastline dynamics, incl. structures (Pelnard-Considère)

4. CoDeS – CoDeS Tools – Coastline dynamics

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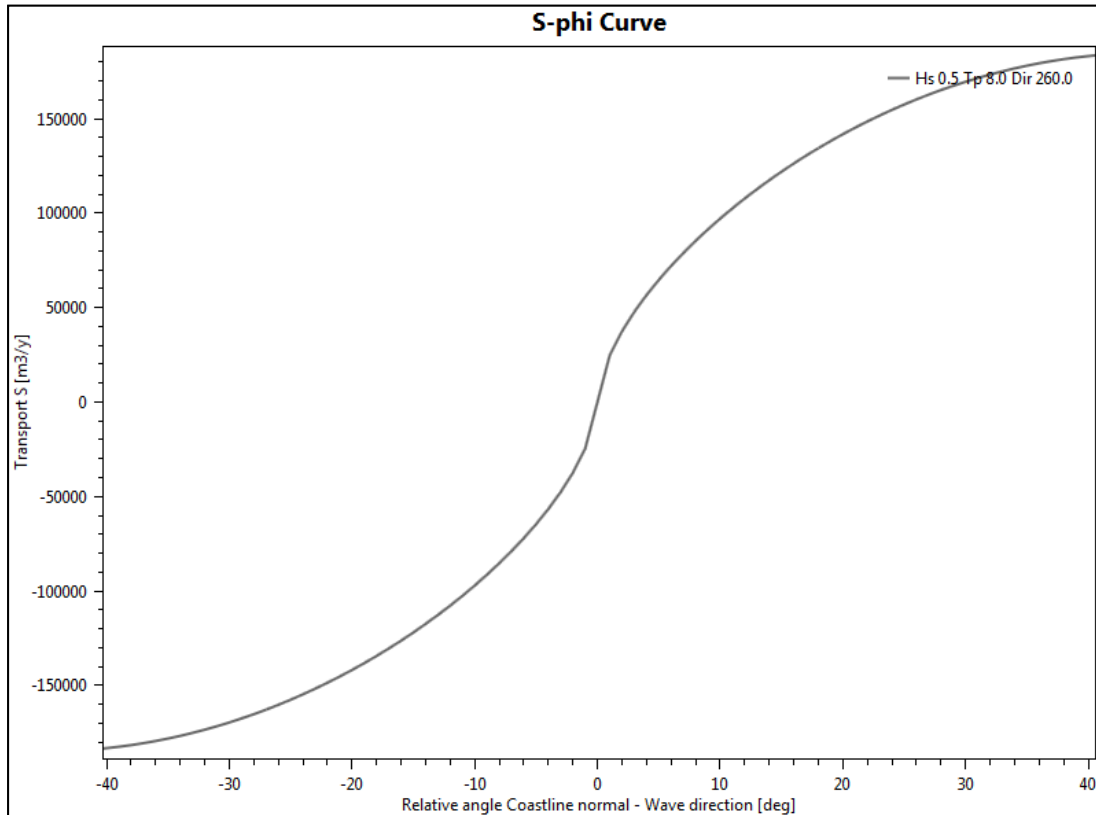
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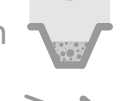


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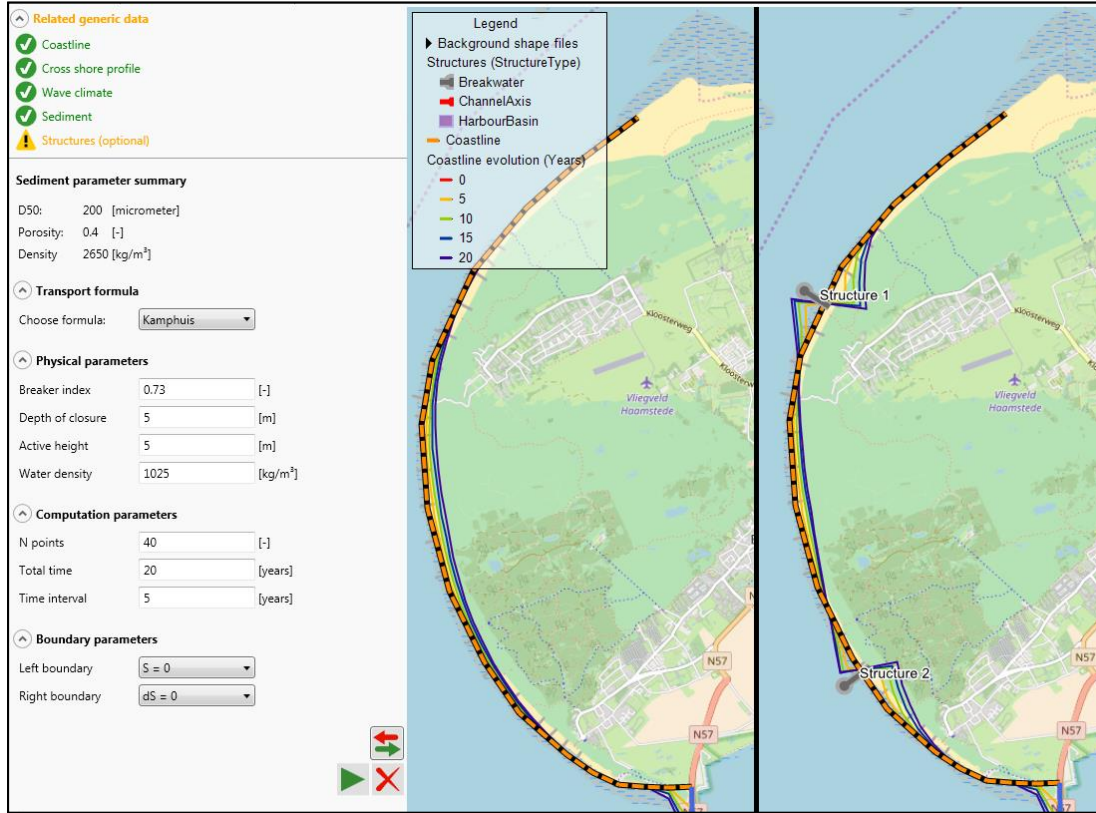
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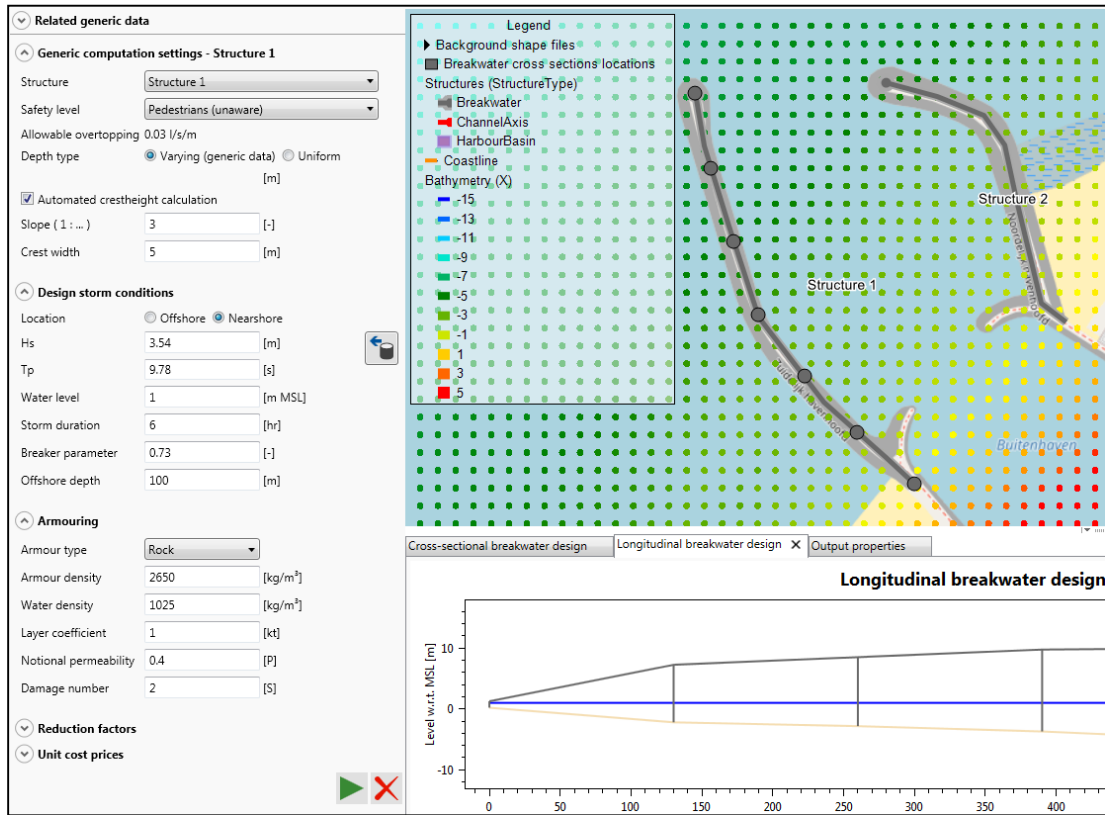
Wave penetration 

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eCoDeS 

Interactive flow fields 




- Design rubble mound breakwaters (rock manual)
- Due to varying waves, bathy, overtopping, safety levels, etc.
- Armor, filter & core layer design, dimensions, volumes & costs estimate

4. CoDeS – CoDeS Tools – Breakwater design

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Coastline dynamics 


Breakwater design 

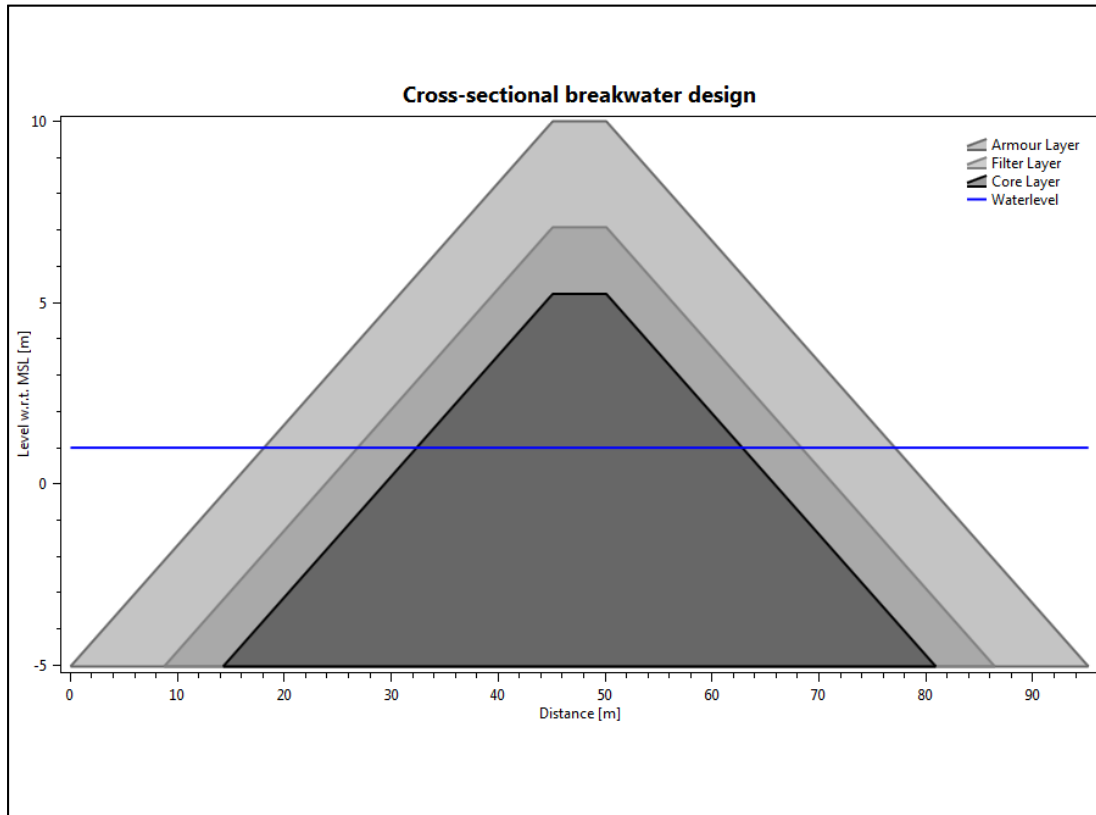
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Channel sedimentation 

Harbour basin siltation 








eCoDeS 

Interactive flow fields 

4. CoDeS – CoDeS Tools – Wave penetration

-  Generic data
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-  Bathymetry
-  Structures
-  Waves
-  Tide
-  Sediment

CoDeS Tools


- Coastline dynamics 
- Breakwater design 
- Wave penetration** 
- Channel sedimentation 
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4. CoDeS – CoDeS Tools – Wave penetration

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Coastline dynamics 


Breakwater design 

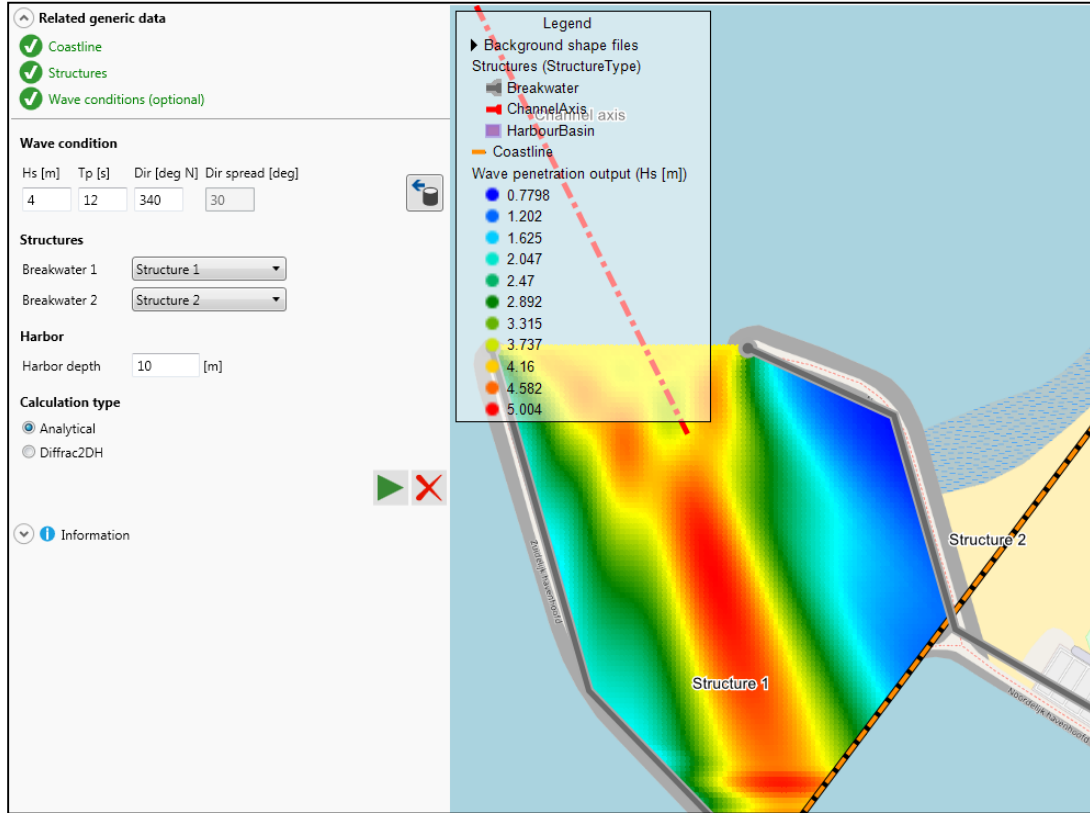
Wave penetration 

Channel sedimentation 

Harbour basin siltation 

eCoDeS 

Interactive flow fields 




- Wave penetration in a harbour basin, based on diffraction patterns
- Combined Sommerfeld solutions (Cornu spirals) or DIFFRAC-2DH

4. CoDeS – CoDeS Tools – Wave penetration

 Generic data

 Settings

 Coastline

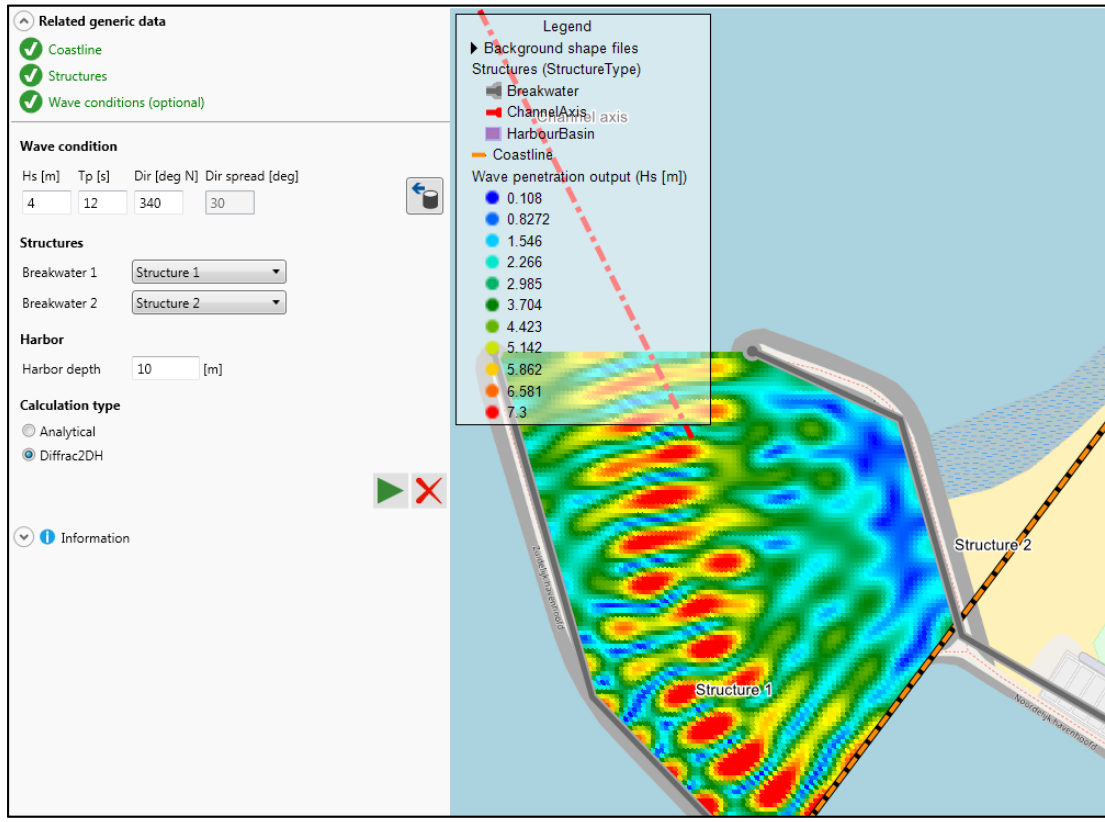
 Bathymetry

 Structures

 Waves

 Tide


 Sediment



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 Generic data

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 Sediment


CoDeS Tools 

Coastline dynamics 


Breakwater design 

Wave penetration 

Channel sedimentation 

Harbour basin siltation 





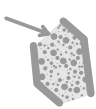


eCoDeS 

Interactive flow fields 

4. CoDeS – CoDeS Tools – Channel sedimentation

-  Generic data
-  Settings
-  Coastline
-  Bathymetry
-  Structures
-  Waves
-  Tide
-  Sediment

CoDeS Tools

- Coastline dynamics 
- Breakwater design 
- Wave penetration 
- Channel sedimentation** 
- Harbour basin siltation 
- eCoDeS 
- Interactive flow fields 

4. CoDeS – CoDeS Tools – Channel sedimentation



CoDeS Tools



Generic data



Settings



Coastline



Bathymetry



Structures



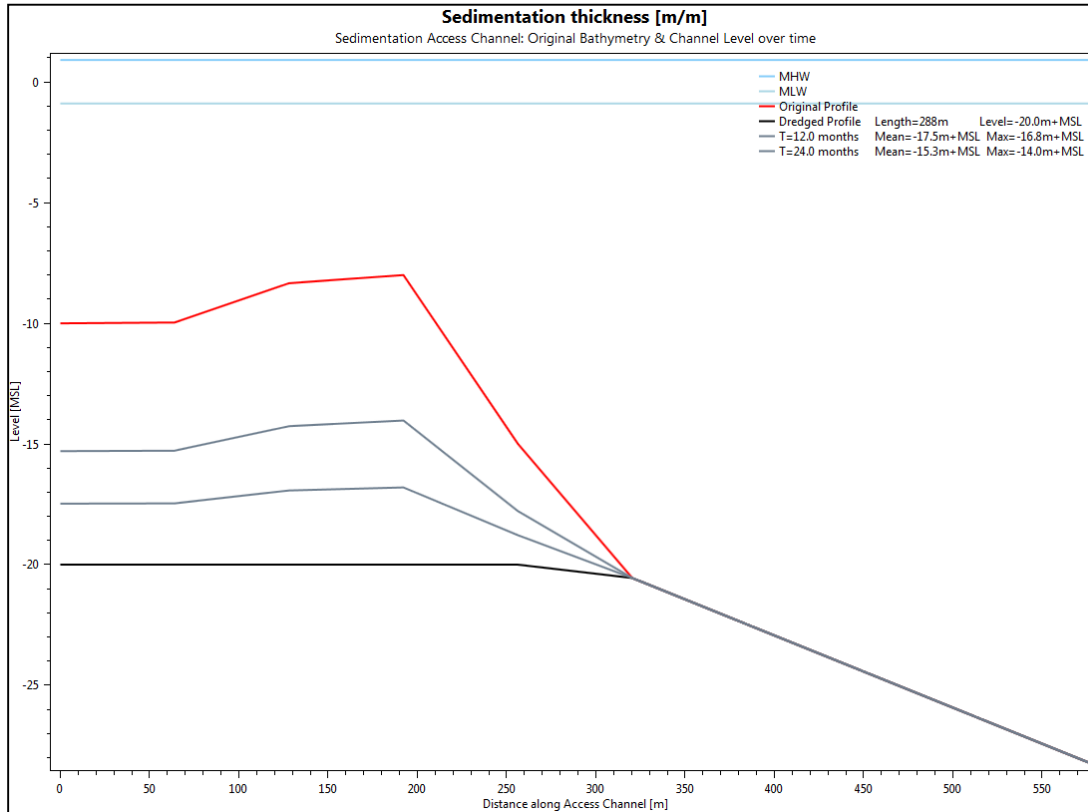
Waves



Tide



Sediment



Coastline dynamics



Breakwater design



Wave penetration



Channel sedimentation



Harbour basin siltation



eCoDeS



Interactive flow fields



- Sedimentation in access channel (based on v. Rijn tool SEDPIT)
- Morphodynamic feedback loop & automated sensitivity analysis
- Along & cross channel visualizations & bulk quantities
- Due to tide, waves, sediment characteristics & geometry

4. CoDeS – CoDeS Tools – Channel sedimentation



Generic data



Settings



Coastline



Bathymetry



Structures



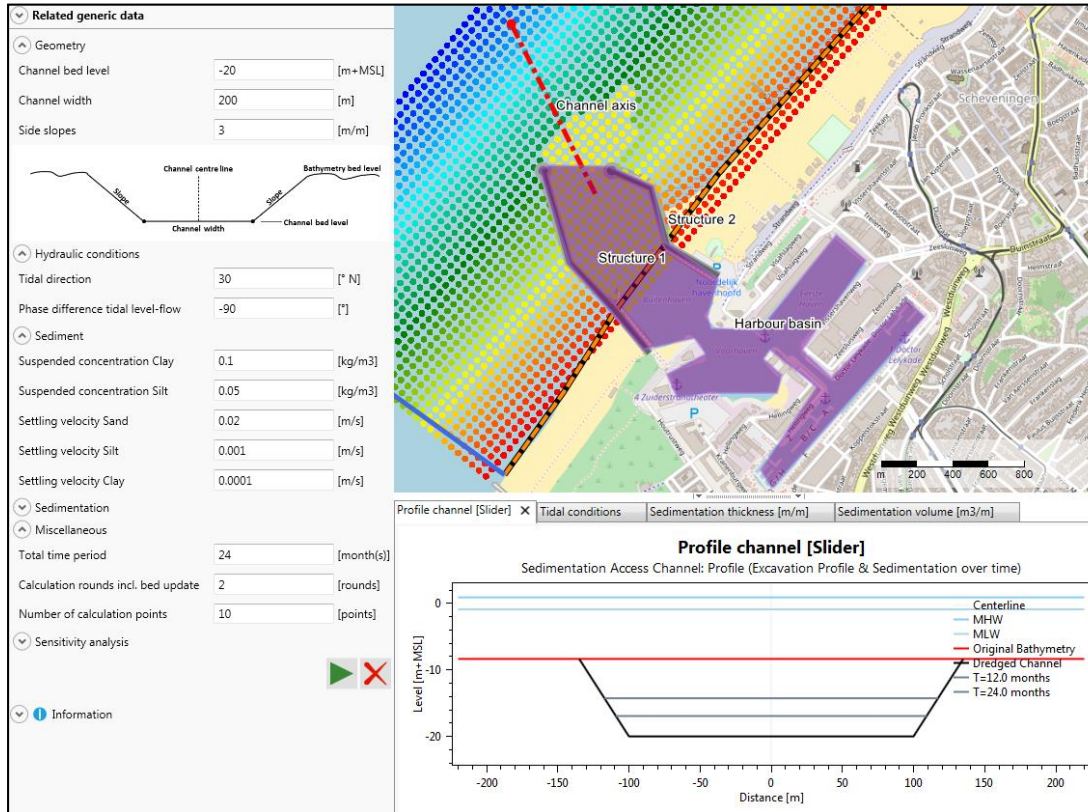
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Harbour basin siltation 

eCoDeS 

Interactive flow fields 

4. CoDeS – CoDeS Tools – Harbour basin siltation

-  Generic data
-  Settings
-  Coastline
-  Bathymetry
-  Structures
-  Waves
-  Tide
-  Sediment

CoDeS Tools


- Coastline dynamics 
- Breakwater design 
- Wave penetration 
- Channel sedimentation 
- Harbour basin siltation 
- eCoDeS 
- Interactive flow fields 

4. CoDeS – CoDeS Tools – Harbour basin siltation

 Generic data

 Settings

 Coastline

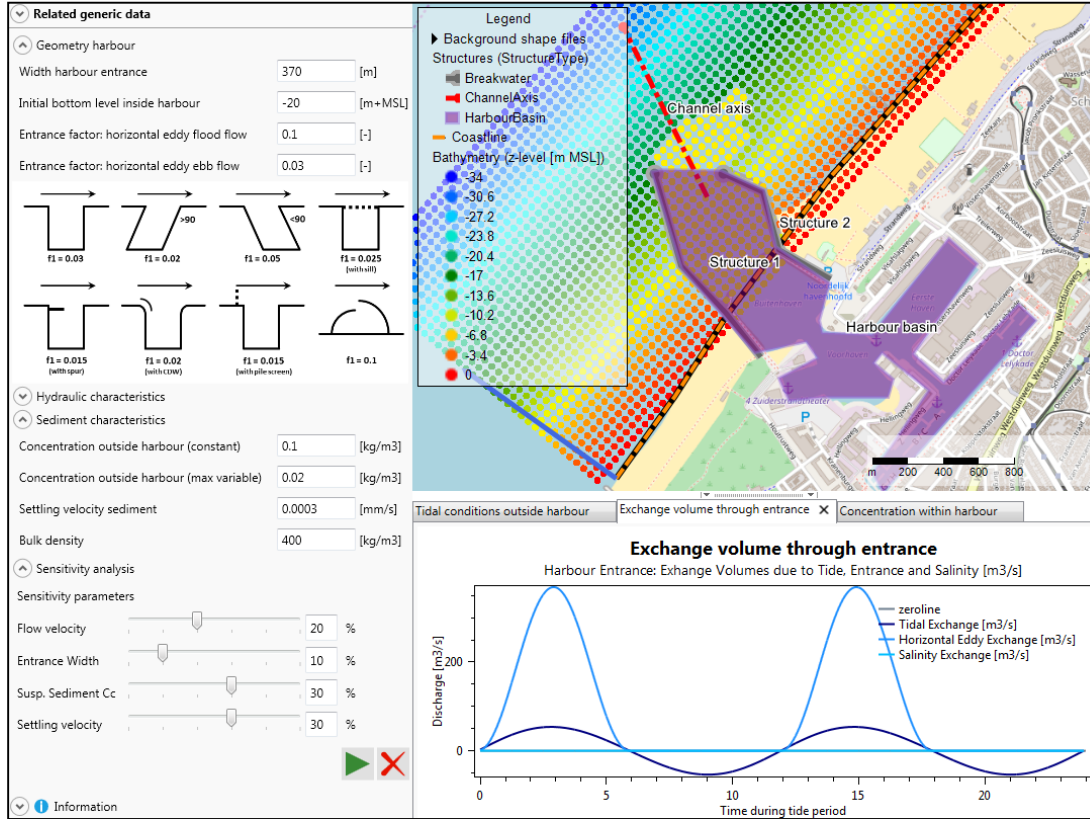
 Bathymetry


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 Tide

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CoDeS Tools 

Coastline dynamics 

Breakwater design 

Wave penetration 

Channel sedimentation 

Harbour basin siltation 

eCoDeS 

Interactive flow fields 


- Siltation in a harbour basin (based on v. Rijn tool SILTHAR)
- Concentrations, siltation quantities & automated sensitivity analysis
- Due to tide, sediment characteristics & geometry

4. CoDeS – CoDeS Tools – Harbour basin siltation

 Generic data

 Settings

 Coastline

 Bathymetry

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 Sediment


CoDeS Tools 

Coastline dynamics 


Breakwater design 

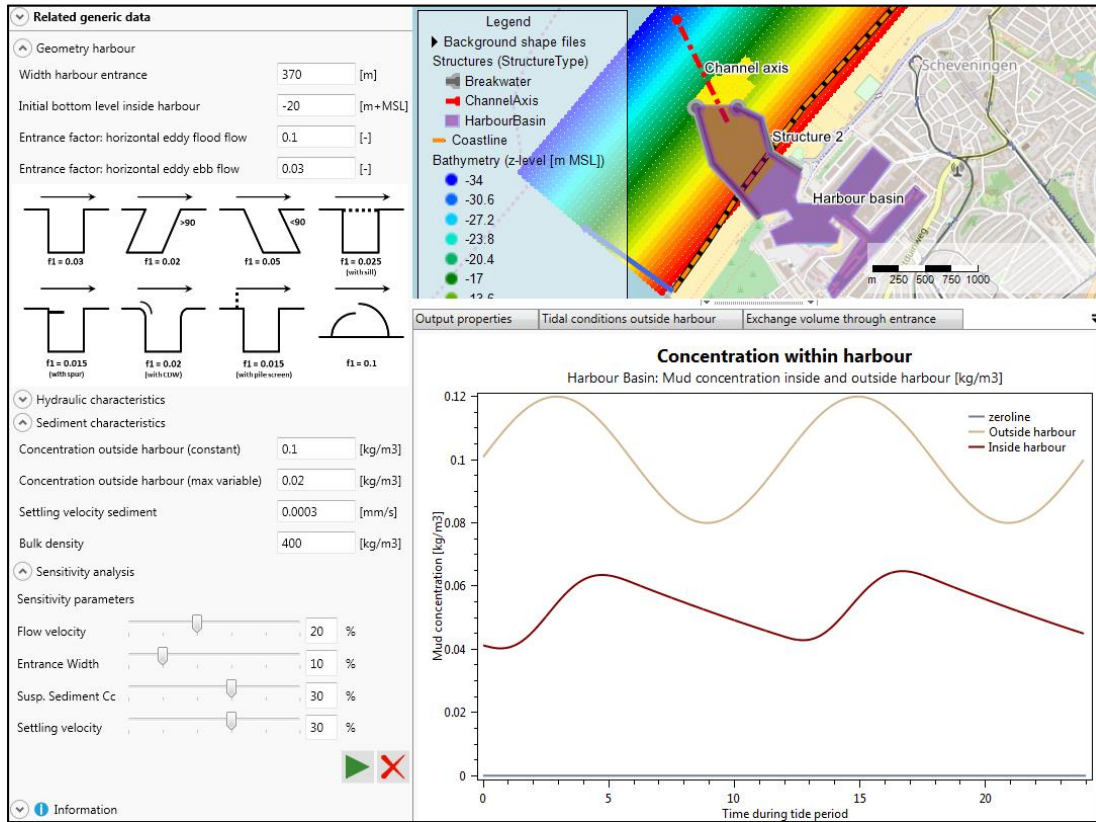
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Harbour basin siltation 

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4. CoDeS – CoDeS Tools – Harbour basin siltation

-  Generic data
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-  Coastline
-  Bathymetry
-  Structures
-  Waves
-  Tide
-  Sediment

CoDeS Tools


- Coastline dynamics 
- Breakwater design 
- Wave penetration 
- Channel sedimentation 
- Harbour basin siltation 
- eCoDeS 
- Interactive flow fields 

4. CoDeS – CoDeS Tools – eCoDeS

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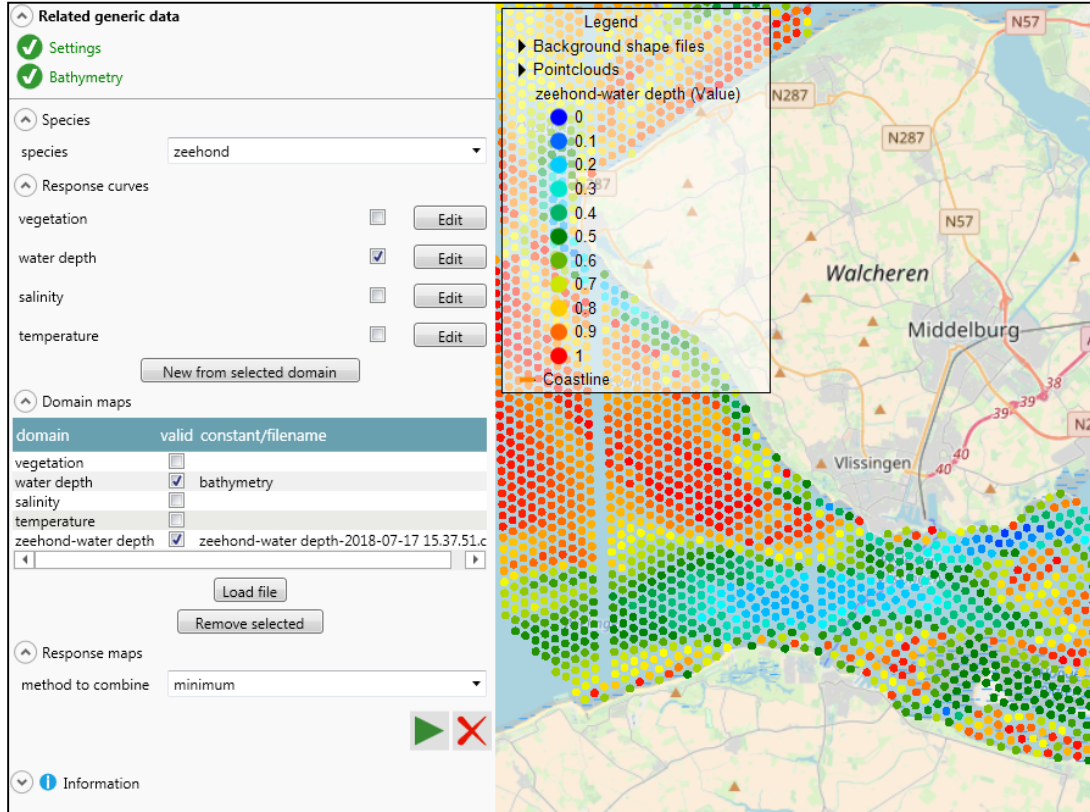
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Interactive flow fields 

- Suitability maps for different species, based on their response curves
- Multi-variable dependencies & integrated species database
- Inter-dependencies between species (e.g. a prey – predator cycle)

4. CoDeS – CoDeS Tools – eCoDeS

 Generic data

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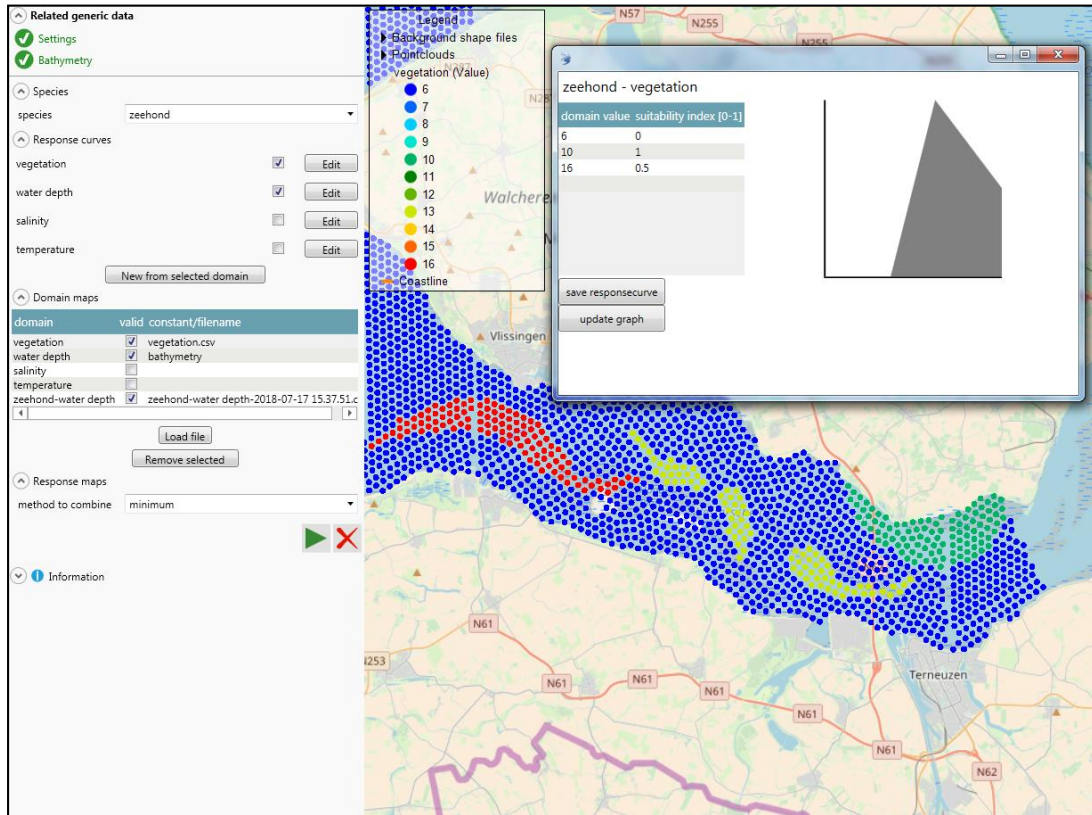
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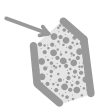


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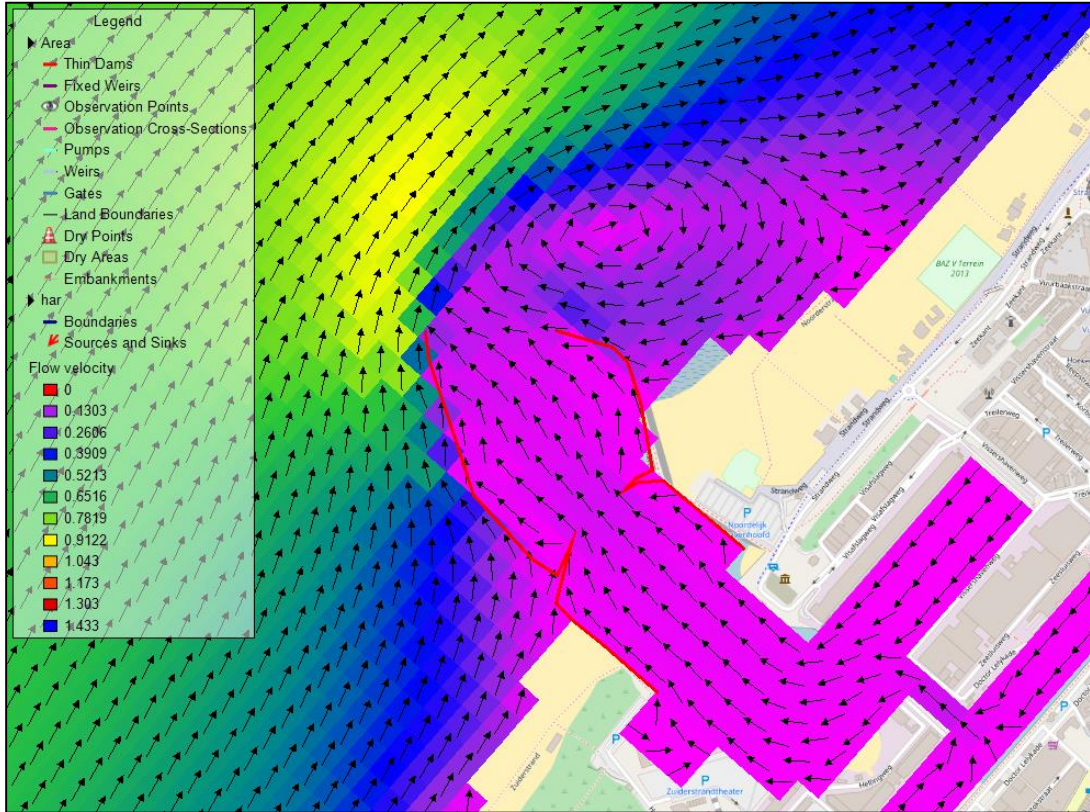
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CoDeS Tools

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Interactive flow fields


- Automatic Delft3D Flexible Mesh model based on harbour design
- Design can be changed while the model runs (instant results)

4. CoDeS – CoDeS Tools – Interactive flow fields

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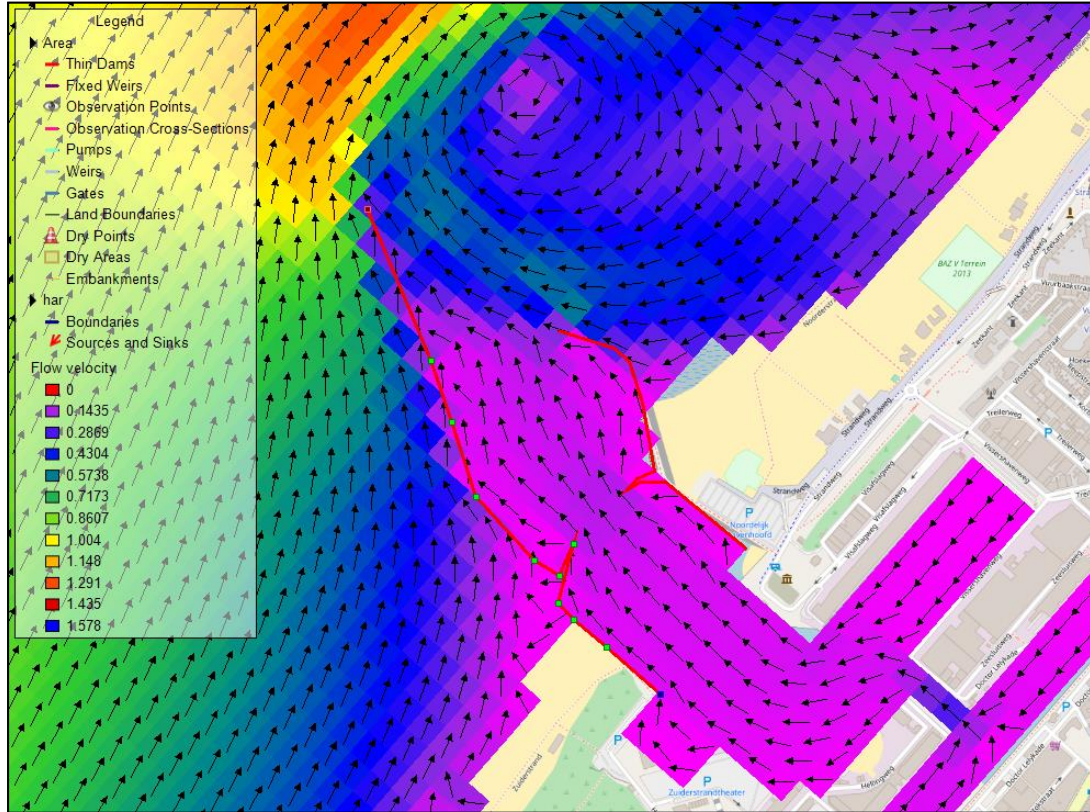
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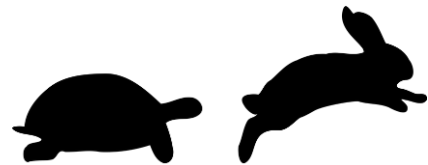
eCoDeS 

Interactive flow fields 



5. Highlights & conclusions

- CoDeS tools are fast & interactive
- Reproducibility & validation through version control & test bed
- Integration of different disciplines & tools
- Applicable anywhere on earth with uniform tool input
- All physics & mathematics scripted in Python



- In practice, CoDeS proved very useful during:
 - Early stages of a project (e.g. tender/proposal, (pre) feasibility, desk studies)
 - Interactive design sessions
 - Engagement, understanding, communication & education of stakeholders

6. Future developments

- Following
 - CoDeS pilot (2014 – 2015)
 - CoDeS 1.0 (2015 – 2016)
 - CoDeS 2.0 (2017 – 2018)



- We are open to welcome new partners for CoDeS 3.0, focusing on:
 - Data?
 - E.g. metocean databases, remote sensing derived data, statistics
 - Coasts/ports?
 - E.g. nautical aspects, channel design, port design, nourishments, reclamations, dredge plumes
 - Offshore renewables?
 - E.g. extreme conditions, workability, metocean conditions, energy islands/offshore hubs
- Feel free to approach me during the conference to discuss or ask for a demo!



THANK YOU FOR YOUR ATTENTION!