PIANC French Section

# PIANC Mediterranean Days

## and Conference «Port of the future» by Cerema

## 25 to 27 october 2023 in Sete France

# Malamocco-Marghera Navigation Channel (Venice Lagoon): study of operational and structural solutions to achieve a sustainable navigation

Andrea Pedroncini – DHI
Paolo Menegazzo – Port of Venice

# Framework and objectives

- The project activities fit into the "**Channeling the Green Deal for Venice**", a Connecting Europe Facility European funded project (2020-2023) that tackles the present limiteded navigational accessibility of the ports of Venice and Chioggia, fully respecting the environment and the Venice Lagoon.

- Following Public Tender procedures, North Adriatic Sea Port Authority – Ports of Venice And Chioggia assigned to a Consortium led by DHI S.r.l. a multi-disciplinary study is ongoing aiming at identifying **possible solutions to achieve sustaniable navigation along the Malamocco-Marghera Channel.**

# Inter-connection of tasks

North Adriatic Sea Port Authority
Ports of Venice and Chioggia

Co-financed by the Connecting Europe Facility of the European Union

## NAVIGATION MODEL OF THE CHANNEL

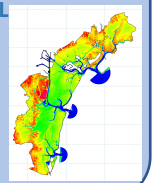
combination of fast time, NCOS and full bridge simulations: different vessel types, load conditions and geometry of the channel

**Limiting weather conditions, UKC, identification of critical stretches of the MM Channel**

FORCE TECHNOLOGY · DHI · CETENA

## 2D LAGOON MODEL

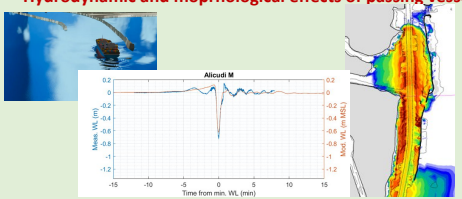
**Establishment of frequent and extreme conditions** at lagoon scale: tide, wind, wave, river discharge



DHI

## 3D MODEL OF THE CHANNEL AND SURROUNDING AREAS

**Hydrodynamic and moprhological effects of passing vessels**




DHI · AROUND WATER di Andrea Zamariolo, Ph.D. Geol.

## DEVELOPEMENT OF COORDINATED SOLUTIONS

**Sustainable vessel traffic**
**Maximization of navigation safety**
**Mitigation of erosion of the tidal flats**

- WIDER CHANNEL?
- LOWER VESSEL SPEED?
- MORPHOLOGICAL STRUCTURES ON TIDAL FLATS

HS marine srl · DHI

DHI · FORCE TECHNOLOGY · HS marine srl · CETENA · AROUND WATER di Andrea Zamariolo, Ph.D. Geol.

# 2D Lagoon Model

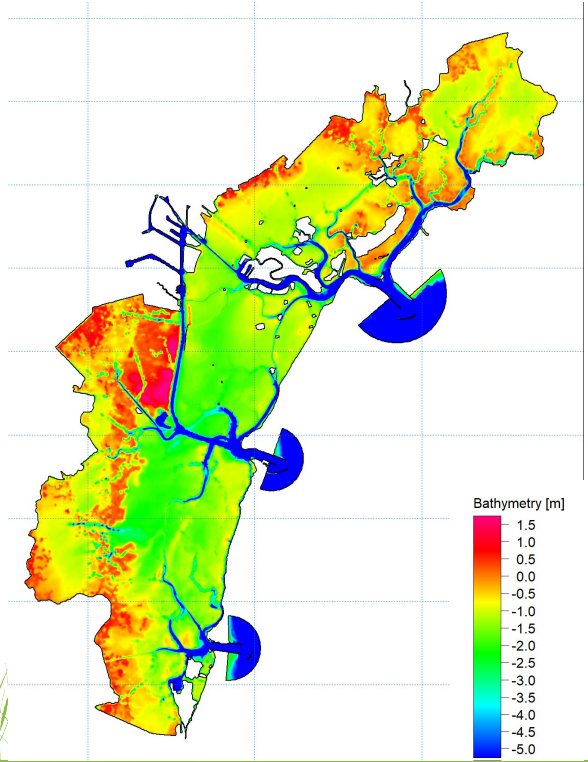
## Establishment of meteomarine conditions at lagoon scale

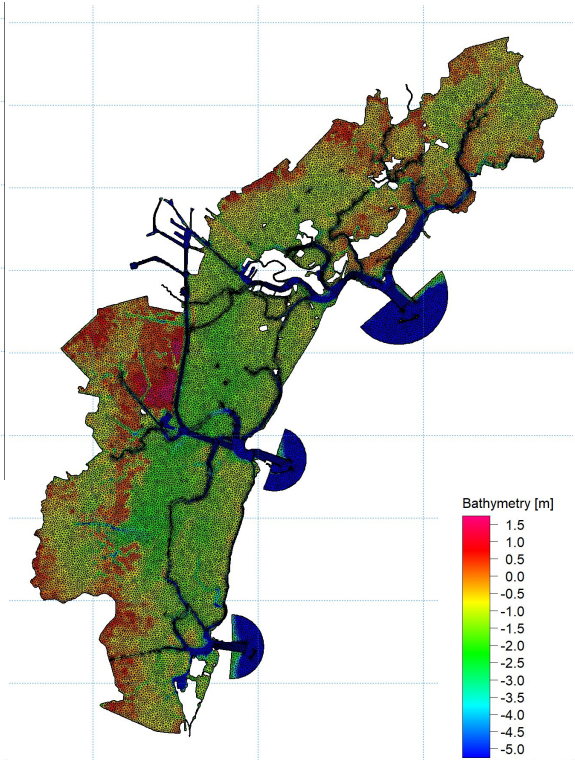
Development of an **integrated modelling system (hydrodynamics + waves)** capable of reconstructing, over a sufficiently long time window and after proper calibration and validation, the **spatial and temporal distribution of the main meteomarine variables of interest at lagoon scale (mainly wind, water levels, currents and wave conditions**)

- the lagoon model **feeds the 3D model of the Channel and surrounding areas**
- the lagoon model **feeds the NCOS simulations** (Under Keel Clearance) + **fast time and full mission simulations**

# 2D Lagoon Model

## Establishment of meteomarine conditions at lagoon scale



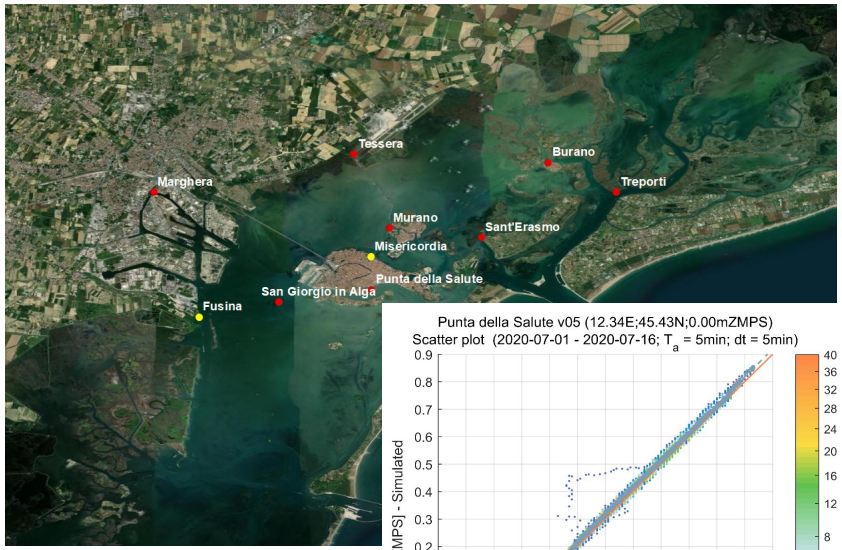


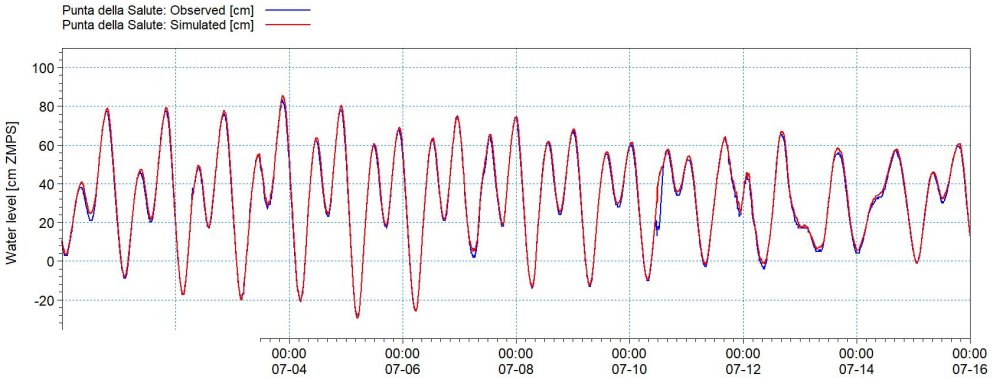
*Available meteo stations in the area*

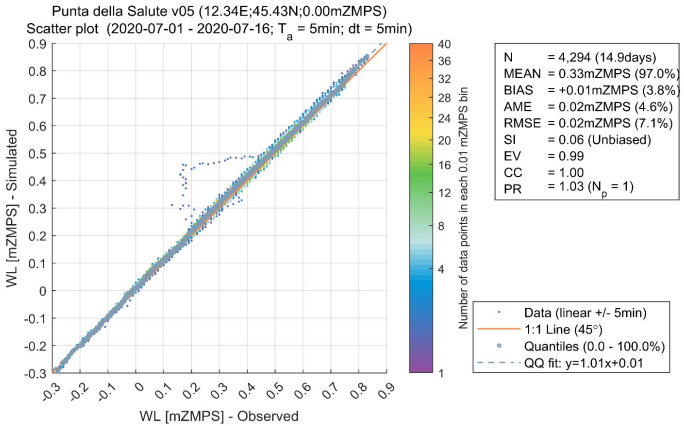
Based on the analysis of wind and water level measurement, the most representative year is assumed to be **year 2020**

# 2D Lagoon Model

## Establishment of meteomarine conditions at lagoon scale



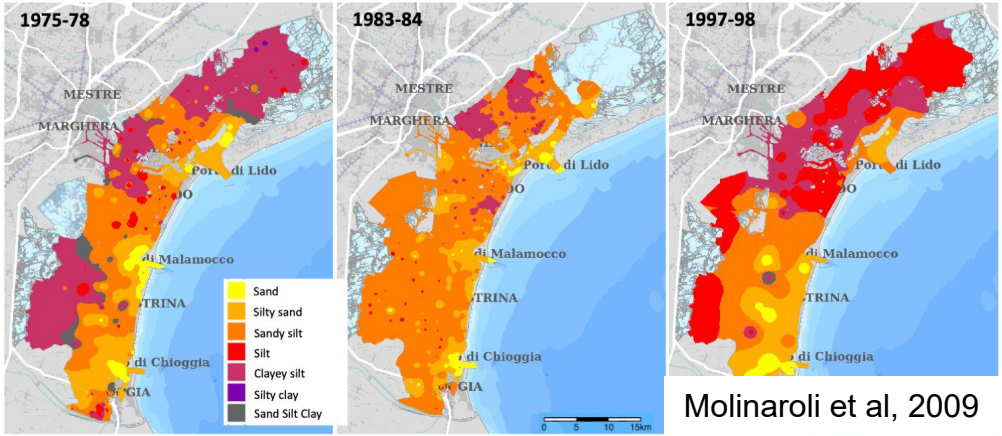




| | |
|---|---|
| N | = 4,294 (14.9days) |
| MEAN | = 0.33mZMPS (97.0%) |
| BIAS | = +0.01mZMPS (3.8%) |
| AME | = 0.02mZMPS (4.6%) |
| RMSE | = 0.02mZMPS (7.1%) |
| SI | = 0.06 (Unbiased) |
| EV | = 0.99 |
| CC | = 1.00 |
| PR | = 1.03 ($N_p$ = 1) |

| Station | RMSE [cm] | BIAS [cm] |
|---|---|---|
| Burano | 2.33 | 0.84 |
| Fusina | 3.12 | 1.74 |
| Marghera | 3.03 | 1.56 |
| Misericordia | 2.47 | -1.14 |
| Murano | 2.95 | 0.99 |
| Punta della salute | 2.44 | 1.32 |
| San Giorgio in Alga | 2.44 | 1.32 |
| Sant Erasmo | 2.08 | 0.61 |
| Tessera | 2.94 | 1.83 |
| Treporti | 2.70 | 1.06 |
| **Average** | **2.65** | **1.24** |

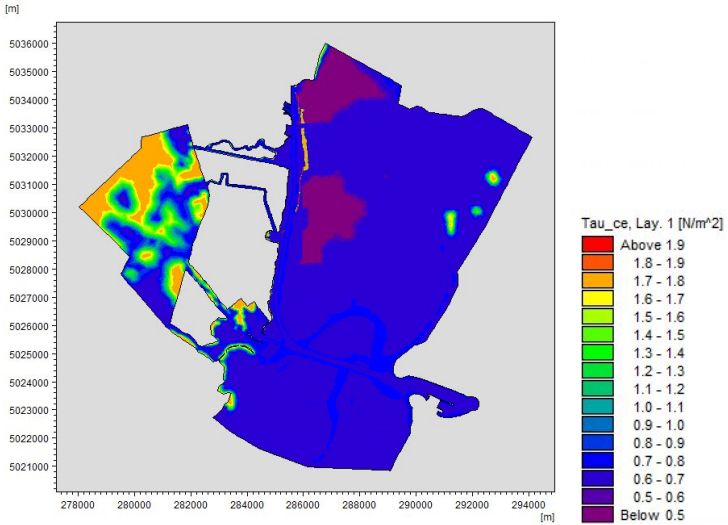
# Sediment and bed shear stress

## Mapping the sediment grain size




Molinaroli et al, 2009

## Mapping the bed shear stress



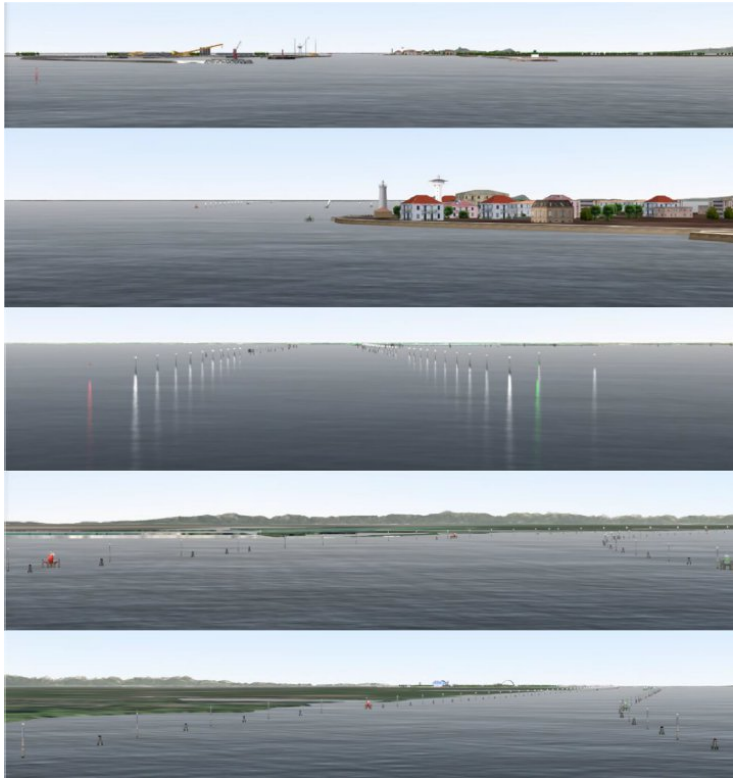

The area consists of three main areas:

- North: Pre-dominantly muddy
- Central: Sandy silt
- South-east: Silty sand

The bed shear stress for erosion is set to 1.8 Pa in salt marsh areas, 0.7 Pa on the flats in general and 0.5 Pa in the clam collection areas.

# Navigation models of the MM channel

## Full mission navigation simulations for the existing channel



Development of a **3D visual database**

# Navigation models of the MM channel

## Full mission navigation simulations for the existing channel

| Run no | Ship | Type | Cond | Wind speed (m/s) | Wind dir (deg) |
|---|---|---|---|---|---|
| 101 | 3644 | Cruise | 294 m | 5 | 23 |
| 102 | 3644 | Cruise | 294 m | 10 | 45 |
| 103 | 3644 | Cruise | 294 m | 10 | 67 |
| 104 | 3644 | Cruise | 294 m | 10 | 67 |
| 201 | 3644 | Cruise | 294 m | 10 | 23 |
| 202 | 3644 | Cruise | 294 m | 12.5 | 67 |
| 203 | 3644 | Cruise | 294 m | 10 | 67 |
| 204 | 3481 | Bulker | 200 m | 7.5 | 23 |
| 205 | 3481 | Bulker | 200 m | 7.5 | 23 |
| 206 | 3481 | Bulker | 200 m | 7.5 | 23 |
| 207 | 3481 | Bulker | 200 m | 10 | 45 |
| 301 | 3481 | Bulker | 200 m | 12.5 | 67 |
| 302 | 3481 | Bulker | 200 m | 10 | 67 |
| 303 | 3481 | Bulker | 200 m | 7.5 | 23 |
| 304 | 3481 | Bulker | 200 m | 10 | 45 |
| 305 | 3481 | Bulker | 200 m | 12.5 | 67 |
| 306 | 3481 | Bulker | 200 m | 12.5 | 67 |

| Run no | Ship | Type | Cond | Wind speed (m/s) | Wind dir (deg) |
|---|---|---|---|---|---|
| 401 | 3601 | Container | 294 m | 7.5 | 23 |
| 402 | 3601 | Container | 294 m | 10 | 45 |
| 403 | 3481 | Bulker | 200 m | 12.5 | 67 |
| 404 | 3601 | Container | 294 m | 15 | 67 |
| 405 | 3297 | RoRo | 200 m | 12.5 | 45 |
| 406 | 3297 | RoRo | 200 m | 12.5 | 45 |
| 407 | 3297 | RoRo | 200 m | 12.5 | 45 |
| 408 | 3556 | Cruise | 295 m | 10 | 45 |
| 409 | 3556 | Cruise | 295 m | 10 | 45 |
| 501 | 3297 | RoRo | 200 m | 10 | 45 |
| 502 | 3601 | Container | 294 m | 7.5 | 23 |
| 503 | 3601 | Container | 294 m | 10 | 45 |
| 504 | 3297 | RoRo | 200 m | 10 | 45 |
| 504 | 3601 | Container | 294 m | 15 | 67 |
| 505 | 3556 | Cruise | 295 m | 15 | 67 |
| 601 | 3297 | RoRo | 200 m | 10 | 45 |
| 602 | 3435 | RoRo | 220 m | 10 | 45 |
| 603 | 3601 | Container | 294 m | 12.5 | 67 |

- **Cruise Ships**
- **Bulker**
- **RoRo**
- **Container Ships**

**Tugs** have also been used to achieve fully realistic conditions

2 main goals:

- Thorough understanding of the navigation conditions in relation to increasing wind speed (up to 12.5 m/s – around 24 knots)
- Identification of critical areas along the Channel (in combination of fast-time and NCOS simulations)

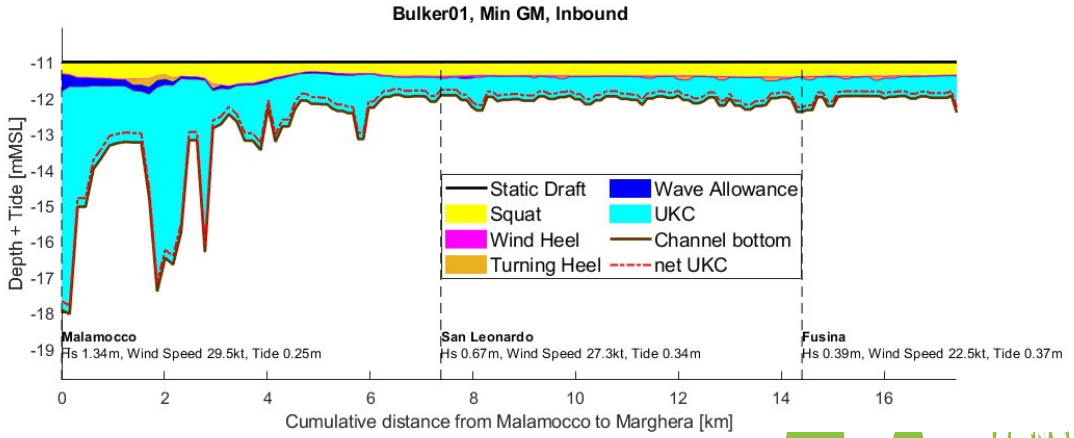
# Navigation models of the MM channel

## Advanced UKC study along the Malamocco-Marghera Channel using NCOS

The one-year long time series of meteomarine conditions along the Channel derived from the 2D model of the lagoon (**wind conditions, water levels, tidal currents and waves, in the form of 2D spectral information**) have been used as direct input for the Nonlinear Channel Optimisation Simulator (NCOS).

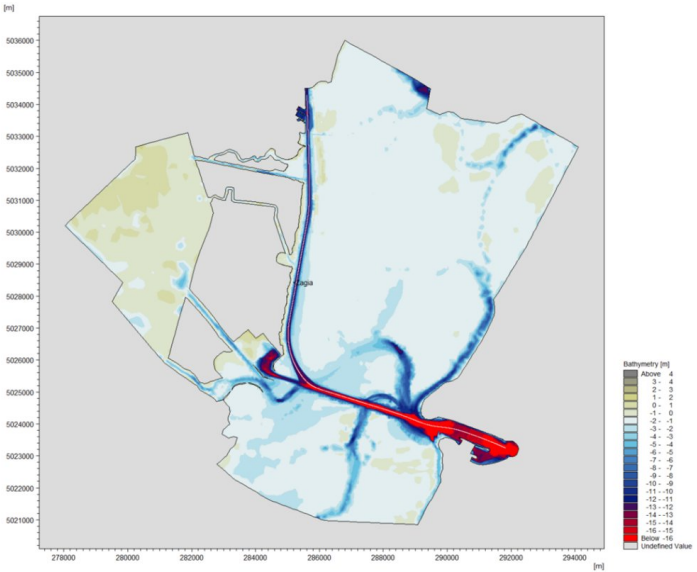
| Vessel | LOA [m] | Beam [m] | Draught [m] |
|---|---|---|---|
| Bulk carrier | 260 | 37 | 11.00 |
| Container ship | 220 | 32.2 | 11.00 |
| Cruise ship | 293 | 32.2 | 7.85 |

The detailed analysis of NCOS results was used to support the proper selection of meteomarine and transit conditions of the navigation simulations



# Hydrodynamic Modelling

## Establishment of 3D hydrodynamic model of the Channel and surrounding areas (navigation forcing)

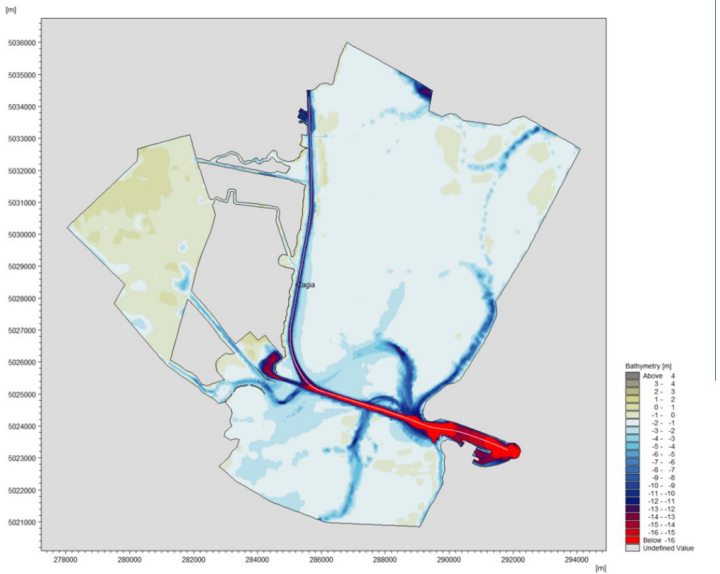


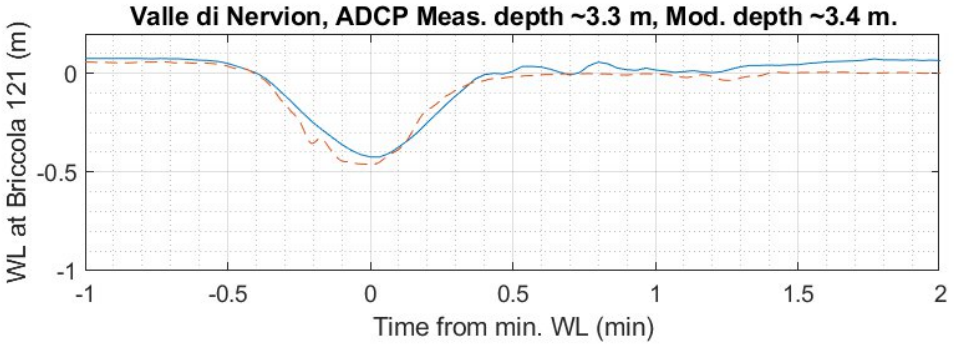

The numerical model for modelling draw-down has been calibrated against two datasets of measurements:

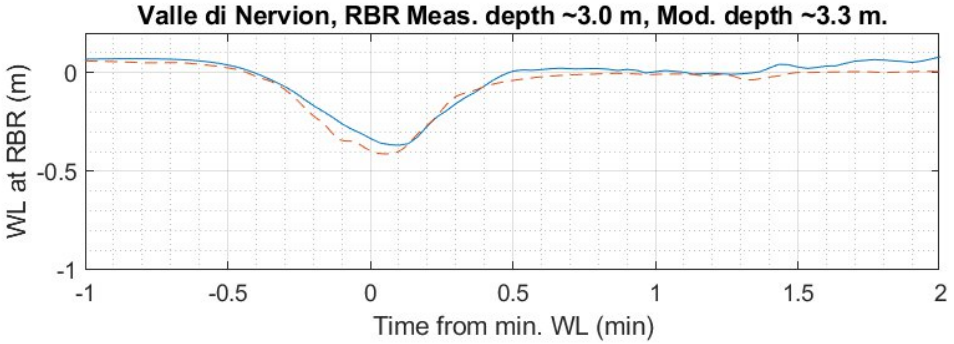
- wave data measured by CNR in the proximity of “Cassa di Colmata B” between August 2019 and February 2020: a selection of “events” (vessel passages creating significant displacement waves);
- new wave data from a dedicated campaign (May 2022) executed by the JV.

# Hydrodynamic Modelling

## Establishment of 3D hydrodynamic model of the Channel and surrounding areas (navigation forcing)



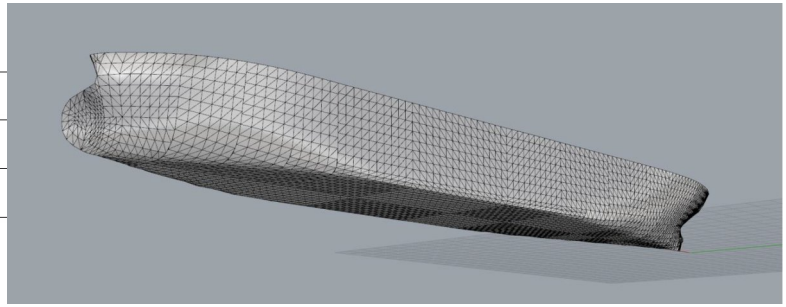
# Hydrodynamic Modelling

## Comparison with CFD modelling of Nervion Valley passage

**RANSE solver STARCCM+**

Oil/chemical tanker Nervion Valley – 16/05/2022 (to Malamocco)

| | |
|---|---|
| **Length Overall $L_{OA}$ [m]** | 176 |
| **Breadth [m]** | 31 |
| **Draft [m]** | 7.3 |
| **Vessel speed SOG ($V_S$) [kts]** | 9 |



# Hydrodynamic Modelling

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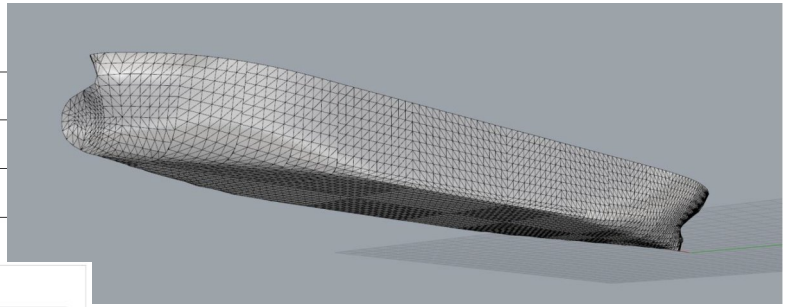
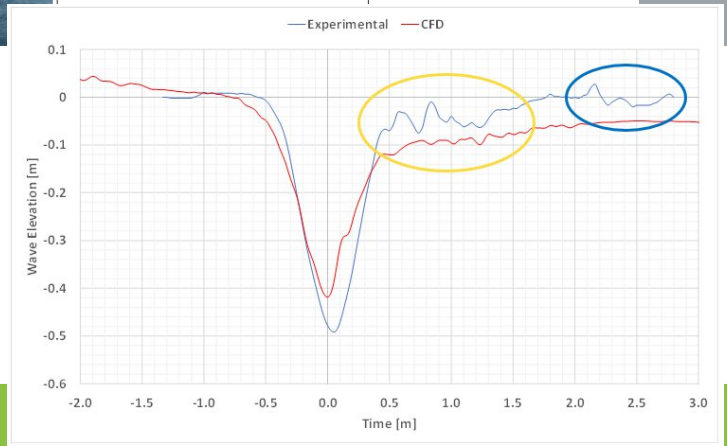




# Importance of Kelvin Waves and Propeller Wash

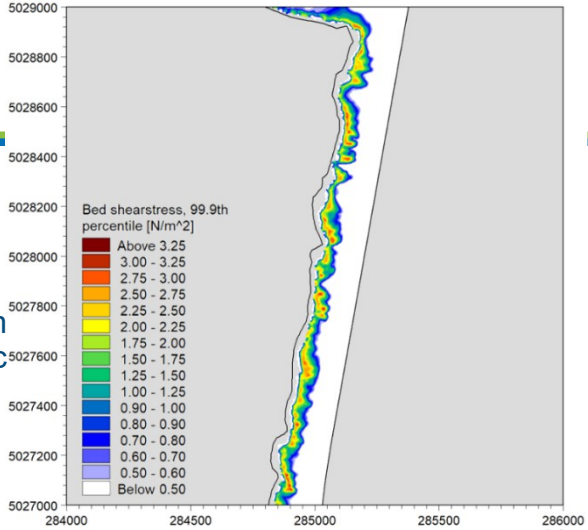
**TOP RIGHT:** Bed shear stresses from out-bound Kelvin waves. Wave height at boundary (0.26 m) calculated as weighted average of all production vessels at 10 knots.

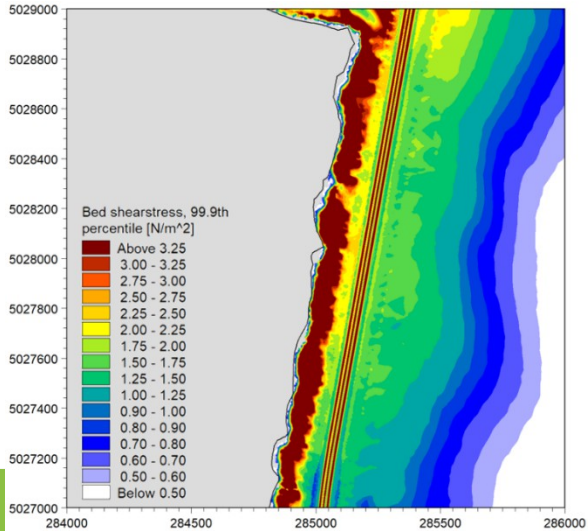
**BOTTOM RIGHT:** Bed shear stress associated with primary wave from outbound passage of Nervion Valley at 9 knots (case used for hydrodynamic model calibration).

- Kelvin waves have an insignificant effect on the erosion of the channel banks and mud flats.
- Propellor mainly has a stirring effect. The bed shear stresses from the propellor are an order of magnitude smaller than those from the primary wave.
- In the model, the erosion is regulated by the bed shear stress, in this regard the propellors will have no significant influence on the sediment transport.
- The model already reaches high sediment concentrations in the water column of the channel only by including the primary waves.

| Rpm (minute$^{-1}$) | D (m) | r (m) | Vo (m/s) | Um (m/s) | $T_b$ max (N/m$^2$) |
|---|---|---|---|---|---|
| 250 | 2.5 | 10 | 6.3 | 0.29 | 0.25 |
| 250 | 2.5 | 9 | 6.3 | 0.32 | 0.31 |
| 250 | 2.5 | 8 | 6.3 | 0.36 | 0.39 |
| 100 | 4.5 | 8 | 4.2 | 0.42 | 0.50 |
| 100 | 4.5 | 7 | 4.2 | 0.47 | 0.65 |
| 100 | 4.5 | 6 | 4.2 | 0.55 | 0.89 |
| 45 | 6.0 | 6 | 2.7 | 0.46 | 0.65 |
| 45 | 6.0 | 5 | 2.7 | 0.56 | 0.93 |
| 45 | 6.0 | 4 | 2.7 | 0.69 | 1.45 |

Bed shear stress varying propellor sizes and distances from bed.



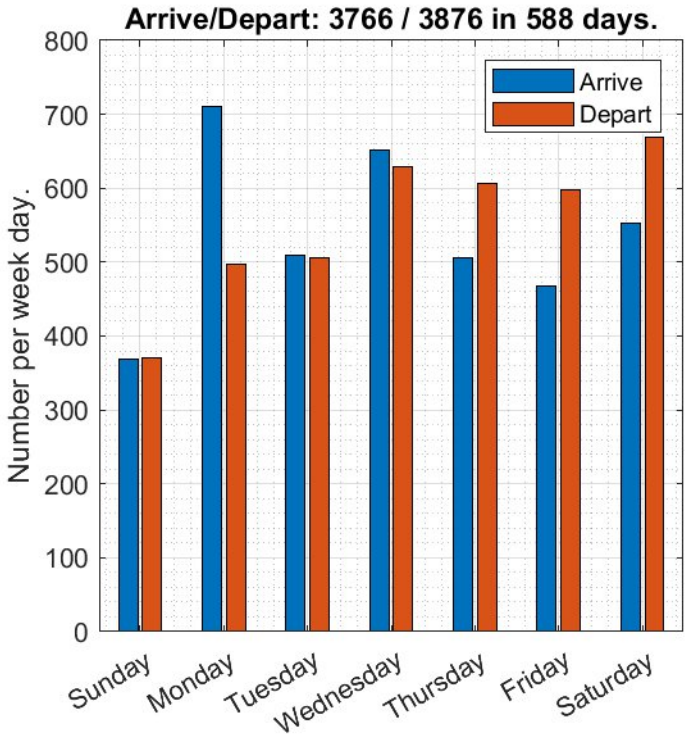



# Hydrodynamic Modelling

## Matrix of representative traffic (from PoV 2021-2022)

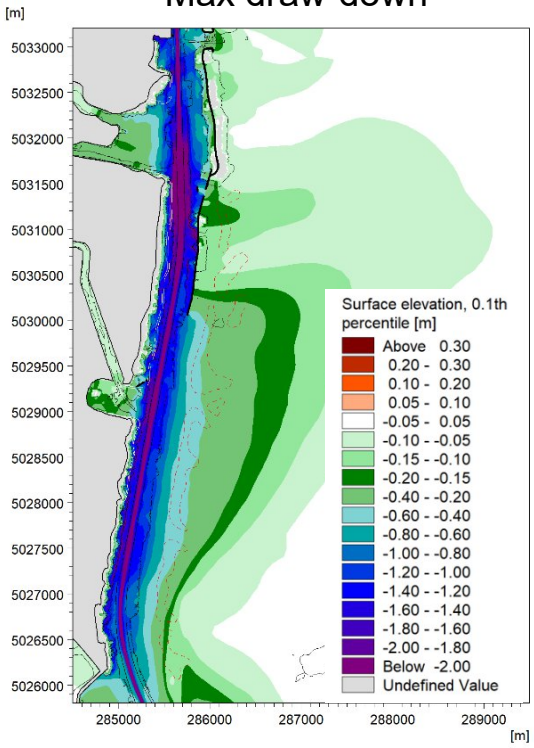
Investigation of PoV Vessel Database

- 5 Categories
  - Container vessels: 27.1% of events
  - Tank ships: 20.5% of events
  - Bulk carriers: 15.5% of events
  - General cargo vessels: 15.3% of events
  - Ro-Ro vessels: 14.6% of events
- Plus 1 category (not included in database)
  - Cruise vessels, two lengths: 300 and 230 m
    - 1 passage per week each from 1st April to 1st November (30 weeks)
    - Relative to total number of events in database this yields ~2% of events.

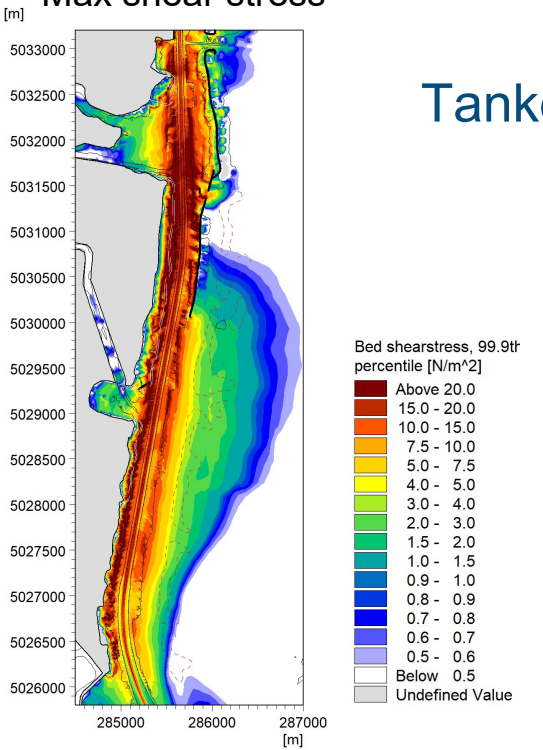


# Hydrodynamic Modelling

## Max draw-down




## Max shear stress




## Tanker Large (75° percentile)
## V = 10 knots

# 2

# ILLUSTRATION OF PROJECT DEVELOPMENT – PROPOSED SOLUTIONS

North Adriatic Sea Port Authority
Ports of Venice and Chioggia

Co-financed by the Connecting Europe Facility of the European Union

# Final Validation of the proposed solutions

## Objectives:

- Improvement of navigation conditions along the channel (improved operability)
- Improvement of navigation conditions along the channel (navigation safety)
- Achievement of enviromental sustainability of vessel traffic along the channel (mitigation of erosion of the tidal flats surrounding the channel)

→ **New navigation simulations**

→ **New hydrodynamic simulations**

# Final Validation of the proposed solutions

## Navigation simulations

- Iterative process, 3 configuration tested in November 2022 and March 2023
- Final optimization with respect to operational and structural solutions

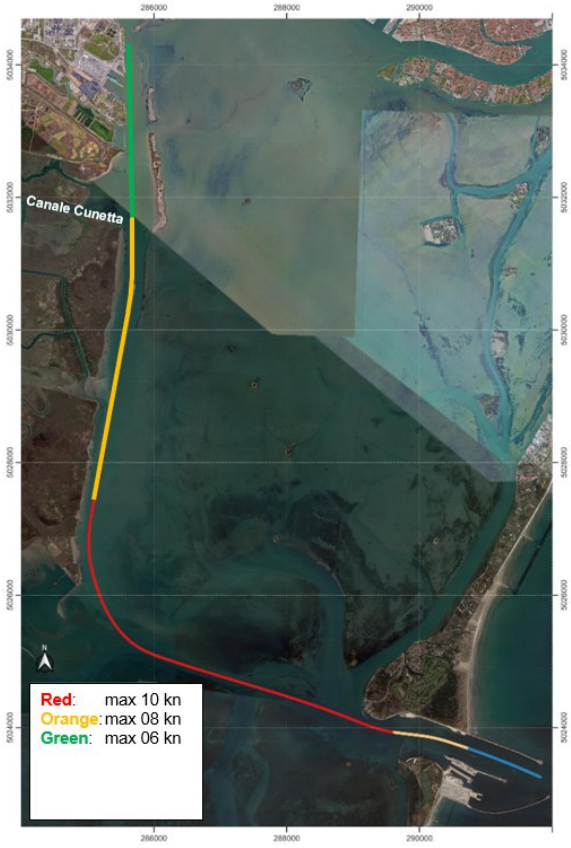
**→ Local widening of the channel**

**→ Navigation safety with lower vessel speed (10 knots → 8 knots north of San Leonardo bend)**

# Proposed solutions

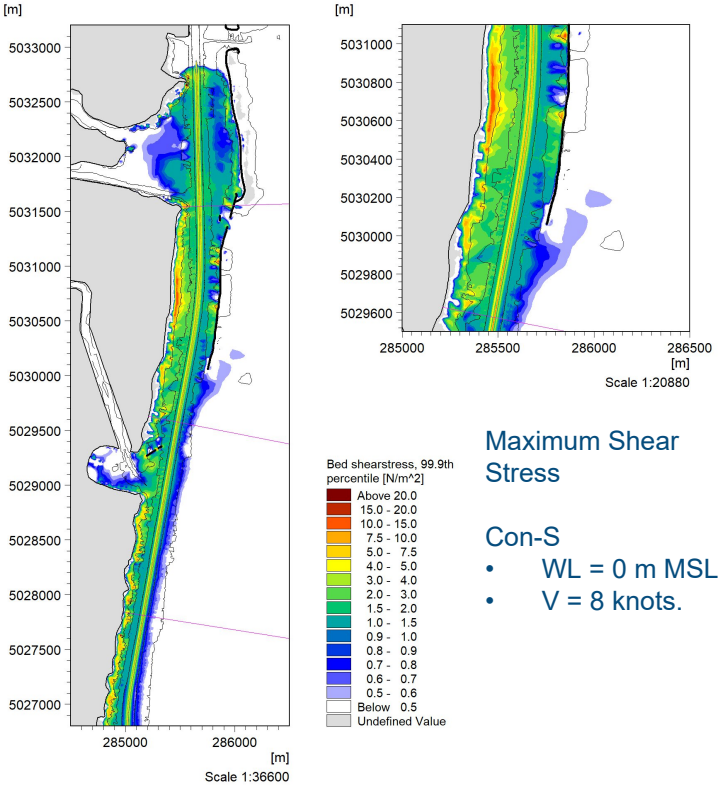
## Operational solutions

Limited vessel speed north of S.Leonardo bend



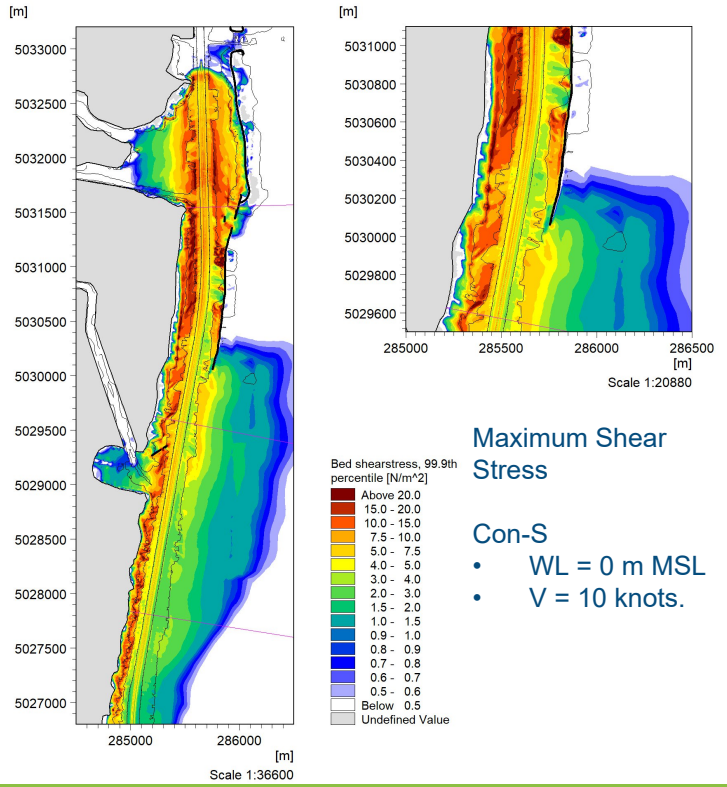
# Proposed solutions

## Operational solutions




Maximum Shear Stress

Con-S
- WL = 0 m MSL
- V = 8 knots.




Maximum Shear Stress

Con-S
- WL = 0 m MSL
- V = 10 knots.

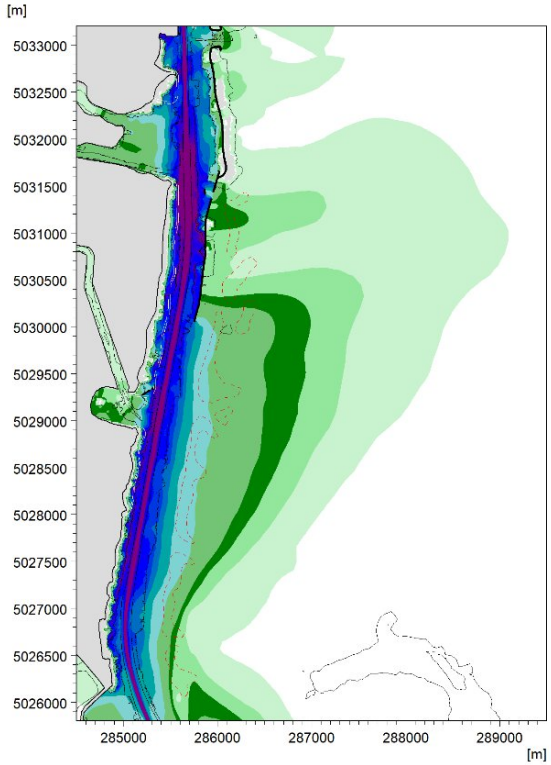
# Proposed solutions

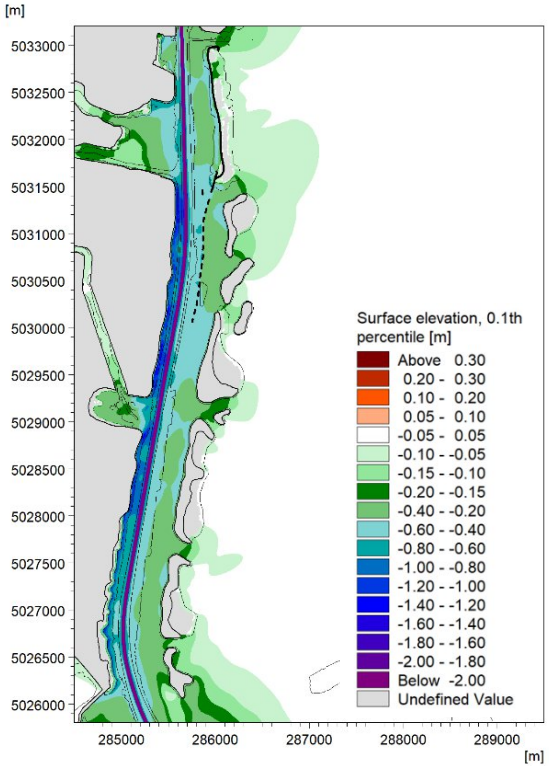
## Structural solutions

- Local widening of the channel
- Construction of 8 morphological structues east of the channel banks (> 250 m)
- Breakwaters lowered from emerged to -1.2 m

# Proposed solutions

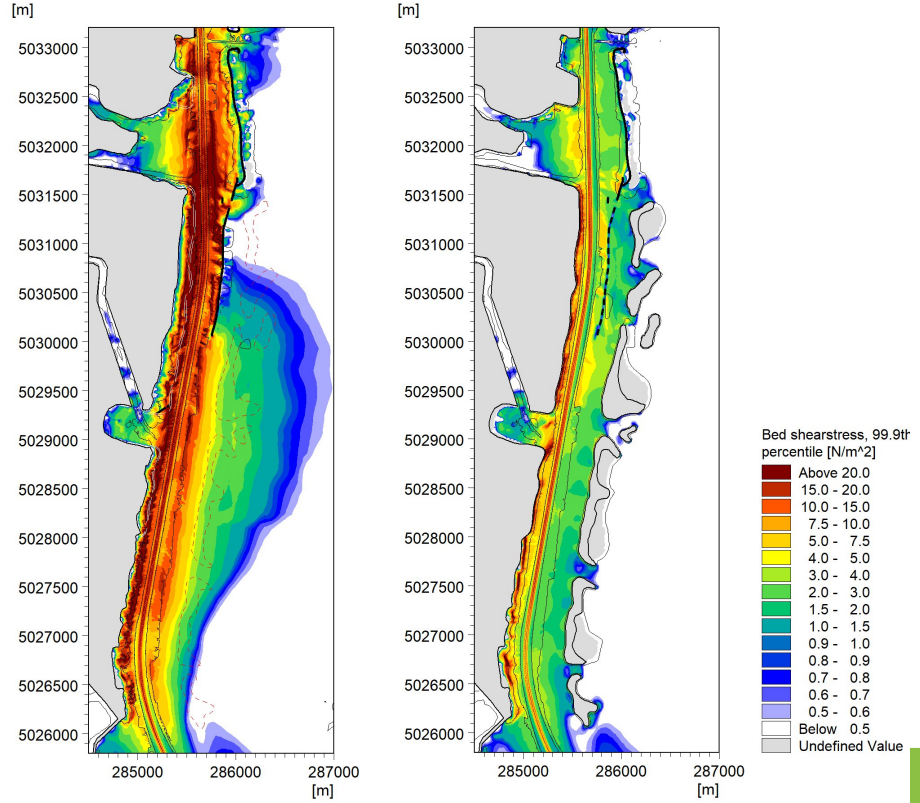
## Structural solutions




# Proposed solutions

## Structural solutions




# Conclusions

The proposed solution:

- is a combination of both infrastructural and navigation management aspects

- is based on a in-deep optimization of nautical needs, vessel speed, re-shaping of the Channel, etc

- is founded on strong scientific evidence, that combines port activities and enviromental protection

# *Thank you for your attention!*

## CONTACTS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