SUBMERGED AQUATIC VEGETATION FOR SEDIMENTATION CONTROL IN NAVIGATIONAL CHANNELS: BIDIMENSIONAL SIMULATIONS

Diogo Fonseca[1]; Léon Guiol[1,4]; Ivana Bosnic[1]; Diogo Mendes[2]; Andreia Gomes[1]; Piet Haerens[1]; João Miguel Dias[3]

[1]HAEDES Portugal, Casais do Arrocho, 2025-452 Azóia de Cima, Portugal
[2]CERIS, Instituto Superior Técnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001, Lisboa, Portugal
[3]CESAM, Universidade de Aveiro, Campus de Santiago, 3810-193, Aveiro, Portugal
[4]SeaTech - Ecole d'ingénieurs de l'Université de Toulon, Av. de l'Université, 83130 La Garde, França

diogo.fonseca@haedes.eu; leon.guiol@haedes.eu; ivana.bosnic@haedes.eu; diogo.silva.mendes@tecnico.usliboa.pt; andreia.gomes@haedes.eu; piet.haerens@haedes.eu; joao.dias@ua.pt;

Abstract

The presence of submerged aquatic vegetation (SAV), such as seagrass, contributes to change the hydrodynamic and morphodynamic patterns of coastal and lagoon systems. In the case of waterways, when placed in the margins, SAV is expected to reduce the sedimentation phenomenon (Fonseca *et al.*, 2022), thereby increasing the required time for maintenance dredging activities.

Considering an idealized solution based on SAV for the control of sedimentation in navigation channels in estuarine environments, previously put forward by Fonseca *et al.* (2022), an attempt is made to increase knowledge on the sedimentation/siltation rates promoted by this solution.

For this purpose, an analysis of the results obtained by two-dimensional and depth-integrated numerical modelling was carried out, using the Delft3D model (Deltares, 2011). This numerical model allows to account for the effect of SAV on hydrodynamics and sediment transport processes. Numerical experiments with and without SAV were compared to understand the differences at Cais da Bestida, Aveiro lagoon. The results suggest that bed shear stresses with vegetation remain below the critical threshold which indicate the adequate performance of SAV to reduce sedimentation in navigation channels and its contribution to increase the time between maintenance dredging operations.

Introduction

According to Van Rijn (2018), the siltation of non-cohesive sediment in navigation channels is caused by: a) the reduction of the sediment transport capacity due to smaller flow velocities; b) the gravitational effects inducing a downward force on bedload sediments on the side slope of a channel; and c) the shifting shoals and banks.

Sedimentation in navigation channel is a well-known phenomenon, but operational management of these channels still require regular maintenance dredging operations to allow a safe navigation. These operations consume fossil fuels due to dredging vessels and thus increase CO2 emissions. Given the EU goals of being climate-neutral by 2050, regular maintenance dredging operations are not compatible with such targets. Therefore, the proposed nature-based solution (NBS) to reduce sediment accumulation within the channels by implanting seagrass vegetation along navigation channels margins, aims to tackle this difficulty and contribute to achieve the EU goals.

This work builds on the work of Fonseca *et al*. (2022) and it aims to be a step further on the evaluation of the performance of submerged aquatic vegetation in the reduction of sedimentation in navigation channels by applying a 2DH (depth-averaged) numerical model forced by regional hydrodynamic (tidal) boundary conditions.

Study area

The present work takes place in the Aveiro lagoon, where Cais da Bestida navigation channel was selected as a case study for this project. This selection is due to known sediment accumulation issues (especially due to the channel geometry and orientation with the main current pattern), that compromise its access.

Furthermore, the channel is in a suitable environment for *Zostera marina* growth and development. This seagrass species is characterized by highly flexible leaf blades that, under favourable conditions, can reach up to few meters length and form extensive meadows over mudflats.

Moreover, this nature-based solution will be designed to be scalable and reproducible in other navigation channels with similar environmental characteristics.

Figure 1 - Cais da Bestida location (red square) in the Aveiro lagoon.

Methodology

General description

The Delf3D (Deltares, 2011) numerical model was used to study the impact of vegetation on sedimentation in the Cais da Bestida area. In this work, only Delft3D-FLOW, the hydrodynamic module of the Delft3D package software, is applied since tidal forcing is the single hydrodynamic forcing considered. In the study, the Delft3D-FLOW module is used in a depth-averaged approach (2DH) to solve mass and momentum conservation equations.

The high-resolution model used to study the dynamics of Cais da Bestida navigation channel was set up using the regional model of the Aveiro lagoon developed by Pinheiro *et al*. (2020). The tidal regime of the regional model was build using the TPXO 8.0 Global Inverse Tide Model and allow us to retrieve boundary conditions for a nested model (water level at south and velocities at north) focusing on the Cais da Bestida area. Using a nested model and the retrieved boundary conditions, a high-resolution model, with a 2x2m resolution around the area of interest (Figure 2), has been created.

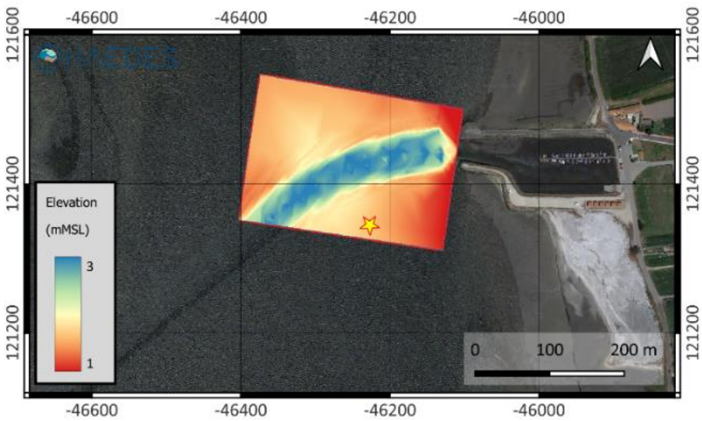

Figure 2 – Bathymetry map of the studied area, with the water level data extraction location (yellow star).

Vegetation

Seagrass vegetation corresponds to intertidal vegetation, usually colonizing intertidal mudflats. It is widely known for its ecosystem engineering action through a contribution on bottom sediment fixation. Due to model limitations on the inclusion of flexible vegetation, more compatible with the considered species *Zostera marina*, vegetation type in the model will be considered as reed.

The vegetation impact on flow, as described in Delft3D FLOW user manual, has an influence on: a) the momentum equations given by the vertical distribution of the friction force as caused by cylindrical elements in oblique flow; b) the kinetic turbulent energy equation due to its influence on vertical mixing; and c) the rate of dissipation of turbulent kinetic energy (epsilon equation) due to the dissipation time scale of eddies in between the plants.

The SAV characteristics inputs are show in Table 1:

Table 1 - Vegetation characteristics used.

Turbulence length scale coefficient between stems	0.8
Number of time steps between updates of plant arrays	50
Height [m]	0.2
Stem diameter [m]	0.005
Cylindrical resistance coefficient (Cd)	1.0
Vegetation type	reed
Number of stems per unit area	25

Results

Figure 3 shows the depth averaged velocity maps and cross-sections during flood (left side) and ebb (right side).

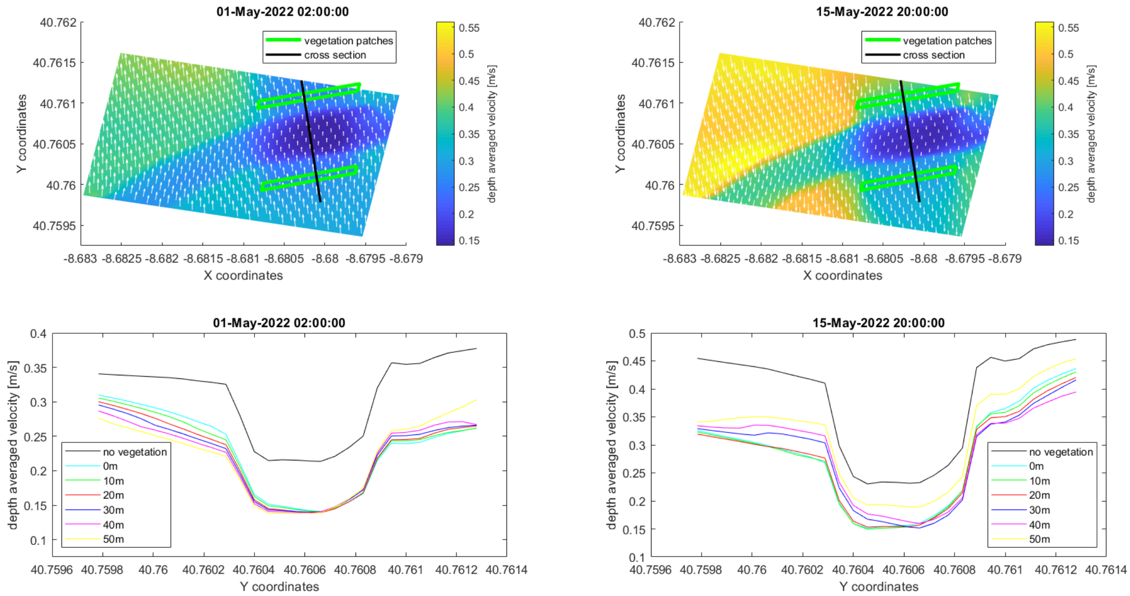

Figure 3 - Depth averaged velocity maps during flood (top left side) and ebb (top right side) with vegetation patches (100m length and 9m width) positioned at 20 m from the channel borders. Depth averaged velocity during flood (bottom left side) and ebb (bottom right side) along the cross section shown in Figure 2 with different distances to channel of the vegetation patches.

Figure 4 shows the impact of the NBS on bed shear stress trough time compared to the current situation (without vegetation).

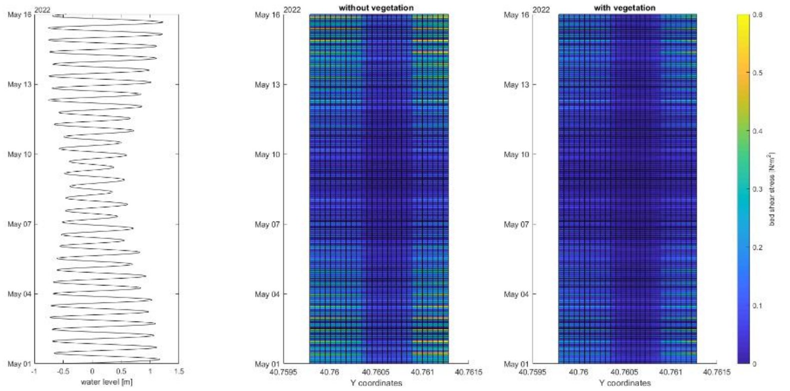

Figure 4 - Water level during the studied time period at location shown in Figure 2 (left panel). Bed shear stress through time, along the cross section shown in Figure 2, without intervention (middle panel), and with two vegetation patches positioned at 30m from channel (right panel).

Discussion

Model results showed that an optimum position of the vegetation (30 m from channel margins) can be found to obtain lower velocities at the channel borders (Figure 3). Using SAV on channel banks will reduce bed shear stresses by 33% compared to the normal situation. It is noticeable (Figure 4) that this decrease induced by the vegetation patches will often reduce bed shear stresses to values lower than the critical bed shear stress value of 0.213 N/m^2 obtained using Soulsby and Whitehouse (Soulsby, 1997) formula for critical Shields Parameter. This result highlights the use of SAV to reduce sedimentation of navigation channels.

Conclusion

This work showed the efficiency of the implantation of SAV along the navigation channel banks to considerably reduce flow velocities and bed shear stresses. This combination is therefore expected to reduce sedimentation rates. This NBS represents a step closer to achieve EU CO2 emission goals by considerably increase the required time for maintenance dredging activities.

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