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MDPI

Supplemental Material

The Impact of Submerged Breakwaters on Sediment Distribution along Marsh Boundaries

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1.

The bedload transport formulation per unit width (S_b) employed by Delft3D is from van Rijn [1993] and computes the total bedload, as estimated by the median diameter:

$$S_b = 0.053\sqrt{(s-1)g\,D_{50}^3}\,D_*^{-0.3}\,T^{2.1}\ ,\ \text{for}\ T < 3.0 \tag{6a}$$

$$S_b = 0.1\sqrt{(s-1)g\,D_{50}^3}\,D_*^{-0.3}\,T^{1.5}\ , for\ T \geq 3.0 \tag{6a}$$

where s is the specific density (ρ_s/ρ) and D_{50} is the median particle diameter (m). D^* is the dimensionless particle parameter:

$$D_* = D_{50}\left[\frac{(s-1)g}{\nu^2}\right]^{\frac{1}{3}} \tag{6c}$$

where ν is kinematic viscosity (m^2 /s). T is the dimensionless transport parameter:

$$T = \frac{(U_*')^2 - (U_{*cr})^2}{(U_{*cr})^2} \tag{6d}$$

where U_{*cr} is the critical shear velocity (m/s) of the median grain size and

$$U_*' = \left(\frac{C}{C'}\right)^2 U_* \tag{6e}$$

is the effective shear velocity, where C is the overall Chezy coefficient and C' is the Chezy coefficient related to grains.

2.

A further analysis was carried out to investigate the wave transmission phenomenon over the breakwater. In general, transmissivity strongly depends on structure characteristics (height and crest width, roughness, permeability) and wave parameters (period, height, angle of attack). Furthermore, transmissivity can vary over time according to the tide, which, or course, greatly influences the exposure of the structure to many of these different factors [55].

As a case study, we developed a unique model scenario, under which the slope=0.8%, wave height=0.5m, tide=± 0.8m, x_d=100m, sediment concentration = 0.4 kg/m³ and D_{50} = 150μm. Under these conditions, three different wave periods were examined against breakwater structures, with breakwaters with one of three geometric modifications. The first breakwater geometry was similar to the standard breakwater reported in the main body of the paper. The second model was also similar to those found in the body of the manuscript, but twice as wide. The third consists of a standard breakwater but 30 cm higher (Figures S1a). To look at the effect that wave period and breakwater geometry have on wave transmission, we compared the wave period with the average transmitted wave height at the marsh boundary (x=200m) within a tidal cycle (Figure S1c).

Our results, in agreement with Oosten et al. (2007) [56], showed how wave transmission was proportional to the wave period, since higher periods allow more transmission over the breakwater and also illustrated that emerged structures can have the highest impact on reducing wave height (Figures S1b and S1c).

The impact that geometric characteristics of the structure and wave period have on the sediment supply for salt marshes remains unexamined, but what transpires is that a higher structure reduces wave energy more, while longer periods transfer more energy over the breakwater. However, a taller structure is also likely to trap more sediments, whereas longer periods should be able to carry more sediments out. Study results suggest that more research is needed to help find a balance between waves' energy reduction and sediments supply during the design and implementation of breakwater infrastructures, and we intend to verify this aspect in future works.

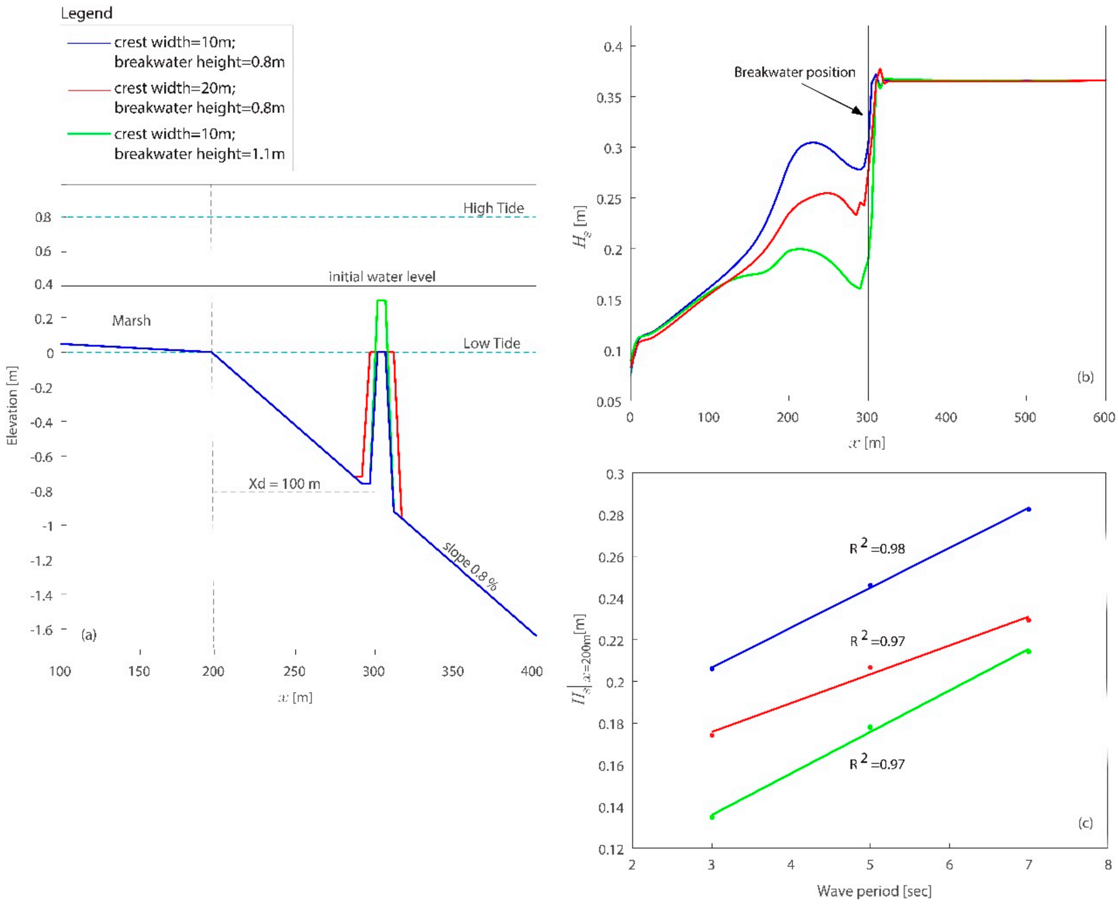

Figure S1. Figure (**a**) the longitudinal profile of the domain used in this analysis, highlighting the three different breakwater configurations. (**b**) An example of wave damping for the case with wave period = 5 s, and (**c**) linear correlations between wave period and wave height measured at the marsh boundary (x = 200m) for the three breakwater configurations.

References

55. Buccino, M.; Calabrese, M. Conceptual approach for prediction of wave transmission at low-crested breakwaters. *Journal of waterway, port, coastal, and ocean engineering*, **2007**, *133*, 213–224.
56. Van Oosten, R.P.; Marco, J.P.; Van der Meer, J.W.; Van Gent, M.R.A.; Verhagen, H.J. Wave transmission at low-crested structures using neural networks. *Coastal Engineering 2006*, **2007**, *5*, 4932–4944.