WAVE SPECTRUM TRANSFORMATION OVER A SALT MARSH UNDER EXTREME STORM CONDITIONS

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INTRODUCTION

In the face of accelerating sea-level rise, coastal structures are dealing with the growing challenge of increased wave loading, requiring innovative solutions for coastal protection. The effectiveness of common hard static structures such as asphalt-covered dikes might drop with increasing sea levels leading to increased cost for their raising. In contrast, salt marshes stand as vital coastal ecosystems with remarkable adaptability (Zhu et al., 2020).

Assuming that there is an adequate supply of sediment, salt marshes can grow with sea level rise and serve as a natural coastal defense against storms (Vuik et al., 2016). In this context, exploring adaptive, cost-effective solutions that could potentially reduce the need for costly dike-heightening investments is crucial. Moreover, salt marshes not only mitigate wave energy, but can also offer other benefits such as nature development, recreational space and they effectively store carbon (Gedan et al., 2011).

The application of salt marshes as a frontline defense is still limited due to knowledge gaps, particularly concerning their capacity to dissipate energy during extreme storm conditions. To bridge these knowledge gaps, this paper explores the transformation of wave spectra over salt marshes, shedding light on their potential as a viable and sustainable coastal protection strategy.

METHODOLOGY

To investigate the wave transformation over salt marshes, a dedicated scaled-down (1:10) experimental setup was devised at the wave flume of the Hydraulic Engineering lab of the Delft University of Technology, 0.80m wide, 1m high and 39m long. The setup, includes a 5.4m long foreshore, a 7m long salt marsh with a vertical cliff at its edge and a dike, as depicted in Figure 1. The foreshore consists of two parts, a steep 1:9 offshore part and a milder 1:45. To mimic the *Spartina Alterniflora* species, approximately 48.000 cylindrical rubber shoots are used to create a meadow with plants l_s=9cm long and a diameter of D_s=2mm on the salt marsh platform. These are scaled down by preserving the Cauchy number, blade length ratio and the buoyancy number (Zhang and Nepf, 2021).

Figure 1 – Side view of the wave flume, at the toe of the dike.

Various irregular hydrodynamic conditions are tested, considering different combinations of water depth, wave height, and wave steepness. The experiments are repeated for six different setups, comprising three different cliff heights (0, 6, and 12 cm), both with and without the meadow. High focus is given to the study of the attenuation performance of a salt marsh for different water levels, while the submergence ratio, defined as the water depth at the salt marsh (d_m) divided by the shoot length (l_s), is varied between d_m/l_s=0-5.7.

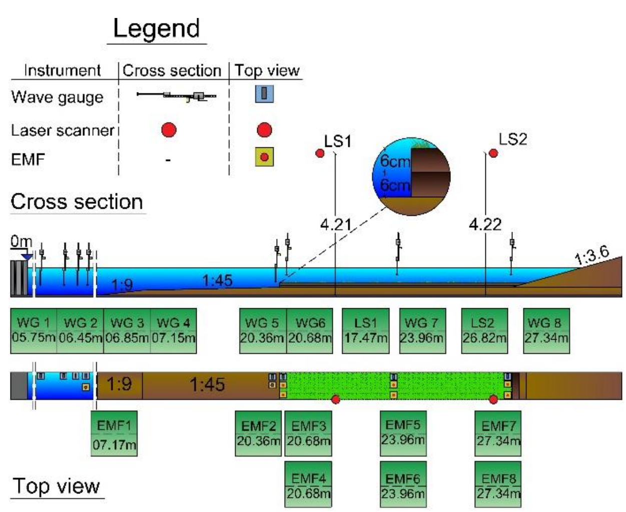

Figure 2 – Experimental set-up.

Over the lengthwise direction of the flume, two SICK

LMS511 lidar laser scanners (LS, Figure 2) are used to record a dense grid of water levels (Blenkinsopp et al. 2012, Hofland et al. 2015). This results in an interpolated grid with a spatial resolution dx=0.1m and a temporal resolution dt=0.015s. In addition, 8 wave gauges are installed at various positions along the flume to validate the readings of the LS.

To further complement our data collection, three electromagnetic flowmeters (EMF3, EMF5, and EMF7) were strategically placed at the beginning, middle, and end of the salt marsh. These flowmeters recorded velocity measurements 8 cm above the marsh bottom. An additional set of three flowmeters (EMF4, EMF6, and EMF8) were positioned in the same locations, capturing velocity data within the middle of the water column.

As a necessary intermediate step, we utilize two different methods to separate incoming and reflected signals: the method by Guza and Thornton (1985) and the Radon transform (Almar et al., 2014). The incident wave signals obtained from these analyses are further processed to calculate the root mean squared wave height H_{rms}, the spectral period $T_{m-1,0}$ and the wave set-up.

RESULTS

Figure 3 shows a visualization of the evolution of the three investigated variables for two experiments accounting for identical hydrodynamic conditions, with and without vegetation. For this relatively low submergence ratio (d_m/l_s=1.8), the effect of vegetation on the dissipation of H_{rms} is significant, while it also leads to an increase of the spectral period $T_{m-1,0}$ and wave set-up.

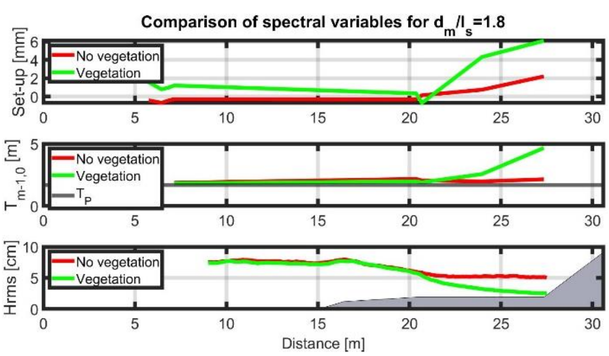

Figure 3 – Visualisation of H_{rms}, $T_{m-1,0}$ and wave set-up along the flume for d_m/l_s=1.8, offshore significant wave height H_s=0.12 cm and peak period T_p=1.7s.

For this case, H_{rms} is reduced by 55% between the salt marsh edge and the toe of the dike, while this reduction effectiveness drops for higher d_m/l_s, as depicted in Figure 4. These results indicate that the salt marsh model contributes to the coastal defense even for very high water depths (d_m/l_s=5.7) as H_{rms} is still reduced by approximately 20%. On the other side, the trend observed in Figure 4 shows that further increase of the water depth would probably result in extremely low dissipation rates, yielding the salt marsh irrelevant to the coastal defense. During the conference we will present a more complete analysis of these variables for the entire range of the tested hydrodynamic conditions.

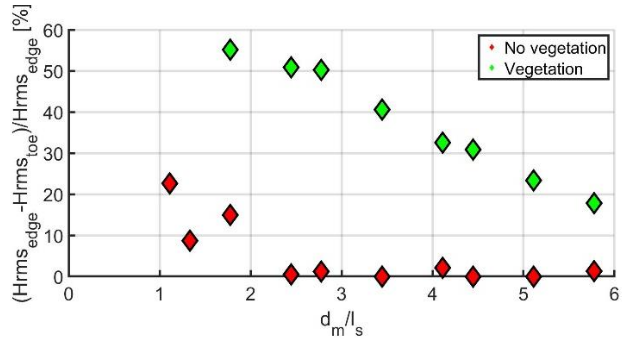

Figure 4 – Reduction of H_{rms} in relation to d_m/l_s, between the salt marsh edge and the toe of the dike, with and without vegetation.

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