

Modelling wave attenuation by vegetation with SWAN-VEG; Model evaluation and application to the Noordwaard polder

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Introduction

As part of the project “Room for the River” the Noordwaard polder will become an inundation area in case of high water levels on the river Nieuwe Merwede. In the northeast corner of the Noordwaard polder a residential area around Fort Steurgat is located that needs to be protected by a higher dike. This plan received much resistance from the residents; therefore it was suggested to damp the waves by placing a field of willows in front of the dike such that the height of the dike could be lowered while maintaining the required safety level. So far no suitable model was available to quantify the effect of vegetation on the wave height. Recently, Deltares developed the SWAN-VEG model to determine the effect of vegetation on wave height. In order to use this model, it is first tested to find out whether the model can describe real cases well enough. Then the model can be used to determine the effect of a vegetation field on the wave height in front of the dike at Fort Steurgat.

SWAN-VEG

The SWAN-VEG model consists of the original numerical wave model SWAN (Ris, 1997; Booij et al., 1999) to which a vegetation module is added (Burger, 2005). This module consists of an additional energy dissipation term due to vegetation based on Mendez and Losada (2004). The dissipation term is determined by vegetation characteristics such as plant height, diameter, density and drag coefficient and wave characteristics like wave height, wave length and wave period. A sensitivity analysis of the model showed that the wave height reduction is larger for higher, thicker, denser or stiffer vegetation as the resistance of the vegetation field increases with these conditions.

Model evaluation

In order to evaluate the applicability of the model to real conditions, the model was calibrated and validated using data from flume experiments carried out by Penning et al. (2009). In these experiments the effect of three macrophyte species on wave heights under different wave regimes and water depths was determined. The macrophyte species were: *Echinodorus grandiflorus*, *Cabomba caroliniana* and *Nymphaea rubra*. These can all be described as (very) flexible plants. The dense vegetation cases were used for calibration, the lower densities were used for validation. All parameters were known, except for the drag coefficient of the plant which was used as a calibration parameter. For each experiment the drag coefficient was varied until the wave height reduction calculated by the model was equal to the wave height reduction measured in the experiment. Table 1 shows the range of values for each species obtained by calibration.

Table 1 Range of drag coefficient per vegetation type

Plant	Drag coefficient range [-]
<i>Echinodorus grandiflorus</i>	0.02 – 0.17
<i>Cabomba caroliniana</i>	0.04 – 0.33
<i>Nymphaea rubra</i>	0.08 – 0.64

The calibration and validation results showed good agreement with the experiments, except the validation for *Cabomba caroliniana*. Apparently the calibrated drag coefficient for the high density, where the plants behave more as a porous block, is less representative for lower plant densities.

Application to the Noordwaard polder

The SWAN-VEG model was used to verify the design of a vegetation field in front of the dike near Fort Steurgat.

A field of willows (*Salix alba*) on top of an elevated bank extending 60 to 100 m in front of the dike should reduce wave heights under extreme conditions by at least 40% to allow a 70 cm lower dike height.

The significant wave height in the Noordwaard polder was assessed with the SWAN model using detailed water and wind conditions for a return period of 1/2000 years. The results show that with an average water depth in the polder of 2.8 m (water level 3.5 m +NAP) and a wind speed of 32 m/s from the southwest waves are generated with a height of around 1.1 meter at Fort Steurgat.

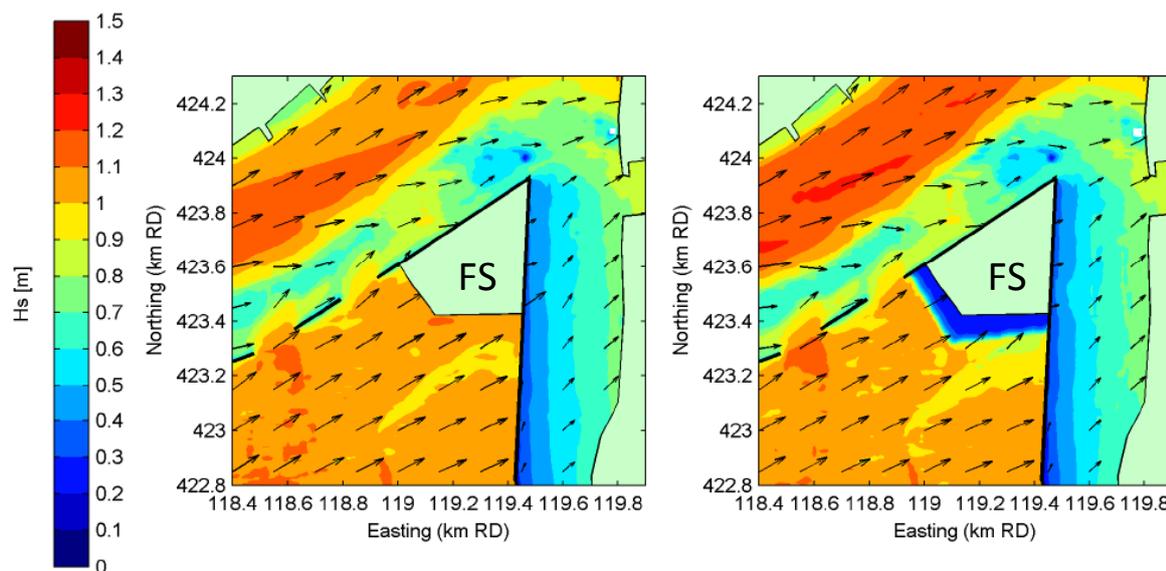


Figure 1 Left: wave height around Fort Steurgat (FS) under extreme conditions without bio-engineering; Right: wave height with elevated bank and vegetation field.

According to the SWAN-VEG model the bank and willows reduce the wave height with 80% to 0.3 m. This is more than the required 40%, hence it is concluded that the vegetation field is able to decrease the wave height sufficiently to implement a lower dike. A vegetation field appears to be an effective way to decrease the wave height and allow smaller dimensions of hard constructions and is therefore a good example of bio-engineering.

References

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