CHALLENGES IN DESIGNING A WIND FARM ON AN ERODING BEACH ALONG THE DUTCH COAST

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INTRODUCTION
The Dutch energy company Eneco received the concession to construct a 116 MW windfarm on the Maasvlakte-2, a recent large seaward port extension of the Port of Rotterdam. The land reclamation is protected partly by a hard sea defence and partly by a soft sea defence, consisting of a sandy beach and adjacent dunes. Twelve wind turbines with a monopile foundation will be constructed on the beach, close to or in the waterline. The beach is erosive and is maintained by regular beach and foreshore nourishments. Designing and constructing wind turbines in this dynamic environment forms an unprecedented challenge.

Figure 1 - Construction of the wind turbines on the beach

SOFT SEA DEFENCE
The soft sea defence of Maasvlakte-2 provides flood protection with a safety level of 1 in 10,000 years. It protects the Port of Rotterdam. Failure of this sea defence during a storm would lead to a huge economic damage. The sea defence is maintained by bi-yearly nourishments of approx. 1 million m³ of sand. The maintenance follows a strict protocol. Any negative impact of hard structures built in this sea defence on flood safety is unacceptable unless adequately mitigated. The wind turbines are also not allowed to impact the maintenance of the sea defence.

FLOOD SAFETY
The sea defence consists of beach and dunes that should sustain a 1 in 10,000 years design storm without breaching. The impact of the wind turbines on dune erosion during storm conditions was assessed using XBeach model simulations. They have shown that locally the wind turbines cause additional dune erosion, with a magnitude varying along the 5 km long beach (Figure 2). To mitigate the additional erosion caused by the hard structures, a surplus of 40 m³/m sand will be added to the dunes.

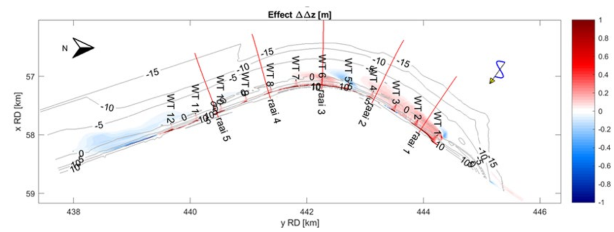

Figure 2 - Additional erosion caused by the wind turbines

BEACH DYNAMICS
The curved beach of Maasvlakte-2 is highly dynamic and is subject to erosion caused by the combined action of waves and tides. Analysis of satellite images (Figure 3) using CoastSat shows that the shoreline can shift significantly between the subsequent nourishments. This causes the position of the wind turbines with regard to the (High/Low) water line to vary during a year. Analysis of historical profiles shows a vertical beach level variation near the wind turbines up to 2-3 m. This highly dynamic environment not only poses a challenge for the design of the wind turbines, but also for constructing them: for the safe supply of materials and construction temporary constructions are needed on this narrow beach.

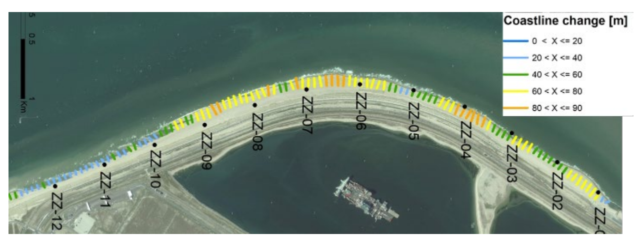

Figure 3 - Coastline change 2016-2020

SCOUR AND SCOUR PROTECTION
Model simulations of Deltares (2020) using Delft3D, XBeach and an empirical scour model show that the tidal and wave-driven currents can create scour holes up to 6-8m depth around the wind turbines. Deep scour holes are undesirable e.g. for cable exposure and beach visitor safety. This scour will therefore be limited by applying a rock scour protection below the beach level. To avoid the risk of rocks being exposed, an advanced volumetric analysis was carried out to determine the optimum

construction level for this protection given the constraints from the maintenance protocol and beach dynamics over the years. The scour protection was tested in a scale model (Figure 4). While the focus of these tests was on the scour protection stability, the tests confirmed the development of deep scour holes.

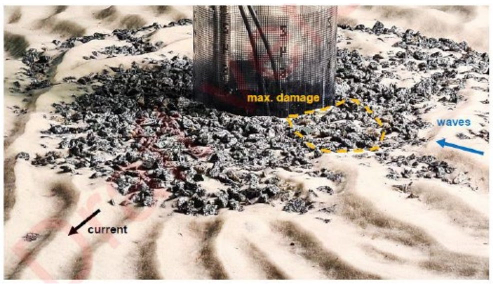

Figure 4 – Scour around a wind turbine (LUFI, 2021)

LESSONS LEARNED

This study illustrates the challenge of combining the beach dynamics at different temporal and spatial scales in the design and construction process of a nearshore wind farm. The combination of multiple tools to address these interactions will be detailed in the proceedings.

REFERENCES

LUFI (2021): Physical model tests to verify the design of a scour protection around monopiles in waves and currents, Gottfried Wilhelm Leibniz Universität Hannover