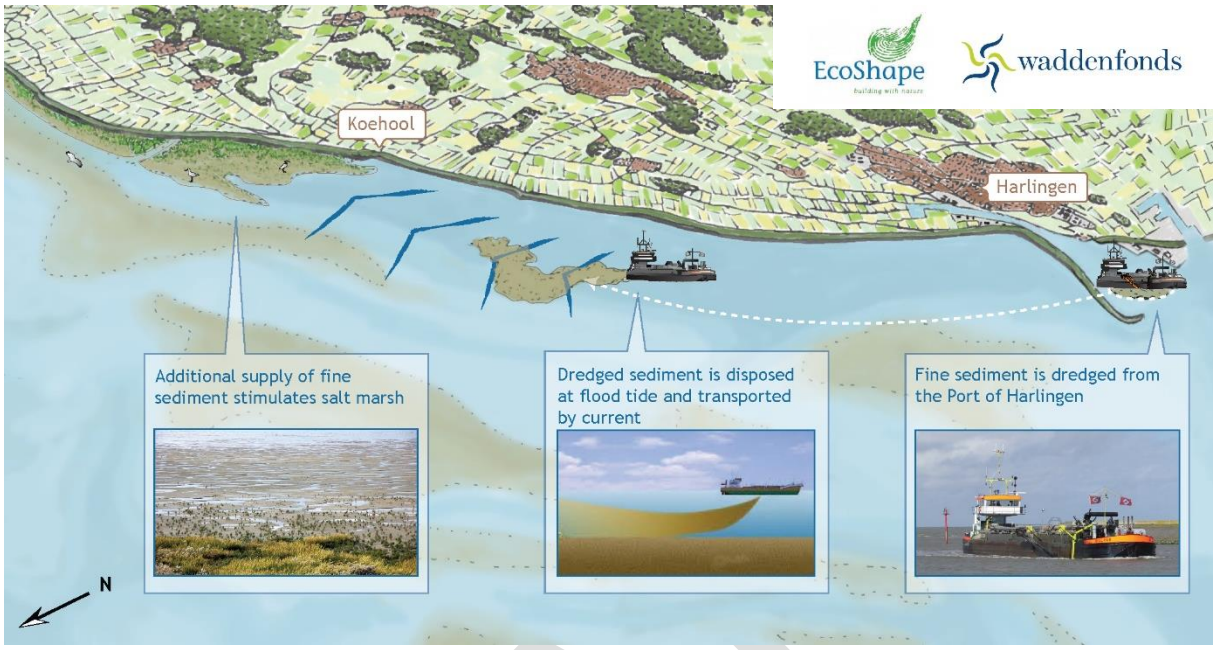
Seaward Solution Factsheet Mud Motor



The Mud Motor is disposal of sediment dredged at the Port of Harlingen at a specific location from where the mud is transported by natural processes, such as tidal flow, to nearby salt marshes and adjacent tidal flats. By increasing the sediment supply to the tidal flats, those will increase in height and create more favorable salt marsh expansion conditions. The aim is to stimulate the growth of salt marshes leading to increased dike safety and to reduce the recirculation of dredged sediment. Thus, three goals are aimed for: nature development, increased height of the foreland of the dike and a more economical way of dredging practice.

Accumulation of sediment is common in ports such as Harlingen and dredging is required. Dredged sediment is disposed offshore, as close to the port as possible to limit the costs. At the same time, a considerable part of the disposed sediment may return to the port under influence of tidal and density driven flows, which increases the maintenance dredging volumes. The goal of the Mud Motor is to re-use the dredged sediment in a beneficial way by stimulation of salt marsh development and reducing the return flow of sediments to the harbor. In this way mud might strengthen the intertidal muddy environment and the supratidal salt marshes. Due to this it may also help to provide extra wave dampening in front of the dikes.

Underlying hypotheses of the Mud Motor concept (using natural transport processes to re-use dredged sediment for salt marsh expansion) are that the sedimentation in and in front of the salt marsh is supply-limited (i.e. increasing the supply will result in increased sedimentation) and the salt-marsh expansion is limited by the coastal profile (inundation times are too large). The advantage of accelerating marsh-development processes in this way, is that the desired gradients that are associated with natural salt-marsh development are preserved and/or enhanced.

The Mud Motor was expected to generate three beneficial effects:
1. less recirculation towards the harbor, and therefore less maintenance dredging;
2. promotion of the growth and stability of salt marshes, improving the Wadden Sea ecosystem;
3. stabilization of the foreshore of the dikes, and therefore less maintenance work on the dike.

The Mud Motor pilot at Koehoal used dredged material from the port of Harlingen in the south (with annual dredging rates up to 1.3 million m^3). From the port to the salt marshes a flood-dominant tidal channel, 'Kimstergat', exists, which has been narrowing and slightly deepening over the last decennia. At Koehoal, the sea dike deflects from the Kimstergat channel and tidal flats are found and a narrow

fringe of salt marshes has developed, which are increasing in width when going in eastward direction. At this transition point, the pilot aimed to enhance salt marsh growth. Eastward of Koehoal, large tidal flats are found, also forming a local tidal divide between the Kimstergat channel and the next tidal channel.

Research

The research for the Mud Motor pilot (within an Ecoshape project and a STW project) focused on field work. In the field, the effectiveness of the proposed disposal location was assessed with a tracer experiment, giving confidence in the disposal location. Over a three-year period, the sedimentation rates at the salt marshes and the tidal flats in front of the salt marshes were monitored, as well as vegetation cover, density and species distribution. The bed elevation was also measured for a shorter time period with a higher frequency, in combination with measurement of waves, currents and wind this showed very large natural dynamics in the bed level elevation at the project site and a large effect of wind-driven flows, even under moderate wind speeds. All beforementioned measurements took place at the tidal flats and the salt marshes. During 13-hour measurement also hydrodynamics and sediment suspensions in the Kimstergat tidal channel have been measured. To a lesser extent, numerical models have been used. First at project initialization, to determine the optimum disposal location and at the end of the project to test the hypothesis (understanding) of the sediment transport processes at the project site. The aim was to develop fundamental knowledge needed to understand and quantify the physical and ecological aspects of the Mud Motor concept for further upscaling and exporting.

Approach

Increasing the sediment supply to enhance of salt marsh growth is an alternative to the traditional approach of slowing down tidal flows and breaking waves with semi-permeable brushwood groins to stimulate sedimentation.

Over a period of two winters (2016 and 2017), 470,000 m^3 of fine-grained sediment (D50 of~10µm) dredged from the Port of Harlingen was deposited at the end of the tidal channel Kimstergat, with an average of 22 sediment disposals per week of operation. It was expected that this mud would be transported by the tidal currents to the study site. Expectations were that level of the marsh would rise 1-2 cm due to the pilot.

Results

A general effect of the Mud Motor on sedimentation could not be shown. The bed-level dynamics at the project site is comparable with the reference location not affected by the Mud Motor (at Zwarte Haan). The field measurements revealed that the sediment disposed at the Mud Motor pilot location is partly transported to the tidal flats at Koehoal by flood-dominant tidal flows. At the extensive tidal flats at the end of the Kimstergat channel, there is ample opportunity for deposition and sediment is (temporarily) stored. When moderate to strong winds from the north-west blow over these shallow and muddy tidal flats, sediments are resuspended and transported and dispersed further, also to the project area. Mud is already abundant in the area and thus not a limiting factor for vertical accretion of the mud flats and salt marshes. Adding mud with a mud motor did not change that significantly. The large natural dynamics of the project site in combination with the relatively small signal from the pilot did not show convincing sedimentation rates that can be attributed to the Mud Motor. In the dredging volumes a decrease occurred during the short pilot period of 2 years, which is not conclusive considering the strong variations over longer time spans.

Measurements showed that the transport rate through the tidal gully was increased by a factor 1.6 - 2 due to the Mud Motor. The sediment dynamics of the area are strongly influenced by the sedimentation of muds since the closure of the Zuiderzee and as a result the tidal marshes grows since 1996, when the coastal profile was accreted enough to have suitable inundation times for vegetation to establish until 2005, a period with few storms and relatively much rain.

During the experiment, the heights of the tidal marshes fluctuated strongly over time with sedimentation and erosion of up to 1 dm, likely depending on the erosion and consolidation of the sediments. During the first Mud Motor period (September 2016 – August 2017) the tidal marsh and the mudflats showed

vertical accretion, but the area of the tidal marsh decreased. In the period September 2017 - August 2018) the tidal marsh and the mud flats were eroded, but the vegetation covered a larger area. The vertical growth of the tidal marsh was hence not directly related to the horizontal extent of it.

Given the surplus of muds the main limitation for tidal marsh growth appears to be too much hydrodynamic energy. The most important factors for sedimentation are: wind conditions (wind can generate large set-up at the project site, resulting in erosion), consolidation of the mud and fixation of the mud by vegetation development. When sediment is deposited at the desired location, a time window with calm hydrodynamic conditions should follow so that sediment can gain enough strength to remain during more dynamic conditions.

Lessons learned

Although the Mud Motor may be a useful concept, it will not contribute to mud deposition on tidal marshes or between brush wood groins in areas where mud is not a limiting factor. Thus, care should be taken to identify areas where extra mud disposal may contribute to a transport of mud in the direction of the deposition site. Furthermore, disposal of mud at larger distances of the harbor may increase transport costs, but decrease return flow of mud to the dredging site. If such disposal is economical viable should be established for each separate case via modelling and measurements.

Stakeholder process

The Port of Harlingen produced large volumes of dredged mud (ca. 1 million m^3 per year), leading the secretary of the Wadden Sea Ports Harlingen to ask EcoShape for solutions. It Fryske Gea had developed a vision in which increasing the tidal marsh area was a goal. In a brainstorm the Mud Motor came up as a possible solution. It was subsequently rewarded by the Waddenfonds. Stakeholders: Port of Harlingen, Van Oord, Royal Haskoning DHV, Arcadis, It Fryske Gea, Wageningen University and Research, Deltares, Gemeente Harlingen.

Discussion points

- A Mud Motor will have the most impact in areas where mud is limited (see Lessons learned) but can only be executed if enough mud is available. Are there areas where both are present within economical viable distances?
- Do we want to build Mud Motors in areas where the bottom is mainly sandy?
- Are Mud Motors a solution to further sediment deposition in de-poldered areas (managed retreat and double dike areas)?

Literature

M. Baptist et al., 2019: Beneficial use of dredged sediment to enhance salt marsh development by applying a 'Mud Motor': evaluation based on monitoring.

J. Vroom et al., 2017: Effectiveness of the Mud Motor near Koehoal - results and interpretation of a tracer study.