Seventy years of sandwave research in the Netherlands

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ABSTRACT: The seabed off the west coast of the Netherlands is almost entirely covered with sandwaves with heights from 2 to more than 8 metres. From the moment when it was technically possible to study these relatively small bed forms, there was interest from governmental authorities concerned with the management of coast and sea and from the scientific community. In fact, the research started with a PhD study done by an engineer of the Ministry of Transport, Public Works and Water Management. From the PhD study of Van Veen (1936) to the PhD study of Van der Veen (2008), more than seventy years of research on sandwaves in the Dutch coastal area was accomplished. In this time period there was, for most of the time, a strong cooperation between scientific institutes, universities and government, both from water and shipping management authorities and from the Hydrographical Department of the Dutch Royal Navy.

1 INTRODUCTION

Knowledge of the seabed is driven by practical needs, especially for shipping. Centuries ago, the sandbanks off the coast of the Netherlands and Belgium were already charted by sounding. From the sixteenth century onwards, the banks are shown on the sea charts of these areas. Even the connection with tidal currents was made in that time. Wagenaer already mentioned in 1584 in his "Spieghel der Zeevaaerdt', a collection of charts with sailing directions, that the current was perpendicular to the banks, both during flood and ebb. Knowledge to improve the safety of shipping was very important in those times, since many ships were lost in the sandbanks area. Sometimes, in the case of a hostile fleet, like the Spanish Armada in 1588, it was a blessing that the enemy did not have the right information about the seabed.

Although classic sounding with a lead line was useful for large-scale bed forms such as sandbanks, it was not good enough to recognise smaller bed forms like sandwaves.

The technical improvement of sounding was crucial for the study of sandwaves. Although, as early as 1838, the first experiments were done with an echo sounder, it was not until the 1920's that the echo sounder was really used (Schlee 1973). Even then, it was not useful for sandwave detection, because it only gives point measurements, whereby relatively small bed forms cannot be seen. In the 1930's the continuous echo sounder was developed. That gives the possibility to study the morphology of bed forms like sandwaves, even when the absolute positioning was not accurate at all. Fishermen were already aware of these smaller bed forms (Van Veen 1935), perhaps due to the irregular movements of fishing equipment over these bedforms.

On the Netherlands Continental Shelf, maintenance dredging, pipeline construction and sand mining are important activities. For the management of these seafloor related activities, insight in the nature and dynamics of sandwaves is necessary. There is especial interest in the prediction of vertical sandwave growth and lateral migration to optimize regulating and execution of these activities in a economic and environmentally-sound way (Stolk 2000)

Reading the older literature one should be aware of the variation and changes in terminology. Often what we call sandwaves are called mega ripples. Mega ripples are called 'smaller ripples'. Sometimes 'sandwaves' and 'mega ripples' are used as synonyms, even within one article.

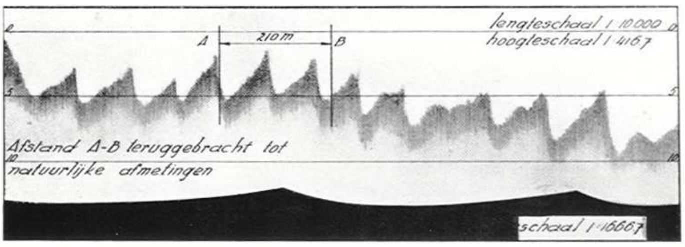
2 EARLY INVESTIGATIONS BY VAN VEEN

For the Netherlands, the work of Johan van Veen is of utmost importance. In 1934 he carried out a survey with the Dutch research vessel 'Oceaan' on the morphology and sedimentology of the sea bed and the currents in the southern North Sea from the Straits of Dover to the coast of the Netherlands. The study was initiated by Rijkswaterstaat, the department of the Ministry of Transport, Public Works and Water Management, that is concerned with water management including the North Sea, and was aimed at the source of sediments supplying the Dutch coast. Van Veen used an echo-sounder which gave continuous reflecting profiles and concluded from these that the southern North Sea, for a large part, was covered with sandwaves (Van Veen 1935, 1936). These were the first Dutch observations of sandwaves. Measuring the sea bed with an echo sounder gave him the impression of flying over a desert. Van Veen compared these undersea bedforms, like sand banks with sandwaves, with large dunes in the Libyan desert with superposed smaller dunes, and suggested a similar development as wave structures on a boundary between a sandy surface with an moving agent (air or water) over it.

Figure 1 shows two profiles from the 1934 survey of the 'Oceaan'. The profile off the peninsula Goeree (the Netherlands) shows symmetrical sandwaves. The profile off the 'Baas', a sand bank off Boulogne, shows asymmetrical sandwaves, but Van Veen mentioned that he later found, on the same spot, another type of sandwave. This indicated that sandwaves are not stable features.

From the asymmetry of a sandwave he concluded a migration direction, but he emphasized that this cannot be taken for the sand transport direction of the broader area without further research. He already points to the influence of grainsize and current velocity on the existence of sandwaves.

a)



b)

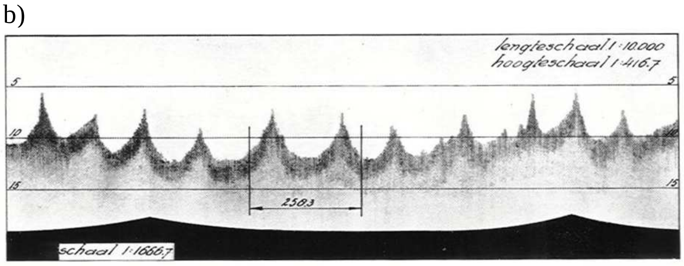


Figure 1. Echo sounding profiles over sandwaves (Van Veen, 1936). a) Symmetrical sandwaves off Goeree. b) Asymmetrical sandwaves on the 'Baas' sandbank off Boulogne.

3 PRACTICAL RESEARCH

In the 1960's, a few new surveys were executed with, for that time, accurate Survey Decca Chain positioning. During the surveys in this period, mega ripples were detected moving over the sandwaves. From these surveys, a slight migration in the direction of the dominant tidal current was concluded (Langeraar 1966, Lekahena 1966).

In the 1970's, a more systematic approach was chosen. Although Van Veen already had warned of sandwave development in shipping routes, his research was not continued till in the seventies and eighties when a deepening of the approaching channel to Rotterdam harbour was planned and executed.

The approach from the North Sea to the Rotterdam harbour consists of several parts. Most coastward, the Maaschannel is deepened in the coastal area off the Netherlands. More seaward is the Eurochannel, a deepened part of the North Sea floor. Seaward of the Eurochannel is the approach area to the Eurochannel. This area is not fully deepened but the sea floor is kept at a minimum depth by dredging sandwaves if necessary. More knowledge of sandwave behaviour was necessary for the planning the intensity of surveying and dredging. The area was intensely studied by the governmental managing authorities, together with the Dutch Royal Navy, the Geological Survey and other institutes and universities.

A special study area was defined off the peninsula of Goeree. This area measured 1 by 2 km and was frequently surveyed to measure the migration of the sandwaves and their height difference during the seasons. This area was also used for the study of the natural burying of small objects such as mines and oil drums. Spatial positioning for sandwave research was improved by the positioning of beacons with radar reflectors on the seafloor, with the sandwaves and their migration being measured in regard to these beacons.

Most of the reports of the studies in the approach to the Euro channel and the Goeree study area were not written for scientific purposes but for practical use, and therefore were never published and exist only as grey literature. However some articles are published as a result of these studies (Houbolt 1968, Terwindt 1971, Smith 1988).

The North Sea Directorate of Rijkswaterstaat made a great effort in this practical research culminating in the yearly 'Ribbel-atlas' by Bicknese (1982-1987), which gives an overview of sandwaves in the approaching area to Rotterdam Harbour. This atlas points both to the migration of sandwaves as well as to their regeneration after dredging.

The geomorphology of the sea floor directlywest and north of the coast of the Netherlands was mapped by Van Alphen & Damoiseax (1989) from bathymetric surveys done by the Dutch Royal Navy. In this map, the sandwave field is identified and the heights of the sandwaves are indicated (figure 2).

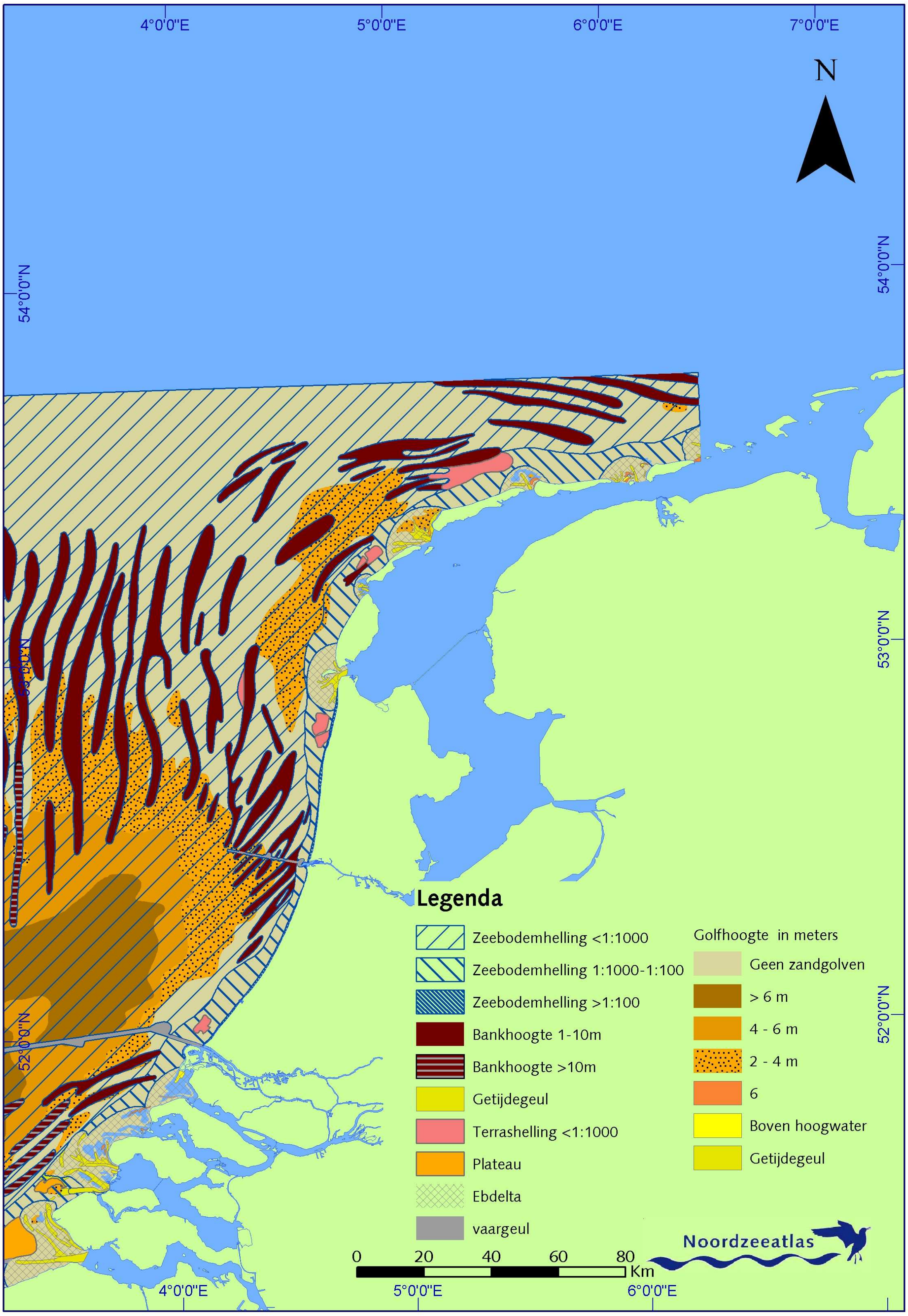
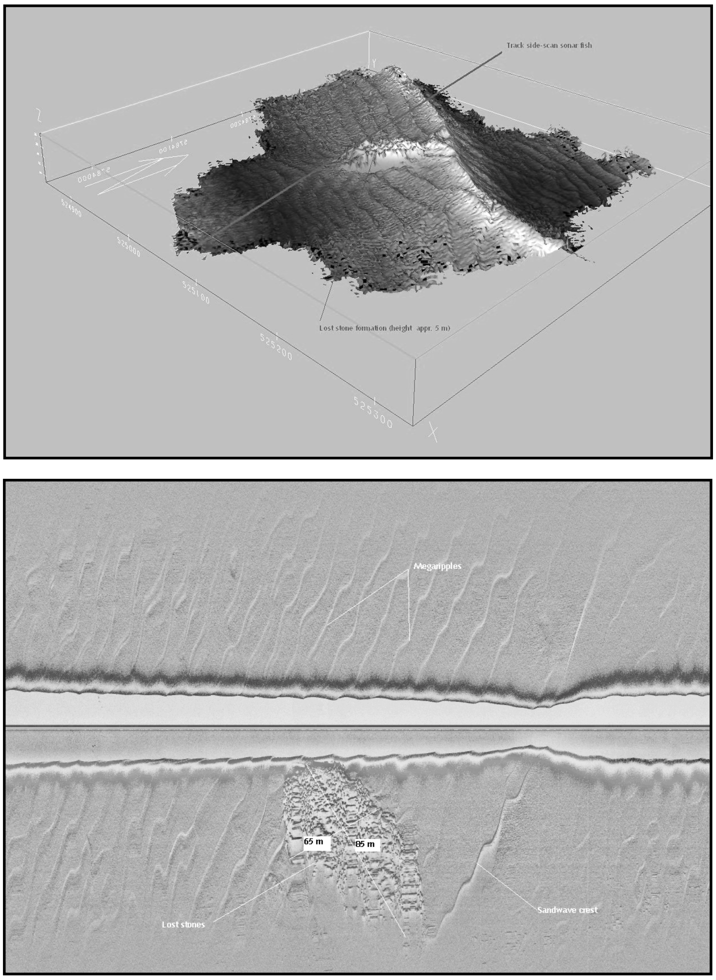


Figure 2. Geomorphology of the Dutch Continental Shelf (www.noordzeeatlas.nl, simplified after van Alphen & Damoiseuax, 1989) (legenda in Dutch)

Time series of soundings improve with the transition from single beam echosounding to multi beam echosounding and with the transition from positioning with Decca and Hyperfix to (D)GPS. A spin off of this work is a large dataset that plays an important role in the validation of models of sandwave behaviour. Also, a more statistical approach of sandwave dynamics is possible with these datasets (Wüst 2004, Van den Berg 2007).

For the management of the sea floor, the new remote sensing techniques, and their combination, are very useful. This also leads to very nice pictures to visualize the bed forms of the sea floor and far more than single beam echo sounding could do. As an example, in Figure 3 a sandwave is shown with, on its flank, a large number of large stone blocs, lost by a ship. Both the multibeam and side scan sonar registrations are shown.

a)



b)

Figure 3. Sandwave with stone blocs (Rijkswaterstaat, North Sea). a. Multibeam registration. b. Side scan sonar registration.

4 SCIENTIFIC RESEARCH

As a result of the cooperation with the managing authorities and the Geological Survey, the universities of Delft, Utrecht and later on Twente were involved in field investigations and modeling of sandwaves. Studies were done focusing on the current behaviour above sandwaves and other processes that are responsible for the dynamics of sandwaves (Van Gastel 1987, Passchier & Kleinhans 2005, Van Dijk & Kleinhans 2005). The sedimentology of sandwaves was studied by examining grain size changes over sandwaves (Steward 1992, Stolk 2000, Koster 2000) and sedimentary structures, as visible in lacquer peels (Stolk 2000). In recent years, more and more interest has grown in the ecological importance of sandwaves as a habitat for benthic fauna (Weber et al. 2004). The involvement of the universities lead to a number of Phd-theses, especially on modeling (Hulscher 1996, Knaapen 2001, Nemeth 2003, Roos 2004, Van den Berg 2007, Van der Veen 2008). Here only the PhD studies are mentioned, but they had a large spin off of numerous scientific articles. Several studies were presented on the previous conferences on sandwave dynamics in Lille (2000) and Enschede (2004).

5 CONCLUSION

A short history of almost 75 years of sandwave research in the Netherlands can only highlight the most pronounced research lines and literature. A rather complete bibliographical overview is given by Van Maren (1998). The most important conclusion from the research concerning sandwaves in the Dutch area is that it was only possible to have this more or less complete view on sandwaves by combining practically-aimed and scientifically-aimed research. The efforts of fieldwork and theoretical research, including mathematical and physical modelling, together give fruitful results and insight on the morphological behaviour and the sedimentology of sandwaves. Nevertheless there is still much unknown about the dynamics of the sandwaves further away from the approaching channels to the harbour of Rotterdam.

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