**Shallow – Shallower – Shallowest**

**Morphological Monitoring Walsoorden**

In 2001, an expert team appointed by the Antwerp Port Authority proposed a new strategy for disposing dredged material, as part of a strategy for managing the morphology of the Western Scheldt estuary. Extensive research carried out by Flanders Hydraulics Research – including physical scale-modelling, numerical simulations and field measurements – indicated that the proposed strategy would likely be successful. The final step to investigate the feasibility was the execution of a full-scale in situ test in view of modifying the shape of the ‘Walsoorden’ shoal. This paper describes the morphological monitoring program in detail. As far as known, the extreme project specifications were never realised before.

**Introduction**

The Scheldt estuary is the maritime access to several ports in Flanders and the Netherlands, the largest being the Port of Antwerp, located some 100 km from the open sea. Until 1970, the navigation route required limited (< 5 million m³) dredging on the sills. During the 1970’s a first deepening campaign was executed, resulting in higher (~ 10 million m³) maintenance dredging works. In 1998-1999 a second deepening was executed, resulting in a tide-independent draught of 38'.

Flanders and the Netherlands agreed in 1999 to cooperate closer for managing the Scheldt estuary and to set up a “Long Term Vision” (LTV), with attention for safety against flooding, accessibility of the ports and nature. One of the main objectives of LTV is the preservation of the dynamic and complex flood and ebb channel system in the Western Scheldt, the middle reach of the estuary.

An expert team appointed by the Antwerp Port Authority came to the conclusion that the morphological evolution results from both the natural changes (adaptation of the coastal morphology as a result of the Holocene sea-level rise) and human interfering in the natural evolution (land reclamation and "poldering", dredging and other river works). They proposed the idea of morphological management, aiming at steering the estuarine morphology in order to preserve the multi-channel system in the Western Scheldt. The proposed management strategy includes morphological dredging and disposal, modifications (removal, adaptation, construction) of the hard bordering to modify the erosion-transport-deposition processes.

To illustrate the management strategy, the Port of Antwerp Expert Team (PAET) proposed, as a pilot project, to dispose dredged material near the shoal of Walsoorden. The seaward tip of this shoal has been eroded during the last decades. Dredging works would be used to reshape this eroded sandbar, so that the flood and ebb flows would continue to maintain the multiple channels. Besides making the estuary ecologically and morphologically healthier, the reshaping of the sandbar would also improve the self-eroding capacity of the flow on the crossing and possibly reduce the quantity of material to be dredged. A diffuser-type device would be used to disperse the dredged material in a controlled way in shallow water along the sandbar edges.

In 2002-2003, the feasibility of this pilot project has been investigated by Flanders Hydraulics Research (Flemish Government). The research programme combined three tools: field measurements, physical scale models and 3D numerical models. The results of the research work confirmed the feasibility of the idea. However it was concluded that a real life (in-situ) disposal test was required to give final prove of the feasibility of this new dumping strategy.

At the end of 2004, 500,000 m³ of sand was disposed at the seaward tip of the shoal of Walsoorden using a diffuser. The main idea was to modify the morphology of this sandbar by disposing dredged material very precisely. The amount of 500,000 m³ was chosen because it is large enough to see an effect of the disposed sediment, while it is small enough to be reversible if something would go wrong. To evaluate the success of this in-situ test, Flanders Hydraulics Research set up an extensive monitoring programme, including bathymetric surveys (morphological monitoring), ecological monitoring, sediment tracing tests and sediment transport measurements.

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never realised before. In order to meet the required specifications, EUROSENSE used the most recent survey equipment and software which was available on the market and used a small but fast survey vessel.

**Project Specifications**
- Multibeam surveys had to be performed up to a level of 1.0 meter NAP (equal to + 3 meter above low water).
- In addition to the very shallow water depths, an area (called “Area B”) of approximately 11 km² had to be surveyed within a time limit of one working day. Once a month a larger area (called “Area A”) of approximately 47 km² had to be covered.
- EUROSENSE had to determine how much of disposed dredged material remained in the disposal area; how much material moved and in which direction. Furthermore, the influences of the disposed dredged material on the bottom patterns and their movements had to be visualized.

**Survey Equipment**
In order to meet the required specifications; a survey system had to be chosen which was able to measure accurately and in detail the bed-forms. Since the river Scheldt is fully covered with LRK-GPS base stations (owned by the Belgian and Dutch authorities) the choice of a positioning system was simple. LRK-GPS gives an accuracy of centimetres in x,y and z. Therefore no tide gauges had to be installed. In order to get a high density of depth values, the SIMRAD EM3002 Dual Head was used. This system is able to measure up to 508 depths per ping and this at 40 pings per second. So, a maximum of 20,000 depths per second could be measured. In consultation with SIMRAD BV, a “MRU-5” motion sensor, combined with a “Seapath 20” heading sensor, was chosen for attitude measurements. However, soon after the first measurements, it was noticed that the “Seapath 20” did not meet the specified accuracies, especially not on a small survey vessel like “EB2”. Therefore, the “Seapath 20” was replaced by the “Seapath 200” heading sensor. For the data acquisition and processing of all data coming from the various sensors, the “Qinsy software” was used.

**Survey Planning**
As mentioned above, “Area B” had to be surveyed within one working day. Within this area, 1.5 km² was located above low water level and also had to be fully covered with multibeam measurements. Being on the right place at the right time was crucial and therefore keeping track of the local tide was essential. Survey tracks on the shallowest parts of the Walsrooden shoal had to be planned very accurately. Also these tracks were surveyed at a speed exceeding 12 knots. As a result of high speed surveys in very shallow water, the vessel was stranded twice during the first month; resulting in damaged transducer heads, which had to be replaced.

**Monitoring Results - Disposed Dredged Material**
To visualize bed-forms, a common bathymetric depth chart showing depth values and contour lines was not usable. Bathymetric data had to be visualised in a different way. Therefore EUROSENSE used “sun illuminated” shaded views and coloured maps. By using this technique, bottom structures and patterns became visible. Figure 4, shows a “sun illuminated” shaded view, where riverbed structures are clearly visible. The red polygon on this figure shows the dumping area, where dredged material was disposed.

The first survey was executed on November 2nd 2004. At this time, no material was dumped yet in the forseen disposal zone (within the red polygon). Soon after the completion of this survey, disposal activities started. Once a week the same area was surveyed in order to monitor the changes in morphology. At a very early stage, it was noticed that the bottom structure had completely changed. Due to the use of a diffuser (to dispose the dredged material) sand ripples disappeared and were replaced by a relative flat surface. On figure 5, one can clearly see the changes in bottom structure. The colours are indicating the depth. Red indicates the very shallow part of
the tip of the Walsoorden shoal and blue represents the deeper area. At this stage only 125,000 m³ of dredged material¹ was disposed.

Figure 6 shows a longitudinal section of the same disposal area.

The vertical and horizontal scales are indicated in meters. The black line indicates the original bottom structure. Sand ripples are still visible. The red line shows the profile after disposing 125,000 m³ of dredged material. The sand was disposed up to a level of NAP² – 5 meter or +2,0 meter below low water. The time difference between the two surveys was 10 days.

The dumping of dredged material continued for three weeks. On December 22nd 2004, the out survey was executed. On “figure 7”, one can see the total amount of disposed dredged material. Within a timeframe of one year (after the disposal activities), 20 surveys were executed. Figure 8 shows the result of the survey of the December 13th 2005. It is visible that the natural dynamics restored the bottom structure. Sand ripples became visible again and the relative flat bottom structure, created by disposal activities, disappeared. Also, it became clear that the disposed dredged material was moved towards the tip of the Walsoorden shoal. This is also visible on the next longitudinal profiles (figure 9 and 10). Again, the black line indicates the original bottom structure. The blue line shows the results of the surveys of the December 13th 2005.

As part of the project specification, the amount of dredged material, which remained in the disposal area, had to be defined. Therefore volume calculations were carried out. It was noticed that only 425,123 m³ was found, instead of the 500,000 m³ measured in the hopper dredgers. This is mainly due to the difference in density of the dredged material in situ compared to the density in the hopper dredger. During the first two months, after the end of the disposal activities, the volume of sand in the disposal area increased. This is probably due to natural sand movements. However, the bottom structure gradually started to change and the amount of disposed material decreased. As already previous shown, a movement of sand towards the tip of the shoal was noticed. The volume calculations also indicated this movement. The amount of sand, which was lost in the disposal area, was moved towards the shoal.

The Detection Of Bottom Pattern Movements

During the course of the monitoring programme, it became clear that the river Scheldt has a very dynamic bottom structure. By making differential charts, the movements of sand ripples and sand dunes became visible. Yellow indicates the areas where no changes in height were found. Red indicates a decrease in height and green an increase in height. Several changes can be seen. The green lines indicate old dredging tracks, which are filled-up again. The red-green pattern shows the movement of sand dunes. When a longitudinal profile is drawn over this pattern, the movement of these sand dunes

¹ Dredged material with a media grain size of ± 210µ.
² NAP: Reference level in The Netherlands (± 2 meter above low water level).
becomes visible. The red line is the result of the first surveys. The green line shows the second survey. The time difference between these two surveys is one month. From these profiles, we can learn that, in this part of the river Scheldt, sand dunes can be found with a height of 3 meters. The width at the bottom of these sand dunes is approximately 70 meters. The speed at which these sand dunes travel is 30 meters per month or 1 meter per day. Also, we notice that the sand dunes in this part of the river move up-stream towards Antwerp.

When looking at other parts of “Area A”, different patterns, sand ripples and sand dunes are identified. To show the differences in patterns, a profile was taken on the east side of the tip of the Walsoorden shoal. Three successive surveys, with a time interval of one week, are shown below. First of all, we notice that the shape of the sand dunes is different, than those shown above. Furthermore, the height is approximately 1.5 meter and the width is 45 meter at the bottom. Also the travelling speed is only 3 meters per week.

Conclusions
EUROSENSE fully complied with the project specifications. Multibeam surveys were executed up to a level of 3 meters above low water level and an area of approximately 11 km² was always surveyed within one day. Furthermore, EUROSENSE determined how much disposed dredged material remained in the dumping area and in which direction this material moved. The influences of the disposed dredged material on the bottom patterns and their movements were visualized. EUROSENSE also showed the benefits of using multibeam systems in very shallow waters. These benefits became clear during the execution of the morphological programme. As shown, it is now possible to determine the dimensions of sand ripples and sand dunes. Also the movements and the speed at which these sand dunes travel can be determined. However, it is important that time intervals between two successive surveys remains minimal in order to follow the changes of the sand dunes.

Since the end of the monitoring programme (2004-2005), another 500.000 m³ of dredged material was dumped on the tip of the Walsoorden shoal (January 2006). At this moment EUROSENSE is executing the continuation of the morphological programme. However, the “long term” impact of dredging works, which were used to reshape this eroded sandbar of the Walsoorden shoal is not clear yet. The continuation of the disposal experiment and the morphological programme will probably show this impact (if any).

References
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