LE PROJET PILOTE WALSOORDEN: LA PREMIERE ETAPE DANS LA GESTION MORPHOLOGIQUE DE L'ESCAUT OCCIDENTAL, RECONCILIANT LA PRESERVATION DE L'ECOLOGIE ET L'ACCESSIBILITE DES PORTS

The Walsoorden pilot project: a first step in a morphological management of the Western Scheldt, conciliating nature preservation and port accessibility

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Résumé

Dans le cadre d'une vision à long terme pour l'estuaire de l'Escaut, une équipe d'experts désignée par le port d'Anvers, a exprimé la nécessité d'une gestion morphologique. Ils ont proposé un projet pilote où on devrait déverser des matériaux de dragage sur le pointe du banc de Walsoorden, pour le reconstruire, car il avait érodé.

La faisabilité de cette idée a été examinée par le Laboratoire Hydraulique de Borgerhout en 2002-2003, en utilisant différents outils de recherche. Les experts ont conclu que les résultats ne contredisaient pas la faisabilité, mais seulement un test in situ pouvait nous donner une réponse définitive..

A la fin de 2004, 500.000 m³ de sable ont été déversés par un arroseur sur le pointe du banc de Walsoorden. Les mesures de la topo-bathymétrie et de l'écologie permettent à évaluer le succès du test. D'un point de vue morphologique ,ce fut un succès et il n'y avait aucune indication que le test a provoqué des changements dans les tendances écologiques. En 2006, un deuxième test a été exécuté, en utilisant la technique traditionnelle « clapping/vannage », dans une zone plus profonde. Le programme de monitoring du premier test a continué. Les résultats ont indiqué que les sédiments étaient transportés vers le banc, ce qui a été jugé positif. Les résultats de l'écologie n'ont pas montré des changements dans les tendances naturelles.

Grâce aux résultats positifs des deux tests, la nouvelle stratégie a été implémentée dans la stratégie de dragage et déversement dans le cadre de l'approfondissement du chenal de navigation dans l'Escaut. Un programme de recherche a été effectué pour réaliser la stratégie de déversement à reconstruire des bancs dans l'estuaire et à créer des zones intéressantes pour l'écologie. Les nouvelles idées du gestion morphologique créent des avantages pour l'économie autant que l'écologie.

Abstract

Within the scope of the Long Term Vision for the Scheldt estuary, an expert team appointed by the port of Antwerp stated the need for morphological management, aiming at steering the estuarine morphology. As a pilot project, they proposed to dispose dredged material near the Walsoorden sandbar, aiming at reshaping the eroded seaward tip of this sandbar.

The feasibility of this idea was in 2002-2003 investigated by Flanders Hydraulics Research, using a combination of several research tools. As a result of the research work executed at Flanders Hydraulics Research, the expert team concluded in 2003 that none of the results contradicted the feasibility of the new disposal strategy at the Walsoorden sandbar, although final judgement would only be possible after the execution of an in situ disposal test.

At the end of 2004, 500.000 m³ of sand was disposed during one month with a diffuser in relatively shallow water at the seaward end of the Walsoorden sandbar. The experiment was thoroughly monitored, morphological as well as ecological. The evaluation concluded that the test was from morphological viewpoint a success, while the ecological monitoring revealed no significant negative changes in trends due to the disposal test. In 2006 a second disposal test took place, using the traditional "clapping" technique. The new experiment was again thoroughly monitored. The evaluation of this second test showed a larger transport of the disposed material towards the Walsoorden sandbar, which was seen as positive within the objectives of the disposal strategy. From ecological point of view no significant negatives changes in trends have been identified from this second test.

Due to both successful in situ tests, the strategy of morphological disposal will be included in the dredging and disposal operations for the future deepening of the navigation channel. Thereby it introduces benefits for both the economy (deepening and maintenance of the fairway) and the ecology (keeping the sediment in the estuary, creating new valuable areas without endangering the multiple channel system). Therefore further research work has been carried out on how to embed this strategy in the future dredging and disposal policy and the possible use of the strategy on other locations.

I THE SCHELDT ESTUARY

I.1 Historical evolutions

The Scheldt estuary in its present form is relatively young. Before the Middle Ages, the Scheldt river discharged near Bergen op Zoom in an inner sea that was created by a sand barrier in front of the Belgian, Dutch and German coast. Today only the Wadden Sea remains of this inner sea. In the central part, this inner sea received sediments from the different rivers (Meuse, Rhine), while in the southern part storms caused breaches in the sand barrier, creating deep channels and importing sandy material from the sea. While some of these channels silted up (e.g. Zwin), some of the branches (Western Scheldt and Eastern Scheldt) connected with the river Scheldt, preventing the siltation of these branches. Till the 11th century, morphological evolutions were significant but fully natural, with almost no human impact. (Meersschaut et al., 2004)

First signs of human impact on the estuary's environment became visible in the 11th century: locals reclaimed land that had silted up high enough and started to protect it against flooding. However, inundations due to levee breaching during storm events repeatedly returned portions of land to the river. From the 16th century on, the poldering techniques had become more sophisticated and larger areas were permanently poldered (e.g. in eastern Zeeuws-Vlaanderen 50% of the total poldering occurred during the 17th century).

Poldering was less intensive during the 19th and 20th century because a large percentage of salt marshes had been reclaimed already. However, hydraulic works and storms continued to reshape the area. In 1867 and 1871, the two remaining links (Kreekrak and Sloe) between the Honte (Western Scheldt) and the Eastern Scheldt were cut-off, modifying drastically the tidal channels network. A catastrophic storm with extensive inundations in 1953, made the Netherlands decide about executing an extensive flood protection plan: the Delta plan.

From historical data can be concluded that these human impacts such as closure of secondary channels and poldering have strongly influenced the tidal regime of the Western Scheldt. Stronger tidal penetration enlarged the main navigation channel.

I.2 Dredging and disposal activities

At the end of the 19th century, dredging activities were required to improve the accessibility of the port of Antwerp. Until the 1920's, these activities were concentrated on the Belgian territory (2 Mm^3/year). From 1920 till 1960 the quantities on Belgian and Dutch territory were comparable (2 + 2 Mm^3/year). The first large deepening campaign happened in the early 1970's, with the main part of dredging works located on Dutch territory (3 + 10 Mm^3/year). Nonetheless, the increased dredging in the Dutch part did not apparently result in significant changes of the trend in morphology or tidal action. During the late 1990's, a second dredging campaign for improving the navigation conditions was conducted. The impact of the deepening by 4 feet was monitored (MOVE programme), but overall no significant negative impact was noticed yet.

Sediment mining for providing building material started at the end of the 19th century. Since 1958, about 1 to 2 million cubic meters of sediment was mined per year, on average.

I.3 A Long Term Vision for the Scheldt estuary

In 1998, the Netherlands and Flanders decided to develop a joint long term vision (LTV) for the Scheldt estuary (DZL & AWZ, 2001), focussed on three main functions: safety against flooding, optimal ports accessibility and the natural ecosystem.

The basic idea of the LTV was: "Developing a healthy and multifunctional water system, supporting human needs in a sustainable way". The Technical Scheldt Commission (TSC) took the lead in drawing up this integral vision and was able to present the result to the government representatives in January 2001. The long term vision was summarised in an overall target for the year 2030.

In 2001 the governments of both countries adopted this overall target and already in 2002 the drawing up of the 2010 Development Outline (DO) for the Scheldt estuary had started. The aim of the 2010 DO was to define those projects and measures which, in a first stage, must be started up no later than 2010 to ensure the realisation of the LTV in 2030. A special project organisation ProSes was created in order to draw up this

DO in close consultation with all stakeholders and under the supervision of the TSC. In December 2004 the official version (ProSes, 2005) was presented to the government representatives, after intensive communication with the stakeholders and a consultation into the general public's views on the outline. Already in March 2005 the execution of the full 2010 DO was decided upon. These are the main projects in the 2010 DO:

- Safety against flooding: implementation of the updated Sigmaplan in Flanders;
- Accessibility: deepening and widening of the fairway to the port of Antwerp;
- Ecosystem: development of 600 ha of estuarine nature along the Western Scheldt in the Netherlands and 1,100 ha of estuarine nature and wetlands along the Sea Scheldt in Flanders;

Both countries will jointly monitor the evolution of the estuary and the effects of the implemented projects in order to extend the knowledge of the estuary and to facilitate possible corrections.

II THE WALSOORDEN PILOT PROJECT

Directly concerned by these issues, the autonomous Port of Antwerp, independent from the Flemish administration, requested a group of experts (called Port of Antwerp Expert Team, or "PAET") to give an opinion about the prospects for a further deepening and widening of the navigation route, mainly needed for the larger container ships. One of the main questions considered in LTV was where to dispose the larger volumes needed for such an enlargement, respecting the preservation of the estuary's physical system characteristics. Based on their analysis of past morphological changes in general and of the (temporary) decay of some flood channels, they stated that not (only) disposal of sediments was to be blamed for this, rather the always more stringent immobilisation of the main channels and shoals (PAET, 2000; PAET, 2001a). To revert the reduction in dynamic morphological behaviour of the estuary, it was proposed to steer the development of channels and shoals. Recent studies show that the continuous disposal of maintenance dredging materials has a much larger impact on the estuarine morphology than the deepening of the channels (i.e. capital dredging) (ProSes, 2004). The main attention should therefore go to new strategies for disposal, although the Port of Antwerp expert team believes that dredging may also be beneficial for morphology, e.g. rectifying the shape of sandbars.

II.1 Morphological management of an estuary

During a meeting with the LTV's working group on morphology in the year 2000, the Port of Antwerp experts suggested "morphological dredging and disposal" as an alternative to the present dredging and disposal strategies. It is based on the principles developed for the maintenance and the capital dredging in the navigation route in the Congo inner delta, for example by redistributing the sediment transport and using dredging and disposal to change the plan form of the river.

Disposal is a way to redistribute the sediment in the Western Scheldt, so as to feed, for example, areas eroding too much. This can be applied not only in the flood channels, but also on some parts of intertidal shoals. The Port of Antwerp expert team worked out a proposal to restore the western tip of the Walsoorden sandbar that erodes since several decades (PAET, 2001b). Several millions of cubic meters of sediment could be stored at that place (Fig. 1). By disposing material near the eroded tip of the Walsoorden sandbar, the multiple channel system could be sustained in a pro-active way, improving the distribution of the flood currents between the ebb and flood channel. The reshaped tip could also increase the self-erosive capacity of the currents on the sill of Hansweert, reducing the amounts to be dredged. While from ecological point of view, the reshaped sandbar could reduce flow velocities on the sandbar, allowing finer sediments to settle on the intertidal area of the sandbar.

Recent analysis of topo-bathymetric surveys showed an ongoing erosion near the seaward tip of the Walsoorden sandbar. Over the period 1990-1996 an average of 650.000 m³ of sediments is eroded every year near the tip of the sandbar. In the period 1996-2002 an average of 250.000 m³ of sediments per year is eroded. A decrease is found over this 12 year period, which may be related to the nodal cycle of the tides. Nevertheless, disposing material near this location should only be seen as a curative solution, the cause of the erosion (orientation of the flood currents towards the tip of the sandbar) should be investigated and solved within the philosophy of morphological management of the estuary.

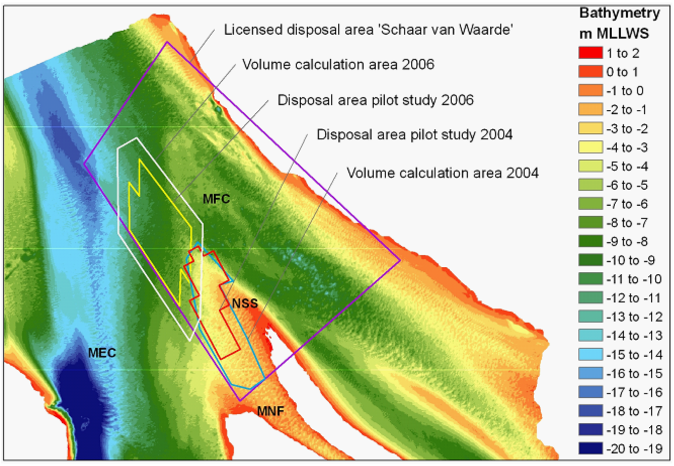

Figure 1. Overview of the licensed disposal area 'Schaar van Waarde' at the northern tip of the Walsoorden sandbar, the disposal areas used in the pilot projects of 2004 and 2006 and corresponding volume calculation areas


Figure 2. Detail of diffuser head (pontoon Bayard II)

II.2 The feasibility study

In 2002-2003 Flanders Hydraulics Research carried out a research program to evaluate the feasibility of the proposed pilot project at the Walsoorden sandbar. The research program included a field measurement campaign with DGPS-floats, in-situ sediment transport measurements, the use of a physical scale model for both hydrodynamic modelling and mobile sediment tests and the use of a numerical model for hydrodynamic simulations. Each of the used study tools has advantages and limitations, as both types of models were in general able to reproduce the flow, although the validation showed that differences remained between the models (e.g. during slack for the physical scale model, distribution of flood currents in the numerical model) and the in situ measurements. However the combination of these different tools allows a complementary assessment of the feasibility of the proposed alternative disposal strategy.

None of the results (FHR, 2003) indicated that the idea would not be feasible. Further research was executed to find the location that was most suited for the execution of an in situ disposal test. Therefore a fixed-bed scale model with artificial sediments was used to investigate sediment transport pathways. Sediment transport investigation revealed that an area in the minor northerly flood channel close to the tip of the northerly sand spit is capable of maintaining large amounts of sediment and that disposal of dredged material on top of the eroded tip of the Walsoorden sandbar has to be avoided. Finally, the effect on flow patterns of a reshaped sandbar was studied by a numerical flow model.

The results derived from the study concerning hydrodynamics and sediment transport indicated that the disposal of material as proposed for the morphological disposal strategy, can likely be used to influence the estuarine morphology (PAET, 2003). PAET insisted on having a small scale in situ disposal test to gain final evidence that the proposed strategy is feasible.

Where most of the research occurred within the scope of ProSes, a second opinion team was asked to give their comments on the methodology used for and the results gathered from the research. They confirmed that the idea to use dredged material to restore sandbars is very valuable and that an in situ disposal test is necessary to remove the remaining uncertainties about the proposed strategy (Berlamont et al, 2003).

II.3 In situ disposal test 2004

II.3.1 Execution of the in situ disposal test 2004

The execution of an in situ disposal test had to bring final proof of the feasibility of the alternative disposal strategy. The idea of the in situ test was to dispose quietly and precisely 500.000 m³ of sand with a diffuser on the bottom. The dredging vessel (self-discharging hopper dredger) was connected to a floating pipeline through which the sand is transported to a pontoon "Bayard II". On this pontoon the sand is pumped to a diffuser (Fig. 2) that disposes the sediment in a precise way on to the bottom. The use of the diffuser required an adjustment of the disposal license.

The amount of 500.000 m³ was chosen because it is on one hand large enough to affect significantly the bed morphology, however on the other hand small enough to be reversible if something would go wrong. The choice of the disposal location was based on the results of the feasibility study.

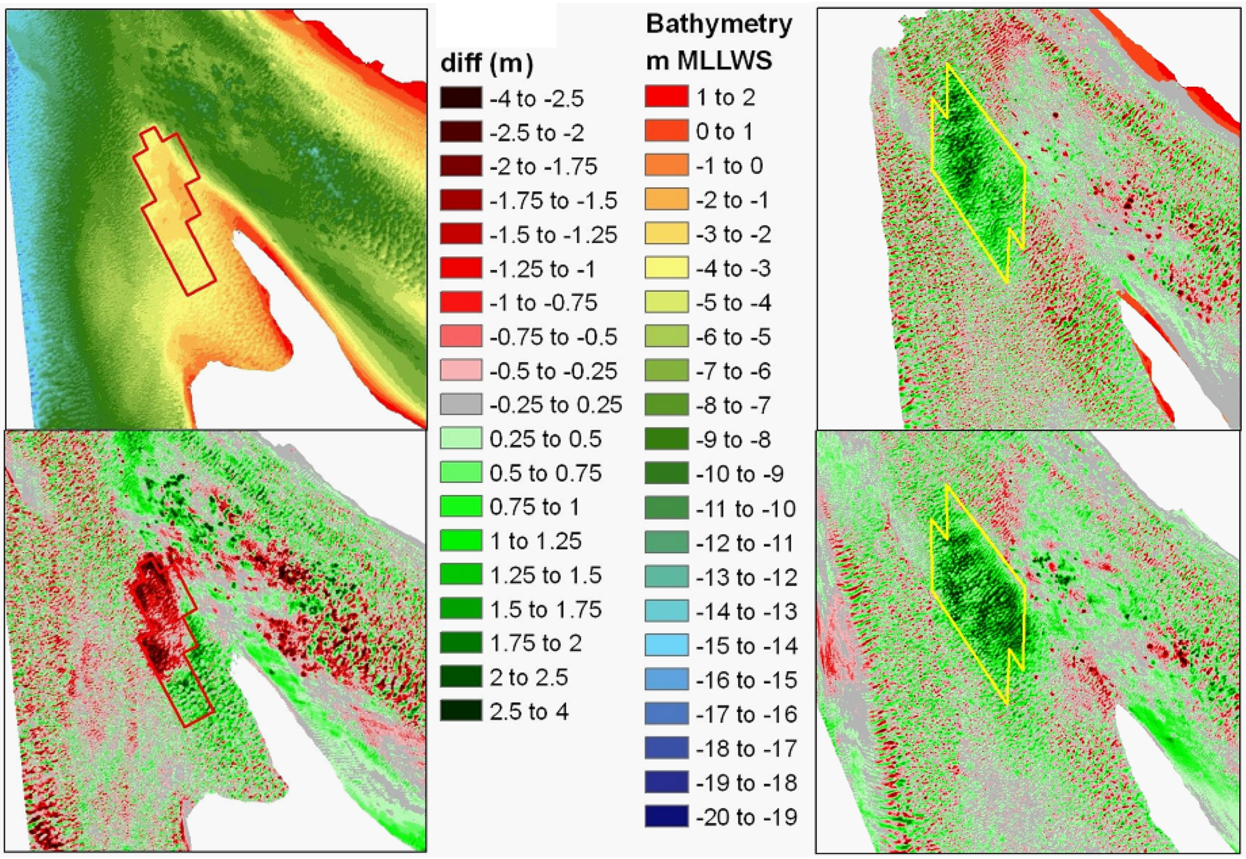

Figure 3. Overview of in situ disposal tests – 2004 (left): bathymetry after disposal test (top) and evolution after 1 year (bottom) & 2006 (right): difference plot for first phase (top) and second phase (bottom)

From November 17th to December 20th 2004 500.000 m³ of sand was almost continuously disposed in the proposed area. Figure 3 (top left) shows the bathymetric data of December 2004, right after the disposal test, and a difference between the bathymetric survey of December 2005 and December 2004 (bottom left).

II.3.2 The monitoring program

To evaluate the success of the test an extensive monitoring programme was set up. This programme included frequent bathymetric surveys, ecological monitoring, sediment tracing tests and sediment transport measurements. Several criteria were defined before executing the in situ test for evaluating its success. One of them stated that 2 weeks after finishing the execution of the disposal test, at least 80% of the disposed sediment should stay within the control area (this was defined as the disposal area, extended slightly towards the sandbar of Walsoorden). After one year the ecological parameters should not indicate a change in ongoing natural trends.

The topo-bathymetric surveys were executed using the multibeam echo sounder technique (Leys et al, 2006) producing high resolution bathymetric charts. From the start of the experiment (November 2004) until March 2005, weekly surveys were executed in an area around the disposal location (area ~ 900 ha). From March until June 2005 the measurement frequency was reduced to one survey every 2 to 3 weeks, while from June 2005 until January 2006 one survey per month was executed. Beside this possible impact area, a larger zone was measured every 2 months, to capture possible larger scale influence of the in situ test. These bathymetric surveys allowed volume computations for the control area.

The ecological monitoring programme included both intertidal as subtidal measurements. Ecologists feared increased sedimentation, especially of coarser sediment, on the sandbar, which could have a negative impact on its ecotopes. The intertidal monitoring comprised of several stations on the Walsoorden sandbar where erosion-sedimentation, sediment composition and macrobenthos was measured. The subtidal monitoring was focussed on sediment composition and macrobenthos samples, using the BACI-technique (Before-After-Control-Impact). Beside the disposal area, 2 control areas were chosen: one at the traditional disposal site "Schaar van Waarde", the other where no influence from disposal activities should be expected.

II.3.3 Evaluation of the 2004 disposal test

From morphological point of view, it can be concluded that the experiment using a diffuser for modifying the morphology of the sandbar by disposing precisely dredged material was very successful (FHR, 2006). Despite a small loss of sediment directly after the execution of the disposal test, which is probably caused by the transport of the finer sands by the currents (natural segregation), the amount of material within the control area equalled the disposed quantities. Only after 2 months a decrease of volume was measured, a loss of ca. 10% after 6 months and less than 20% after one year. The main part of the eroded sand is transported during flood towards the Walsoorden sandbar (figure 5). This evolution is in agreement with the predictions of the feasibility study.

The ecological monitoring did not reveal any significant negative impact, neither in the intertidal areas, nor in the subtidal areas (NIOO, 2006). None of the results from this monitoring indicated that the in situ disposal test was responsible for a significant change in ongoing trends. For the subtidal samples an initial decrease in mud-percentage was found for the impact area. This is explained by the absence of finer mud material in the dredged sediments that were disposed. The macrobenthos samples did not show deterioration (biomass, diversity and density) for the impact area compared to the 2 other control areas.

II.4 In situ disposal test 2006

The first disposal test proved that the new disposal strategy is feasible. Where the diffuser allows a very precise disposal, the question was raised whether the traditional "clapping" technique could also be used to dispose the dredged material. Hereby a higher time-efficiency can be realized, using the flood current to transport the material towards the sandbar. Therefore a second in situ disposal test was conducted in 2006, using the traditional "clapping" technique. Since this technique requires larger depths to dispose the material (i.e. the draught of the dredger vessel) research using the validated numerical hydrodynamical model was performed to determine the most suited disposal location for this second test (FHR, 2006).

II.4.1 Execution of the in situ disposal test 2006

The second disposal test occurred in two phases (figure 3, right): in the first phase (January – March 2006) 500.000 m³ was disposed, while in the second phase (September 2006 – March 2007) 900.000 m³ was disposed using the traditional disposal technique. These disposals were carried out within continuous maintenance dredging works in the Western Scheldt. Therefore a larger spreading in time is found for this test in comparison with the test of 2004, where the disposals were concentrated in time.

II.4.2 The monitoring program

The extensive morphological and ecological monitoring program, that was started at the beginning of the first disposal test, was continued in time. The same criteria were incorporated from the first test, both morphological as ecological.

The topo-bathymetric surveys were continued using the multibeam echo sounder technique. During the execution of the second disposal test (both phases), weekly or 2-weekly surveys were performed in an area around the disposal location. After the execution of the tests the measurement frequency was reduced to one survey every month, later every 2 or 3 months. Beside this possible impact area, a larger zone was measured every 3 months, to capture possible larger scale influence of the in situ test. These surveys allowed volume computations for the control area.

The ecological monitoring program, with both subtidal as intertidal monitoring, of the first pilot study is continued considering both the first and the second disposal area as an impact zone. A new control area was defined with similar hydrodynamic characteristics as the disposal areas.

II.4.3 Evaluation of the 2006 disposal test

The volume calculations reveal that the sediment disposed during the second disposal test is less stable than the sediment disposed during the first test in 2004 (FHR, 2009). For the first phase of the disposal test, 6 months after the execution of the test ca. 30% of the sediment is transported out of the polygon. For the second phase ca. 35% of the disposed material is transported out of the control polygon after 10 months. It should be mentioned that for this second phase, the analysis is influenced by the first disposal phase: the material that is disposed in the first phase is still being partially transported, while also part of the material disposed during the second phase is transported.

The fact that a higher percentage of the disposed material is transported out of the polygon, can be explained by several factors. The disposal location of the 2006 test has a larger depth (necessary for trailing suction hoppers dredger), and is characterized by a higher dynamism, both hydrodynamic (current) as morphodynamic (sediment transport). On the other hand, the traditional disposal technique has a lower disposal efficiency compared to the diffuser. This is confirmed by a comparison between the amount of dredged material (in hopper) and the amount of material (in situ) found based on volume calculations between topo-bathymetric surveys. A correction factor (0,90) was used to take into account the difference in density between the hopper and in situ. The diffuser technique has an efficiency of ca. 95%, while the traditional disposal technique has an efficiency of 85-90%.

An analysis was performed to investigate in which direction the disposed sediments of the 2004 and 2006 tests were transported. It was found that part of the material is transported towards the Walsoorden sandbar. For the 2006 disposal test, both the difference plot (figure 4, left), as the volume calculations in the major zones (figure 4, right), show sedimentation in the zones near the Walsoorden sandbar. In the 2004 disposal area, an increase of the sediment volume is found of ca. 220.000 m³. Although part of the sediment is transported towards the Walsoorden sandbar, a mediocre amount (25%) of the sediment is eroded out of the area. Based on the historical bathymetric evolutions of the seaward tip of the Walsoorden sandbar, the erosion found 6 months after the in situ disposal tests is of the same order of magnitude (500.000-750.000 m³ per year) as these of the historical erosion.

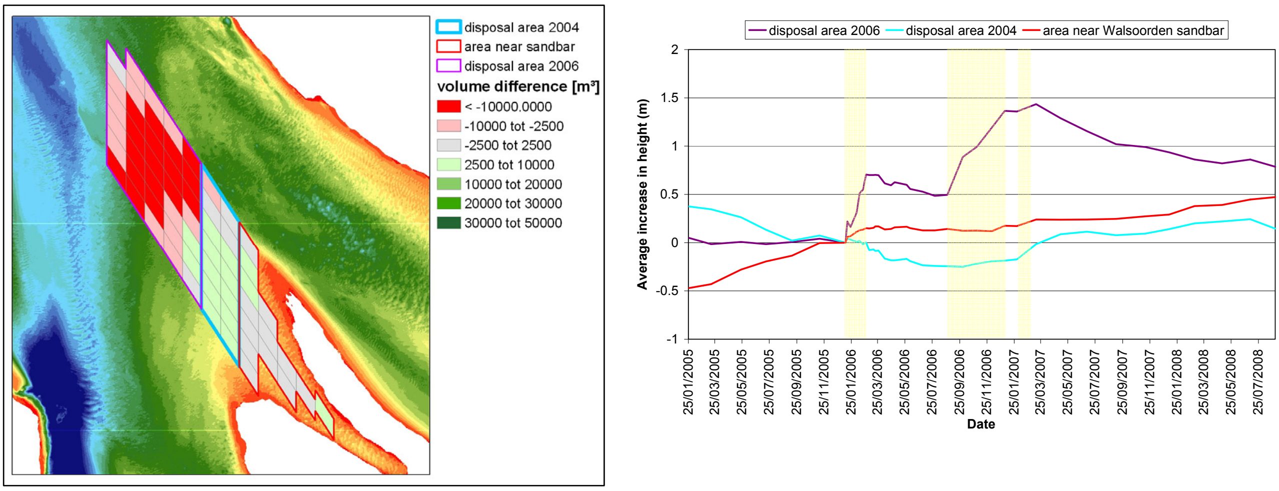

Figure 4. Analysis of disposal tests: calculated volume differences after 2006 disposal test (left) and volumes calculations in 3 major zones for both disposal tests

The ecological monitoring program showed no significant changes in the ongoing trends for the sedimentation on the Walsoorden sandbar, the percentage of finer sediments on the intertidal zone and the macrobenthos (NIOO, 2007). The macrobenthos community is an important indicator in the ecological evaluation, because of its essential role in estuarine ecology and its sensitivity to environmental changes.

III A NEW DISPOSAL STRATEGY FOR THE WESTERN SCHELDT

III.1 A further deepening of the navigation channel

One of the projects within the DO 2010 is a further deepening of the navigation channel to guarantee optimal port accessibility. An environmental impact assessment (RWS & MOW, 2007a) was carried out by an external consortium, studying the optimal way to deepen the navigation channel without endangering the ecological system. Within the appropriate assessment (RWS & MOW, 2007b), it was concluded that disposing dredged material near sandbars in the Western Scheldt could create benefits for the ecological system. Besides the Walsoorden sandbar (0), 3 other locations in the Western Scheldt were appointed to dispose material from the capital dredging required to deepen the navigation channel: (1) Rug van Baarland, (2) Hooge Platen Noord and (3) Hooge Platen West.

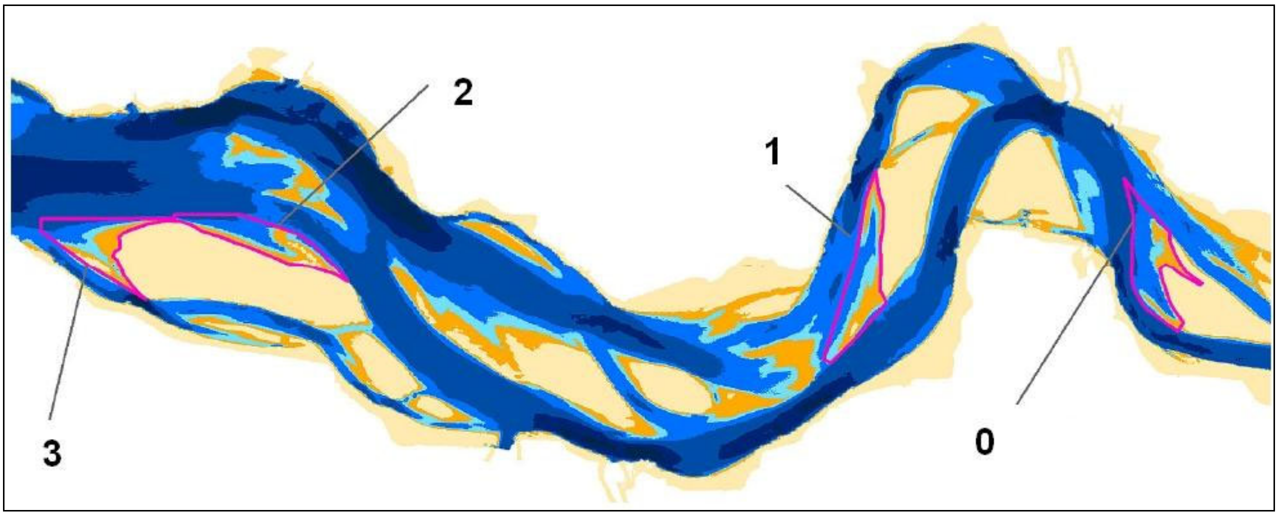

Figure 11: Disposal locations along sandbars for the deepening of the navigation channel

III.2 Determining the disposal strategy

Where the environmental impact assessment and the appropriate assessment concluded that disposing material from capital dredging works near sandbars is the most valuable alternative, further research was necessary to determine the disposal strategy at these new locations. Crucial aspect for the disposal strategy is the creation of ecological valuable ecotopes, i.e. subtidal and intertidal areas with low currents. The experience gained near the Walsoorden sandbar was used to investigate the optimal disposal strategy at these locations. Therefore an extensive research program was carried out, based on the interpretation of results from field measurements (both GPS-floats and sediment transport) and validated hydrodynamic numerical models.

The study (FHR, 2008a; FHR, 2008b; FHR, 2008c) revealed that fundamental differences existed between the 4 locations.. On one hand both the locations near the Walsoorden sandbar and the Hooge Platen West are located near the seaward tip of a sandbar, attacked by flood currents. On the other hand the location near Rug van Baarland and Hooge Platen Noord are located along the sandbar, guiding the currents. Another difference was found in the flow dynamics: the 2 locations near Hooge Platen are characterized by far more dynamic conditions in comparison with the location Rug van Baarland and Walsoorden sandbar. Each location will have a specific morphologic behaviour and that the proposed disposal strategy is site-specific.

For the Walsoorden sandbar, the disposal strategy aims at creating a subtidal macro-dune which will migrate towards the sandbar under influence of the flood-dominated currents. This macro-dune will be created using both the traditional disposal technique and the diffuser technique. A similar strategy is proposed for the Hooge Platen West.

Near Rug van Baarland the disposal strategy aims at constructing a sand spit near the southern tip of the sandbar. This new sand spit, in combination with the existing sand spit in the northern part, aims for the creation of an underwater barrier reducing the currents between the barrier and the sandbar, creating a low dynamic shallow water area. A similar strategy is proposed for the Hooge Platen Noord.

IV CONCLUSIONS

The Long Term Vision for the Scheldt estuary presents a view on the preferred functioning of the system, accepted by both the Dutch and the Flemish government. The LTV acknowledges that the dynamic state of the estuary is strongly impacted by a range of human interventions including land reclamation, defence and training works, channel deepening and sand extraction. The LTV states that further interventions should not endanger the preservation of the existing dynamic evolution of the multiple-channel estuary.

The Port of Antwerp expert team (PAET) and the authors also recognises the essential role of morphology to harmonize safety, accessibility and naturalness. Morphological diversity in the Western Scheldt can be attained by a well-considered morphological management, of which a new disposal strategy should be an essential part. A thorough understanding of morphological behaviour can only be obtained by a thorough analysis of historical data and of experience gained by field observations and measurements, supported by the interpretation of physical and numerical modelling results.

During the Walsoorden pilot study (2002-2003), all these investigation tools were combined to assess its feasibility and the results sustained the concept of the alternative disposal strategy as proposed by PAET in 2001. The execution and extensive monitoring of two small-scale in-situ disposal tests was needed to confirm this proposal. From morphological viewpoint the 2 disposal tests are a success, with relative large amounts of the disposed material remaining in a control polygon. The ecology revealed no changes in the ongoing natural trends due to the tests. Therefore it was concluded that the new disposal strategy has been validated.

This new disposal strategy will be applied on a large scale during capital dredging works of the deepening of the Scheldt's fairway and during the maintenance dredging works thereafter. This step-by-step assessment of a new disposal strategy shows that the realisation of a new concept needs many efforts for validation and acceptation. The approved new disposal strategy is not the only tool for attaining morphological diversity in the Scheldt estuary. Research for other alternative dredging and disposal strategies should continue. Also the possibilities for adaptation of river training works must not be forgotten, because river training works determine the boundary conditions for the future morphological development.

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VI REFERENCES

Berlamont J., K. Dyer, L. Hamm, C. van de Kreeke and M. Stive (2003). An alternative strategy for dumping in the Scheldt estuary – Comments of the expert team.

DZL & AWZ (2001). Langetermijnvisie Schelde-estuarium. Ministerie van Verkeer en Waterstaat, Directoraat-Generaal Rijkswaterstaat, directie Zeeland (DZL) en Ministerie van de Vlaamse Gemeenschap, departement Leefmilieu en Infrastructuur, administratie Waterwegen en Zeewezen (AWZ), (In Dutch – Long Term Vision for the Scheldt-estuary).

Flanders Hydraulics Research (FHR) (2003). Model 678/1 Alternative dumping strategy Walsoorden. Results physical & numerical modelling. Flanders Hydraulic Research. Final report to PROSES.

Flanders Hydraulics Research (FHR) (2006). MOD 754/2C. Alternatieve stortstrategie Westerschelde. Proefstorting Walsoorden. Eindevaluatie monitoring. Report (in Dutch – Alternative disposal strategy Westerschelde – Evaluation of the in situ disposal test 2004).

Flanders Hydraulics Research (FHR) (2008a). MOD 791/06. Determinatieonderzoek plaatrandstortingen – Deelrapport 1, Historische morfologische analyse en analyse en interpretatie terreinmetingen. Report (in Dutch – Detailed study of the disposal of dredged material near sandbars – Report 1 – Field measurements).

Flanders Hydraulics Research (FHR) (2008b). MOD 791/06. Determinatieonderzoek plaatrandstortingen – Deelrapport 2, Numerieke modellering. Report (in Dutch – Detailed study of the disposal of dredged material near sandbars – Report 2 – Numerical modelling).

Flanders Hydraulics Research (FHR) (2008c). MOD 791/06. Determinatieonderzoek plaatrandstortingen – Deelrapport 3, Voorstel praktijk-stortstrategie. Report (in Dutch – Detailed study of the disposal of dredged material near sandbars – Report 3 – Disposal strategy).

Flanders Hydraulics Research (FHR) (2009). MOD 754/3B. Alternatieve stortstrategie Westerschelde. Proefstorting Walsoorden. Eindevaluatie monitoring 2006. Report (in Dutch – Alternative disposal strategy Westerschelde – Evaluation of the in situ disposal test 2006).

Meersschaut Y., W. Parker, J.J. Peters, Y. Plancke (2004). A dredging and disposal strategy for managing the Western Scheldt's morphology and ecology. WODCON 2004, Hamburg, Germany.

Leys E., Y. Plancke and S. Ides (2006). Shallow – Shallower – Shallowest. Morphological monitoring Walsoorden. In Proceedings Hydro '06, Antwerpen, Belgium, p. 93-96.

NIOO (2006). Alternatieve stortstrategie voor de Westerschelde. Ecologisch monitoringsprogramma proefstorting Walsoorden. NIOO rapport 2006-02, (in Dutch - Alternative disposal strategy Westerschelde – Ecological monitoring programme).

NIOO (2007). Alternatieve stortstrategie voor de Westerschelde. Voortzetting monitoringsprogramma proefstorting Walsoorden. Lot 2 – Ecologische monitoring. Report (in Dutch - Alternative disposal strategy Westerschelde – Continuation of the ecological monitoring programme).

Port of Antwerp Expert Team (PAET) (2000). Westerschelde. Baseline Report.

Port of Antwerp Expert Team (PAET) (2001a). Improving navigation conditions in the Westerschelde and managing its estuarine environment. How to harmonize accessibility, safetyness and naturalness? Final report to ProSes.

Port of Antwerp Expert Team (PAET) (2001b). A strategy for managing the Westerschelde's morphology. An addendum to the final report.

Port of Antwerp Expert Team (PAET) 2003).. Alternative Dumping Strategy. The Feasibility of Morphological Dredging as a Tool for Managing the Westerschelde.

ProSes (2004). Strategisch Milieueffectenrapport Ontwikkelingsschets 2010 Schelde-Estuarium – Hoofdrapport (In Dutch – "Strategic Environmental Impact Assessment Development Scheme 2010 Scheldt Estuary – Main Report).

ProSes (2005). Ontwikkelingsschets 2010 Schelde-estuarium - Besluiten van de Nederlandse en Vlaamse regering (In Dutch – "Devellopment Scheme 2010 Scheldt estuary – Decisions by the Dutch and Flemish government).

Rijkswaterstaat Zeeland en Departement Mobiliteit en Openbare Werken, afdeling Maritieme Toegang (RWS & MOW), 2007a, Hoofdrapport Milieueffectrapport Verruiming vaargeul Beneden-Zeeschelde en Westerschelde. (in Dutch – Environmental impact assessment of the deepening of the navigation channel).

Rijkswaterstaat Zeeland en Departement Mobiliteit en Openbare Werken, afdeling Maritieme Toegang (RWS & MOW), 2007b, Hoofdrapport Passende Beoordeling Verruiming vaargeul Beneden-Zeeschelde en Westerschelde. (in Dutch – Appropriate assessment of the deepening of the navigation channel).