An Alternative Strategy for Dumping in the Scheldt Estuary - Comments of the expert team.

1 Introduction

The PROSES Bureau asked RIKZ to organise a workshop with a team of international experts (ET) to express a second opinion on a draft report prepared by the Port of Antwerp Expert Team (PAET), which addressed the feasibility of an alternative dumping strategy (REF 1). This strategy has been elaborated for a specific location, the Plaat van Walsoorden, but it is suggested that it may well apply to other locations. The ET has had the opportunity to discuss the draft report and associated reports and to exchange views with the PAET. The definition of morphology was discussed in the Second Opinion meeting and no essential disagreement occurred (see report of workshop: ARCADIS, 2003). This document expresses the opinion of ET on the alternative dumping strategy in general, on studies carried out for the Plaat van Walsoorden to assess the appropriateness of this location and on a proposed pilot experiment. Suggestions are given to further investigate the feasibility of the alternative dumping strategy.

2 Broader perspective

2.1 Long Term Vision (LTV) Project

Preceding the present PROSES Project a joint Flanders-Netherlands project, the LTV Project, was conducted, in which an agreed view on the preferred functioning of the system was developed. Within the three policy requirements:

- safety against flooding,
- navigable access to the harbours,
- and naturalness,

the perceived functioning was described as that of 'a dynamic, multiple channel estuary'. It was acknowledged that the present dynamic state is strongly impacted by a range of historic and present human interventions such as land reclamation, defence and training works, channel deepening, and sand mining. It was emphasised that any further interventions should not endanger the preservation of the existing, although constrained, dynamic (natural) evolution of the multiple channel estuary. In order to make the concept of a multiple channel estuary more clear the so-named cell-concept was introduced, in which the channels were ordered in macro- and meso-multiple-channel cell systems, with gross and net sediment transport estimates (REF 2, REF3). Theoretically, an estimate was derived of the maximum capacity of adjacent channels to receive volumes of dredged sediment without the danger of choking, as well as the degree of interaction between cells.

In Annex 1 the cell-concept as developed sofar is described more elaborately. The ET remarks that the PAET has expressed general doubts about the cell-concept. It would be valuable if these doubts were specified, and alternatives were suggested.

2.2 Present dredging and dumping strategy

The dredging and dumping strategy has been to dredge sills and width constraints in the navigation channels and to dump the dredged material in adjacent, nearby channels. Initially most of the material was dredged and dumped in the eastern sections of the Western Schelde estuary, where the channels were most limited in depth. Increasing volumes of dumping were observed to lead to degeneration of channels, to a diminishing of dynamical processes and to a decrease of areas that are important for ecology. In a quantitative sense these limiting volumes were in order-of-magnitude agreement with theoretical estimates (REF 3 and 4). The initial strategy has been changed since the increased deepening of 1997-1998 and dredged material in the eastern sections was dumped in more western located secondary channels. The underlying strategy has been not to withdraw sediment from the estuary. Nevertheless, sand mining takes out about 2.5×10^6 m^3 yr^{-1}.

2.3 Future dredging and dumping strategy

Current information in relation to the critical dumping volumes in secondary channels indicates that it is not unequivocally certain that there is space for a further increase of dredging and dumping material within the same management concept, i.e. preserving a dynamic multiple channel system (LTV) and not withdrawing sediment from the estuary by dumping in secondary channels (REF 5). Hence, the development of alternative strategies is necessary. However, since there is a number of other natural and human developments of which the impacts are uncertain, viz. sea-level rise, the estuary's outer delta (Vlakte van de Raan) development and sediment extraction, a change in morphological management of the estuary has to be introduced with utmost care. Careful monitoring, process studies and pilot experiments specifically focused on this issue are essential.

3 Comments on Present PAET Studies and Alternative Dumping Strategy

The present report and the studies associated with it (REF 1, 6 and 7) are useful in that they highlight a major possible problem with the current development and dredging strategy in the Scheldt Estuary. The contention is that the estuary, given extrapolation of the current dumping strategy, is likely to develop into a single channel system, and that this is an unhealthy state and would lead to deterioration in the navigational and environmental characteristics of the estuary as a whole.

It is therefore opportune to consider alternative dumping strategies. The PAET has developed such a strategy. It concerns the dumping of sediment in relatively shallow areas close to intertidal flats where sufficient storage capacity is expected to exist and where sediment is thought to be only moderately mobile.

3.1 General comments

· Unfortunately, so far not all of the available information has been assembled in support of the thesis that extrapolation of current dredging management strategy leads to disintegration of the multiple-channel estuary. There are bathymetric charts of the long time series of surveys, but they have not been analysed and interpreted in a comprehensive way so that a picture of development of the estuary appears and a conceptual model can be constructed which can be applied to prediction of future developments. The conceptual model would need to have several elements. The cell concept (REF2) is considered to be a good model for the present sedimentary system of the estuary, but it gives little insight into how it might develop in the future. It needs to be integrated with a conceptual model of how the cells might develop. Additionally, a conceptual model is needed to describe the existing changes within the cells, and how the tidal flats may change in form and location. Of particular concern is the possibility that there are progressive changes that may lead to major bank and channel shifts.

· Because of the lack of a well-described concept, it is possible that there are other strategies, which could prevent the deterioration of the estuary. Also, it makes the risks associated with the present proposals difficult to assess. Such an analysis of historic bathymetric charts would be of great help in determining the trend of changes and the justification for the proposals.

· Evaluation of the state of the estuary would have been helped by using an empirical modelling approach, based on dimensional distributions of e.g. along estuary cross-sectional areas, which often display an exponential form. These may be used as indicators of estuarine equilibrium.

· The present dumping practice is well known, but it is not well spelled out in the report. It is apparent that up to 11 million cubic metres sediment per year is dredged from a number of critical shallow points in the estuary and is deposited primarily on the sides of ebb-channels and centrally in flood-channels, taking the tidal stage into acount. Quantification of the distribution would assist interpretation of cause and effect scenarios.

· There is also a problem with both time and space scales, in that it takes the estuary a long time, possibly years to decades, to respond to changes, such as capital dredging of channel deepening, sea level rise, poldering, etc. This aspect needs to be addressed by a conceptual model of future evolution.

3.2 Comments on the alternative dumping strategy

Following the discussions between both expert teams the ET interprets the PAET concept to contain the following elements:

· sediment is dumped at locations on the fringes of intertidal flats where it is expected to have residence times sufficient to realize significant delays in re-siltation of nearby channels and channel sills;

· the dumping sites are given a geometry such that they are expected to impact positively on the current pattern, i.e. to stimulate a multiple-channel system and to reduce maintenance dredging;

· the strategy is elaborated for the Plaat van Walsoorden, but is expected to be applicable to other sites in the estuary as well.

The critical locations are those where the sediment is crossing the estuary at channel intersections, where the transport direction changes from ebb to flood. An area is defined at the western end of the Walsoorden tidal flat where the flood current is coming round the bend below (Hansweert) and attacks and erodes the downstream end of the tidal flat. The hypothesis is that there is not enough sediment available to stop the erosion and that if it were to continue, the flood channel may disappear and a single channel remains.

The ET comments:

· The hypothesis that guiding of the flow can be used beneficially to stop the channel deteriorating to a single channel would require several actions, not only sustaining and enhancing the form of the tidal flat. For instance fixed bank realignments might be necessary.

· The report does not make clear how much modification is necessary to achieve the required effect. The hypothesis that guiding of the flow can be used beneficially to stop the channel deteriorating to a single channel

should be supported by proper arguments and studies linking the short-term hydrodynamic changes with the long-term morphodynamic feedback of the system.

At the moment the strategy is presented in a very empirical and qualitative sense, rather than in a quantitative sense. The absence of a proper quantitative assessment makes it very difficult if not impossible to judge the feasibility of the PAET concept, certainly in its full extent of storing some 4 million cubic metres of sediment at the Plaat van Walsoorden. Yet, the concept is sufficiently promising that it needs careful quantification. Hence it is worthwhile to investigate the feasibility by a stepwise empirical and theoretical approach.

3.3 Comments on methodology

A certain number of studies have been undertaken to examine the situation round the Walsoorden flat and to develop an understanding of its present state. These studies comprise field measurements, physical scale model investigations and numerical modelling, which ideally should be complementary. However, they have not been used and carried out fully following this philosophy.

The ET makes the following specific comments:

· Float tracking has shown the near surface trajectories of the water flow, and these show the patterns of flow on both flood and ebb tides. However, these may not be representative of the near bed flow or the movement of sediment. The flow patterns after any dumping may be different, but significant flow pattern changes are likely to arise if large quantities are dumped. It is unclear what degree of tidal flat modification is required to be beneficial.

· While the feasibility of measuring sediment transport rates in the field was investigated, it has not yet led to a useful dataset. ET thinks the Delft Bottle method gives useful results.

· The physical (laboratory) model may be useful for an overall description, but it is unclear what its future usefulness may be. Also, there are scaling problems, especially for sediment transport simulation. If a role for the physical model is established, it needs to be allied to numerical process-based models.

· Numerical models are not extensively used to their best. Differences between the measurements and the physical modelling should be evaluated. Numerical models could have explored the relationship between the shape of the tidal flat, the flow and the likely sediment transport pathways in an assessment for the pilot experiment. A morphological model would have been a useful additional guide to assist expert judgement.

In conclusion, it is obvious that not enough is known about the detailed sediment transport around the tidal flats and the interaction of the flow with an evolving morphology, and this might be greatly helped by a well prepared and carefully executed field trail (pilot experiment) in which dumped material in the area considered crucial is carried out. Although a definite answer should not be expected, the pilot experiment is expected to provide additional insight on the feasibility of the strategy of modification of the tidal flats in preventing deterioration of the estuary to a single channel, and making best use of the dumped material in enhancing the estuary.

4 Recommendations on the Pilot Experiment

Extensive discussions between PAET and ET were held regarding the minimum size requirements for the experiment to be successful. The experiment depends crucially on there being sufficient material dumped that there is likely to be enough change in the bed levels to be detectable and provide sufficient information on the interaction between the flow and a developing morphology.

Within the present authorisation a pilot dumping of 200.000 cubic metres can be executed on the short term. Both ET and PAET question whether this is sufficient. The opinion was that the volume should be as large as possible but less than a million cubic metres to reduce the chance of the flood channel being choked. This is however based on estimates of the quantities available. It is highly recommended that the actual minimum and maximum amounts be defined by the PAET using a limited modelling effort allied to the conceptual model that is essential as a guide to the changes expected. The modelling effort could include running existing models on the short term to help in the design of this experiment as presented by PAET, i.e. to check whether current patterns are modified as expected and whether the deposit is stable enough. If nevertheless a pilot of 200.000 cubic metres is decided on, there are risks that the experiment might not give the expected results, and that the reasons for failure may not be apparent.

Some more detailed comments by ET are as follows:

· The timing of the experiment needs further consideration. From ecological considerations it might be better to do the experiment before wintertime. However, sediment mobility is likely to be greater in the winter.

· Minimum technical requirements are use of tracer material, Medusa and multibeam measurements, with a good definition of the baseline situation covering spring-neap-spring cycle.
· There is a necessity for near bed measurements of velocity profiles allied to hydrodynamic modelling.
· If practically feasible, efforts should be undertaken to establish a relationship between sediment mobility, bed forms and friction. This is important for full interpretation and use of the tracer results. In this respect the assessment of the vertical distribution of the horizontal velocity may be a better approximation.

5 Recommendations for Further Research

5.1 Implementation of the strategy

Following the discussion with PAET, we recommend a step-by-step approach to evaluate the proposed dumping strategy. This approach includes the following five steps:
· Pilot experiment, (provided that the recommendations in chapter 4 are taken into account)
· Refinement of the strategy, incorporating a conceptual model of the morphological response of the bank and of the whole cell,
· Larger pilot experiment,
· Implementation of the reshaping of the tidal flat (4 million m^3),
· Generalisation of the approach to other locations.
It is advised that a refinement of the strategy including the development of a conceptual model is initiated simultaneously with (preparations for) the pilot experiment.

The ET emphasizes the large importance of the refinement of the strategy, which should lead to the development of a conceptual model for wider application. This model should at least be based on three elements:
· analysis of historical maps;
· evaluation of past and present practices at each dumping site;
· monitoring of the pilot experiment.

5.2 Analysis of historical maps

Using the bathymetric maps as presented in the final report of PAET and its addendum (REF5 and 6), the ET recommends plotting cross-sectional areas versus distance, focusing on the 50 last years. From this it might be possible to determine a general trend in space, the evolution of the tidal prism and trends in bank movement. Areas that deviate considerably from the trend might be considered for reshaping by appropriate dumping. An analysis of the cross-sectional areas and shapes in time could also reveal insight in the dynamics of particular locations. The ET recommends that due account is given of lunar nodal tide effects.

5.3 Evaluation of past and present practices

We recommend analysing more precisely the difference bathymetric maps at each dumping site to compute the deposited and eroded volumes and compare these to the dumped volumes. Conclusions should be drawn on the local impact of the dumping on the morphology.

5.4 Development of a conceptual model

Analysis of the historical data together with the monitoring of the pilot experiment should provide enough information to develop a conceptual model. At a local scale it could be a simple sand balance for the dumping site. At estuary scale it is a more elaborate description of the morphodynamics of the estuary as a whole, aiming at preparing the next step of implementation of the new strategy. Because of the lack of a well-described concept, it is possible that there are other strategies, which could prevent the deterioration of the estuary. These should be discussed and evaluated.

5.5 Expected impacts

If the conclusion can be drawn that the proposed alternative dumping strategy is a feasible concept, PAET has to attempt making a quantification of the expected advantages and to consider both local, short term impacts and system, long term impacts.

Local, short term impacts concern:
· flat-channel interaction processes, with respect to the residence time and hence the influence on natural capability of restoring dynamic equilibrium (resilience);
· impact on sediment composition of both the dumping material and the flat sediments, with respect to the ecological impacts of the interaction of these two;
· impact on the ecology with respect to the dumping activity in itself (disturbance of the benthos, changes in turbidity, loss of biomass).

System related, long term impacts concern:

- the existing dynamics of the system and the concern whether the strategy does not work against the "natural" dynamical trends, but rather with it, to speed up movement to an acceptable equilibrium;
- the morphodynamic resilience –or the natural capability of restoring (capacity to restore) interventions- is expected to have a quantitative limit (compare the traditional dumping maxima). These limits will have to be assessed with a combined model/concept and an empirical approach;
- the concerns have to be considered in relation to the other developments, such as sea-level rise, the interaction with the Vlakte van de Raan and sediment extraction. Also the effect of possible adjustments of the (now fixed) riverbanks should be considered.

5.6 Recommendations about modelling

A numerical and a physical scale model have been used in the latest study and difficulties appeared, as reported in the PAET report (2003). Proper use of numerical and physical hydrodynamic, sediment transport and morphodynamic models can be useful in determining the sensitivity of the conceptual models for different geometries and parameters. Given the expertise of the PAET however, we recommend the collaboration is necessary in the use of models in the step leading to the overall predictive conceptual model.

5.7 Soundboard group

The PAET would benefit from liasing with a 'soundboard' group being familiar with different complementary techniques and different estuaries in order to help generalise the results.

Prof. Jean Berlamont
Prof. Keith Dyer
Dr. Luc Hamm
Prof. Co van de Kreeke
Prof. Marcel Stive

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Annex 1 The cell concept

This concept has been elaborated following several steps:

a) The definition of cell systems at meso- and macro-scales based on the analysis of bathymetric maps following observations and analysis by Van Veen (1950). The method used is general and can be applied to the different bathymetries available. There is no need for a numerical model to define these cells on maps,

b) A qualitative description of how a cell is functionning i.e. recirculation of the sediment mainly inside a cell with flood and ebb currents with second order exchanges between cells. Here again, empirical observations suggest this description,

c) A quantification of the intensity of the recirculation using a numerical model in which assumptions on sediment grain size, distribution of velocities, effects of river floods and wave agitation are made to get a mean annual gross and net sediment transport. This quantification is specific at present to only two bathymetric situations (REF 2) and has not been fully validated against comprehensive field measurements so far,

d) The development of a stability concept with numerical simulations to predict the impact of deepening a channel or filling it. This is a major refinement of the cell concept , a kind of second module, which could be discussed and improved without modifying or rejecting the "first module" described under a) to c). The validation of this concept is described in REF 3, 4 and 5.