LIMITATIONS IN MORPHOLOGICAL MODELING WITHIN THE FRAMEWORK OF THE EUROPEAN BIRD AND HABITAT DIRECTIVES

Limitations d'une modélisation morphologique dans le cadre des directives européennes oiseaux et habitat

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ABSTRACT

Estuaries are very dynamic systems in terms of hydraulic, morphological and ecological functioning. They have been undergoing significant changes due to natural processes and under influence of human activities. In the past, little attention was paid to the possible ecological impact provoked by engineering, bank protection works and dredging activities. Today, many European ports located on estuaries demand a better maritime access by dredging. Because of the European Bird and Habitat Directives, projects must undergo EIA or SEA studies, which traditionally are executed with numerical modeling tools. Most stakeholders do not know enough about the limitations of numerical modeling of the morphological and ecological effects. Information of the stakeholders about these limitations is necessary. However, uncertainties exist about these effects and because of the precautionary principle, projects might be rejected while these would be needed for curbing negative evolutions in the estuary. A cautious approach is therefore needed, assessing new projects with not only numerical models, rather with in addition scale modeling, desk studies, field surveys and studies and, last but not least expertise. In this paper the case of the Western Scheldt estuary is discussed, in which the involvement of the stakeholders was crucial in the acceptance process.

RESUME

Limitations d'une modélisation morphologique dans le cadre des directives européennes oiseaux et habitat
Les estuaires sont des systèmes très dynamiques du point de vue de leur fonctionnement hydraulique, morphologique et écologique. Ils ont subi des changements importants à cause de processus naturels et sous l'influence des activités humaines. Anciennement, peu d'attention a été portée aux impacts écologiques produits par l'ingénierie, les protections des berges et les dragages. Aujourd'hui, beaucoup de ports européens localisés sur des estuaires demandent d'améliorer leur accès maritime par dragage. L'application des Directives Européennes Oiseaux et Habitat requiert des études EIE et EES, traditionnellement exécutées à l'aide d'outils de modélisation numérique. La plupart des acteurs concernés n'ont pas une connaissance suffisante des limitations de la modélisation numérique pour évaluer les effets sur la morphologie et l'écologie. Du fait des incertitudes existantes concernant ces effets et à cause du principe de précaution, des projets pourraient être rejetés alors qu'ils seraient nécessaires pour corriger des évolutions défavorables dans l'estuaire. Une approche prudente est dont requise, évaluant les nouveaux projets non seulement avec des modèles numériques, mais aussi avec des essais en modèle réduit, des études sur documents, des investigations de terrain et, à ne pas oublier, de l'expertise. L'article concerne l'estuaire de l'Escaut Occidental, pour lequel la participation des divers acteurs a joué un rôle crucial dans le processus d'acceptation des projets.

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1. INTRODUCTION

Estuaries are among the most productive ecosystems with both high ecological and economic values. They offer a wide variety of ecosystem services [1] and provide a wide range of economic benefits to many sectors, including fishermen, industrial complexes and amenity services such as tourism and recreation.Worldwide, ports and harbours have been located along estuaries, sometimes far inland, as these estuaries provide the necessary shelter for ships as well as access to the hinterland along rivers and canals. Many estuaries have been undergoing worldwide significant changes due to the Holocene sea level rise and human interference, such as land reclamation, flood protection works and port development. It is only recently that the need for preservation of their ecological values was properly acknowledged.

Estuaries are also amongst the most dynamic and complex morphological and ecological systems in the world, with a wide range of habitats, which undergo continuously transformations due to the natural morphological processes, also affected by human activities. These estuarine habitats include sand banks, mudflats and sand flats, salt marshes, sand dunes in the mouth areas, shallow channels remaining from abandoned arms. All are protected under the Council Directive (92/43/EEC) on the conservation of natural habitats and wild flora and fauna (Habitats Directive). Many birds are dependent on estuarine and coastal habitats during their migrations and many estuaries and coastal areas are therefore protected under the Council Directive 79/409/EEC on the conservation of birds (Birds Directive).

Many European ports are logistic hubs for cargo coming from all over the world. The importance and demand for maritime transport has increased significantly in the last 50 years and is likely to continue to do so in the future. When navigation conditions in the maritime access to ports and harbours have to be improved, engineering works such as deepening and widening of the fairway by dredging is needed, so that port development and Natura 2000 designation overlap. The Habitats and Birds Directives do not preclude possibilities for further development and use of estuaries within or around Natura 2000 sites. Instead it lays down a stepwise procedure for ensuring that such developments are done in a way that is compatible with the species and habitats of European importance for which the sites have been protected. Or in the case of projects of overriding public interest that need to be implemented, it provides a mechanism for compensation and adaptation that ensures that the overall coherence of the Natura 2000 Network is not compromised.

This has favoured a more integrated and efficient spatial planning that, combined with early stakeholder dialogue, has proven over the years to be an effective way to promote sustainable development that is in line with EU environmental legislation. Article 6 of the Habitats Directive plays a crucial role in the management and sustainable use of the estuarine sites that make up the Natura 2000 network and the Commission has drawn up guidance documents to assist in their understanding and interpretation. It also has drawn up guidance on the use of EIA (Environmental Impact Assessment) and SEA (Strategic Environmental Assessment) as well as on Article 4 of the WFD (Water Framework Directive) all of which are highly relevant for any development, maintenance programme or other project in and around Europe's valuable estuaries. Recently, an EC working group set up a guidance document to clarify, explain and undertake a prospective exercise on the implementation of the EU nature legislation in Natura 2000 sites located in estuaries, fairway channels and coastal zones, with particular attention to port-related activities including dredging and industry.

The issues related to develop a sustainable dredging strategy was dealt with in the "New!Delta" project, Theme 6 (an INTERREG III B Community Initiative) [1]. "Sustainable dredging strategy" is defined as one in which management of dredging operations is a part of an integrated estuary management that strikes a balance between environmental, economic, social and technical aspects while respecting the legal requirements. The final report states that it is essential to use other tools than only modeling. All tools, especially the modeling ones, have not yet reached the required development for predicting quantitative effects, among others because of the poor understanding of physical processes. It also states that the complexity and intricacy of the processes ongoing in estuaries requires a multidisciplinary approach with the input of experts in the different relevant disciplines.

This paper aims at explaining how an important project for improving the maritime access to the Port of Antwerp could be brought to a good end, how the various stakeholders could reach a consensus and what

was the role of hydraulic modeling in this process. It also shows which difficulties arise when the effects of planned activities such as dredging can not be thoroughly proven with the present available modeling tools.

2. EUROPEAN DIRECTIVES

2.1 European Bird Directive (79/409/EEC)

European Community meets its obligations for bird species under the Bern Convention and Bonn Convention by means of the Council Directive 79/409/EEC on the conservation of wild birds (the 'Birds Directive'). The Directive provides a framework for the conservation and management of, and human interactions with, wild birds in Europe. It sets broad objectives for a wide range of activities, although the precise legal mechanisms for their achievement are at the discretion of each Member State. The main provisions of the Directive, among others, include:

- The maintenance of the favourable conservation status of all wild bird species across their distributional range (Article 2) with the encouragement of various activities to that end (Article 3).
- The identification and classification of Special Protection Areas (SPAs) for rare or vulnerable species listed in Annex I of the Directive, as well as for all regularly occurring migratory species, paying particular attention to the protection of wetlands of international importance (Article 4). Together with Special Areas of Conservation (SACs) designated under the Habitats Directive, SPAs form a network of pan-European protected areas known as Natura 2000.
- The establishment of a general scheme of protection for all wild birds (Article 5).
- Procedures under which Member States may derogate from the provisions of Articles 5-8 (Article 9) that is, the conditions under which permission may be given for otherwise prohibited activities.

2.2 European Habitats Directive (92/43/EEC)

The main aim of the EC Habitats Directive is to promote the maintenance of biodiversity by requiring Member States to take measures to maintain or restore natural habitats and wild species at a favourable conservation status, introducing robust protection for those habitats and species of European importance. In applying these measures Member States are required to take account of economic, social and cultural requirements as well as regional and local characteristics.

The provisions of the Directive require Member States to introduce a range of measures including the protection of species listed in the Annexes; to undertake surveillance of habitats and species and produce a report every six years on the implementation of the Directive. The 189 habitats listed in Annex I of the Directive and the 788 species listed in Annex II, are to be protected by means of a network of sites. Each Member State is required to prepare and propose a national list of sites for evaluation in order to form a European network of Sites of Community Importance (SCIs). Once adopted, these are designated by Member States as Special Areas of Conservation (SACs), and along with Special Protection Areas (SPAs) classified under the EC Birds Directive, form a network of protected areas known as Natura 2000.

The Habitats Directive introduces for the first time the precautionary principle for protected areas [2]; that is that projects can only be permitted having ascertained no adverse effect on the integrity of the site. Projects may still be permitted if there are no alternatives, and when there are imperative reasons of overriding public interest. In such cases compensation measures will be necessary to ensure the overall integrity of network of sites. As a consequence of amendments to the Birds Directive these measures are to be applied to SPAs also. Member States shall also endeavour to encourage the management of features of the landscape to support the Natura 2000 network.

3. ASSESSMENT OF PROJECTS

3.1 Environmental assessment

Environmental assessment is a procedure that ensures that the environmental implications of decisions are taken into account before the decisions are made. The process involves an analysis of the likely effects on the environment, recording those effects in a report, undertaking a public consultation exercise on the report, taking into account the comments and the report when making the final decision and informing the public about that decision afterwards. In principle, environmental assessment can be undertaken for individual projects ('Environmental Impact Assessment') or for plans, programmes and policies ('Strategic Environmental Assessment').

3.2 Appropriate assessment

Within the framework of the European Bird and Habitats Directives, the effects of planned projects have to be assessed. The Habitats Directive requires that any plan or project not directly connected with or necessary to the management of a designated habitat site, but likely to have a significant effect thereon, either individually or in combination with other plans or projects, is to be subject to an Appropriate Assessment (AA) of its implications for the site in view of the site's conservation objectives.

To assess the possible effects of a project, both on the short term as on the long term, different tools can be used. Where each of the existing tools have their limitations, effect predictions are surrounded by uncertainties. Within the framework of the European Directives, the precautionary principle can lead to juridical procedures about the interpretation of uncertainties in relation to the significance of possible effects.

Hereafter, the case of the environmental impact and appropriate assessment of the channel deepening and widening in the Scheldt estuary is discussed. Numerical models, in combination with expert judgement, were used to assess the effects of the project, what implies a certain level of uncertainty.

4. IMPROVING THE MARITIME ACCESS TO THE PORT OF ANTWERP

From 1999 on, Flanders and The Netherlands have developed a "Long Term Vision" (LTV) for managing the Scheldt estuary in which various projects have been proposed. One of them is the deepening and widening of the maritime fairway to the Port of Antwerp. Most of the dredging has to be made on Dutch territory and permits have therefore to be obtained from the Dutch administration. The fairway was already deepened twice: in the early nineteen seventies and in 1998. Based on a monitoring of the Dutch stretch of the Scheldt (the Western Scheldt), some had suggested that a degradation of the nature values, especially the reduction or disappearing of marshland, could be linked to the dredging works.

4.1 Institutional aspects about the decision-making

4.1.1 The stakeholders and their agenda's

Since the start, the various stakeholders were involved in the process to set up the Long Term Vision and to participate in the decision-making. Obviously, they have different views about the management of the estuary: the ports want to have a deeper and wider access channel; the environmental NGO's want to have a better nature (whatever it means); the biologists oppose negative changes in fauna and flora they pretend to happen; the riparian populations want a better protection against flooding; especially the farmers who do not want, in general, to give back land to the river; the local, regional or national authorities have also quite different approaches, some of these blaming dredging for a degrading of the nature values. The memory of the 1953 storm, with flooding of a large area of South Holland and also in Flanders, is a key element fostering the opposition to the further deepening of the Western Scheldt fairway. Evidently, competition between harbours is interfering in the decision-making, especially because Rotterdam and Antwerp are strong competitors.

4.1.2 Decision-making framework

In 1998, a Dutch-Flemish Technical Scheldt Commission (TSC) took the lead in drawing up an integral vision presented in January 2001 to the competent government representatives. The long term vision was summarised in an overall target for the year 2030, consisting of 5 characteristics: 1) The preservation of the estuary's physical system characteristics, point of departure for management and policy; 2) Maximum safety against flooding; 3) Scheldt ports optimal accessibility; 4) Preserving estuarine's ecosystem, healthy and dynamic; 5) The Netherlands and Flanders cooperate in the administrative-political and operational fields. In 2001 the governments of both countries adopted this overall target and begun in 2002 the drawing up of the 2010 Development Outline for the Scheldt estuary. A Dutch-Flemish advisory group was established, composed of representatives of the various stakeholders, which intervened in the various phases of the Development Outline (DO).

The Port of Antwerp is not in charge of the capital and maintenance dredging works in the maritime access fairway. These works are executed by dredging companies contracted by the Flemish Ministry of Public Works, Maritime Access Division that has to request permits from the Dutch Ministry.

4.2 The Walsoorden experiment, a first step to a new strategy

The Port of Antwerp requested an independent group of experts to formulate an opinion on the feasibility of a new deepening and widening of the access channel in the Western Scheldt. This Port of Antwerp Expert Team (PAET) started with issuing a diagnostic report stating that the observed degradation of nature values was mainly due to the land reclamation and river training works that was ongoing since the Middle Ages, evolution in which dredging did not have a significant impact [3]. They recommended a new approach, using the sediments extracted during the dredging operations for correcting the shape of sandbars which ecological values had been degrading [4]. The proposal was presented at a session of the Commission Infrastructure of the Flemish Parliament, together with the Long Term Vision Plan and was retained as an option that should be studied. This proposal was not sustained by modeling results, only based on expertise in morphological management with dredging.

PAET formulated the study strategy, combining several tools: 1) desk studies on historical data (especially the analysis of the morphological evolutions over past centuries with historical maps), 2) scale model tests, 3) numerical simulations, 4) use of expertise in morphological management of large river systems and 5) real-life experiment to check the outcome of the studies. These studies showed that the strategy was feasible [5] and the real-life experiment started by the end of 2004 by disposing half a million cubic meter of dredged sand along the edge of the "Walsoorden" sandbar.

The strategy was developed expertise in morphological functioning of large rivers and estuaries, using dredging to influence morphological evolutions [7]. Interesting is the fact that most opposition to this new method of disposing sediment came from the engineering world, while the environmental NGO's, at first opposed, decided to support the idea because they believed in the beneficial effects on the nature values. Their opinion changed not with modeling results, rather by the expert's pragmatic approach and by the outcome of the Walsoorden in situ test disposal.

4.3 Assessment of the effects

After several meetings of Dutch-Flemish working groups on morphology and ecology, some jointly, one of the alternatives to be investigated in the EIA was defined as using the dredged materials to reshape sandbars in the Western Scheldt. This strategy was based on the ideas of the Port of Antwerp Expert Team [3, 4], the working groups and the positive results of 2 in situ disposal tests near the Walsoorden sandbar in the Western Scheldt [8, 9]. Within the EIA and AA the effects of the project were assessed on the short term (5 years) and the long term (20 years) by a consulting consortium. Within the EIA the effects of the different alternatives of the project were investigated on the hydrodynamics (water levels, velocities), salinity gradient, suspended sediment concentration, morphology (as related to the habitats) and species (birds, fishes and seals), while the AA assessed the effects of the selected alternative on the habitats and species protected by the European Directives

4.2.1 Research tools

During the study 2-D numerical models were used, both hydrodynamic as morphological. Although these models are state-of-the-art, they have their limitations. For the hydrodynamic simulations, the models were calibrated and validated for both tidal penetration (water levels) and flow velocities (discharges on transects through ADCP-measurements and flow fields through GPS-float measurements). The model was able to reproduce rather well the hydrodynamics, although for some aspects larger differences remained, e.g. flow velocities on the intertidal flats [10].

For the morphological simulations, an extensive study was executed in preparation of the EIA. Both 1D-morphological models (SOBEK and MIKE11-software) as well as 2D-morphological models (Delft3D and FINEL) were used. It was concluded that due to the complex multiple channel system in the Western Scheldt, the 2D-model was necessary to be able to reproduce the morphological changes. The models were first calibrated for a 5 year historical period (1998-2002) and then validated for a 15 year period (1970-1985). A hind-cast was performed where the morphological evolutions reproduced by the models were compared with the measurements.

The modellers seemed happy with the outcome, as the simulated morphological changes corresponded relatively well with the observed ones when considering the volumes over large areas, i.e. as large scale sand balances. However, the correspondence was poor, even sometimes very bad, when looking at a smaller scale, such as the scale of shifting channels or sandbars (see figure 1).

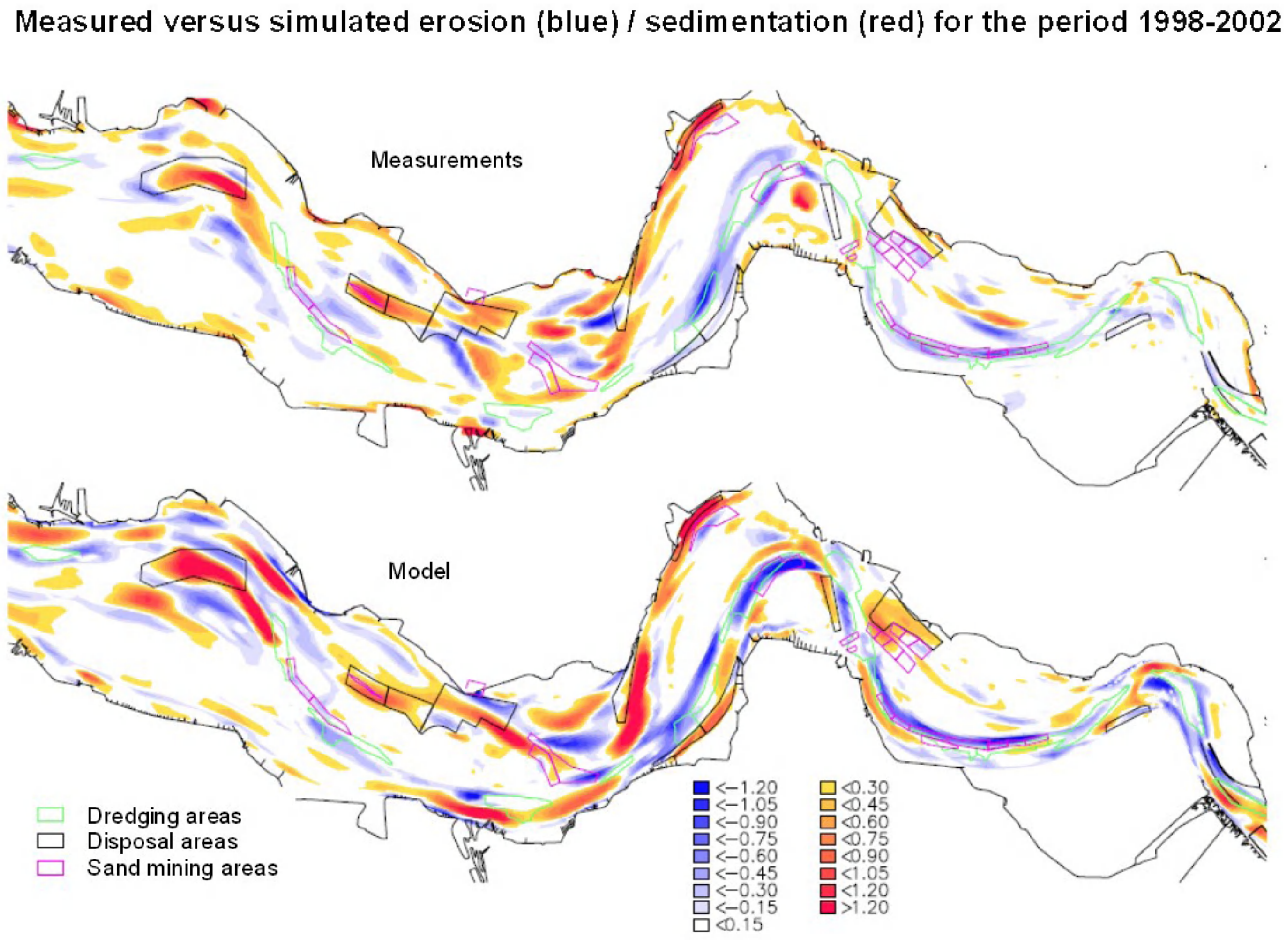

Figure 1: Modeling results compared with observed data [11]

It became soon obvious that the morphological effects of disposing sediment from dredging in particular spots, such as along sandbar edges, could not be correctly represented with the morphological models at the scale relevant for ecotopes. This limitation is crucial in the assessment of the effects: although the Habitats Directive is set up for large-scale ecological classes (e.g. type 1130 – Estuaries), definition of conservation

goals are based on sub-classes, taking into account qualitative aspects. The evolution of these sub-classes is determined by morphodynamic processes on a smaller scale. For predicting evolutions of the sub-classes, especially on the long term, researchers run into the limits of the present models. For predictions on the longer term (more than 5 years), uncertainties increase significantly. Therefore the interpretation of model results with expert judgement remains crucial.

The progress of the modeling and the results were screened by an external team of 8 experts, 4 morphologists and 4 ecologists. This appeared to be extremely useful, certainly because of the uncertainties in the modeling, also because of the differences in the interpretation of the results by the external experts, especially about the morphological effects. Even if their respective interpretation was different, their final conclusion on the feasibility of the project was similar, while some insisted on the need for better interpreting the results in terms of physical processes.

The SEA study recommended a "flexible" strategy for the disposal of dredged sand, because of the large uncertainty about the effect on the morphology. This means that the morphological and ecological response would be carefully monitored and the strategy adapted on the basis of the observations.

5. DEALING WITH THE MODEL LIMITATIONS

5.1 Modeling morphological and ecological responses in coastal plain estuaries

At present, it is not possible to predict accurately with numerical models the response of river works in dynamic systems such as complex coastal plain estuaries. This is due to the limitations of the models themselves, also to the incomplete understanding of the physical processes. Surveys have till now mainly been used to gather data for calibrating and validating models, not enough for understanding these physical processes. Thanks to new development in field survey technologies, field studies become possible, taking the prototype as a model.

In the case of the Scheldt estuary, large efforts were devoted to collecting detailed topo-bathymetric charts, flow information – especially flow patterns with GPS floats and ADP current measurements – and sediment transport measurements. Bedform characteristics could not be linked to flow resistance ("roughness") coefficients. Some morphological evolutions are controlled by "hard" points or layers, such as in some areas the underlying geological clay formations, also spur dikes or groynes and other engineering structures. Numerical models are not yet able to take all of this into account.

Our understanding of sediment transport mechanisms is still poor. The role of bedload and near-bed sediment transport is underestimated as compared to suspended load, as was revealed in the "Walsoorden" experiment. This lack of understanding makes morphological modeling uncertain, giving arguments to those opposing engineering projects such as dredging.

There is a need to better understand the link between morphology and ecology and this requires close collaboration between engineers and biologists/ecologists. The latter have not yet succeeded in defining well enough morphological and hydraulic criteria for healthy ecotopes.

5.2 Uncertainties and the precautionary principle

It is important that the precautionary principle is used in an appropriate way. For instance, the estuary should be regarded in a holistic way, not just the local effects. All sources of knowledge (models, expert judgement etc.) should be used to study the system. The imperfect understanding of the functioning of the estuarine systems and the availability of reliable predictive tools (models) makes the impact assessment uncertain for dredging activities. An inappropriate application of the precautionary principle could hinder a sound management of the estuary.

The European Directives allow executing projects despite uncertainties. However, the precautionary principle requires mitigation and compensation measures if the predictions in the worst-case scenario

(including uncertainties) cannot exclude occurrence of significant negative impacts. Although an assessment of these results is required, examples have shown that juridical courts tend to apply a conservative approach.

6. CONCLUSIONS

Estuaries are evolving. Their morphology and ecology are changing under influence of the natural factors and human activities. Today, projects for improving maritime access to ports or flood defences are treated separately, while an integrated, holistic approach is needed. Morphology is a key element as it determines also the ecological values within the estuaries. Numerical modeling is the preferred tool for the EIA and SEA studies. Most stakeholders do not know enough about the limitations of numerical modeling of the morphological and ecological effects. Information of the stakeholders about these limitations is necessary. However, the precautionary principle could be applied because of the uncertainties and projects rejected while these would be needed for curbing negative evolutions in the estuary. A cautious approach is needed, assessing new projects with not only numerical models, rather with in addition scale modeling, desk studies, field surveys and studies and, last but not least expertise.

REFERENCES AND CITATIONS

[1] New!Delta Theme 6 "*Sustainable dredging strategies*" http://www.newdelta.org/navigatie/frameset.asp?knop_id=20100025&mnu=1

[2] De Sadeleer et al. (2006). Implementing the Precautionary Principle - Approaches From The Nordic Countries, EU and USA

[3] Peters J.J., R.H. Meade, W.R. Parker and M.A. Stevens (2001A). Improving Navigation Conditions in the Westerschelde and Managing its Estuarine Environment. How to Harmonize Accessibility, Safetyness and Naturalness? (Port of Antwerp report)

[4] Peters J.J. and W.R.Parker (2001B). A Strategy for Managing the Westerschelde`s Morphology (Port of Antwerp report)

[5] J.J. Peters, R.H. W.R. Parker & M.A. Stevens - 2001, Alternative Disposal Strategy. The Feasibility of Morphological Dredging as a Tool for Managing the Westerschelde. September 2003. (*www.proses.nl => rapporten => September 2003*)

[6] Flanders Hydraulics Research (2008). Western Scheldt – Study of disposal sites near sandbars – evolutions of subtidal and intertidal areas on the short term (in Dutch)

[7] Peters, J. J., (2008). Can morphological dredging help improving natural values in rivers and estuaries? CEDA Dredging Days 2008, *Dredging facing Sustainability*. Antwerp,Belgium

[8] 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.

[9] Plancke Y.M.G., S.J. Ides, J.J. Peters & G.R. Vos (2009). *Le projet pilote Walsoorden: la première étape dans la gestion morphologique de l'Escaut Occidental, réconciliant la préservation de l'écologie et l'accessibilité des ports*. 31ième Journées de l'hydraulique: «Morphodynamiques et débits solides dans les estuaires, les baies et les deltas» Paris, France, 22-23 septembre 2009

[10] S.J. Ides, Y.M.G. Plancke & G.R. Vos (2010). *Validation of a 2-dimensional hydrodynamic model within a stuy to propose the optimal disposal strategy in the Western Scheldt*. SimHydro2010 « Hydraulic modeling and uncertainty », Nice, France, 2-4 June 2010.

[11] K. Kuijper, T. van der Kaaij, E. de Goede (2006). *LTV O&M plan for morphological modeling tools: Delft3D*. WL Delft Hydraulics, report Z3950.