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MORPHODYNAMICS OF TIDAL DELTAS

(MORTIDEL)

A COMPARATIVE STUDY OF THE DELTAS OF THE WESTERSCHELDE AND THE GIRONDE

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A comparative study of the deltas of the Westerschelde and the Gironde
(MORTIDEL)

1. INTRODUCTION

Inshore and offshore tidal deltas form an integral part of tidal inlets and mouths of estuaries. These deltas normally consist of large shoals dissected by one or more channels. They are located in the area where the shore-perpendicular channel and shoal system of the estuary or inlet meets the shore-parallel coastal system.
Tidal deltas have been the subject of many studies, focusing on the geological development, the hydrography, the sediment transport patterns, the development of channel and shoals and morphological forms and the biodiversity and -properties. However systematic studies, addressing and integrating all these aspects in a structured manner are very limited. Especially the morphodynamics, which is the changes in the morphology of channels and shoals in relation to the governing water and sediment movement, is hardly understood quantitatively. Consequently predictive models of the morphodynamic behaviour of tidal deltas are still at its infancy.
In order to understand the morphological development of tidal deltas it is essential to have a good insight in the patterns of net sediment flow over a certain time frame all over the channels and shoals and along the beaches bordering the mouth of the inlet. Also the interaction between beaches, channels and shoals is important in this respect. Therefore investigations of these sediment flow patterns should be directed towards the tidal delta as a whole; as one major system.

The present proposal aims at a comparative study into the net sediment flow patterns of two major estuaries along the NW European coast in order to develop conceptual modules, which later on may be used in morphodynamic modelling of tidal deltas. Such a comparative study is regarded as highly rewarding because it offers the opportunity to exchange and share knowledge on the phenomenology of the tidal deltas; to exchange existing data; to harmonise model concepts and model formulations and apply these in different areas in order to test the applicability; to share instruments, facilities and software and finally to identify processes which may be very dominant in one area but may be obscure and overlooked in another area.

The present proposal is organised in the following manner. The state of the art is briefly discussed in chapter 2. In chapter 3 the unifying general concept and the

innovation aspects of the proposal are presented. The objectives of the proposal are identified in chapter 4. The scientific, economic and social benefits of the proposal are presented in chapter 5. The criteria for the selection of both deltas to be included in the comparison are discussed in chapter 6. In chapter 7 the work content which is an elaboration of the above research questions will be presented. A detailed description of the tasks of each partner with milestones and deliverables is presented in Annex A. In chapter 8 the management of the program is discussed. In Chapter 9 the role of each of the partners is identified. Finally, details about the budgets are given in chapter 10.

2. STATE OF THE ART.

Since the seventies a growing interest on tidal deltas emerged. This interest was stimulated for several reasons. Shipping routes have to be deepened because of the increase in draft of ocean vessels; tidal deltas appeared to play an important role in the transfer and bypassing of sediments from the coastal zone of one side of the tidal inlet to the other and finally tidal deltas are huge sand bodies, which may act as oil reservoirs in older geological formations and their properties can be well investigated on recent examples. Studies were further stimulated by the development of better methodologies, measurement facilities and model capabilities.

Studies on tidal deltas were especially performed along the US Atlantic coast (Walton and Adams, 1976; Hubbard et al. 1979; Hayes, 1980; Nummedal and Penland, 1981; Dean, 1988; FitzGerald, 1988; Oertel, 1988) and along the Dutch and German North Sea coast (Bakker and Joustra 1970; Terwindt, 1973; Luck, 1976; FitzGerald and Penland 1987; Niemeyer, 1990; Sha, 1990; Sha and Van den Berg, 1993; De Vriend et al, 1994)

Although every tidal delta has its specific conditions they have some general characteristics in common. Tidal deltas normally consist of two parts: viz. the seaward outer delta, mostly having a triangular form with top angle in the throat of the inlet, and a landward inner delta. Tidal deltas contain a few tidal channels separated by extensive shoals. The size of the outer delta is strongly correlated with the tidal prism of the inlet (Walton and Adams, 1976; Marino and Metha, 1987). However Dean (1988) demonstrated that with increasing wave energy the outer delta tends to become smaller. In contrast Sha and Van den Berg (1993) showed that the offshore protrusion of the outer delta seems not to be inversely related to wave energy but appears to be a function of the tidal range and for larger inlets probably the tidal prism. The reason for this phenomenon is unclear. Also little is known about the relative importance of the wave versus the current action for the geometry and morphodynamics of the outer delta as a whole and the channels and shoals on it. Basically, for a simple inlet system the tidal flow pattern in the outer delta includes a slackening ebb "jet" flow that expands in the central part of the outer delta and an accelerating flood current, that everywhere on the delta, is directed to the inlet gorge. Over a full tidal cycle this results in a residual current pattern, made up of two horizontal circulation cells, consisting of an offshore directed flow in the central part and an inshore directed flow along the margins of the outer delta. Several efforts have been made to relate the variation in the ebb-tidal delta geometry to the regional variability in wave climate and tidal regimes (Oertel, 1975; Nummedal and Fischer, 1978; Davis and Hayes, 1984; Sha, 1989). A general descriptive model of the variation in outer delta morphology in relation to the dominant wave direction and the

interaction of inlet and longshore tidal currents is proposed by Sha and Van den Berg (1993).

In the past few years important progress is made to develop more quantitative methods of predicting the long term changes (over periods of several decades) of the outer delta geometry (Louters et al, 1991; Steijn and Louters, 1992; De Vriend and Bakker, 1994; De Vriend et al 1994; Steetzel, 1995). However most of these methods only predict the general outline of the outer delta geometry and do not account for the location and shifting of the individual channels and shoals. Also in some of these models empirical values are assumed of the net sediment exchange between the outer delta and its surrounding environments as a boundary condition, without considering the processes of morphodynamic interaction that produces this exchange. It seems that more phenomenological information is needed to understand how the system really works before these modelling problems can be handled.

Long-lasting bathymetric records in some estuaries and tidal inlets show that the migration of the channels is rather complicated. Two systems can be recognised. Some channels show a clockwise movement over the outer delta around a fixed point. The position of this turning point is rather stable but may shortly shift position and then remain in place for another period of time. The clockwise movement on the outer delta implies also a clockwise movement of the same channel over the inner delta. The reason for this movement is thought in the direction of the propagating tidal wave (Van Veen, 1936). The movement of the channel from one side of the mouth to the other seems to be limited by the tidal water gradients along and across the mouth. During migration the gradients along the bank off the mouth may become so large that a new channel is formed besides this bank. As a result the former system detoriates soon and a new system takes over. This hypothesis however is not substantiated by measurements yet.

Other channels don't shift so much and not so systematically but their function in the drainage of the basin shifts in time: from flood dominated they become ebb dominated or vice versa. So they exhibit a function change.

The reasons why in one case there is channel migration and in another case a function change are not clear. One of the reasons might be the existence at some places of very erosion-resistant older deposits along the bank of a channel. The processes which drive the channel migration and which determine the speed of this migration are also still not fully understood. In bending channels, like in rivers, centripetal forces may concentrate the flow along the outer bend, creating higher velocities and shear stresses and higher transports. Superimposed are the Coriolis forces, which may work with or against the centripetal forces, depending on the alignment of the channel and the direction of the flow (ebb or flood). The water movement may be modelled

(Kalkwijk and De Vriend, 1980) for a limited number of successive tides but the long-term effect on the channel migration is still obscure.

The shoals between the channels on the outer delta seems to be prone to severe wave action, especially during storm and swell events. Also tidal currents may affect the shoals especially during flood. However little is known about the relative importance of wave versus current action for the morphodynamic development of the shoals.

In recent years it became clear that the dimensions of tidal deltas and also the cross-sectional area of the channels are related to the tidal prism. (Eysink, 1990; Gerritsen et al. 1990). Little is known which processes determine the general morphological configuration or the sediment volume stored in tidal deltas. The question here is which function has the tidal delta in the total sediment budgets of the estuaries and the nearshore areas. Are the sediments stored in the tidal delta derived from net erosion in the estuaries and/or by delivery of sand from the nearshore?

In many estuaries, especially where navigation or other managerial problems exist, numerous measurements of the tidal flow have been executed, although under various conditions and with varying coverage of the areas. Recently tidal computations became a valuable tool for investigations into the morphodynamic properties of tidal inlets too. Especially 2D and now also 3D flow models with small grid sizes, capable to cover the morphology adequately, are important in this respect. Such models now become available, however only for a limited number of estuaries or tidal inlets (Wang et al, 1991; Bakker and De Vriend, 1993; Wang et al, 1993). At the present time they address only representative tidal conditions, but they may be extended to spring tidal circumstances too. From observations on intertidal shoals it appeared that springtide has a dominant effect on the sediment movement (Terwindt and Brouwer, 1986; Kohsiek, et al 1988). This also followed from observations in older deposits.

Another important problem is the determination of the sediment transport pathways, of prime importance to understand the morphological development. In recent years major improvements of the accuracy of tidal sand transport computations were achieved (Van Rijn, 1987; Voogt et al, 1991; Van den Berg and Van Gelder, 1993). However the quantification of the bed load is still problematic, because no good measuring devices exist to control the theoretical formulations. A way to check these formulations might be an analysis of the dimensions and migration of bedforms (Van den Berg, 1987). In few tidal deltas an inventory of bedform fields have been achieved (Castaing and Froidefond, 1978; Braud et al, 1985; Braud, 1986; Berné et al. 1993; Sha, 1990). However systematic records of bedform behaviour are practically absent.

The evaluation of the effect of waves and especially the long-lasting effect of extreme wave attack is still very difficult. The number of adequate field observations in this respect is still very limited and hampers this evaluation. A major point of concern is

whether waves only stir up the sediment which is further transferred by currents or that waves generate a net flow of sediment. Modelling and field observations on the tidal delta in the SW part of the Netherlands, after closure of one of the tidal inlets indicate indeed a net landward net sediment transport due to the wave asymmetry (Kohsiek et al, 1988; Kohsiek, 1988). Whether this is an incidental phenomenon, due to the adaptation of the morphology after the closure or a systematic long-term net sediment flow, which will persist after the adaptation is completed, is still a matter of discussion. If true, one might construct a general sediment circulation pattern along and over the tidal delta: wave action may drive sediments over the shoals in landward direction. These sediments are delivered to the tidal channels, in which currents transfer the sediment back to the offshore areas where it is replenished again to the shoals. In (quasi-)equilibrium conditions this means an almost closed circulation pattern. Observations in a part of the Gironde tidal delta (Castaing, 1981, 1989; Howa, 1987) and also of the SW part of The Netherlands (Louters, et al. 1991) have identified such general sediment circulation systems.

3. THE UNIFYING CONCEPT AND INNOVATIVE ASPECTS.

It is quite obvious that our knowledge of the steering factors and especially the domination of the current-driven over the wind/wave-driven sediment transports determining the morphodynamic evolution of tidal deltas is still rather limited. It is also quite obvious that due to the limited possibilities (financial, logistic, methodological, environmental) to execute field measurements, observations are scattered, of limited duration, non-systematic, with limited areal coverage and with different disciplinary entries. However in some estuaries or tidal inlets, extensive and important observational records and associated modelling exercises do exist.
Moreover it should be mentioned that in recent years powerful new methods as well as instrument and model facilities have become available such as better coring devices, high resolution seismics, presentation of sonar mosaics, GIS systems for former bathymetries, new flow and sediment transport measuring devices, remote sensing techniques and 2D and 3D tidal flow and sediment transport models. These new methodologies have not systematically been applied in any estuary mouth area. Sharing these possibilities and experiences in an European research group focusing on the important problems in two exemplary tidal deltas is therefore very challenging. The integration of existing and newly gathered observations, analysed with a certain general, unifying concept in mind might provide important steps forward into our understanding of the tidal delta system and the possibilities for managerial problems.

The unifying concept of the present proposal consists of the following elements:

- use in both deltas all sources of information: viz. the information contained in the sedimentary record e.g. the wave-current dominance in the bed sediments; the available bathymetric maps; the existing flow and wave measurements; the remote sensing and radar imageries; the existing flow and wave models; etc.
- investigate both deltas with a comparable level of detail and the same methodologies viz. high resolution seismics; undisturbed cores; sonar mosaics and sounding maps; morphometrical and morphological map analysis; comparative wave and current recordings; agreed flow and wave models; etc.
- integrate the results of all these methodologies in general concepts: viz. generalisation of the results of the detailed analyses; application of GIS techniques to identify relations and trends; formulation of statements concerning the way(s) the system behaves by hindcasting former developments and measuring systematically present process systems and products; etc.
- model these concepts: e.g. by construction of flow diagrams; quantification of the important relations; etc. resulting in conceptual models

- evaluate these models in both areas by confronting them to the results of observations, which have carefully defined in order to meet this requirement.

The unifying concept also addresses the modelling concept in this Proposal because it should be explained what is meant by "conceptual models". This subject will be treated in chapter 7.2 on the Work Content.

From the foregoing the following innovative aspects emerge:

- The MORTIDEL project intends to perform systematic and integrated studies into the morphodynamics, sediment dynamics and hydrodynamics of in- and offshore tidal deltas and to introduce on a larger scale the use of available technologies and innovations in the field of navigation and positioning accuracy, geophysics, underwater acoustics, hydrodynamic parameter modelling, remote sensing and instrumented sediment transport measurements.
- The results of 2D and 3D tidal flow models with appropriate grid size will be used intensively in the determination of the large scale flow and sediment circulation systems and in the hindcasts of former morphologies.
- Remote sensing techniques will be used to measure the flow patterns and to compare these with the tidal flow model results.
- Instrumented tripods, which form an important part of this investigation, equipped with modern flow, wave and sediment concentration sensors will be deployed on the shoals and in transects normal to the coast providing systematic longer term observations of the flow and sediment transport conditions on a scale unpreceded up till now. Such data are indispensable for the testing of models and model concepts.

  These measurements will be completed by careful analysis of the bed level changes, bedform dimensions and migration.
- Conceptual models will be generated describing the large scale behaviour of the channel and shoal system, the sediment circulation patterns and the spatial and areal variability of these patterns. Such conceptual models are rather novel at the present time but are urgently needed in order to make progress in morphodynamic modelling.

4. OBJECTIVES

On the basis of the unifying concept the following general objectives of the present proposal can be formulated.

1. To investigate with similar means, methodologies, and level of detail the tidal deltas of two major estuaries in order to establish a general applicable conceptual model of the net sediment circulation and the morphodynamic behaviour of these deltas.
2. To combine and integrate all sources of existing and newly gathered information concerning the extension, development and shifting of channel and shoal systems, interaction with adjoining beaches, areas of current and wave dominance, sediment transport paths and human interference in order to arrive at an indication of the spatial and temporal variations of the determining processes over the tidal deltas
3. To analyse extensively the results of existing 2D and 3D tidal flow and transport models and of wave models in order to investigate the possibilities of these models for the identification and quantification of the net sediment circulation and for longer term developments of tidal deltas and to execute field verification measurements on selected sites to test the reliability of these models.
4. To provide a basis of better understanding of the behaviour of tidal deltas for practical management of these areas.

5. SCIENTIFIC, ECONOMIC AND SOCIAL BENEFITS.

The Project will result in a better understanding of the sediment transport pathways and of the steering factors which determine the morphological development of the channel and shoal system of tidal deltas. It further intends to use and check existing models on flow and sediment transport and it provides conceptual models, essential for the further development of morphodynamic models of tidal deltas.

The increase in knowledge is essential for a proper management of these areas. Two important managerial problems have been included in the Project viz. the relation of channel migration on the position of the coastline and the effect of dredging and dumping on the behaviour of the channel and shoal system (see chapter 7). Based on knowledge of the speed and direction of migration of channels, exercising a threat to the coastline, one might consider to deviate the channel from the coast by correcting the alignment of the channel by appropriate dredging. Such an interference in the natural system can only be done after a thorough appraisal of the consequences for the morphological development. The present Project aims at providing essential information for such an appraisal.

The second problem addresses dredging. In both estuaries the main dredging area is located at the seaward sill in the channels. This is the area where the estuarine and coastal system meets each other. The effect of this dredging on the alignment and the depth development of the channel on a longer time scale is hardly investigated. Obviously repeated soundings have been made in the dredge areas, but a systematic analysis of the mentioned effects is still not performed. The same holds for the dumping sites of the spoil. Normally economic considerations have determined the "optimal" location . But the position of the dumping site in relation to the overall sediment circulation pattern is not well investigated. Recently in both estuaries studies into the optimalisation of such dumping sites have been executed. The present Project can deliver important inputs in such studies.

The shoals especially on the inner delta have an important function as natural reserve areas, e.g. bird refugia and fishing grounds. A better understanding of the acting processes may assist in the development of management plans for these areas.

The results of the Proposal may suit feasibility studies of coastal management and engineering plans.

The great practical importance of the present Proposal is illustrated by the incorporation of three authorities, responsible for the management of the studied deltas viz. Dienst der Kusthavens (DDK), the Port Autonome de Bordeaux (PAB) and the Rijkswaterstaat (RWSDZ). These three authorities will provide shiptime and research facilities and will take part in the scientific studies to an extent much larger than their claim to the budget. Especially the costs of the shiptime will exceed largely

the amount which may be claimed to the EC-MAST. The same hold for IFREMER. These contributions to the Project are made available from their own budgets because of the great interest these authorities attach to the goals of the Proposal.

Finally the core of the present research group of the proposal is made up of participants of the former MAST I RESECUSED and the MAST II STARFISH project. In this inter-disciplinary projects an intense interaction and co-operation between partners was established as demonstrated by the joint publications in high standard international journals.

Thus the proposal offers very good opportunities for further extension of knowledge and possibilities in the European framework.

6. THE SELECTION OF THE DELTAS FOR COMPARATIVE STUDIES

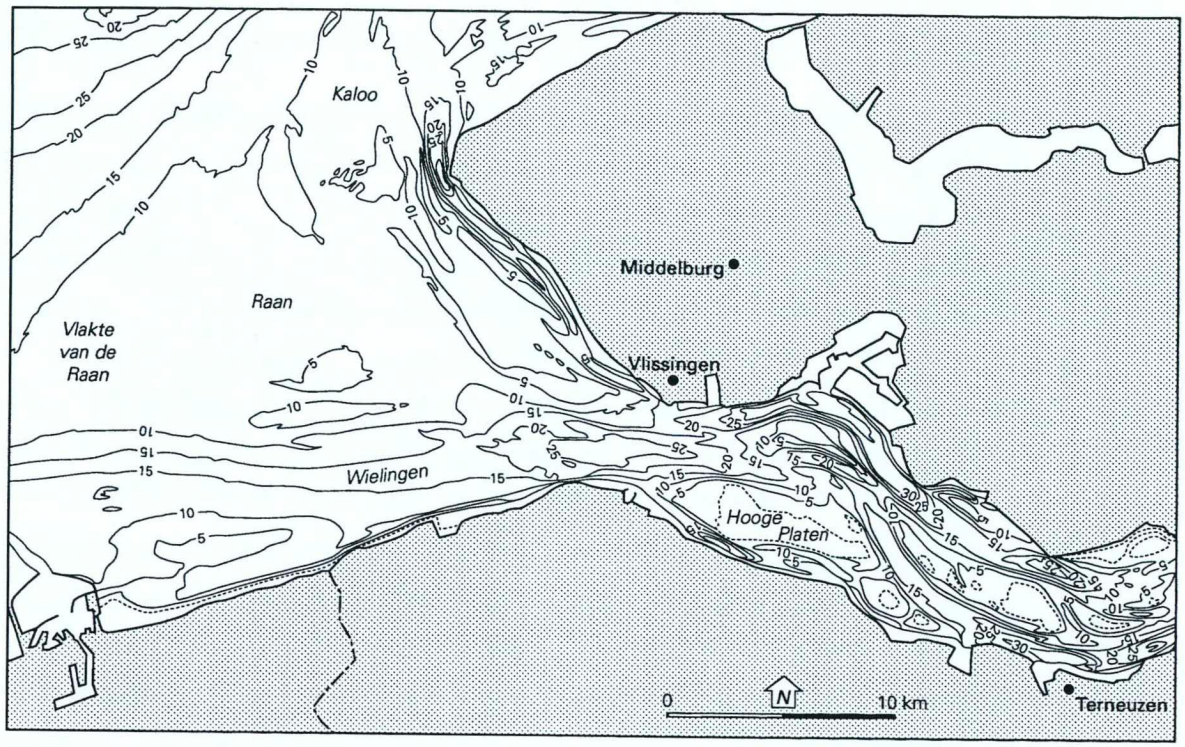
Two or more completely similar tidal deltas do not exist. Each tidal delta has its own specific character. Thus we need to specify what we want to compare. Several, although arbitrary, entries into this comparison can be chosen. In the present proposal the main focus lies on the development and comparison of conceptual models. That means that the selected deltas are approached with a unified idea of the general process system, with unified methodologies and unified data definitions. This approach which incorporates the knowledge, experience and possibilities of all partners is applied to two distinctly different tidal delta systems. Thus the dominant selection criterion was: which deltas allow this unified approach of analysis. The subordinate criteria address some practical aspects relevant for the dominant criterion.

- the hydro- and morphodynamics of the deltas should be well-studied, so that the unified concept can be achieved because of the comparable level of knowledge. Bathymetric maps should be available for at least one century. (Sub)-recent data on tidal curves, flow velocities, wave characteristics, sediment concentrations, salinity distributions, bedform and grainsize characteristics are necessary, encompassing the whole study area. Preferentially this information should be available in an elaborated and accessible form
- the geological setting and development should be well-studied too
- (tested) tidal flow models of the delta areas should be available, suitable for the analysis of the channel and shoal system
- the size and characteristics of the deltas should be in line and more or less representative for tidal deltas over NW Europe in order to make the results of the studies applicable to other deltas
- the dimensions, characteristics and the nature of the human interference of the selected deltas should be comparable
- research groups of various disciplines but with a record on interdisciplinary co-operation must be active in the selected areas, thus forming the basis for the discussions on the unified concept. These research groups and other governmental or research institutes must be interested to participate in the research program in line with the concepts of the present proposal.

Some logistic aspects referring to the possibilities of the execution of the proposal are:

- the deltas should be accessible for measurement ships handling the seismic, coring and measuring equipment

Westerschelde



Gironde

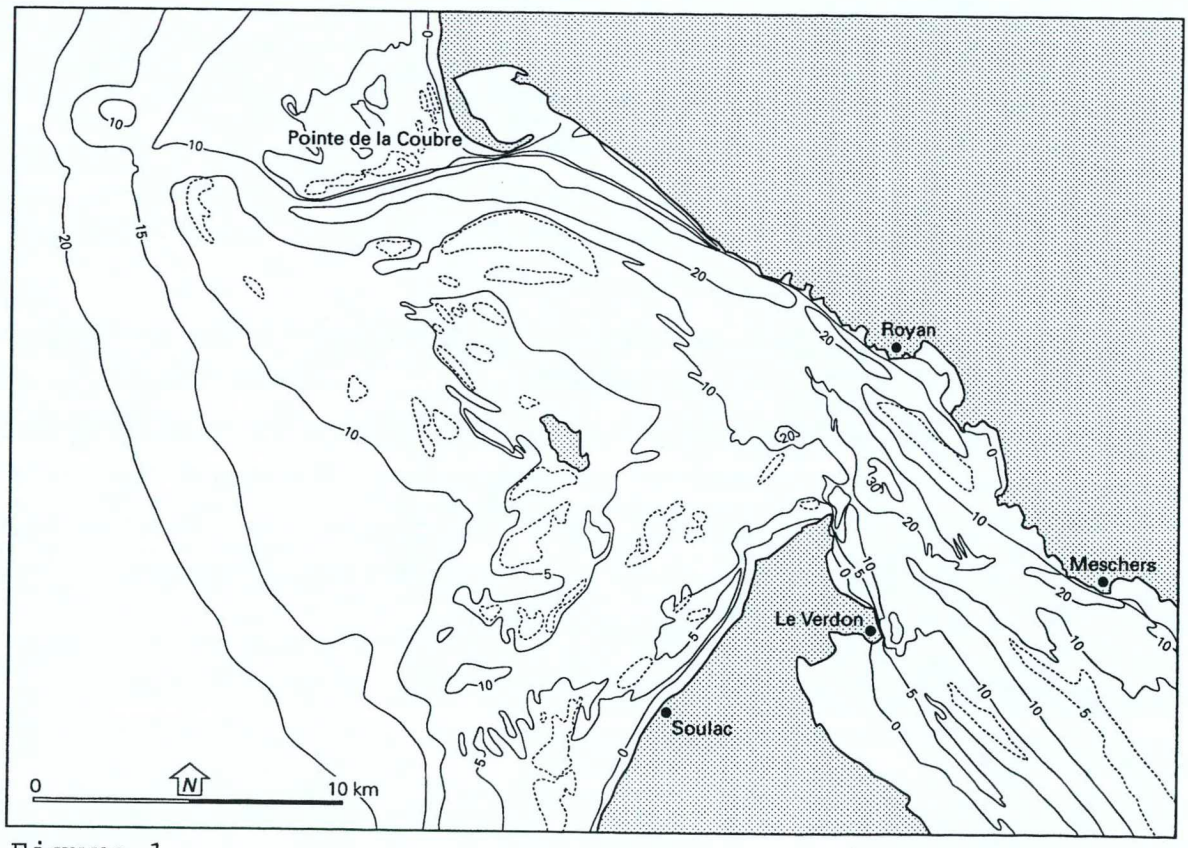


Figure 1

- ship-time should be available for the execution of necessary additional measurements. Governmental or research institutes which may provide the necessary ships must be willing to support the research program.

After considering several options all over Europe the tidal deltas of the Gironde and of the Westerschelde estuary are chosen as the best locations for the proposed study. These deltas show some similarities as well as differences (figure 1). They are located in the mouths of well-mixed estuaries, with a spring tidal range of about 5 m. Maximum depth-averaged current velocities at springtide reach comparable values of 1.3-1.5 m/s.

Both tidal deltas are not too large in size and exhibit all the characteristics, normally encountered in such deltas: migrating channels, extensive shoals and interaction with adjoining coastal systems, they are therefore a good examples of such deltas along the Atlantic and the North Sea. Both deltas have one major channel and one subordinate channel with an extensive shoal in between. Channel migration affect the adjoining beaches.

A difference is that the Gironde flows in a Holocene-filled drowned river valley, while the Westerschelde took its present course only since the late Middle Ages. They both are situated on well-known older geological formations. It may be possible to reconstruct the development and extension of the estuary mouths by coring as well as by comparing old maps and written historic data.

Wave attack on the Gironde tidal delta is much stronger than on the Westerschelde, because the heavy swell waves and occasional storm waves at this part of the Atlantic and because the Westerschelde mouth is protected from wave action by the offshore banks.

Because of the energetic hydrodynamic character of both deltas reworking of the top layers of the bed might occur very frequently. Therefore it is not expected that biological constraints will influence the morphodynamics in an appreciable manner. That is the reason that the present study doesn't include large scale biological investigations. It seems that in both deltas morphodynamics is steering biology and not vice versa. However in both deltas detailed biological inventories have already been executed. These data are available. In the present proposal only checks are foreseen by analysing the boxcores for the biological content and to perform some additional calculations.

The morphology in general is different too. In the Gironde a rock outcrop dissects the tidal delta area into two parts, each exhibiting probably a well delineated flow and sediment circulation system, while in the Westerschelde, most probably, only one large circulation system exists.

Both deltas ar well-studied. Bathymetric maps are available for over 150 years; for a long time cur nt measurements are executed in the areas; wave and meteorological data are avail le.
Since the 19 s tidal computations connected with verification measurements have been perform and recently 1D, 2D and even 3D tidal models have been or are made for both delta which offers the opportunity for comparative evaluations. Much work has been don o establish the transport patterns of sand as well as muds.
Both deltas h ve been subjected to dredging and training works. Much results of research into e effects and optimalisation of dredging are available for both areas.
Furthermore ere is a huge amount of reports and areal knowledge in French, Belgian and tch scientific and governmental organisations, who have offered to participate in e program; to give free access to the data and to provide shiptime for the execution the proposed program. The deltas are accessible for research vessels.

7. WORK CONTENT

7.1. Introduction

Looking at tidal deltas and knowing that they are built up by sand and mud in various proportions and that channels and shoals shift in position during time, many important questions as to the reasons for the observed behaviour may evolve. For the purpose of this proposal the following basic questions are highlighted:

1. how much sediment is stored in the "tidal delta sediment body"; do underlying different geological formations have a constraining effect on the outbuilding of the deltas or on the position and migration of channels and shoals; is it possible to reconstruct the outbuilding of the inner and outer tidal deltas and the development of the channel/shoal system
2. is there a systematic behaviour of the channel/shoal system: do channels and shoals extend and/or diminish in time; do the channels move systematically in one direction, does the shoals follow this migration; are there trend breaks, thresholds or critical values at stake in the behaviour of channels and shoals e.g. critical radii in bends, critical barriers in the channels, critical depth/width ratios (cross-sectional areas of channel profiles), necessary for the maintenance of the channel/shoal; is there a plausible reason for that
3. do tidal deltas have a protective effect on the adjacent beaches; in which manner does channel migration determine the coastal developments
4. do dredging and spoil disposal as well as the presence of fixed points (harbour moles etc.) have a determining, subordinate or neutral effect on the morphological changes of channels and shoals
5. what are the dominant differences in processes which maintain the channels and the shoals; where are the transition zones between the different process systems located
6. how much sediment is transferred through the channels and over the shoals; is there a sediment circulation pattern which impose a systematic net sediment flow in a certain direction

Question 1 refers to the long-term (centuries) development of tidal deltas; question 2 to 4 to the medium-term (decades) and question 5 and 6 to the short-term (days/years) conditions. These questions will be dealt with in the proposed project, focusing on the Westerschelde and Gironde tidal deltas.

Given the financial boundary conditions accents and limitations have to be made. The area of investigation is limited to the outer and inner delta of the estuaries (figure 1). The long-term reconstruction and hindcasts are treated rather roughly, which means

that the areal scale of information assemblage is rather large. More emphasis is given to the medium-term developments, but here use is made of already available data which have to be processed to meet the objectives. The major effort will be devoted to the short-term problems. Here too limitations have to be envisaged. Within the three-year time-frame of the project only a limited number of instrumented tripod deployments can be achieved. Attention will be focused on the outer deltas. In fact some 4-6 deployments (including 3 tripods) each of 4-6 weeks duration are foreseen in the Westerschelde outer delta and an even smaller number in the Gironde. The sites will be chosen after careful study of the tidal flow model results and the side scan sonar surveys. Another limitation is that in the present proposal no new models will be developed, but existing wave models and 2D or readily 3D flow models will be used. The measurements are especially meant to check the model results and to provide new information especially on the wave/current interaction. Another limitation is that the project doesn't address the processes on the shallow nearshore areas and the beaches but only deals with the sediment fluxes from the coastal zone to the channels and vice versa. On the other hand the Proposal focuses on the determination, with all possible means, of the sediment transport pathways and the accompanying morphological developments.

7.2 The modelling concept.

The data of the long- and medium-term morphological developments derived from geological and from map analyses will be stored in a GIS system. This system allows to determine the rate of morphological change over a certain time steps (say decade). Morphological change includes the position of the channel axis, the changes in slopes, depth, cross-sectional area and the erosion and sedimentation etc.
Comparison of the morphological changes over the time steps provides the spatial distribution of the rates of change. In some areas the changes may be greater than in other.
A fundamental assumption is that the rate of morphological change *in the channels* is determined by the tidal flow. This means that waves doesn't affect the alignment and migration of the channels. Waves may stir up sediments, which may be transferred by currents and in this way influence the velocity of the change but have not a steering effect on the morphological changes itself. This assumption implies that the tidal flow models may be applied to explain the morphological changes. The results of tidal flow and connected sediment transport models may be analysed in relation to the rate and position of morphological changes. This relation may be modelled in a "conceptual model".

On the shoals however it is uncertain whether the above assumption can be applied. Over shoals the tidal flow models may be less reliable than in the channels, because of the difficulties of estimating the bed roughness. In addition it is uncertain whether waves induce a net landward flow of sediment and thus having indeed a steering effect on the morphological development. It may well be that on the shoals the currents and waves both have a variable contribution to the net sediment flows. Here systematic measurements are needed to establish this interaction. Existing wave (refraction) models may assist the analysis and interpretation of these measurements and may be used in sensitivity analyses and the choice of the optimal location of the measurement sites.
The wave-current interaction may be modelled and this is also included in the "conceptual modelling". Thus these conceptual models don't aim at a quantitatively reliable output of morphological changes but more at an increase in our knowledge of the system: it are more research models than practical application models.

7.3. Long-term development of tidal deltas (question 1).

As stated earlier in chapter 6 the geological history of both deltas is different. The area of the present Westerschelde tidal delta was originally a marine sedimentation basin responding to the Holocene rise of sea level. Here, around 3500 BP, a beach barrier developed, protecting a tidal lagoon, which gradually silted up and became a peat bog area. During the late-Holocene transgression the area became a tidal basin again but very shallow. Small inlets and tidal creeks penetrated the area. After the Middle Ages some of these creeks captured the Schelde River and so the Westerschelde came into existence. (Van der Spek, 1994). The Gironde is a drowned river valley, which gradually is filled in by fluvial and marine deposits during the Holocene sea level rise. Here too, early Holocene infill deposits are overlain by late Holocene coarser-grained tidal inlet/delta sands (Allen and Posamentier, 1993). In the late Holocene channels may have migrated in the area of the tidal delta, thus locally eroding the older deposits. These deposits may be sands but also resistive clays of Holocene, Pleistocene and in the case of the Westerschelde even Tertiary age. These clay layers, outcropping in the channel banks may restrict or prevent a free movement of the channels. Thus it is of importance to determine if the late Holocene channels indeed are constrained by the presence of these erosion resistant layers.
In addition it is also important to determine the volume of the real "tidal delta sediments" underneath the present outer and inner delta. Furthermore, if possible, it would be interesting to reconstruct the history of the outbuilding of the tidal deltas. Finally, if the lower boundary of the "delta deposits" can be ascertained the sediment core above may contain valuable information as to the dominant processes active

during deposition. Careful analysis of the sedimentary structures may differentiate wave-dominated from current-dominated areas as well as the vertical and lateral changes in these properties. Probably it might also be possible to determine old channel positions in the "tidal delta sediment body" aiming at a palaeo-morphological reconstruction.
Thus investigation of the "tidal delta sediment body" is a basis for further analysis of the morphological developments and sediment transport systems. This can be achieved by high resolution seismics, completed by a number of undisturbed borings, providing the stratigraphic and sedimentological information.

Research subjects

a. determine the boundary between the older geological formations and the Westerschelde/Gironde tidal delta sediment body from a grit of shallow high resolution seismic lines (RCMG, IFREMER)
b. identify former channels and shoals from the same seismic lines (RCMG, IFREMER)
c. locate and perform undisturbed borings from the results of a and b, to check the seismic data and to provide samples for stratigraphic datings and further sedimentological analysis; analyse the cores for bio-information: species, bioturbation (degree and nature); date relevant samples (RCMG, RGD, IFREMER, UB, UL)
d. analyse the sedimentological structures in the core-peels to check the seismic and stratigraphic information and to determine the dominance of current or wave action during deposition of the sediments (RCMG, RGD, IFREMER, UB, UL)
e. analyse from older and recent bathymetric maps the shifts of channels and shoals (DDK, RWS, PAB)
f. integrate the obtained information in palaeo-reconstruction maps of the delta, showing the development of the channels, the splitting of the channels, the development of bends, the outbuilding and alignment of the shoals etc. (RCMG, IFREMER, UB, UL, RGD, DDK, RWS, PAB)

7.4. Medium-term development.

7.4.1. Development and movement of channel and shoal systems (question 2).

This development can be substantiated by a morphological analysis of sounding maps of the area covering the last 100-150 years. From these maps morphometric data sets

can be derived, including the position of the channel axis, cross-sectional areas, dimension of shoals, radii of bends etc. In time, by comparison of the successive maps the changes in alignment, the position of the channel axis, cross-sectional areas, amount and situation of erosion and sedimentation sites etc. can be derived quantitatively. It is envisaged that the data gathering and handling will be done according to pre-set, similar instructions for both research areas, resulting in comparative data sets.

There are empirical relationships connecting the area of tidal deltas to the tidal prism. Perhaps a similar relation holds for the stored sediments in the deltas. There are also empirical relations connecting the cross-sectional area of a tidal channel to the tidal prism of that channel. It may further be anticipated that the orientation and the alignment (bending) of the channels may also be related to the tidal prism. Thus the tidal prism seems to be the steering factor for the size of the tidal delta and the dimensions and alignment of the channels.

The tidal prism of the inlet and of the various tidal channels may change gradually in time, due to sea level rise or changes in the tidal basin. Adaptation of the morphology to changes in tidal prism may be rather slow because of the large volume of sediment involved. From the bathymetric maps the above-mentioned parameters may be tested against known former tidal prisms.

On the basis of all these data hindcast exercise may be accomplished. Starting from the known relationship between cross-sectional area and tidal prism, the tidal prisms of the former channels can be evaluated (Eysink, 1990; Gerritsen et al , 1990). By comparing the data from outside to inside of the same channel and similarly the various channels, the tidal storage of the basin can be estimated. These data can be introduced into the known relations between tidal storage and extension of the delta. A verification can be achieved by applying the relation between cross-sectional area and the mean flow velocity in the channels. A transport formulation (e.g. the Van Rijn equation) can be used to estimate the net transport in the channels, which can be related to the observed sedimentation and erosion rates. Special attention should be given to the wave-dominated areas. These areas follow from the core-data (see 7.3). In these areas a seaward source can be present, which may be determined on the basis of grain size characteristics.

Available 1D and 2D tidal models can be used for the hindcasts as demonstrated by Van der Spek, (1994). Starting from the present day tidal situation and using the former morphology as bed input and assumptions as to the bed roughness the tidal flow regime can be computed. These results can be compared with those from the foregoing morphological analysis. Thus different sources of information can be combined in the hindcast.

The results of the hindcasts can be helpful in the formulation of the descriptive modules, mentioned in the Introduction. It should be noted that the formulation of these modules will take place in a joint effort of researchers of both study areas. It is envisaged that these modules are tested in both areas too.
Thus the objective of the morphological and hindcast exercises is to arrive at a more detailed, quantitative analysis of the morphological development of the studied tidal deltas in recent times (order last century) and to develop modules for this development.

Research subjects

a. select sounding maps with time frames of order of a decade; from a cross-sectional network determine morphometric data like position of channel axis, cross-sectional area of the channels, dimensions of the shoals, (a)symmetry of the channels, radii of the bends, position of the coastlines, slopes of the beaches etc. ; (RWS, DDK, UB, RUMACOG, PAB)
b. establish a GIS system for these data; (RUMACOG, RWS, DDK)
c. use GIS-techniques for the schematisation of the channel migration, shoal development, changes in radii, slopes, coastal positions etc.; (RUMACOG, UB, RWS, DDK)
d. determine the cross-sectional areas of former channels and of the dimensions of the shoals (time steps depend on available data and accuracies; time steps may increase going further back in history); (RUMACOG, DDK, RWS, UB)
e. estimate the tidal prism of the channels and of the tidal deltas and determine the palaeo-flow velocities. (MUMM, RWS, DDK)
f. estimate the sand transports by using transport formulations (MUMM, RWS, UB, LHS)
g. use flow models with palaeo-morphology as input in combination of d. and e. (MUMM, RWS, UB)
h. determine erosion and sedimentation areas; check with morphological data. (RWS, DDK, MUMM, UB)
i. evaluate the reconstruction and hindcast to determine the presence or absence of dynamic equilibrium and the dynamic evolution. (RWS, DDK, MUMM, UB)
j. develop a conceptual and/or a descriptive model or adapt an existing model for the schematised developments derived under c.; (RWS, MUMM, LHS, UB)
k. test the model in both research areas. (RWS, MUMM, LHS, UB)

7.4.2. The effect of tidal deltas on the development of the estuarine coast lines (question 3)

There is a certain general interdependence between the tidal deltas and the nearby beaches at the mouths of the estuaries. The tidal delta acts as a protective shield against severe wave attack, especially during storms. On the other hand the tidal channels in the tidal deltas may shift towards the coast, resulting in steeper coastal profiles and intensive current action in the nearshore zone. Sediments stirred up by waves can easily be transported alongshore by tidal currents. Generally it is observed that coastal erosion and sedimentation follows the on- and offshore migration of the channels, although with a certain relaxation time. It is further observed that when coastal accretion occurs a bulge of sand is deposited on the foreshore which may be transferred along the coast in the form of a beach wave. Several empirical studies have been executed in recent years dealing with the relationship between the on- and offshore migration of tidal channels and the adaptation of coastal profiles and the erosion or accumulation of the beaches. However quantitative relationships including parameters describing the current and wave-climate over the medium term, the migration rate of the channels, the development of descriptive parameters for the beach profile characteristics and the net amounts of erosion and sedimentation are scarce.
The present proposal aims at a harmonised analysis of existing data sets for the above mentioned relationships. It is anticipated that the results of such an analysis will be different for both research areas because of the differences in wave climate and tidal characteristics. Nevertheless it will be most interesting to compare the empirical relationships and to test them in both research areas. Furthermore it is challenging to try to arrive at generalised formulations, applicable for both areas.

Research subjects

a. determine the rate of changes in alignment of nearshore estuarine channels, channel dimensions, slopes; (RWS, DDK, UB)
   determine the changes in coastal profiles, slopes and other morphometric characteristics and the net erosion and sedimentation in time; (RWS, DDK, UB)
b. introduce these data in a GIS; (RUMACOG, DDK, RWS, UB)
c. determine the critical distance of the channel axis and the associated erosion and sedimentation of the coast, the development of the coastal profiles and the alongshore variation; (RUMACOG, DDK, RWS, UB)

d. select existing or develop new parameters describing the current and wave characteristics over the time frame of the development of the coastal stretch under study; introduce these data in the GIS; (MUMM, RWS, DDK, UB)

e. relate the data gained under c to those under d; (RUMACOG, MUMM, UB, RWS, DDK)

f. develop a conceptual or adapt an existing model for these relations. (MUMM, RWS, LHS, UB)

7.4.3. The effect of dredging and spoil deposition on the morphology (question 4)

Records of location and amount of dredging and of spoil deposition of both research areas will be assembled. A detailed analysis of the cross-sections of the channels in the vicinity of the dredging will produce data on the recovery of the dredged areas and the possible effects on the channel alignments. It can be rewarding to make borings in the recovery areas in order to determine which type of sediments are accumulating in comparison to the surrounding areas. Similar analysis may be performed for the dump sites.

Indications of the direction of transport of the sediments from the dump sites can be gained by careful map analysis and by coring and grain size studies. Here too the data gathering and the methods of analysis and the formulation of the modules will be set up and harmonised for both study areas in order to allow proper comparisons.

The objective of this part of the project is to determine the effect of dredging and spoil deposition on the medium-term development of the morphology of the deltas. This includes the effects on the dimensions and alignments of the channels, the sedimentation and erosion of the channels, the dispersal of material from the spoil deposition sites, the extra contribution in the sedimentation, the transport patterns from the site and the ultimate effect on the morphological development of the site areas.

Research subjects

a. determine (from existing information) the areas where repeated relevant amounts of dredging are executed; determine the history of the dredging areas, volumes involved, etc.
   determine (from existing data) the major disposal sites, the history volumes, etc. (DDK, RWS, UB)

b. introduce these data in a GIS system; (RUMACOG, DDK, RWS)

c. analyse the development of the cross-section characteristics in the vicinity of the dredged areas; analyse the recovery (time/amounts), the cross-sectional development, the channel slopes and other morphometric data; similarly analyse the deposition sites for adaptation characteristics, spreading out of the spoil, slopes of dump site, dimensions of dump site and other morphometric data;
introduce these data in the GIS-system; (DDK, UB, RWS, RUMACOG)

d. analyse the morphological development of the dredge and dump sites by map analyses, (box)-coring and grain size analyses in order to establish the transport and transport directions of the materials; (DDK, RWS, UB,UL, RUMACOG)

e. schematise the gained information; produce a conceptual model for these effects; and develop a model formulation or extend existing models; test the formulations with the data mentioned above for both research areas. (MUMM, RWS)

7.5. Short term development, processes and sediment circulation (question 5 and 6)

For the development and testing of morphodynamic models of tidal delta environments there is an urgent need for systematic long-lasting observations of the water and sediment movement in the various sub-environments of channels, shoals and coastal zones.

It is not the purpose of the present proposal to develop new morphodynamic models. It is only envisaged to execute field studies on a small number of carefully selected locations in both research areas in order to get a better insight in the complex interaction between currents-waves-sediment movement and the variability of this interaction in time and space.

Basically the following concept is applied. At the moment there exists a 2D water flow model for both tidal delta areas. It is envisaged to take the computed flow field from this model as a basis. This model may be checked by satelite radar image analysis from which the velocity components at the surface may be derived. Remote sensing techniques may also be used to provide data of the submerged morphology. The result of the 2D model and the remote sensing data will be a reliable flow field for the area.

This flow field refers to mean tidal conditions. The 2D model may also be extended to spring tidal conditions, which are assumed to be more important for the sediment flow. At the moment 3D models are developed or existent. These models may be

elaborated to small grid sizes of about 200 m, thus adding importantly to the objectives of the present study.

Similarly wave refraction programs may be operated to provide wave patterns and characteristics during rough sea state conditions. Areas under severe wave attack may be distinguished from these analyses. The results of the current and wave analyses will be used to distinguish areas having a dominant current as well as dominant wave character and areas where both forces occur in variable degree. Such a distinction should be verified by field observations on selected spots, which follow from the above distinction of the different areas.

The main purpose of these field studies is therefore to determine for which areas tidal currents are the dominant steering factor for sediment movement and morphological changes and for which areas the waves are the dominant steering factor.

Furthermore the field studies aim at the parameterization of the transition areas where both currents and waves determine the sediment movement and morphology but to a variable degree. Is it possible to determine the degree of interaction?

Finally the field studies will provide data for testing already developed fundamental relationships between currents/waves at the one hand and sediment transport at the other.

It is essential in this respect to distinguish between the real time direct relation between water movement and sediment transport which addresses the gross sediment transports and morphological changes, which have to do with the net transport over a certain time frame. In the first mentioned case it is envisaged just to measure as careful as can be, the water movement and the associated bed and suspended load and to test and improve existing sediment transport formulations. For the currents the Van Rijn formula, with recent extensions can be used. For the wave case the recent developed formulations can be used. The main problem is the case where waves and currents both influence in variable degrees the sediment transport. Here too some formulations may be tested if only the suspended sediment transport is considered. The combined effect on bed load is hardly to be measured at the moment but may be estimated by the migration of ripples and dunes as a function of the grain-roughness related Shields parameter, median grain size and a wave-parameter.

Measurements include: current velocity profiles, which special emphasis on the near-bed conditions, orbital velocities, and sediment concentration. In addition measurements of bed form characteristics (dimensions, pattern) by means of side scan sonar observations and bedform migration by soundings and box-core sampling under various boundary conditions of tidal and wave characteristics are important contributions in this respect.

Model-steered field experiments

The objective is to select field sites on the basis of an analysis of the tidal flow field and of the wave refraction patterns. It is envisaged that the field sites should be representative for and be related to the overall flow and wave structure of the research areas. The results of the field experiments should be introduced into these overall models. In addition more specific models will be tested by the field data.

Research subjects

a. select the best available 2D tidal flow model covering the tidal delta of the research areas and execute the tidal flow fields for mean and spring tidal conditions (MUMM, RWS, LHS)

b. execute an analysis of satelite radar images for the surface and depth-averaged velocities. Compare the results with the 2D model. (RUMACOG, UB)

c. if necessary adapt the 2D model in line with the results of the satelite image results (RUMACOG, MUMM, RWS, LHS, UB)

d. introduce the development of 3D models and make similar checks as under a/c (MUMM, RWS, LHS, RUMACOG)

d. use a simple wave refraction model to investigate the overall wave climate for different conditions of wave characteristics, water levels and wave directions. Condense the results into parameters representative for the wave effects over a longer time frame; (MUMM, RWS, UB, IMAU, UEA)

e. distinguish areas having a dominant current and dominant wave character and areas where both are operating in a certain degree. Select the field sites. (IMAU, UB, UEA)

f. define the exact formulations to be tested by the field measurements (IMAU, RWS, MUMM, UB, UEA)

g. define the detailed set up of the field experiments: parameters to be measured, position of measuring instruments, length of experiments, data handling and elaboration; aspects to be included are current velocity profiles, shear stress and roughness predictors, orbital velocities and wave driven currents, vertical sediment concentrations, bed form characteristics and migration; (RUMACOG, UL, IMAU, UEA, UB, PAB, RWS, DDK, MUMM)

h. elaborate the field data according to the definitions under f.; RUMACOG, UL, IMAU, UEA, UB, PAB, RWS, DDK, MUMM)

i. make sonar mosaics of the bed of channels and shoals to identify the characteristics of the bedforms; select certain areas for repeated

measurements to determine time effects of bedform changes; (RUMACOG, IFREMER)

j. take a large number of box-cores over the delta; analyse the lacquer peels of these box-cores for sedimentary structures, indicative for current and wave dominance; prepare an overall map of these dominance's; (UL)

k. integrate the flow and bed observations; (RUMACOG, IFREMER, UL, UB, IMAU, UEA, RWS, DDK)

7.6. Overview of tasks of partners

This section gives an overview of the tasks of the partners. A detailed description of the tasks is given in Annex A.

Responsible Partner	Task	Subject
	1	Assessment of the 3D facies architecture by high-resolution seismics
RCMG	1.1	Seismic investigation Westerschelde tidal delta
IFREMER	1.2	Seismic investigation Gironde tidal delta
	2	Assessment of the 3D facies architecture by vibrocoring
UL	2.1	Vibrocoring in the Westerschelde tidal delta
UL	2.2	Vibrocoring in the Gironde tidal delta
	3	Assessment of the medium term morphodynamic behaviour
RWS	3.1	Cartographic and morphometric analysis of the northern part of the Westerschelde tidal delta
DDK	3.2	Cartographic and morphometric analysis of the southern part of the Westerschelde tidal delta
UB	3.3	Cartographic and morphometric analysis of the Gironde tidal delta
	4	Assessment of short term morphodynamic behaviour by linear and multibeam bathymetric echo-sounding.
RUMACOG	4.1	Bathymetric investigation Westerschelde tidal delta
IFREMER	4.2	Bathymetric investigation Gironde tidal delta
	5	Assessment of short term morphodynamic behaviour and bedform patterns by side-scan sonar surveys.
RUMACOG	5.1	Side-scan sonar investigation Westerschelde tidal delta
IFREMER	5.2	Side-scan sonar investigation Gironde tidal delta
	6	Assessment of lithology and sedimentary structures in the upper sediment layer by boxcoring
UL	6.1	Sedimentological investigation by boxcoring in the Westerschelde tidal delta
UL	6.2	Sedimentological investigation by boxcoring in the Gironde tidal delta
	7	Meteo-Marine data: acquisition and analysis
DDK	7.1	Meteo-Marine data Westerschelde tidal delta
UB	7.2	Meteo-Marine data Gironde tidal delta
	8	Wave and current analysis deduced from satellite (optical and radar) images
RUMACOG	8.1	Application of satellite data Westerschelde tidal delta
UB	8.2	Application of satellite data Gironde tidal delta
	9	Preliminaries to the hydrodynamic and sediment transport field measurements
IMAU	9.1	Preliminaries to the deployment of instrumented tripods
MUMM	9.2	Preliminaries to the deployment of current meter stations
UEA	9.3	Preliminaries to the deployment of Acoustic Backscatter Systems

	10	Analysis of sand transport processes: measurement of physical processes induced by wave s and currents
IMAU	10.1	Execution of hydrodynamic and suspended sediment measurements Westerschelde tidal delta
UB	10.2	Execution of hydrodynamic and suspended sediment measurements Gironde tidal delta
	11	Modelling of sediment transport
MUMM	11.1	Modelling of sediment transport Wester schelde tidal delta
UB	11.2	Modelling sediment transport Gironde tidal delta
IMAU	12	Integration of research on Westerschelde and Gironde tidal deltas
IMAU	13	Coordination and scientific integration of the project
IMAU	14	Preparation of final report
RUMACOG	15	Preparation of a database

7.7. Risks

The organisation, availability of ship time, the access to existing data and the agreement about the cooperation are well-established and will not create a risk to the execution of the Proposal. The only risk to be considered is the malfunctioning or severe damage of the instrumented tripods. Experiences elsewhere have shown that such a risk is real. Therefore spare parts and additional sensors are included in the instrumentation budget. In addition based on past experiences the budget claim for technical personnel accounts for this risk.

The planning of measurements in the field may be affected by bad weather conditions. In general the execution of operations at sea is limited by wave heights of 1.5 m.

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Proc. 2nd Int. Conf. on Comp. Model. in Ocean Eng. Balkema, Rotterdam: 235-245.
Wang, Z.B. 1993: Morphodynamic modelling for a tidal inlet in the Wadden Sea: Het Friesche Zeegat"
Progress Report H 840-50, Part II. Delft Hydraulics.
Wang, Z.B., Louters, T and De Vriend H.J. 1993: Morphodynamic modelling for a tidal inlet in the Wadden Sea.
In: List, J.H. (ed) Large scale coastal behaviour. U.S. Geol. Survey. Open File Report 93-381: 216-219.

8. MANAGEMENT OF THE PROJECT

***Beginning of the project:** 1 January 1996 (optional)
***Duration of the project:** 3 years

***Project Coordinator:** Prof. Dr. J. H.J.Terwindt (IMAU)

Prof. Terwindt has coordinated national and international interdisciplinary research projects for more than 25 years. He is presently coordinating a NSF funded project on the behaviour of mud on tidal flats and a national program on the effects of sea level rise on tidal marshes. He has a long record of research in tidal areas.

*** Contractor for the Dutch participants:** Prof. Dr J.H.J.Terwindt (IMAU)
*** Contractor for the Belgian participants:** Prof. Dr. I. Heyse (RUMACOG)
*** Contractor for the French participants:** Dr. G. Lericolais (IFREMER)

***Associated contractors and principal investigators:**

The Dutch participants:

- *The Utrecht University (MAU)*
  Prof. Dr. Joost Terwindt
  Dr. Jan Hendrik van den Berg
  Drs. Ad Stolk

- *Rijkswaterstaat, Directorate Zeeland (RWSDZ)*
  Ir. Maarten Meulblok
  Drs. Onno van Kleef
  Ir. Ton Pieters
  Ir. Ad Langerak

- *Geological Survey of The Netherlands (RGD)*
  Ing. Cees Laban
  Dr. Ad van der Spek

The Belgian participants:

- *The University of Gent (RUMACOG)*
  Prof. Dr. Irenee Heyse
  Prof. Dr. Guy De Moor
  Prof. Dr. C. Vernemmen
  Drs. Geert De Schaepmeester

- *Renard Centre of Marine Geology (RCMG)*
  Dr. Marc De Batist
  Dr. Wim Versteeg

- *The Management Unit Mathematical Model North Sea (MUMM)*
  Ir. André Pollentier
  Drs. Dries Van den Eynde

- *Belgian Service of Coastal Harbours (DDK)*
  Ing. Carlos Van Cauwenberge
  Ir. Bernard De Putter

The French Participants:

-*IFREMER*
  Dr. Serge Berné
  Dr. Gilles Lericolais
  Dr. Tania Marsset
  Dr. Jean Francois Bourillet

-*IFREMER ,Laboratoire d'Hydraulique et Sédimentologie (LHS)*
  Dr. J.C. Salomon
  Dr. P. Lazure

- *University of Lille (UL)*
  Prof. Dr. Hervé Chamley
  Dr. Bernadette Tessier
  Dr. Alain Trentesaux

- *University of Bordeaux (UB)*

Prof. Dr. Patrice Castaing
Dr. Helène Howa
Dr. J.M.Froidefond
Ing. A. de Resseguier
Dr. P. Cirac
Dr. O. Weber

- *The Port Authority of Bordeaux (PAB)*

Dr. A. Feral
Mrs P. Fourcassies

The British participant:

- *The University of East Anglia (UEA)*

Dr. Chris Vincent
Dr. Alastair Grant
Dr. Chris Porter

The US participant:

- *The US Geological Survey (USGS)*

Dr. D. Cacchione
Dr. D. Drake

*** Ship operations**

- The planning of ship operations will be performed by the main Contractors and will be harmonised by the Coordinator. Joint campaigns of the participants will be executed.

*** Meetings**

- General meetings

Date	Place	Meeting
January 1996	Utrecht	Introductory meeting
September 1996	Lille	Progress Report meeting no 1
January 1997	Bordeaux	Progress Report meeting no 2
September 1997	Brest	Progress Report meeting no 3
January 1998	Norwich	Progress Report meeting no 4
September 1998	Gent	Progress Report meeting no 5
January 1999	Oostende	Final Report meeting

- Working group meetings

Several working groups are envisaged:

- a reconstruction group, dealing with the reconstruction and hindcast of the former developments of the deltas (RCMG, IFREMER, RGD,UL)
- a morphology group, dealing with the medium term morphological developments of both deltas (RUMACOG, MUMM, RWSDZ, DDK, UB, IFREMER)
- a modelling group, dealing with the tidal and wave models and with the formulation and testing of the modules (MUMM, RWS, LHS)
- a field measurements group, dealing with the set up and execution of the field measurements (IMAU, UEA, UL, DDK, MUMM, RWSDZ, RUMACOG, UB, IFREMER).

Every group will have separate working group meetings, discussing in detail the scientific problems, results, integrative actions and work plans.

In each group special attention, expressed in a considerable amount of man-months of scientists and technicians, will be given to data management. The objective of the data management is to bring all the data together during the project, in combination with the interpreted results, into a GIS based database. This datebase can be linked to general databases on marine sciences and will be accesable by those interested like other scientists and coastal management authorities.

9. PARTNERSHIP

IDENTIFICATION OF CONTRIBUTIONS OF EACH PARTNER

Contractor.
Utrecht University, Institute for Marine and Atmospheric Research, (IMAU)

1. Contribution of the contractor

The Institute for Marine and Atmosferic Research wil be responsible for the coordination of the project.
It will concentrate its research on the short term morphodynamic processes. The Institute for Marine and Atmospheric Research will be responsible for the development and operation of the instrumented tripods for near bed measurements and for the analysis of the current and optical backscatter data provided by the tripods. The Institute for Marine and Atmospheric Research will be responsible for the integration of field data and models.
Concerning the long and medium term developments the Institute for Marine and Atmospheric Research is responsible for the execution of the vibrocoring program in the Westerschelde area.

* Subcontractor: Geological Survey of The Netherlands (RGD)

The Geological Survey of The Netherlands, Marine Geology Department will be responsible for the handling of the vibrocorer at sea, and for the description, analysis and interpretation of the cores.

2. Experience of the contractor in relation to the proposed research domain.

The Institute for Marine and Atmospheric Research, Physical Geography Department (IMAU) is involved in coastal morphodynamic and sediment transport studies both in the Netherlands and abroad. In 1984/85 it took part in the Indonesian-Dutch Snellius II Expedition. In that framework the coastal morphodynamics and sediment transport in two delta areas on E. Java was studied. From 1985 onwards the investigations were directed to the morphodynamics of the nearshore/beach system, and on the formation and maintenance of (shoreface connected) ridges and their influence on the coastal development. IMAU is also involved in research in estuarine and tidal flat areas. It is coordinator and partly executor of the NSF-funded Research Project on Intertidal Mud Areas. Morphodynamical, hydrodynamical and sedimentological investigations are carried out in the Westerschelde and the Oosterschelde estuaries and in the Wadden Sea tidal flat area. IMAU participated in the MAST II Project NOURTEC. In the MAST I RESECUSED and the MAST II STARFISH Projects IMAU participated in the studies of the Middelkerke Bank in the Flemish Banks Area.

* Subcontractor: Geological Survey of The Netherlands

The Geological Survey of the Netherlands is the national centre for information and research on geosciences. The Survey carries out extensive and complex projects for bodies such as government institutions, water and engineering companies on land as well as at sea. The Survey has great experience on the development and handling of core systems, and on core analysis, e.g. dating, grain-size analysis etc.

Relevant publications

for the contractor:

Sha, L.P. & J.H.van den Berg (1993): Variation in ebb-tidal delta geometry along the coast of the Netherlands and the German Bight.
Journal of Coastal Research 9:730-746.

Stolk, A. (1993): Hydrodynamics and suspended load; shipborn tidal cycle and stand-alone frame measurements.
In: G.De Moor & J.Lanckneus (eds.) Sediment mobility and morphodynamics of the Middelkerke Bank. Univ. Gent, CEC, Brussels, pp.194-210.

Terwindt, J.H.J. (1988): Palaeo-tidal reconstructions of inshore tidal depositional environments.
In: P.L.de Boer, A.van Gelder & S.D.Nio (eds.) Tide-influenced sedimentary environments, D.Reidel Publ. Comp. Dordrecht, pp.233-263.

Terwindt, J.H.J. & J.A.Battjes (1991): Research on large-scale coastal behaviour.
Proc.22nd Coastal Eng. Conf, pp.1975-1983.

Terwindt, J.H.J. and K.M. Wijnberg, (1991): Thoughts on large scale coastal behaviour.
Proc. Conf. Coastal Sediments '91, Seattle, 2: 1476-1487.

for the subcontractor

Cameron, D., D.van Doorn, C.Laban & H.-J.Streif (1993): Geology of the Southern Bight of the North Sea Basin. Coastlines of the Southern North Sea.
Proc., 8th Symp. on Coastal and Ocean Management, New Oleans, Louisiana: 14-26.

Ebbing J.H., C.Laban, P.J.Frantsen & H.P.Nederlof (1992): Geological Map 1:100,000 series of the Dutch sector. Sheet Rabsbank (Westernscheldt area)

Eisma, D., W.G.Mook & C.Laban (1981): An early Holocene tidal flat in the Southern Bight.
Spec. Publ. Int. Ass. Sedimentologists 5:229-237.

Sha, L.P., C.Laban & P.C.Zonneveld (in press): Holocene coastal development off Texel - Influence of the Pleistocene topography.
Meded. RGD.

Van der Spek, A.J.F. (1994): Large-scale evolution of Holocene tidal basins in the Netherlands.
Ph.D.Thesis, Utrecht University, 191 pp.

3. Relationship between proposal and research policy of the partner

The IMAU, Department of Physical Geography develops a research policy on coastal morphodynamics since the early seventies. Since 1985 this research policy on coastal morphodynamics is partly incorporated in the Coastal Genesis Project. This is an interdisciplinary research program on coastal behaviour set up in close cooperation between the Dutch Ministry of Transport, Public Work and Water Management, as coastal maintenance authority, and several institutes and universities that were involved in coastal research. Since 1990 the Department cooperate with other European universities and governemental organisations in European Research Programs like MAST.
In 1991 the cooperation on coastal and shelf research between several institutes and departments of universities are intensified with the establishment of the Netherlands Centre for Coastal Research.

4. Policy concerning application and dissemination of results

There is a free application and dissemination of the results obtained by the department, with or without cooperation with other institutes. A great interest in our coastal research is showed by the scientific community as well as by the coastal management authorities. There are no patent problems.

Associated Contractor:
University of East Anglia, School of Environmental Sciences

1. Contribution of the partner

The School of Environmental Sciences at the University of East Anglia will be responsible for the acoustic measurement of suspended sediments, both concentration and size, in the water column close to the sea bed. Two further multi-frequency ABS systems and logging units will be constructed to work alongside the 2 existing units. The ABS units will be interfaced with the IMAU logging system and deployed on their frames. UEA will also be responsible for calibration of the ABS units and for the post-processing and analysis of the results. The acoustic sensors will provide data on the sediment transport rates in the 1 m above the seabed unobtainable by other means.

2. Experience of the partner in relation to the proposed research domain

UEA is a major contributor to many research programmes which measure suspended sediments acoustically to obtain the fine scale structure of resuspension and transport processes: it is one of only two institutes in the UK with this ability. Recently the ABS has been extended to measure both sediment size and concentration, and to consider the problems of fine flocculating sediments. As well as well-known beach sand transport studies such as C2S2 and C-COAST, UEA has recently taken part (using its acoustic backscatter expertise) in the MAST II STARFISH programme, the UK community project LOIS - Holderness Experiment (Land Ocean Interaction Study) and the US Army Corps of Engineers field experiment DUCK '94 at Duck, N.Carolina.

Relevant publications

Downing A.J., P.D.Thorne & C.E.Vincent (in press): Backscattering from a suspension in the near-field of a piston.
Journal of Acoustical Society of America.

Green M.O., C.E.Vincent ,I.N.McCave, R.R.Dickson, J.M.Rees & N.D.Pearson (in press): Storm sediment transport: observations from the British North Sea.

Osborne P.D., C.E.Vincent & B.Greenwood (1994): Measurements of suspended sand concentrations in the near-shore: field intercomparisons of optical and acoustic backscatter.
Continental Shelf Research 14: 159-174.

Vincent C.E. & P.D.Osborne (1993): Bedform dimensions and migration rates under shoaling and breaking waves.
Continental Shelf Research 13: 1267-1280.

Vincent C.E. & A.J.Downing (1994): Variability of suspended sand concentrations, transport and eddy diffusivity under non-breaking waves on the shore-face.
Continental Shelf Research 14: 223-250.

3. Relationship between proposal and research policy of the partner

The School of Environmental Sciences is a Grade 5 (top grade) interdisciplinary Research Department with a policy of active support towards research in all fields of Environmental Sciences. It has well found workshops and technical support of the highest quality. This MAST proposal fits well within its field of expertise and it will offer practical and administrative support to this programme.

4. Policy concerning application and circulation of results

The School of Environmental Sciences operates a completely free policy of dissemination of scientific results and positively encourages cooperation and collaboration between its faculty and other researchers. It considers that the results of research programmes should be disseminated through refereed international scientific journals.

Associated Contractor:
Netherlands Department of Public Works and Water Management, Directorate Zeeland (RWSDZ)

1. Contribution of the partner

The Directorate Zeeland will place at the projects disposal all available historical maps and will carry out analysis on digital bathymetric datasets, pointed towards morphological changes. The Directorate will provide shiptime for the project and will participate in the hydrodynamic field measurements. The existing (2D and 3D) current and wave models will be made available to integrate models and field measurements. The directorate will assist in the development of conceptual models.

2. Experience of the partner in relation to the proposed research domain

The Directorate Zeeland is responsible for maintaining the coastline of the province of Zeeland. The Directorate Zeeland is also responsible for managing the shipping routes to Antwerpen and Vlissingen. Although most dredging activities are carried out by Belgian authorities, the Dutch are concerned about environmental effects and effects on safety.

Relevant publications

Israel, C. (1994): The development of the inlet of the Westerschelde at the south-western coast of Walcheren, Thesis HTS, Vlissingen (in Dutch).
Lambeek, J.J.P. (1991): Sandwaves in Zeeland.
Geopro-rapport 91.30, Utrecht Univ. (in Dutch).
Louters, T., R.B.Kalf & A.M.Walburg (1993): Horizontal fluctuations along the coastline of Zeeland.
Nota GWAO-93.126x, RWS Dienst Getijdewateren (in Dutch).
Uit den Bogaard, L.A. (1992): Spatial distribution of heavy minerals in the Westerschelde.
Geopro-rapport 92.05, Utrecht Univ. (in Dutch).
Technische Scheldecommissie (1984): Deepening of the Westerschelde, Programme 48'-43, Study Report, Middelburg-Antwerpen (in Dutch)

3. Relationship between proposal and research policy of the partner

The Directorate Zeeland has been involved for many years in research concerning the dynamics of sediments in tidal basins and along the North Sea coast. Several research projects are initiated (e.g. East/West Project; Channel and Shoal Project) to investigate the sediment transport patterns within the inner part of the Westerschelde estuary.

4. Policy concerning application and dissemination of results

Results of studies and research executed by the Directorate Zeeland are freely accessible to the general public.

Contractor:
University of Gent, Research Unit Marine and Coastal Geomorphology (RUMACOG)

1. Contribution of the partner

The Research Unit Marine and Coastal Geomorphology will be the Belgian national partner within the project. It will concentrate its research on the morphodynamics and sediment dynamics of the sub-tidal delta of the Westerschelde. Support will be given to tasks accomplished in the Gironde delta. The field measurements will include a preliminary side scan sonar reconnaissance, chronosequential echo-sounding operations, chronosequential side scan sonar mosaic registrations and side scan sonar sustaining operations for other participants. The Research Unit will also be responsible for setting up and maintaining a GIS-database, and for the wave patterns analysis by radar satellite. Assistance will be given to the cartographic analysis of the shoal and channel system in historical times.

2. Experience of the partner in relation to the proposed research domain

The Research Unit has been working for many years in the field of off-shore and beach sediment dynamics. It has an experience in the use of modern navigation and positioning systems, echo-sounding techniques, subbottom profiling techniques, side scan sonar (acoustic remote sensing of sea floor characteristics) techniques and sampling techniques. The Research Unit has also the necessary know-how of computerised acquisition and processing and of computerised cartography, and in the domain of satellite image interpretation. The principal objectives of the offshore research comprise the analysis of residual sediment transport paths and the study of volumetric and morphologic changes of bedforms ranging from sandbank to megaripple. The Research Unit is as well active in the field of beach dynamics and shoreline displacement.

Relevant publications

De Moor, G. & J. Lanckneus (1988): Acoustic teledetection of sea-bottom structures in the Southern Bight.
Bull. Soc. Belg. Géol. 97:199-210.

De Moor, G., J. Lanckneus, F. Van Overmeire, P.Van den Broek & E.Martens (1989):
Volumetric analysis of residual sediment migrations on the continental shelf sandbanks in the Southern Bight (North Sea).
In: Pichot, G. (ed.) Progress in Belgian Oceanographic Research 1989, MUMM,Brussels, pp.129-146.

Lanckneus, J., G.De Moor, G. De Schaepmeester & L.Libeer (1989): Acoustic teledetection of shelf bedforms and their meaning for the sediment dynamics. Int. Comm. Explor. Seas, Hydrogràphy Comm., Den Haag meeting, CM 1989/C 47:1-19.

Lanckneus, J., G. De Moor, L.Vande Velde, E.De Winne, I.Sanchez Almazo & T.Garrido Martin (1993): Morphodynamics and sediment dynamics in the Southern Bight.
Progress in Belgian Oceanographic Research (Proc. 21-22 January 1993, Brussels).

Lanckneus, J., G.De Moor & A.Stolk (1994): Environmental setting, morphology and volumetric evolution of the Middelkerke Bank (southern North Sea).
Marine Geology 121:1-21.

3. Relationship between proposal and research policy of the partner

The Research Unit Marine and Coastal Geomorphology has been developing a research policy on marine morphodynamics and sediment dynamics for more than 10 years. As a result RUMACOG acquired a large dataset, and lots of experience in marine research. Marine research at the University of Gent is well established with several laboraties working on specific marine research domains. The research on the continental platform carried out by the Research Unit Marine and Coastal Geomorphology has mainly been financed by the Ministry of Economic Affairs, the Ministry of the Flemish Executive, the Flemish Department of education and EC-DGXII.

4. Policy concerning application and dissemination of results

There is a free application and dissemination of all scientific results obtained by the Research Unit. There are no patent problems.

Associated Contractor:
Belgian Service of Coastal Harbours (DDK)

1. Contribution of the partner

The Belgian Service of Coastal Harbours, Section Waterways Coast, will carry out a detailed analysis of all relevant cartographic documents of the western part of the Westerschelde tidal delta. It will realise bathymetric surveys in the same area.
The section waterways will make available to the other participants the necessary data of the physical parameters, such as the vertical/horizontal tides and the wave data. These data will be produced in a user-friendly digital format.

2. Experience of the partner in relation to the proposed research domain

The Belgian Service of Coastal Harbours has been responsible for many years for all hydrographic activities on the North Sea off the Belgian coast, including bathymetric measurements, current and tide registrations, etc.
These activities are executed in the scope of the services responsibilities towards:

- publication of nautical charts
- maintenance of access channels to the sea ports
- coastal protection works

The Service is operating since the 1980's as a fully equipped hydro-meteorologic centre for the collecting and processing of all meteorologic and hydrologic data on the North Sea off the Belgian coast.

Relevant publications

De Putter, B., P.De Wolf, J.Van Sieleghem & F.Claeys (1992): Latest developments in hovercraft bathymetry.
Hydro 1992, Copenhagen.
Houthuys, R., A.Trentesaux & P.De Wolf (1994): Storm influences on a tidal sandbank's surface (Middelkerke Bank, southern North Sea).
Marine Geology 121:23-41.
Kerckaert, P., P.De Wolf, W.De Wispelaere, J.Van Rensbergen & D.Fransaer (1989):
Remote sensing techniques for harbour and coastal observations in Belgium.
In: O.Magoon, H.Converse, D.Miner, L.Tobin & D.Clark (eds.) Proc. 6th Symp. Coastal and Ocean Management, Coastal Zone 89. pp.720-728.
Van Cauwenberghe, C. & D.Den Duyver (1993): The positioning system Syledis along the Belgian coast and adjacent areas.
Rapport 41 van de Hydrografische Dienst der Kust. Ministerie van de Vlaamse Gemeenschap, Departement Leefmilieu en Infrastructuur, 22 pp., (in Dutch).
Van Cauwenberghe, C., L.Dekker & A.Schuurman (1993): M2 tidal reduction method for coastal zones.
Rapport 33 van de Hydrografische Dienst der Kust. Ministerie van Openbare Werken, Bestuur der Waterwegen, 12 pp.

3. Relationship between proposal and research policy of the partner

The Service of Coastal Harbours has been already involved for many years in research concerning the dynamism of sediments off the Belgian coast and in the evolution of sea bottom, foreshore, beach and dune area.

4. Policy concerning application and dissemination of results

Results of studies and research executed by the Service of Coastal Harbours are freely accessible to the general public.

Associated Contractor:
Management Unit Mathematical Model North Sea (MUMM)

1. Contribution of the partner

A first task of MUMM will consist in the execution of direct measurements of current velocity and sediment transport. Two instrumented tripods will be prepared. Several long-term deployments of the instrumented tripods and of current meter stations will be executed. MUMM will also provide shiptime for the project.
Further MUMM will be involved in the modelling efforts. Operational hydrodynamic and wave models will be used to study the sediment transport patterns in the present time, by the study of the short term developments and processes and to study the medium term developments of the tidal deltas. by hindcast runs. MUMM will assist in the development of conceptual models.

2. Experience of the partner in relation to the proposed research domain

The Management Unit of the Mathematical Model of the North Sea is a research department of the Belgian Ministry of Public Health and Environment and is responsible for the Belgian policy related to the North Sea. In this function, MUMM prepares the Belgian contribution in international conventions, manages the research vessel Belgica and an aircraft for detecting oil pollution and

operates mathematical models for studying the impact of decision or events. In the framework of this last task, MUMM executed different scientific research projects.
MUMM has a large experience in executing oceanographic measurements and more specific in the deployment and recovery of current meters and of instrumented platforms. Since 1972, over 250 moorings have been carried out. The obtained data are processed with the most modern computer facilities.
MUMM also has a large experience in mathematical modelling of hydrodynamic processes. MUMM operates operational hydrodynamic and wave models and developed different sediment transport models. MUMM can dispose over the CAMME Computer Centre, which possesses, amongst others, the CONVEX C230 mini-supercomputer, with three parallel vector processors. MUMM is therefore well-equiped to execute alike studies.

Relevant publications

Ovidio, F., J.-R.Bidlot, D.Van den Eynde, W.Luo and J.Monbaliu (1994): Validation of the second generation wave forecasting model MU-WAVE: comparison with ERS-1, buoy data and WAM forecasts.
In: Proc. First Workshop on ERS-1 Pilot Projects, 22- 24/6/94, Toledo, Spain, 21-28.

Ruddick, K.G., E.Deleersnijder, P.J.Luyten and J.Ozer (1995): Haline stratification in the Rhine/Meuse freshwater plume: a 3D model sensitivity analysis. Submitted to Cont. Shelf Res.

Van den Eynde, D. (1992): MU-WAVE: an operational wave forecasting system for the Belgian coast.
In: Proc. of the 3th International Workshop on Wave Hindcasting and Forecasting, 19-22 May, 1992, Montreal, Quebec, Canada, 313-324.

Van den Eynde, D. and J.Ozer (1994) Sediment Trend Analysis : calculation of the sediment transport with a mathematical model.
Report BMM/STA/TR01, 111 p.

Van den Eynde, D. (1995): Mathematical modelling of sediment transport at the Belgian coast: first results.
In: Proc. Workshop on "Influence of dumpings of dredging material on the environment in the southern North Sea" 2/3/94, Brugge, in preparation.

3. Relationship between proposal and research policy of the partner

One of the main tasks of MUMM is the scientific support of the water management policy related to the North Sea, both national and international. MUMM is e.g. involved in the North Sea Task Force and contributed to the Quality Status Report of the North Sea. In this frame, MUMM performed the task of the modelling coordination. To be able to provide useful and valuable support, MUMM also executes scientific research in the field.
More specifically, as being responsible for the North Sea environment, MUMM provides the permits for the dumping of dredging material in front of the Belgian coast. In this framework, MUMM studies, together with the Service of the Coastal Harbours, the sediment transport patterns on the Belgian Continental Shelf. A project, studying the sediment transport on the outer delta of the Westerschelde estuary and studying the influence of the dredgings and dumpings on the medium term development of the delta therefore is very challenging and interesting for MUMM.

4. Policy concerning application and dissemination of results

There is a free application and dissemination of all scientific results, obtained by MUMM. There are no patent problems.

Contractor:
IFREMER, Department of Marine Geosciences

1. Contribution of the partner

IFREMER will be the French national partner within the project. IFREMER will carry out high resolution seismics to reveal paleo-geomorphology, vibrocoring for assesment of 3D facies architecture and multibeam and side scan sonar reconnaissance surveys. The results will be interpreted and presented as seismic profiles, image mosaics and integrated maps.
IFREMER will provide shiptime for the operations in the Gironde tidal delta area.

2. Experience of the partner in relation to the proposed research domain

IFREMER has a wide experience on continental shelf research. Several projects were carried out within Europe and in Asia:

* FASE (FAcies and SEquences) is an IFREMER project managed by the sedimentary laboratory of the DMG devoted (1) to the study of dynamics and architecture of sand bodies of the continental shelf and (2) to the reconstruction of recent depositional sequences related to variations of sea-level.
* Participation to MAST I (project RESECUSED) and MAST II (project STARFISH)
* A Chinese-French project concerning the relation between sea-level changes and depositional processes on the Chinese margin.
* A research program devoted to sand transport in the bay of Arcachon (cooperation with Bordeaux 1 University).

Relevant publications

Lericolais G., J.P.Allénou, S.Berné & P.Morvan (1990): A new system for acquisition and processing of very high resolution seismic reflection data. Geophysics 55: 1036 - 1046.

Lericolais G., R.Girault, R.Tofani & M.Olagnon (1991): Recent advances in shallow seismic reflection processing - O.T.C. Proceedings 6556, Houston, pp.501-507.

Berné, S., P.Castaing, E.Le Drezen & G.Lericolais (1993): Morphology, internal structure and reversal of asymmetry of large subtidal dunes in the Gironde lower estuary (France). J. Sediment. Petrol. 63: 780-794.

Lericolais, G., M.Olagnon, R.Krone & H.Nouzé (1994): Multiple removal in very high resolution seismic site survey data. Presented at the Boss 94, Behaviour of offshore structures, Boston (USA), 1: 125-136.

Reynaud, J. Y., B.Tessier, J.N.Proust, G.Lericolais, T.Marsset, S.Berné & H.Chamley (1995): Apport de la sismique très haute résolution à l'interprétation génétique d'un banc sableux de la mer Celtique - C.R. Acad. Sci. Paris 320: 125-132.

3. Relationship between proposal and research policy of the partner

IFREMER has been developing a research policy on the study of continental shelfs all over the world with modern geophysical tools. Part of the research is devoted to the exploration of marine aggregates and calcareous sands.

4. Policy concerning application and dissemination of results

IFREMER is a scientific institution and has no restrictions on the disseminantion of the results of this project.

Associated Contractor:
University of Gent, Renard Centre of Marine Geology (RCMG)

1. Contribution of the partner

The Renard Centre of Marine Geology will be responsible for the study of the long-term evolution (seismic research) of the Westerschelde tidal delta. Task will comprise:

* Acquisition, processing and interpretation of a reconnaissance grid of high- to very high resolution reflection seismic profiles on the Westerschelde tidal delta.
* Acquisition, processing and interpretation of detail grids (pseudo 3D) of high- to very high resolution reflection seismics on selected parts of the Westerschelde tidal delta.
* 3D reconstruction and visualisation of the internal structure of the Westerschelde tidal delta.
* Interpretation of the long-term mobility of morphological features (e.g. channels, shoals) on the Westerschelde tidal delta.
* Selection of the locations for vibrocoring.

RCMG will participate to comparable tasks on the Gironde tidal delta, in cooperation with IFREMER, University of Lille and University of Bordeaux.

2. Experience of the partner in relation to the proposed research domain

The Renard Centre of Marine Geology has nearly 20 years of experience in high resolution reflection seismic surveying in shallow waters, and especially in the Belgian-Dutch North Sea sector and Westerschelde area: e.g. geological reconnaissance in the framework of the Zeebrugge harbour expansion project, regional mapping projects for the Belgian Geological Survey, major research contributions to the EC MAST I (RESECUSED) and MAST II (STARFISH) projects. As a result, RCMG has accumulated a data set of over 16000 km of high-resolution seismic profiles in the southern North Sea; part of the data extend into the present study area.
RCMG is very well equipped with independant, mobile and versatile, up-to-date seismic sources (Uniboom boomer, in-house developed Centipede sparker, 15 in^3 watergun) and receivers, and offering the possibility for analog as well as high-resolution digital acquisition. Traditional and experimental processing of the digital seismic data (signal enhancement, multiple suppression,..) can be done on RCMG's industry standard seismic processing system. Seismic and sequence stratigraphic interpretation will be supported by standard interpretation software and data base structures. Modelling and 3D visualisation of the seismic data can be done on RCMG's in-house developed (EC THERMIE Project) 3D geological modelling system Geofox.

Relevant publications

Berné, S., A.Trentesaux, A.Stolk, T.Missiaen & M.De Batist (1994) : Architecture and long-term evolution of a tidal sandbank: the Middelkerke Bank (southern North Sea).
Marine Geology 121:57-72.

Corsmit, J., W.H.Versteeg, J.H.Brouwer & K.Helbig (1988): High-resolution 3D reflection seismics on a tidal flat: acquisition, processing and interpretation.

First Break 6:9-23.
Liu, A.C., M.De Batist, J.P.Henriet & T.Missiaen (1993): Plio-Pleistocene scour hollows in the Southern Bight of the North Sea.
Geologie en Mijnbouw 71:195-204.
Trentesaux, A., S.Berné, M.De Batist & H.Chamley (1993): Architecture interne d'un banc sableux tidal de la Mer du Nord méridonale.
C.R. Acad. Sc. Paris 316: 99-106.
Versteeg, W., M.Verschuren, J.P.Henriet & M.De Batist (1992): High-resolution 3D and pseudo 3D seismic investigations in shallow water environments.
In: M.Weydert (ed.) European Conference on Underwater Acoustics. Elsevier Applied Science, pp.497-500.

3. Relationship between proposal and research policy of the partner

The proposal is in entire agreement with RCMG's main research topics: the (3D) study of marine sedimentary geology by reflection seismics. As such it is complementary with other projects, such as the Concerted Research Action 'Marine Geology', the Belgian Scientific Research programme on Antarctica, and a number of other projects in preparation.

4. Policy concerning application and dissemination of results

Free application of the results or use of the original data by third parties, in cooperation with RCMG. Data information is communicated to all relevant international data base systems. Dissemination of results by scientific publications, international meetings, etc..

Associated Contractor:
University of Lille, Laboratoire de Dynamique Sédimentaire et Structurale (UL)

1. Contribution of the partner

The Laboratoire de Dynamique Sédimentaire et Structurale will be responsible for the collection, analysis and interpretation of sediment information. The collection will be done by vibrocoring, boxcoring and grabsampling. The analysis includes lithological description, grain-size analysis and analysis of sedimentary structures. The interpretation includes a determination of sedimentary facies on the basis of core and sample information, seismic profiles and side scan sonar mosaics.

2. Experience of the partner in relation to the proposed research domain

Since 1984, the staff of the University of Lille has been involved intensely in coastal sedimentary research programs, including morpho- and sediment-dynamics in the English Channel and the southern North Sea. Since 1990, three Ph.D. theses have been completed on this topic, two of them dealing with the dynamics and stratigraphy of tidal sand banks in the framework of the MAST-I RESECUSED and MAST-II STARFISH projects.

UL experience includes:

- Side scan sonar mosaics and HR-VHR seismic profile interpretation;
- Sampling technics (grabs, boxcoring, vibrocoring);
- Sedimentological analysis (classical facies analysis, grain-size analysis (sedigraph, Laser diffraction particle size analyser), X-Ray diffractrion, atomic absorption, thermal analysis, organic matter measurements, magnetic susceptibility bridge, microprobe.

Relevant publications

Beck, C., P.Clabaut, S.Dewez, O.Vicaire, H.Chamley, C.Augris, R.Hoslin & A.Caillot (1991): Sand bodies and sand transport paths at the English Channel-North Sea border: morphology, hydrodynamics and radioactive tracing.
Oceanol. Acta, Vol. sp. 11 : 111-121.

Chapalain, G., H.Smaoui, A.Lepretre, D.Nguyen, A.Ouahsine & B.Tessier (1993): Modelling of tidally-induced hydro-sedimentary processes in the coastal zone of the southern part of the Dover Strait.
Oceanol. Acta, 16 (5-6): 517-529.

Stolk, A. & A.Trentesaux (1993): Small scale sedimentary structure analysis by vibrocoring.
In G.De Moor & J.Lanckneus (eds.) Sediment mobility and morphodynamics of the Middelkerke Bank, Gent, Brussels, pp.133-143.

Tessier, B. (1990): Enregistrement des cycles tidaux en accrition verticale dans un milieu actuel (la baie du Mont-Saint-Michel et dans une formation ancienne (la molasse marine miochne du Bassin de Digne).
Thèse de Doctorat, Université de Caen, 122 pp.

Trentesaux, A. (1993): Structure et dynamique sédimentaire du Middelkerke Bank, Mer du Nord méridionale.
Thèse de doctorat, Université de Lille I, 229 pp.

3. Relationship between proposal and research policy of the partner

The Laboratoire de Dynamique Sédimentaire et Structurale and URA 719 CNRS develop since 1985 a policy of coastal research development in sedimentology and related environmental investigations. This policy is supported by:

* Lille I University (a major research topic among ten in 'Interfaces de la géodynamique externe et environnement')
* the Regional Administration Région Nord Pas-de-Calais (a major research topic among seven is 'Valorisation et gestion des ressources marines')
* the CNR 3 (Centre National de la Recherche Scientifique, France): annual support of the URA 719 on the topic 'Sources et Flux Sédimentaires Récents'.

4. Policy concerning application and dissemination of results

There is a free application and dissemination of the results obtained by the department, with or without cooperation with other institutes. A great interest in our coastal research is showed by the scientific community as well as by the coastal maintenance authorities. There are no patent problems.

Associated Contractor:
University Bordeaux 1, Department of Geology and Oceanography (UB)

1. Contribution of the partner

The Department of Geology and Oceanography of the University Bordeaux 1 will be responsible for the task concerning the medium-term development of the Gironde tidal inlet. It will concentrates its research on morphodynamics of the tidal delta. It will assist the partner working on the long-term and short-term studies within the Gironde tidal delta by providing advices and all information available at the department (thesis, reports).

Subcontractor: Port Autonome de Bordeaux (PAB)

The Port Authorities are willing to give free access to all geological, sedimentological and hydrodynamical information concerning the Gironde inlet which is available in form of maps, internal reports, notes etc... PAB offers to put its data treatment system at UB disposal. PAB will also provide shiptime for some operations in the Gironde inlet.

Subcontractor: IFREMER, Laboratoire d'Hydraulique et Sédimentologie (LHS)

The LHS is willing to utilize its 3D flow model of the Gironde estuary and from it to realize a 2D or 3D model which concentrates its calculation on the Gironde tidal delta with a 100m grid size (less if necessary). Runs of this model will provide information about fields of currents and sediment fluxes.

Subcontractor: United States Geological Survey (USGS)

The USGS which works already in close cooperation with IFREMER, is ready to deploy in the Gironde delta its instrumentation: a GEOPROB tripod.This will provide in situ data of current velocity, orbital velocity, sediment concentration and measurement of bedform characteristics.
The meaning of the participation of the USGS is to share experience and expertise in the field of sedimentary dynamics with an European team. It should be rewarding for both communities to compare methodology and approach to solve important questions about morphodynamics within a MAST programme.

2. Experience of the partner in relation to the proposed research domain

The Department of Geology and Oceanography is a research unit working in an associative contract between the University Bordeaux 1 and the National Center of Scientific Research (Unité de Recherche Associée CNRS n°197). One of its main research axes is the knowledge of the coastal marine environment by using a pluridisciplinary approach including geology, sedimentology, hydrology, geochemistry and biology. The Department of Geology and Oceanography has been working for many years in the field of interactions between continent and ocean occurring within estuarine areas, lagoonal system, coastal and nearshore zones. Researches are now in progress which focus on coastal changes and sediment fluxes in response of climate forcing and human impact.

Relevant publications

Castaing P. & G.P.Allen (1981): Mechanisms controlling seaward escape of suspended sediment from the Gironde : a macrotidal estuary in France. Marine Geology 40, Sp.Issue : Estuary shelf interrelationships, pp.101-118.

Gourlez P. & P.Castaing (1985): Etude des mouvements sédimentaires le long du littoral de part et d'autre du canyon de Capbreton au moyen de traceurs

radioactifs et fluorescents. Actes du 1er Colloque d'Océanologie côtière, Bordeaux, 9-11 Octobre 1985.
ADERMA, Bordeaux, pp.474-486.
Howa H., (1987): Le littoral du Nord Medoc - Evolution d'une cote sableuse en erosion.
Thesis of the University Bordeaux 1, n°146, 258 pp.
Froidefond J.M., P.Castaing, M.Mirmand & P.Ruch (1991): Analysis of the turbid plume of the Gironde (France) based on SPOT radiometric data.
Remote Sensing Environment 36 : 149-163.
Berné S., P.Castaing, E.Le Drezen & G.Lericollais (1993): Morphology, internal structure and reversal of asymmetry of large subtidal dunes in the entrance to Gironde estuary (France).
Jour. Sed. Petrol. 63: 780-793.
Howa H., (1993): Hydrodynamique et flux sédimentaires dans un domaine d'embouchure.
4ème Congres Francais de Sédimentologie, Publication ASF 19, Paris, pp.259-260.
Salomon J.C., P.Garreau & M.Breton M. (1994): The lagrangian barycentric method to compute 2D and 3D long term dispersion in tidal environments.
In : C.Pattiaratchi (ed.) Mixing processes in estuaries and coastal seas. A.G.V. Series (in press).

3. Relationship between proposal and research policy of the participant

The Department of Geology and Oceanography participates in the following projects concerning sedimentary dynamics and morphodynamics:

* Mast II programme n° CT92- 0024 - C "CSTAB" as a subpartner. This project analyses the sediment circulation around sandbanks in a macrotidal shelf environment in relationship with the nearby beaches.
* Programme "Dynamics of a lagoonal system (Arcachon lagoon)" in the national framework under the responsability of IFREMER and University Bordeaux 1 : Unité de Recherche Marine URM n°13. As one of the main objectives, this project deals with the morphological evolution of a tidal inlet.
* National programme PNOC, charged by the "Centre National de la Recherche Scientifique" (CNRS). This programme is devoted to coastal oceanography research along the French Atlantic Coast where the University Bordeaux 1 is involved in problems concerning remote sensing of the coastal zone.

4. Policy concerning application and dissemination of results

There is a free application and dissemination of the results obtained by the department, with or without cooperation with other institutes. A great interest in our coastal research is showed by the scientific community as well as by the coastal maintenance authorities. There are no patent problems.

10. FINANCIAL INFORMATION

CONTRACTOR: 1. IMAU

Coordination

Scientific personnel (2 mm):	20	kECU
Technical personnel (24 mm):	39	kECU
Durable equipment:	-	
Consumables:	5	kECU
Meeting + travels:	10	kECU
External assistance: (incl. subcontractors)	-	
Administration:	-	
Overheads:	11	kECU
Total:	85	kECU

Scientific tasks

Scientific personnel (36 mm):	157	kECU
Technical personnel (18 mm):	68	kECU
Durable equipment: (2 tripods; 3/5)	60	kECU
Consumables:	22	kECU
Meeting + travels:	10	kECU
External assistance: (incl. subcontractors)	70	kECU
Administration:	-	
Overheads:	57.5	kECU
Total	444.5	kECU

CONTRACTOR: 2. RUMACOG

Database

Scientific personnel (12 mm):	46	kECU
Technical personnel:		
Durable equipment: (computers)	24	kECU
Consumables:	2	kECU
Meeting + travels:	2	kECU
External assistance: (incl. subcontractors)	3	kECU
Administration:	-	
Overheads:	8	kECU
Total:	85	kECU

Scientific tasks

Scientific personnel (53 mm):	180	kECU
Technical personnel (19 mm):	53	kECU
Durable equipment: (computers)	31	kECU
Consumables:	15	kECU
Meeting + travels:	24	kECU
External assistance: (incl. subcontractors)	6	kECU
Administration:	-	
Overheads:	31	kECU
Total:	340	kECU

CONTRACTOR: 3. IFREMER

Scientific personnel (9 mm):	45	kECU
Technical personnel (15 mm):	80	kECU
Durable equipment: (seismic source + sonar processor; 3/5) (computer 3/3)	71	kECU
Consumables:	25	kECU
Meeting + travels:	22	kECU
External assistance: (incl. subcontractors)	53	kECU
Administration:	-	
Overheads:	64	kECU
Total:	360	kECU *

* The above mentioned budget is based on allowable costs.
The EC requested funding is 50% * 360 = 180 kECU.

ASSOCIATE CONTRACTOR: 4. UEA

Scientific personnel (36 mm):	107.5	kECU
Technical personnel:	-	
Durable equipment: (computers)	10	kECU
Consumables:	25	kECU
Meeting + travels:	12	kECU
External assistance: (incl. subcontractors)	-	
Administration:	-	
Overheads:	31	kECU
Total:	185.5	kECU

ASSOCIATED CONTRACTOR: 5. RWSDZ

Scientific personnel (10 mm):	80	kECU
Technical personnel (6 mm):	40	kECU
Durable equipment: (computers)	5	kECU
Consumables:	1	kECU
Meeting + travels:	24	kECU
External assistance: (incl. subcontractors)	40	kECU
Administration:	-	
Overheads:	-	
Total:	190	kECU *

* The above mentioned budget is based on allowable costs.
The EC requested funding is 50% * 190 = 95 kECU

ASSOCIATED CONTRACTOR: 6. RCMG

Scientific personnel:		
Technical personnel (12 mm):	41	kECU
Durable equipment: (source receiver; 3/5)	18	kECU
Consumables:	5	kECU
Meeting + travels:	9	kECU
External assistance: (incl. subcontractors)	-	
Administration:	-	
Overheads:	7	kECU
Total:	80	kECU

ASSOCIATED CONTRACTOR: 7. DDK

Scientific personnel:	-	
Technical personnel (36 mm):	140	kECU
Durable equipment: 64 Mb Ram for Workstation 1 PC Pentium software	20	kECU
Consumables:	20	kECU
Meeting + travels:	20	kECU
External assistance: (incl. subcontractors)	-	
Administration:	-	
Overheads:	-	
Total:	200	kECU *

* The above mentioned budget is based on allowable costs.
The EC requested funding is 50% * 200 = 100 kECU

ASSOCIATED CONTRACTOR: 8. MUMM

Scientific personnel (20 mm):	87	kECU
Technical personnel (26 mm):	80	kECU
Durable equipment: (one tripod (3/5)	30	kECU
Consumables:	18	kECU
Meeting + travels:	8	kECU
External assistance: (incl. subcontractors)	-	
Administration:	-	
Overheads:	27	kECU
Total:	250	kECU

ASSOCIATED CONTRACTOR: 9. UL

Scientific personnel: Technical personnel (8 mm):	9	kECU
Durable equipment: (boxcorer+core table; 3/5) (computer 3/3)	30	kECU
Consumables:	15	kECU
Meeting + travels:	11	kECU
External assistance: (incl. subcontractors)	12	kECU
Administration:	-	
Overheads:	8	kECU
Total:	85	kECU

ASSOCIATED CONTRACTOR: 10. UB

Scientific personnel (48 mm): Technical personnel:	115	kECU
Durable equipment: (wave gauge + current meter (3/5)	31	kECU
Consumables:	10	kECU
Meeting + travels:	10	kECU
External assistance: (incl. subcontractors)	88	kECU
Administration:	-	
Overheads:	16	kECU
Total:	270	kECU

OVERVIEW OF TOTAL BREAKDOWN OF COSTS IN KECU

Partner No	1. IMAU		2. RUMACOG		3. IFREMER	4. UEA	5. RWS	6. RCMG	7. DDK	8. MUMM	9. UL	10. UB	Total
	coord.	scient.	data-base	scient									
Scient. pers.	20	157	46	180	22.5	107.5	40	-	-	87	-	115	775
Techn. pers.	39	68	-	53	40	-	20	41	70	80	9	-	420
Equipment	-	60	24	31	35.5	10	2.5	18	10	30	30	31	282
Consumables	5	22	2	15	12.5	25	0.5	5	10	18	15	10	140
Travel	10	10	2	24	11	12	12	9	10	8	11	10	129
External Ass.	-	70	3	6	26.5	-	20	-	-	-	12	88	225.5
Administration	-	-	-	-	-	-	-	-	-	-	-	-	-
Overheads	11	57.5	8	31	32	31	-	7	-	27	8	16	228.5
Total	85	444.5	85	340	180	185.5	95	80	100	250	85	270	2200

ANNEX A MORTIDEL

DETAILED DESCRIPTION OF TASKS

1. LONG TERM EVOLUTION OF THE WESTERSCHELDE AND GIRONDE TIDAL DELTAS

TASK 1. Assessment of the 3D facies architecture by high-resolution seismics

Objectives:

1. To determine the base and 3D internal structure of the tidal deltas.
2. To understand the control of the underlying deposits and morphology on the initial development of the tidal delta.
3. To map the 3D (laterally and vertically) distribution of seismic facies within the system in order to evaluate facies consistency, to locate possible burried channel-shoal assemblages, to reconstruct past channel migration paths and to study the possible control of internal shoal structure on channel migration.
4. To select the optimal sites for vibrocoring.

The seismic investigation will be carried out in two phases:

1. Acquisition of a reconnaissance grid of very-high and high-resolution seismic profiles covering the entire delta system.
2. Acquisition of dense grids of very-high and high-resolution seismic profiles on 1 or 2 selected sites. The vibrocoring programme will also focus on these detail zones.

Interpretation of the data will focus on identifying specific facies assemblages (e.g. channel facies) and their 3D distribution, and on evaluating the influence of the nature and morphology of underlying deposits on the dynamic behaviour of channels and shoals. Digitisation and 3D visualisation of the seismic data will be an essential step towards this.

Subtask 1.1. Seismic investigation Westerschelde tidal delta

Partner responsible:	RCMG
Person responsible:	Marc De Batist
Partners participating	
acquisition:	RCMG, IFREMER
processing:	RCMG, IFREMER
interpretation:	RCMG, UL

Subtask 1.2. Seismic investigation Gironde tidal delta

Partner responsible:	IFREMER
Person responsible:	Gilles Lericolais
Partners participating	
acquisition:	IFREMER, RCMG
processing:	IFREMER, RCMG
interpretation:	IFREMER, UL

MILESTONES AND DELIVERABLES

		after months	6	12	24
1.	Results reconnaissance survey		X		
2.	Results detailed survey			X	
3.	3D representation of the morphology and nature of the base of the tidal delta system.			X	X
4.	Visualisation (in 3D by fence diagrams, maps,..) of the internal architecture of the entire system.			X	X
5.	Integration of data in palaeo-reconstruction maps			X	X
6.	Visualisation (in 3D, by fence diagrams, maps,..) of the distribution of specific seismic facies assemblages.			X	X
7.	Selection of the locations for vibrocoring.			X	

TASK 2. Assessment of the 3D facies architecture by vibrocoring

Objectives:

1. To compare the vertical distribution of sedimentary facies with the actual lateral distribution on the tidal delta in order to determine at different points of the system the level of reworking (high mobility versus stability).
2. To understand the sedimentary signature of wave versus current action in sub-environments such as channels and shoals.
3. To fit the VHR seismic information and the sedimentary facies interpretation (reflector nature)

This analysis will be made on the upper part of the sedimentary cover of the tidal delta by using 3-5 m long vibrocores. In each tidal delta 50 vibrocores will be taken. Because the entire tidal delta can not be investigated by vibrocoring, the study area will focus on selected areas determined on basis of the seismic surveys.

Subtask 2.1. Vibrocoring in the Westerschelde tidal delta

Partner responsible:	UL
Person responsible:	Bernadette Tessier
Partners participating	
acquisition:	IMAU, RGD, UL
analysis:	UL, RGD
interpretation:	UL, RGD,RCMG

Subtask 2.2. Vibrocoring in the Gironde tidal delta

Partner responsible:	UL
Person responsible:	Bernadette Tessier
Partners participating	
acquisition:	UL, UB
analysis:	UL
interpretation:	UL, IFREMER

MILESTONES AND DELIVERABLES

		after months 18	24	30
1.	Coring and laquer peels	X		
2	Description and interpretation of laquer peels		X	
3.	The sedimentological interpretation of the seismic information.		X	
4.	Determining of the hydrodynamical significance of the sediments (wave or current dominated, erosional structures)		X	
5.	Facies distribution map of the upper 4-5 m in order to test the consistency of the sedimentary facies in the system, with respect to the actual surficial distribution.		X	
6.	Identification of zones of high mobility and stable zones within the system.			X
7.	A map of the average underlying lithology in order to compare this information with the channel migration aptitude.			X

2. MEDIUM TERM MORPHOLOGICAL EVOLUTION OF THE WESTERSCHELDE AND GIRONDE TIDAL DELTAS

TASK 3. Assessment of the medium term morphodynamic behaviour

Objective:

This task is devoted to the study of the cartographic and numerical data available at the coastal harbour authorities (RWS, DDK & PAB) in order to determine the trends of channel, shoal and beach behaviour in time, departing from existing cartographic data (historical charts) and numerical data (databases), including information about human interventions (dredging, coastal devices).

Collection of the data into one interpretation system is a must for reliable results and to avoid the danger of mis-interpretation due to different systems and approaches. The aim of this task is to collect all the data from the different harbour authorities and transform them to a uniform GIS system in order to make them comparable.

Morphodynamic analysis will be performed to determine the stability or mobility of shoal/channel systems and the impact upon the nearby beaches. Trends in the shifting of these systems, irregular or rapid migration and magnitude in relaxation time if exists will be determined.
Precise morphometric analysis will provide acces to the volumes of sand stored in the delta and to the variations of the tidal prism.

The results of this study will be a major contribution to the model validation and will provide a starting point and a reliable reference in the past for modelling and reveal the most sensitive areas in the subtidal delta.

Subtask 3.1. Cartographic and morphometric analysis of the northern part of the Westerschelde tidal delta

Partner responsible:	RWS
Person responsible:	Maarten Meulblok
Partners participating	
acquisition:	RWS, DDK
processing:	RWS, DDK, RUMACOG, UB
interpretation:	RWS, DDK, RUMACOG, UB

Subtask 3.2. Cartographic and morphometric analysis of the southern part of the Westerschelde tidal delta

Partner responsible:	DDK
Person responsible:	Carlos Van Cauwenberghe
Partners participating	
acquisition:	DDK, RWS
processing:	DDK, RWS, RUMACOG, UB
interpretation:	DDK, RWS, RUMACOG, UB

Subtask 3.3. Cartographic and morphometric analysis of the Gironde tidal delta

Partner responsible: UB
Person responsible: Helène Howa
Partners participating
acquisition: UB, PAB
processing: UB, PAB, RUMACOG
interpretation: UB, PAB, RUMACOG

MILESTONES AND DELIVERABLES

		after months	6	12	18	24
1.	Collection of hydrographic maps		X			
2.	Collection of existing bathymetric databases		X			
3.	Digitalisation and uniformisation of hydrographic maps			X		
4.	Implementation in a GIS system			X		
5.	Evaluation of morphological changes				X	
6.	Calculation of morphometric parameters				X	
7.	Determination of erosion and sedimentation areas					X
8.	Interpretation in term of adaptation of coastal profiles and estuarine coastline to the morphodynamics of the delta					X
9.	Interpretation in term of the effect of dredging and spoil deposition on the morphodynamics of the delta					X
10.	Intergration of data in palaeo-recontruction maps				X	

3. SHORT TERM MORPHODYNAMIC BEHAVIOUR AND PROCESSES

TASK 4. Assessment of short term morphodynamic behaviour by linear and multibeam bathymetric echo-sounding.

Objectives:

1. To get an overview of the existing morphological features.
2. To evaluate short-term morphodynamic behaviour by monitoring present day insta-bilities and changes of the shoal and channel system.
3. To detect zones of erosion and sedimentation.
4. To detect changes in slope gradients.
5. To select optimal sites for side scan sonar surveys

The bathymetric investigation will be carried out in three ways:

a. Reconnaissance survey, directed to the large scale morpholigical units provided by the map analysis.
b. Detailed multibeam bathymetry on selected sites.
c. Chronosequential linear bathymetry along selected profiles.

Reconnaissance surveys will be carried out on the Westerschelde as well as on the Gironde tidal delta. These reconnaissance surveys contribute to the selection of areas for detailed bathymetric and side scan sonar surveys, sedimentological investigations and hydrodynamical measurements.
Moreover, multibeam and chronosequential linear bathymetric soundings will be carried out on selected sites and profiles within the Westerschelde tidal delta in order to evaluate its short term morphodynamic behaviour.

Subtask 4.1. Bathymetric investigation Westerschelde tidal delta

Partner responsible:	RUMACOG
Person responsible:	Irenee Heyse
Partners participating	
acquisition:	RUMACOG
processing:	RUMACOG, DDK
interpretation:	RUMACOG

Subtask 4.2. Bathymetric investigation Gironde tidal delta

Partner responsible:	IFREMER
Person responsible:	Jean-Francois Bourillet
Partners participating	
acquisition:	IFREMER
processing:	IFREMER
interpretation:	IFREMER

MILESTONES AND DELIVERABLES

Westerschelde:	after months	12	24	36
1. Results reconnaissance survey		X		
2. Multibeam echo sounding		X	X	
3. Corrected hypsometric profiles		X	X	X
4. Volumetric data		X	X	X
5. Correlation of result with meteo/marine data				X
6. Evaluation of morphological changes				X

Gironde:	after months	12	24	36
1. Results reconnaissance survey		X		
2. Multibeam echo sounding		X	X	
3. Morphological description		X	X	
4. Contour map			X	X

TASK 5. Assessment of short term morphodynamic behaviour and bedform patterns by side-scan sonar surveys.

Objectives:

1. To get an overview of the existing bedforms.
2. To investigate geometric characteristics of bedforms.
3. To monitor changes of bedform patterns,e.g. ebb/flood dominance.
4. To detect residual sediment transport paths.
5. To select optimal sites for boxcoring and hydrodynamic field measurements

The side-scan sonar surveys will be carried out in three ways:

a. Reconnaissance survey in relevant parts of the tidal delta.
b. Detailed side-scan sonar mosaics on selected sites.
c. Chronosequential side-scan sonar surveys on selected sites.

In order to get an overview of the existing morphological structures, their geographical spreading and configuration in the subtidal delta, a reconnaissance with side scan sonar is necessary during the starting phase of the project. The data obtained during this reconnaissance will be a key tool in the localisation of the most interesting areas of investigation. A side scan sonar mosaic will be made in the most relevant representative as large as possible areas of the subtidal delta system.

An accurate study of the sediment transport paths in the subtidal delta comprises a thorough investigation of the morphology of the sea-bottom with the help of side scan sonar and supporting echo-sounding. Sonographs detect the geometric characteristics of bedforms, ranging from sandwaves to megaripples and provide a tool for the assessment of the residual sediment transport because their strike and transversal asymmetry are indicative for the direction of residual displacement. The sonograph recordings will be chrono-sequential and thus focus on changes of bedform patterns. Special attention will be given to the genetical classification of the bedforms, with an attempt to distinguish into wave dominated or current dominated (ebb or flood) structures. Relationship between bedform changes and hydrodynamic parameters will be highlighted.
Sonographs of bedforms will be recorded in some test areas preferably several times a year. The test areas will be chosen upon the result of the side scan sonar reconnaissance of the subtidal delta. Relation between morphodynamic bedforms and lithological
characteristics will be investigated by using a remote hydro acoustic sensor for automatic seabed identification. For the construction of the mosaic a digital mapping method will be implied. The sonograph mosaics will be incorporated in the global MORTIDEL GIS system.

Subtask 5.1. Side-scan sonar investigation Westerschelde tidal delta

Partner responsible:	RUMACOG
Person responsible:	Irenee Heyse
Partners participating	
acquisition:	RUMACOG
processing:	RUMACOG,
interpretation:	RUMACOG, UL

Subtask 5.2. Side-scan sonar investigation Gironde tidal delta

Partner responsible:	IFREMER
Person responsible:	Tania Marsset
Partners participating	
acquisition:	IFREMER
processing:	IFREMER
interpretation:	IFREMER, UB, UL

MILESTONES AND DELIVERABLES

		after months	6	12	24	36
1.	Results reconnaissance survey		X			
2.	Classification of bedforms		X			
3.	Bit mapped side-scan sonar mosaics			X	X	X
4.	Bedform maps			X	X	X
5.	Maps of sediment transport paths			X	X	X
6.	Correlation of result with meteo marine data					X

TASK 6. Assessment of lithology and sedimentary structures in the upper sediment layer by boxcoring

Objectives:

1. To define the horizontal distribution and consistency of wave- and tide-dominated facies.
2. To detect the stability of the sediments related to the morphology.
3. To determine general sediment circulation within the tidal delta.
4. To select sites for the hydrodynamic field measurements.

Sediment movement and actual sedimentary processes are reflected in the structures of the upper sediment layers. To analyse the internal sedimentary structures it is necessary to obtain indisturbed samples. In these samples the lithology and structures can be studied to determine the sedimentary processes.
An orientable boxcorer with compass will be constructed. With this boxcorer a minimum of 100 boxcores will be taken on each tidal delta.
From the boxcores lacquer peels will be made to study the sedimentary structures and the degree of bioturbation. Subsamples will be taken for grainsize analysis.

Subtask 6.1. Sedimentological investigation by boxcoring in the Westerschelde tidal delta

Partner responsible:	UL
Person responsible:	Alain Trentesaux
Partners participating	
acquisition:	UL, IMAU, RWS
processing:	UL
interpretation:	UL, UB, UEA, IMAU

Subtask 6.2. Sedimentological investigation by boxcoring in the Gironde tidal delta

Partner responsible:	UL
Person responsible:	Alain Trentesaux
Partners participating	
acquisition:	UL, UB, PAB
processing:	UL
interpretation:	UL, UB, UEA, IMAU

MILESTONES AND DELIVERABLES

		after months	6	12	24	36
1.	Construction of orientable boxcorer		X			
2.	Coring and lacquer peels				X	X
3.	Description and interpretation of lacquer peels				X	X
4.	Sediment transport pathways maps					X
5.	Synthesis about surface sedimentology					X
6.	Current/waves dominance map				X	

TASK 7. Meteo-Marine data: acquisition and analysis

Objectives:

1. To monitor wave data (height and direction).
2. To monitor waterlevel data (tide and wind setup).
3. To monitor meteorological data (wind force and direction; air pressure).
4. To make these data available to the partners.

This task comprises registration of surface wave height and direction as well as monitoring of meteorological and maregraphical phenomena, recorded within or just outside the tidal deltas. All parameters will be analysed for evolution trends. Relevant parameters will be presented in a graphic way and made available to other participants in a user friendly digital format.

Subtask 7.1. Meteo-Marine data Westerschelde tidal delta

Partner responsible:	DDK
Person responsible:	Carlos van Cauwenberghe
Partners participating	
acquisition:	DDK, RWS
processing:	DDK, RWS
interpretation:	DDK, RWS, IMAU

Subtask 7.2. Meteo-Marine data Gironde tidal delta

Partner responsible:	UB
Person responsible:	Helene Howa
Partners participating	
acquisition:	UB, PAB
processing:	UB, PAB
interpretation:	UB, PAB, IMAU

MILESTONES AND DELIVERABLES

		after months	12	24	36
1.	Set of meteo-marine parameters		X	X	X
2.	Graphic representation of relevant parameters		X	X	X
3.	Statistic analysis of recorded data		X	X	X

TASK 8. Wave and current analysis deduced from satellite (optical and radar) images

Objectives:

1. The calibration of satellite data
2. The application of these data to tidal deltas
3. To establish wave- and current patterns
4. To quantify erosion and sedimentation areas

Optic and radar satellite images are available data to observe and to quantify the wave fields and their interactions with currents in coastal areas. In tidal deltas many hydrodynamic processes take place mainly 1) the local current velocities influenced by the tidal fluctuations and the fluvial discharges,.2) the wave energy in relation to the local or regional wind conditions (direction and forces). The satellite data completed with in-situ measurements, are the best way to obtain this type of information.

Subtask 8.1. Application of satellite data Westerschelde tidal delta

Partner responsible:	RUMACOG
Person responsible:	C. Vernemmen
Partners participating	
acquisition:	RUMACOG
processing:	RUMACOG
interpretation:	RUMACOG, UB

Subtask 8.2. Application of satellite data Gironde tidal delta

Partner responsible:	UB
Person responsible:	J.M. Froidefond
Partners participating	
acquisition:	UB
processing:	UB
interpretation:	UB, RUMACOG

MILESTONES AND DELIVERABLES

	after months	12	24	36
1.	Processed satellite images to identify the main physical processes	X	X	X
2.	Comparison of satellite images with models		X	X
3.	Calibration of images with in situ field data		X	
4.	Erosion and sedimentation processes derived from image processing			X

TASK 9. Preliminaries to the hydrodynamic and sediment transport field measurements

Task 9.1. Preliminaries to the deployment of instrumented tripods

These preliminaries will comprise:

1. Construction of 2 instrumented tripods by IMAU
2. Construction of 1 instrumented tripod by MUMM
3. Calibration of instruments
4. Selection of deployment sites in collaboration with other partners

Partner responsible: IMAU
Person responsible: Ad Stolk
Partners participating: IMAU, MUMM

MILESTONES AND DELIVERABLES

Three instrumented tripods operational with datalogging systems and calibrated sensors (after 12 months).

Task 9.2. Preliminaries to the deployment of current meter stations

These preliminaries will comprise:

1. Preparation of 3 self recording current meter stations
2. Calibration of instruments
3. Selection of deployment sites in collaboration with other partners

Partner responsible: MUMM
Person responsible: André Pollentier

MILESTONES AND DELIVERABLES

Three current meter stations operational with datalogging systems (after 12 months).

Task 9.3. Preliminaries to the deployment of Acoustic Backscatter Systems

These preliminaries will comprise:

1. Construction of 2 Acoustic Backscatter systems
2. Calibration of instruments
3. Selection of deployment sites in collaboration with other partners

Partner responsible: UEA
Person responsible: Chris Vincent

MILESTONES AND DELIVERABLES

Three calibrated Acoustic Backscatter systems operational with datalogging systems (after 12 months).

TASK 10. Analysis of sand transport processes: measurement of physical processes induced by waves and currents

Objectives:

1. To determine the relative influence of currents and waves on the entrainment and transport of sediments.
2. To determine the difference in current/wave influence in different parts of the tidal delta.
3. To establish the sediment transport (circulation) system within the tidal delta.
4. To validate and calibrate the 2D and 3D wave and current models.

Sediment at the seabed moves when the instantaneous shear stress exceeds the gravitational and frictional forces acting on the sediment grain. In a complex flow regime when both waves and currents are present, the bed shear stress is difficult to measure directly. Therefore, several hydrodynamic parameters are measured to detect the conditions under with the sediment is transported.
It is intended to use autonomous tripods to make simultaneous current and suspended sediment concentration measurements close to the seabed at several sites in the study areas. The current velocity and the water motion due to waves will be measured (at 2 Hz) at two heights using electro-magnetic flow meters (EMF). The suspended sediment concentrations will be measured (at 2 HZ) by optical backscatter (OBS) at two heights.
Together with the instrumented tripods current meter stations will be deployed. The stations measure the current velocities at heights of 2 and more meters above the bed to allow a good fit of the current velocity in the water column. From these measurements the depth mean velocity can be calculated for the verification of numerical models.
The use of instrumented tripods and current meter stations offers the possibility to do continuous measurements during several neap/spring tidal cycles up to a maximum of 50 days. Deployments during quit weather (summer measurements) will give information about the influence of the tidal currents on sediment transport. Deployments during rough weather (winter deployments) will give information about the influence of (storm) waves on the sediment transport.
Fife deployments are planned on the Westerschelde tidal delta. three deployments are planned on the Gironde tidal delta. During the deployments the tripods and current meter stations will be located on sites selected on basis of results of morphological analysis, side scan sonar analysis, boxcoring, analysis of satellite images and modelling.

Subtask 10.1. Execution of hydrodynamic and suspended sediment measure-ments Westerschelde tidal delta

Partner responsible:	IMAU
Person responsible:	Ad Stolk
Partners participating	
acquisition:	IMAU, MUMM, UEA, RWS
processing:	IMAU, MUMM, UEA, RWS
interpretation:	IMAU, MUMM, UEA, RWS

Subtask 10.2. Execution of hydrodynamic and suspended sediment measurements Gironde tidal delta

Partner responsible: UB
Person responsible: Helène Howa
Partners participating
acquisition: UB, USGS, IMAU
processing: UB, USGS, IMAU
interpretation: UB, USGS, IMAU

MILESTONES AND DELIVERABLES

	after months	18	24	30	36
1.	Deployment of tripods and stations	X	X	X	X
2.	Graphical display of time series of measurements	X	X	X	X
3.	Analysis of current data		X	X	X
4.	Analysis of suspended sediment data		X	X	X
5.	Calculation of bed shear stresses and wave asymmetry under different meteo-marine conditions		X	X	X
6.	Realisation of input for the verification of numerical models			X	X
7.	Comparison of measurements and calculated parameters for different parts of the tidal delta			X	X
8.	Hydrodynamical and suspended sediment data prepared for implementation in database				X

MODELLING AND INTEGRATION

TASK 11. Modelling of sediment transport

Objectives:

1. To simulate the flow field under different natural conditions.
2. To simulate the sediment transport under different natural conditions.
3. To establish the influence of dredging and dumping.
4. To evaluate the development and movement of the channel and shoal systems.
5. Validation of the models with field data from hydrodynamic measurements.
6. Validation of the models with historic morphological data by hindcasting.

At the start of the project, different operational models will be available to be used in the framework of the project. A 2D hydrodynamic model will be available for the tidal delta of the Westerschelde estuary; this model will have a grid size of approximately 200 x 200 m^2 and will be coupled with a hydrodynamic model for the Continental Shelf at the open boundaries and with a 1D model of the Schelde estuary. Also a 3D hydrodynamic model will be available for the same area, with a grid size of approximately 750 x 750 m^2 and with 10 layers over the vertical (sigma-transformation). Further an operational 2nd generation spectral wave model (grid size in the area around 5 x 5 km2) and a spectral wave refraction model are available, which can be used to estimate the concentration of the wave energy on certain areas. At last a sediment transport model will be operational, which assumes a local equilibrium between the sediment transport and the flow and wave conditions in a point. The model can be used to calculate the local bedload transport of the sand in the area.
For the tidal delta of the Gironde estuary a 2D flow model will be developed from an already available 3D model with a grid size of 100x100m^2.

Subtask 11.1. Modelling of sediment transport Westerschelde tidal delta

Partner responsible: MUMM
Person responsible: Dries Van den Eynde
Partners participating: MUMM, RWS, UB, LHS, IMAU

Subtask 11.2. Modelling sediment transport Gironde tidal delta

Partner responsible: UB
Person responsible: Helène Howa
Partners participating: UB, LHS, MUMM, RWS, IMAU

MILESTONES AND DELIVERABLES

after months	12	24	36
1. Construction of suitable 2D and 3D models	X		
2. Validation and calibration by field measurements		X	X
3. Validation and calibration by hindcasting		X	X
4. Interpretation in terms of flow patterns		X	X
5. Interpretation in terms of sediment transport patterns		X	X
6. Determination of the influence of dredging and dumping			X

TASK 12. Integration of research on Westerschelde and Gironde tidal deltas

This task comprise the comparison of the results of the investigations in both tidal deltas in order to develop conceptual modules which can be used in morphodynamic modelling of tidal deltas. This implies the identification of similarities and differences in spatial and temporal variation in determining processes on both tidal deltas.
Models developed for one tidal delta will be applied to the other tidal delta to harmonize model concepts and formulations. The objective is to establish generalized formulations for sediment circulation and morphodynamic behaviour who are applicable in both tidal deltas.

Partner responsible: IMAU
Person responsible: Joost Terwindt
Partners participating: IMAU, MUMM, RWS, UB, HLS

MILESTONES AND DELIVERABLES

	after months	36
General applicable conceptual model of sediment flow patterns and morphodynamic behaviour of tidal deltas.		X

COORDINATION AND DATA MANAGEMENT

TASK 13. Coordination and scientific integration of the project

This task comprises the internal management and administration of the project, liason with the Commission, organisation of meetings and finalising of the main reports.

Partner responsible: IMAU
Person responsible: Joost Terwindt

TASK 14 Preparation of final report

In the last months of the project special attention will be given to the preparation of the final report. This report will include and discuss the results of the various partners and will integrate these into a major framework. This report may be used by scientists and practioners as a source of information, provided by the project.

Partner responsible: IMAU
Person responsible: Ad Stolk

TASK 15 Preparation of a database

During the project the existing framework of the data base will be used to incorporate the numerical data in an accessable format. The same formats as used in the MAST II STARFISH Project will be applied. In addition data from existing GIS bases of some partners (DDK,RWS,PAB,MUMM) which are relevant for the project will be included. It should be noted that it is relatively simple to connect these databases. This will finally lead to a databank, which will be accessable to other European scientists.

Partner responsible: RUMACOG
Person Responsible: Geert De Schaepmeester