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Scientific Report Year 3 (01/04/2004 – 31/03/2005)

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INTRODUCTORY NOTE

This report presents the Marebasse related scientific results for the third year obtained by the following partnership with its researchers:

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For the specific tasks of the partners and their progress, reference is made to the administrative reports.

The 3rd scientific report mainly reflects the results that were obtained on the basis of several field campaigns. The Belgian oceanographic vessel RV/Belgica was the preferred platform since it is equipped with state-of-the-art instrumentation. The officers and crew are greatly acknowledged for their cooperation as well as MUMM for approving shiptime. For 2005, Marebasse shiptime was approved in February, July and November.

We want to acknowledge and thank the end-users for their interest and willingness to provide data and/or instrumentation: Federal Public Service Economy, SMEs, Self-employed and Energy – Marine Sand Fund; Zeegra; Ministry of the Flemish Community, Administration Waterways, Infrastructure and Nautical Affairs, Waterways and Coastal Section (AWZ-WWK); European Dredging Association; 3E; Flanders Marine Institute and The Department of Sea Fisheries. VLIZ is particularly thanked for the purchase of a Hamon grab for the sampling of coarser seabed material. MUMM is thanked for providing logistic support to use the Hamon grab on the RV Belgica.

On an international level, the cooperation with the FP5 Research training network EUMARSAND is continued and will result in joint publications on the impact of aggregate extraction on the Kwinte Bank. Related to the research activities of UG-RCMG, the complementarities of the InterregIIIb project MESH with the objectives of Marebasse need to be highlighted. The Marebasse results will in particular be refined, validated and more standardised in the wider european framework.

The Marebasse project team, July 2005
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INTRODUCTION

The 3rd report of the research project Marebasse (Management, research and budgeting of aggregates in shelf seas related to end-users (2002-2006)) is a step forward in support of a science-based approach to a sustainable management of the Belgian exclusive economic zone (EEZ). In complement of the 1st and 2nd report (Van Lancker et al. 2003; 2004), extensive results have been obtained that are relevant towards the impact of dredging/dumping operations and the effects of marine aggregate extraction on the marine environment. Figure 1 shows the present and past concession zones for marine aggregate extraction (zone 1a/b, zone 2a/b/c, zone 3a/b and exploration (zone 4). Marebasse is active on all levels and is providing highly valuable baseline information and fundamental research results. These are obtained using state-of-the-art instrumentation and methodologies. Moreover, Marebasse, builds-on and integrates past results and as such provides an additional added value.

-zone 1a/b: a resource evaluation was conducted on the new concession zone of the Gootebank (zone 1b) (data from the Marine Sand Fund, Federal Government);
-zone 2a/b/c: multidisciplinary and integrated research is conducted on the Kwinte Bank (zone 2b)
-zone 3a/b: extensive research is carried out on the old dumping site of dredged material that has been designated as a new concession zone;
-zone 4: Marebasse especially focussed on the area south of the exploration zone to evaluate the presence and quantities of gravely deposits; data of this kind is very scarce on the Belgian shelf

Marebasse is indeed essentially meant to develop an integrated assessment framework of the physical seabed in which the set-up of evaluation tools and strategies, both on a large and small-scale, are equally important (Van Lancker et al. 2002). Especially, nowadays that exploitation demands of the shelf steadily increase and that new developments such as offshore windmill farms are becoming real, integrated knowledge on the seabed nature and dynamics is essential in support of the estimation of the potential effects and to provide baseline information for any detailed investigation. In that perspective new maps have been compiled that can support various initiatives:

-New digital terrain model of the Belgian shelf at a resolution of 250 m on the basis of soundings of the Hydrographic Office, Ministry of the Flemish Community
-New sedimentological map covering the whole of the Belgian shelf, based on the sedisurf database which is a compilation of sediment samples taken from 1976 onwards
-New bedform map covering the whole of the Belgian shelf
-Refined hydrodynamic and sediment transport modelling results on a 250 m grid, covering the whole of the Belgian shelf

The set-up of evaluation tools and strategies should be viewed with respect to the optimisation and scientifically upgrading of ‘environmental (impact) assessments’. These are in principle multidisciplinary and ideally Marebasse wants to contribute to this through the provision of integrated knowledge on the physical, geomorphological, sedimentological and partly biological nature of the seafloor or to give recommendations how to acquire such data. With the expertise in the Marebasse group, these aims can to a large extent be fulfilled, still in terms of its relevance and value towards management issues; a strengthening of research initiatives is needed and highly recommended.

In that framework, it is of utmost interest to valorise the results in a bigger framework and to seek for complementarities, both on a national as international level. With respect to marine aggregate issues, research is conducted in cooperation with the EU-FP5 research training network EUMARSAND. Related to the impact of aggregate extraction on the Kwinte Bank, joint research initiatives were carried out. This also allowed testing different modelling initiatives that will strengthen the value of the impact
assessments. Both Eumar sand and Marebasse results on the Kwinte Bank will be published in a Special Issue on European Marine Sand and Gravel Resources.

The Marebasse results are also being validated and refined in the Interreg IIIb project MESH (Mapping European Seabed Habitats). This project develops protocols and guidelines for habitat mapping and allows upgrading the Marebasse results according to European standards. The MESH project is especially valuable towards data and GIS management.

Figure 1. Present and past concession zones for marine aggregate extraction (zone 1a/b, zone 2a/b/c, zone 3a/b and exploration (zone 4).
RESUL T S

1. ENVIRONMENTAL CHARACTERISATION OF THE BELGIAN CONTINENTAL SHELF

Introduction

An appropriate evaluation of a sedimentary system can only be carried out if it can be situated in a larger scale sediment dynamical framework and hence a including, is an inherent component of the project (Task 1.1). It remains an approach, since it is difficult to carry out detailed investigations that take into account the whole Belgian continental shelf (BCS). Up till now, the main industry end-user groups are the marine aggregate (MA) and dredging industry and since they impose most stress on the sedimentary system, it is regarded important to get acquainted with their needs and demands, now and in the future (Task 1.1.1; 1.1.2). Still, towards the implantation of windmill farms or, generally, any major anthropogenic impact, there is a need for tools and strategies to prospect and evaluate the state, dynamics and stress of the seabed. Since a variety of issues should be considered, it seems essential to review environmental (impact) assessments on a European level (Task 1.1.3). It should be mentioned that emphasis is put on the characterisation of the sedimentary system; pure biological or fisheries issues are not considered.

1.1. Review of existing knowledge on marine sediments (ref. 1st & 2nd scientific report)

1.2. Refinement of a 2D sediment transport model and its application

1.2.1. 2D sand transport simulations (also ref. first scientific report)

1.2.2. Quantification of mud transport in the southern North Sea (ref. 2nd scientific report)
2. DEVELOPMENT OF ENVIRONMENTAL ASSESSMENT EVALUATION TOOLS AND STRATEGIES

Introduction

On a regional scale, strategies and evaluation tools are developed for the set-up of optimised environmental assessments in view of the sustainable management of the Belgian exclusive economic zone (EEZ) (WP2). To accomplish this aim, fieldwork programmes are designed and sites are selected that are resource, but also issue-driven (Task 2.1.1). On a resource level, it is important to cover the variety of marine sediment types found on the BCS in order to test and tune the best available techniques to the evaluation and prospecting of muddy to gravelly sediments. The choice of the sites is biased towards areas that are important within the context of the sustainable exploitation of the EEZ such as areas of interest related to MA extraction, dumping/dredging and to the implantation of windmill farms. The final selection of the sites is done in consult with the advisory committee. The Marebasse measurements started with the sand/mud dominated environments and the measurement boxes were located around dumping locations. For both the Sierra Ventana (S1) as the Oostende region, the old dumping sites had to be abandoned as they reached their maximum capacity. As such, the old areas became interesting from a MA extraction perspective. Presently, two extraction zones (3A, 3B) have been defined in the vicinity of the old S1 dumping site. The site for an environmental impact study was fixed to the central part of the Kwinte Bank as marine aggregate extraction is there prohibited for three years and as such the potential recovery of the area can be studied. Additionally, based on data from the Fund for Sand Extraction, an aggregate resource evaluation was carried out on the new extraction zone at the western extremity of the Gootebank. The data were worked out in the framework of an Msc thesis (Delye 2005).

Presently, gravely areas in the Hinder Banken region are being surveyed. Part of the results are reported.

![Figure 2. General overview of the main areas under investigation within the Marebasse project.](image-url)
2.1. Field experiments

In the period 01/04/2004-31/03/2005, the measurements mainly took place in the region of the Hinder Banks. Additional data was acquired along the Sierra Ventana and extra seismic lines were sailed along the Kwinte Bank. The measurement boxes are shown in the different sections. Table 1 gives a more detailed overview of the field data obtained.

2.1.1. Geo-acoustical surveying (ref. first scientific report)

2.1.2. Ground-truthing (also ref. 1st & 2nd scientific report)

2.1.3. Hydrodynamic and sediment transport measurements (ref. first scientific report)
Table 1. Overview of the data acquired in the period 01/04/04 to 31/03/05 (amount of km is approximate); () limited data is available. **NEEDS COMPLETION**

<table>
<thead>
<tr>
<th>Type of measurement</th>
<th>Kwinte Bank</th>
<th>Hinder Banken</th>
<th>Oostende Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geo-acoustical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multibeam</td>
<td>152 km 22 km</td>
<td>No data 10 km</td>
<td>298 km 103 km</td>
</tr>
<tr>
<td>Side-scan sonar</td>
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<td>No data</td>
<td></td>
</tr>
<tr>
<td>RoxAnn</td>
<td>No data</td>
<td>No data</td>
<td></td>
</tr>
<tr>
<td>Ground-truthing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Van Veen</td>
<td>97 samples</td>
<td>No data 23 stations</td>
<td>39 samples</td>
</tr>
<tr>
<td>Boxcoring</td>
<td>17 samples</td>
<td>No data</td>
<td></td>
</tr>
<tr>
<td>Reineck</td>
<td>21 samples</td>
<td>No data 1 sample</td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td>17 stations</td>
<td>No data 7 stations</td>
<td></td>
</tr>
<tr>
<td>Hydrodynamic / sediment transport</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Name of location of 13hrs cycle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom-mounted ADCP</td>
<td>TT20/T21/TT21 C1/C2 13hrs/-</td>
<td>TT22 C1</td>
<td>TT23/TT24 C1/C1 9days/13hrs/-</td>
</tr>
<tr>
<td>Hull-mounted ADCP</td>
<td>13hrs/13hrs +tracks +5 tracks</td>
<td></td>
<td>+1 track (C2-C5) (13hrs)</td>
</tr>
<tr>
<td>LISST 100c</td>
<td>13hrs/7days</td>
<td>13hrs</td>
<td>9days/13hrs (13hrs)</td>
</tr>
<tr>
<td>CTD</td>
<td>13hrs/-13hrs</td>
<td>13hrs</td>
<td>13hrs/9days/13hrs</td>
</tr>
<tr>
<td>OBS</td>
<td>13hrs/-13hrs</td>
<td>13hrs</td>
<td>13hrs/9days/13hrs</td>
</tr>
<tr>
<td>SPM measurements</td>
<td>13hrs/13hrs</td>
<td>13hrs</td>
<td>13hrs/13hrs</td>
</tr>
</tbody>
</table>
2.2. Environmental characterisation of the Sierra Ventana dumping site of dredged material and its potential rehabilitation into a site for aggregate extraction

2.2.1. Introduction

The Sierra Ventana region was chosen as an example of a sand/mud dominated environment. Moreover, the area was particularly interesting due to the possibility to investigate both the influence of dumping of dredged material as the recovery of a dumping site after the cessation of dumping. The investigation also contributes to the assessment of the nature of the sediments of the newly defined extraction zones 3a and b, partially overlapping with the dumping zone S1.

2.2.2. Setting

The Sierra Ventana region, located in the Southern bight of the North Sea, is situated north of the main shipping channel ‘Scheur-West’; the major access to the Western-Scheldt and the harbour of Zeebrugge. Both the dumping site Br&W S1 as the extraction zones 3a and 3b for marine aggregates are located in this region (Figure 1).

The dumping site S1, into use since 1966, is the main dumping site on the Belgian continental shelf. It has been relocated four times (in 1970, 1980, 1984 and 1999) because of reaching its maximum dumping capacity. All the dumping grounds are areas of 7.1 km² (radius = 1500 m), located 17 km offshore. For this study, the focus will be on the two most recent dumping sites. They will be called the ‘old’ dumping site (1984 - 1999) and the ‘new’ dumping ground (1999-present). The old dumping zone is characterised by depths ranging from 6 to 14 m MLLWS. The new dumping site can be divided in two parts, the southern part which overlaps with the old dumping ground and the northern part which covers a swale (20-21 m MLLWS). The dredged material, dumped on S1, originates mainly from the navigation channels ‘Pas van het Zand’, ‘Centraal Deel Nieuwe Buitenhaven Zeebrugge’, ‘Scheur Oost’ and ‘Scheur West’. The extraction zones 3a and b, partially overlapping with the old and new dumping site S1, have an area of 9.3 km² each. The zone 3a is open for extraction during the whole year, opposed to the zone 3b, which is closed as long as the new dumping site S1 is in use (Koninklijk Besluit, September 1, 2004).

Figure 3. Localisation of the Sierra Ventana region on the Belgian continental shelf.
2.2.3. Morphological evolution from 1995 till 2004

The morphological evolution of the Sierra Ventana region was studied based on the single-beam bathymetrical data of 1995, 1999, 2000, 2002 and 2004 (Figure 4). The data was provided by AWZ-WWK. Comparing the bathymetry over the different years, both the effects of the dumping activities as the effects of closure of the old dumping site in 1999 can be observed.

Between 1995 and 1999, dredged sediments were dumped on the northern part of the old dumping site, creating a sand pile on the edge of the dumping ground extending towards the north. This configuration of sand piles on the edges and an apparent depression in the centre is due to the way the split hopper suction dredge vessels dump their dredged sediments. They navigate to the farthest point with regard to the coastline, than they turn and while they are sailing back to the navigation channel they dump the dredged material by opening longitudinally, describing a half circle. This method is the most time saving and consequently the most economic.

From 2000 onwards there is an accumulation of dredged material on the southeastern part of the new dumping zone. However the slumping downwards of sediments on the northern part of the old S1 also contributes to this accumulation. This erosion is probably caused by dumping of a minor part of dredged sediments (<0.5 ton/ m²) on the southern part of the new dumping zone (source: dumping intensity maps, AWZ).

After the closure, in 1999, sand dune structures are formed on the southeast side of the old dumping zone indicating the recovery process.
Figure 4. Morphological evolution of the dumping site S1, based on successive single-beam maps from 1995 to 2004 and obtained from AWZ-WWK.

The quantitative morphological evolution of the old and new dumping site can be studied by means of a cross-section through the dumping sites from NW to SE for the different years (Figure 5a) and the volume difference map between 1999 and 2004 (Figure 5b).

The major morphological patterns, described earlier, are observed: a 1 m depth reduction from 1995 to 1999 in the north-western part of the old dumping site, a decrease in depth up to 6 m in the south-western part of the new one between 1999 and 2004 and for the same period a deepening up to 4 m in the northern part of the old S1.
2.2.5. Detailed morphology

The study of the detailed morphology is based on multibeam data recorded during the Belgica campaigns ST0303 (13-14 February 2003), ST0304 (17-21 February 2003), ST0309 (March 2003), ST0425a (October 2004) and ST0502 (February 2005) (Figure 6).
Based on bathymetrical multibeam data

The composite bathymetry image, compiled on multibeam data of the campaigns ST0303, ST0304 and ST0309, reveals that on the southwest part of the new dumping ground dredged spoils and small negative structures occur, whereas the old dumping site is characterised by bedforms (Figure 7).

Figure 7. Bathymetrical chart based on multibeam data (RV Belgica Simrad EM1002 multibeam system)

Figure 8 shows a detailed image of the non-overlapping part of the new dumping ground with the old one, where dredged spoils and negative structures are found, and a cross-section through this area. The dredged spoils have a height of maximum 1 m and are irregular shaped. The negative structures are maximally 40 cm beneath the general topography. Their origin is unclear, but they might be the impact structures from dredge spoils into soft sediments (Poppe et al., 2002). The same structures were found on the dumping site of Ostend (Van Lancker et al., 2004).

The old dumping site is characterised by sand dunes, which are parallel to each other and have their crests southeast–northwest oriented, indicating that the residual transport is perpendicular to that direction.
To study the height and the shape of the dunes, transects perpendicular to their crest lines were defined. The obtained five profiles, together with their location, are shown in Figure 9. The distribution of the bedforms shows a well-defined pattern. Large dunes, defined by Ashley (1990) as dunes having a height between 0.75 m and 3 m, are found on the sand piles in the southern half of the old dumping site S1. As such they occupy the shallowest areas where the maximum interaction of both flood and ebb currents occur. The wavelength of the large dunes ranges from 180 to 200 m and the highest dunes have a height of 2 m. Small dunes, defined by Ashley (1990) as dunes having a height between 0.5 m and 0.75 m, are located on the slope of the sand piles. Their wavelength varies around 50 m. Fields of ripples, defined by Ashley (1990) as having a height smaller than 0.5 m, occur centrally.

The profiles also indicate that most dunes are asymmetrical. The direction of the steep slope of the small dunes (indicated by black arrows), is pointed towards the northeast for dunes on the western flank of the sand piles and towards the southwest for dunes on the eastern flank. Lanckneus & De Moor (1991) observed the same distribution pattern on the Flemish Banks and proposed the following sediment dynamic model: banks receive sand from both adjacent swales through the opposing tidal flows. As a result sand piles up on the bank summit. The large dunes on the southwest side in profile 5 are ebb-oriented, while the dunes on the northeast side are flood-oriented, although less pronounced than the ebb-oriented ones. As the asymmetry of the large dunes can be used as an indicator for the residual transport direction (Lanckneus et al., 2001), we could conclude that the dominant tidal current is the ebb-current. This statement is confirmed by Figure 10, which shows that the same pattern can be found for campaign ST0425a. However one should keep in mind that this setting could be due to temporal hydro-meteo conditions (i.e. storms, prevailing wind directions for a longer period, ...), which are able to change the asymmetry of dunes. To know if this setting is a temporal one or a permanent, further investigations are needed. The same comment applies for the dune migration towards the southwest by 10 to 20 m and for the reduction in height, especially for the dunes most to the southwest (an 0.4 m decrease in height on average).

Figure 8. Detailed image and cross-section through the new dumping site based on multibeam recordings.
Figure 9. Location and representation of the profiles along the southwest-northeast transects across the old dumping site S1
2.2.6. Surficial sedimentology

Results from ground-truthing

Ground-truthing was performed on the basis of a preliminary on-board analysis of the multibeam/side-scan sonar data and as such they would allow to validate acoustically distinct areas in a later phase. In total, 58 boxcores/Van Veen and Hamon Grabs were taken and this during the campaigns ST0303 (15), ST0304 (15), ST0309 (11), ST0425a (5) and ST0502 (12) (Figure 11).

After recovery of the boxcores, two subcores were taken and cut longitudinally in two. Subsamples were taken out of each layer. However, as the Van Veen and Hamon Grab samples are disturbed, only one subsample of each could be taken. Both the boxcore and the Van Veen/ Hamon Grab subsamples were dry sieved on a column with mesh sizes ranging between 2000 and 710 µm. Subsequently the carbonate and organic matter content of the fraction smaller than 710 µm was analysed. After the destruction of the carbonate and the organic matter, the fraction larger than 75 µm was dry sieved on a column with mesh sizes ranging between 600 and 90 µm. Finally the fraction smaller than 75µm was analysed using a Micromeretics SediGraph 5100 (Royal Belgian Institute of Natural Sciences). The procedure of Wartel (2004) was followed. Based on the results from the grain-size analyses on a ¼ of phi sieve interval of the campaigns ST0303, ST0304 and ST0309, grain-size distribution curves and the sedimentological parameters of each sample were determined. The Van Veen and Hamon Grab samples of respectively campaign ST0425a and ST0502 still have to be analysed.
Figure 11. Positioning of the sample locations of the campaigns ST0303 (orange), ST0304 (blue), ST0309 (green), ST0425a (purple) and ST0502 (pink).

Figure 12. Spatial distribution of the mean grain-size (phi) (Folk & Ward, 1957).
Figure 12. Spatial distribution of the sorting (Folk & Ward, 1957).

Figure 13. Spatial distribution of the weight percentage gravel (shell fragments) (%).
Figure 14. Spatial distribution of the weight percentage silt-clay (%).

Combining the observations of the different sedimentological maps the following conclusions can be drawn (Figure 12, 12, 13 and 14).

The sediments on the old dumping site are well-sorted sandy sediments, regardless of the dumped material that consisted of a high mud content and that was dumped between 1984 and 1999 (Malherbe, 1991). This is due to the presence of the old dumping site in highly dynamic shallow environment, which causes the occurrence of a hydraulic segregation mechanism during the dumping process. This mechanism yields a clear separation of the less mobile sand, which remains on the disposal ground, and the highly mobile mud fraction, which is suspended by currents and transported away (Malherbe, 1991 and Van Parijs et al., 2002). Besides the sandy nature of the sediments also the decrease in the mean grain-size and an increase in the silt-clay fraction towards the northeast and further towards the north (following the direction of the slope) are consequences of this process.

There is also a clear correlation between the morphology and the textural differentiation of the surficial sediments on the old dumping site. Finer sediments, with no shell fragments, occur in the depression, where ripples are presented, while coarser sandy sediments containing shell fragments are found on the sand piles. This differentiation is due to the interaction of currents with the morphology, which causes a hydraulic sorting of the sediments. A similar correlation was found for the Baland Bank – Westdiep – Stroombank interaction zone and in the Westdiep – Broers Bank interaction zone by Van Lancker & Jacobs (2002) and Van Lancker et al. (2000).

The sediments of the non-overlapping part of the new dumping site with the old one are, in contrast with the sediments of the old one, moderate to very poorly sorted sediments with a high silt-clay fraction. Stronkhorst et al. (2003) made the same observations for a new and an old dumping site near the harbour of Rotterdam.

Towards the extraction of sand for fill and replenishment purposes, it seems that the sediments of the old dumping site might be suitable. They have a grain-size ranging between 0.35 mm (1.5 phi) and 0.177 mm (2.5 phi), are well sorted, have a silt-clay fraction lower than 12 % and contain less than 20 % shell fragments. Chemical analysis, done by the firm ‘Servaco’ by order of ‘NV Nieuwpoortse
Handelsmaatschappij’, on 7 samples (ST0303_SV1-5, ST0309_SV4-5), also show that the sediments are not contaminated. Nevertheless there is only limited information available, as only a small part of the extraction zone has been investigated. A more sound investigation on the physical and chemical characteristics of the sediments, the internal architecture of the dumpsites and the available stock is highly recommended. It seems unlikely that it concerns a homogenous mass, moreover that in the past the dumpings did contain waste material.

Regarding the sediments of the non-overlapping part of the new dumping site with the old one, other conclusions have to be drawn. As it is situated in a swale, sedimentation is much more heterogeneous, muddier sediments occur and as such potential pollution may be trapped in depth. The boxcore ST0304_SV24, which contains two silt layers enclosing a sand layer, is a good proof of this process (Figure 15).

As a final conclusion one can state that an overall assessment is recommended, whereby in depth coring and sampling should be considered.

![Figure 15. Sedimentological results of the boxcore SV24 of campaign ST0304.](image)

**Results from acoustic seabed classification**

Besides the bathymetrical data, the multibeam system also acquires backscatter (BS) data. Based on these BS data, an acoustical image of the seabed can be established by using the Poseidon and Triton module of Kongsberg Simrad (Kongsberg Simrad, 2001).

The Poseidon module produces a sonar mosaic by calculating a grid (equivalent to a digital terrain model where z = BS) using two algorithms. The Triton module is used to perform an acoustic seabed classification and this based on a statistical ground. By comparing the BS values to each other, classes can be defined using 5 statistical features: quantile, pace, contrast, mean and standard deviation. Only the first three are used here. A class is created after identifying regions with homogenous values of these features and afterwards the class is used on the whole dataset. In view of striving towards a restricted amount of classes that are applicable over the whole BCS, existing classes of the Federal Public Service Economy, SMEs, Self employed and Energy – Marine Sand Fund were used. They were defined in sandbank areas on the BCS (Figure 16) (Roche, 2002), but proved to also work in this region.
The classification maps of campaign ST0304 (February 2003) and ST0309 (March 2003) show a clear similarity (Figure 17). Only small changes in the non-overlapping zone of the new dumping ground with the old one occur due to dumping activities. As the backscatter data of campaign ST0309 have a better quality, they will be used for further analyses. The line patterns are artefacts reflecting the insufficiency of the Simrad algorithm to compensate the geometry of the backscatter strength.

Combining the BS map and the acoustic seabed classification map of the campaigns ST0303 and ST0309 gives a good indication about the nature of the sediments (Figure 18 & 19). However to validate the statements, we need to ground-truth them with the sedimentological results. Table 2 gives the characteristics of each class based on the analysis of the boxcores. A comparison with the morphology map is also made to investigate the correlation between the BS and the morphology (Figure 20).
Between the two campaigns there is a difference of ± 2 dB. As the BS strength is influenced by many things, like weather conditions, the geometry of the sensor-target system, the type of tidal current, ...), it is not surprising that there is a small difference between the two campaigns, only 1 month apart. A higher difference of ± 5 dB occurs within the BS values of campaign ST0303. A light red line indicates the boundary. The cause of this jump is not clear.

To enable a better comparison, a manual classification of the BS data was done and the resulting polygons were overlaid on the other maps. Based on the BS values 3 types of regions were defined: regions with high (red polygons), intermediate (blue polygons) and low (black polygons) backscatter values (Figure 18). The low backscatter values (-35 dB) are found in the central zone of campaign ST0309 and along the southwest part of ST0303. These zones correspond with a region of low reflectivity, likely indicating the presence of soft sediments. In order to confirm the origin of these low reflecting areas, the results are compared with the classification and sedimentological results. It is clear that class C4 is present in this zone and Table 2 shows that fine well-sorted sands are associated with it. This is in agreement with the observations of Roche (2002). Comparison between the backscatter and morphological map shows that low BS strengths are found on the highest parts of the study area.

High BS values (-10 dB), corresponding with regions with a high reflectivity, were especially registered during campaign ST0309. This would lead to the conclusion that harder sediments characterize this zone. Compared to the classification map, this zone is associated with class C3. However when looking at the sedimentological table, this class can be split into two groups. The first one is characterised by fine to medium sandy sediments containing shell fragments, which could cause the high BS values. The same high BS values are found on the map based on side-scan sonar data (Figure 21). When using the standardised table as developed by Van Lancker et al. (2003), the acoustic facies was described as having a grainy texture with a mottled to patchy pattern (acoustic facies 15). The sediment interpretation was predicted as sand with a silt/clay enrichment and high shell hash amount. Processes involved are biologically altered and the facies mainly occurs along sandbank slopes to swales. Following the Table, the macrobenthos prediction would be a rich to very rich Abra alba - Mysella bidentata community. It needs emphasis that the Table was set-up for the near coastal area, but apparently it is also applicable further offshore. The second group is characterized by muddy sand with no shell fragments. The reason for this high backscatter is not clear. Roche (2002) suggested the occurrence of annelida, polychaetes cementing the sediments.

The remaining zones are characterized by intermediate BS values and are mainly found in the northern part of campaign ST0309 and, except for the southwest area, all over the campaign ST0303. Within this BS range a distinction can be made between the higher (-16 -19 dB) (light blue polygon) and lower (-20 -23 dB) intermediate values. Compared to the classification map, the higher and lower intermediate values correspond to respectively class C3 and class C2-5. Looking to the sedimentological results, class C3 is characterized by fine muddy sand. There are no shell fragments, which could explain the lower reflectivity compared to the zone on the northern slope of the old dumping site. Class C2-5 represents sands with different grain-sizes (range medium sand: 4– 65 %; range fine sand: 30–90%) (Table 2). Compared to the morphology map, this zone is characterised by bedforms, with ripples occurring in the lower parts and small to large dunes on the sand piles. Similar results were found by Roche (2002). In this zone of intermediate BS, the central part of campaign ST0303 is a more complex zone, where bedforms pattern can be distinguished (pink polygon). Draping the BS map over the terrain model (2 x 2 m resolution, 10 x magnification) gives a better insight in the BS pattern (Figure 22). It seems that fine sediments (low backscatter values) occur on the crests and the steep slope of the large dunes, while coarse sediments (high backscatter values) are present on the gentle slope. As the location of the boxcore samples ST0303_03/04/05 was not ideal to prove this statement, supplementary measurements were done during campaign ST0425a. However the analyses are still ongoing, so no results can be presented at this moment.
Figure 18. Backscatter map based on multibeam recordings during campaigns ST0303 and ST0309 (©Kongsberg Simrad).
Figure 19. Acoustic seabed classification map based on multibeam recordings during campaigns ST0303 and ST0309 (Kongsberg Simrad)
Figure 20. Morphology map based on multibeam recordings during campaigns ST0303 and ST0309 (Kongsberg Simrad)
Table 2. Correlation diagram representing the BS values and the characteristics of each class (number of samples, mean and range of the sedimentological parameters (FWb_mean: mean of the bulk fraction calculated according to Folk & Ward (1957); FWb_sort: analogous, but for the sorting)).

<table>
<thead>
<tr>
<th>BS value</th>
<th>Acoustic dB class</th>
<th>Nb of samples</th>
<th>Grain-size fraction</th>
<th>Mud (%)</th>
<th>FWb_mean (phi)</th>
<th>FWb_sort (phi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coarse</td>
<td>Medium</td>
<td>Fine</td>
<td>Very Fine</td>
</tr>
<tr>
<td>highest</td>
<td>Kw0131c1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>4</td>
<td>59</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td>21-57</td>
<td>0.2-0.3</td>
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<td></td>
<td></td>
<td>Mean</td>
<td>0</td>
<td>39</td>
<td>0.2</td>
</tr>
<tr>
<td>intermediate low till -19</td>
<td>Kw0131c25</td>
<td>13</td>
<td>Range</td>
<td>0-8</td>
<td>92-100</td>
<td>4-65 30-90 2-6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>2</td>
<td>98</td>
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<td></td>
<td></td>
<td></td>
<td>1</td>
<td>26</td>
<td>70</td>
</tr>
<tr>
<td>-20 till -19</td>
<td>Kw0131c3</td>
<td>4</td>
<td>Range</td>
<td>0.00</td>
<td>30-100</td>
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<tr>
<td>low</td>
<td>Kw0131c4</td>
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<td>Range</td>
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<td>15-100</td>
<td>0.1-0.9</td>
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<td></td>
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<td>19</td>
<td>77</td>
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</tbody>
</table>
Figure 21. Side-scan sonar image recorded image ST0309. The red delineated zone corresponds with acoustic facies 15, as defined by Van Lancker et al. (2003). This facies was correlated with rich to very rich benthic communities.
2.2.7. Macrobenthos diversity and species richness

Within the area of the Sierra Ventana, 40 stations were sampled for their macrobenthos: 29 stations in February 2003 and another 11 stations in March 2003. The sampling was concentrated in the zones of the old and new dumping site.

The macrobenthic density was found between 0 and 2690 ind./m² in February 2003 and between 88 and 741 ind./m² in March 2003 (average: 257 and 278 ind./m², respectively) (Figure 23). The species richness ranged between 0 and 18 spp./0.12m² (February 2003) and 4 and 14 spp./0.12m² (March 2003) (average: 3 and 7 spp./0.12 m², respectively). The area can thus be considered as relatively density- and species-poor.

![Figure 22. Backscatter data draped over a digital terrain model of 2*2 m (vertical exaggeration: 10x).](image)

![Figure 23. Macrobenthic density and species richness in the Sierra Ventana region during the three sampling campaigns. Macrobenthic density: full circles, left Y-axis; Species richness: open circles, right Y-axis.](image)
The study area is characterised mainly by the presence of the *Nephtys cirrosa* community and its transitional species associations (Table 3), though in February 2003 a high number of stations (10 stations; 34%) were not classified because no macrobenthic fauna was found within the samples.

Table 3. Macrobenthic species association sample designation. MB, *Macoma balthica* community (Degraer et al., 2003); Species association 1 (SA1), *Abra alba – Mysella bidentata* community; SA4, *Nephtys cirrosa* community; SA6, *Ophelia limacina – Glycera lapidum* community; other SA’s: transitional species associations (Van Hoey et al., 2004); INC, inconclusive samples; EMP, no fauna present.

<table>
<thead>
<tr>
<th></th>
<th>MB</th>
<th>SA1</th>
<th>SA2</th>
<th>SA3</th>
<th>SA4</th>
<th>SA5</th>
<th>SA6</th>
<th>SA7</th>
<th>INC</th>
<th>EMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 2003</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>10</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>March 2003</td>
<td>6</td>
<td>2</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
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<td>5</td>
<td>6</td>
<td>20</td>
<td>3</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Figure 24 is a spatial distribution map of the macrobenthic communities including an indication of the total amount of individuals per sample. Note the clustering of the samples with no fauna present (0), respectively in SW and SE of the old dumping site. The highest amount of individuals is found to the NE; the area where acoustic imagery also gave an indication of biological alteration.
Figure 24. Spatial distribution of the macrobenthic communities and the total number of individuals per sample ( ). Sample group C corresponded with the Abra alba – Mysella bidentata community. Sample group E corresponded with the Nephtys cirrosa community. Sample group G corresponded with the Ophelia limacina – Glycera lapidum community. Sample groups D and F were defined as transitional species assemblages, each representing a link between two “parent communities”.

2.2.8. Summary

There is a clear morphological and sedimentological difference between the new and the old dumping ground. The new one is characterised by dredge spoils and negative structures consisting of muddy sand, whilst on the old one bedforms consisting of medium to fine sand occur. It seems that the old dumping site has restored a morphodynamic equilibrium after the closure in 1999. Since then, a clear correlation between the morphology and sedimentology has been established, with the highest dunes, consisting of the coarsest sand, occurring on the sand piles; smaller dunes occur on the slopes and ripple fields in the depression.

Generally, the acoustic seabed classification based on multibeam backscatter values reveals in general a good correlation between the BS strength and the type of sediments, especially for fine sediments.

Towards the extraction of sand for fill and replenishment purposes, it seems that the sediments of the old dumping site might be suitable. Nevertheless there is only limited information available, as only a small part of the extraction zone has been investigated in the <Marebasse> framework. More information on the physical and chemical characteristics of the sediments, the internal architecture of the dumpsites and the available stock is needed. It seems unlikely that it concerns a homogenous mass, moreover that in the past the dumpings did contain waste material. As the new dumping site is situated in a swale, potential pollution may be trapped in depth; so before opening the extraction zone 3b an overall assessment is recommended, whereby in depth-coring and sampling should be considered.

For the area of the old dumping site, biological analyses showed the presence of mainly the Nephtys cirrosa community and its transitional species associations. The area is regarded density- and diversity poor.
2.3. Environmental characterisation of the southern part of the region of the Hinder Banks

2.3.1. Introduction

The region around the southern parts of the Westhinder and Oosthinder is known to be characterized by gravely sediments (Deleu, 2001) and these are mainly found in the swales between the sandbanks. Moreover, they probably represent the largest stocks close to the seabed surface of the Belgian continental shelf. As these sediments form the third key sediment type in the Marebasse project, it was decided to focus on these swales bordering the southern parts of the Westhinder and the Oosthinder. This can be seen as an area comparable, from a sediment-dynamical point of view, to the new exploration zone for future gravel and sand extraction further up north. The Fund for Sand Extraction (FSE) will mainly explore the latter zone and as such the present measurements are complementary.

2.3.2. Setting

The focus in this large area is the swales east and west of the Oosthinder and Westhinder. These reach depths of 35m below MLLWS and witness almost no dune structures. The dominant sedimentology is a mixture of coarse sand with gravel and sometimes a slight amount of mud. The banks in between the swales show the occurrence of very-large dunes consisting of sand.

2.3.3. Historical perspective

Geology

According to D’Olier (1981), the Flandrian sea-level rise caused a transgression over an initial surface topography whereby the present sandbank positions and shapes reflect ancient transitory islands, coalesced beaches, confluent channel bars and changing coastline positions. It is known that in this region of the North Sea, most of the underlying Palaeogene units consist of muddy sediments, alternated with only a few sandy layers (for a synthesis see Le Bot et al., 2003). On top of these are, apart from scour hollow infillings with Pleistocene sediments, the sandbanks, which consist of Holocene sediments. Over this area of the BCS, a Holocene thin gravel lag veneer forms the lower part of the Holocene sediments followed by a sandy succession. Kirby & Oele (1975) found out that in the nearby Sandettié – Fairy Bank area there is a well-developed graded succession from flint and shell gravel at the base through shelly quartz sands. This succession indicates a decrease in energy conditions at the bed during the period of deposition and a slow regional rise in sea-level during the Flandrian. Most probably the succession is a drape over an originally irregular seabed. This is clear in Figure 25 where the contours of the thickness of the Holocene clearly follow the present bank topography and reveal the initial lows and highs. Moreover, the yellow polygons representing the Holocene thickness less than 2.5m are located in the swales between the banks, indicating possible source areas where gravel can be found.

A clearly identifiable geological feature is the scarp that traverses the region of the hinder Banks from east to west (Figure 25). The scarp is easily recognized in the multibeam imagery (Figures 28 & 30) and even on a larger-scale digital terrain model based on single-beam measurements. From south to north this scarp involves a depth decrease of 2 to 3m.
Sedimentology

An investigation by Veenstra (1964) based on 50 Van Veen samples in the region of the Hinder Banks reveals the present distribution pattern of gravel in the swales with the highest amounts to be found near the southern parts of the Westhinder and Oosthinder (Figure 26).
2.3.4. Morphology

Multibeam measurements

UG-RCMG has been recording multibeam data with the Simrad EM1002S aboard the RV Belgica during several campaigns. The first recordings were done during campaigns ST0025 and ST0030. One mosaic was recorded over the Westhinder kink (Deleu et al., 2004) and several parallel lines were recorded over the whole region of the Hinder Banks with a line spacing of 2km (Deleu, 2001). These lines served as a basis for an acoustic seabed classification (Figure 42) and give an overview of the present morphology (Figure 27).

The full coverage multibeam data of the region of the Hinder Banks, recorded during later campaigns, have not been all tide-corrected, but will be in the near future (Figure 28). This causes the map not to have a uniform colour scale. Full coverages have been established during campaign ST0030 on the Westhinder kink (Figure 29), during campaign ST0404 in the swale east of the Oosthinder (Figure 30), during campaign ST0424 in the swale between the Westhinder and the Oosthinder (Figures 31 & 32), during campaign ST0425 over the southern part of the Oosthinder (Figure 33) and during campaign ST0502 over the Westhinder and over the southern part of the Oosthinder (Figure 34).

A closer look at the detailed morphology reveals the known veering pattern of the very-large dunes over the sandbanks. The swales are characterized by a “bumpy” pattern revealing clearly the underlying gravel topography. Playing with the colour scale clearly shows this specific topography.
Figure 27. Overview of the uncorrected multibeam bathymetry recorded in parallel lines from campaign ST0025 and ST0030 (UG-RCMG).
Figure 28. Overview of the recorded multibeam data until June 2005. Not all data are tide-corrected.

Figure 29. Corrected multibeam bathymetry image from campaigns ST0025/ST0030 covering the kink in the Westhinder and the swale east of it (Deleu et al. 2004).
Figure 30. Corrected multibeam bathymetry image from campaign ST0404/ST0405 covering the southern part of the Oosthinder and the swale east of it.

Figure 31. Uncorrected multibeam bathymetry image from campaign ST0424 in the swale between the...
Westhinder and Oosthinder. The Norfra pipeline can be found in the upper left inset.

Figure 32. Uncorrected multibeam bathymetry image from campaign ST0424 in the swale between the Westhinder and Oosthinder sandbank. The lower left inset shows the typical “bumpy” pattern, characteristic for gravel areas. The upper right inset shows the poor quality of the last trackline recorded during bad weather conditions.

Figure 33. Uncorrected multibeam bathymetry image from campaign ST0425 partly in the swale
between the Westhinder and Oosthinder sandbank and partly over the southern part of the Oosthinder. The lower left inset shows a wreck (Kilmore SS (http://users.pandora.be/tree/wrakken/wrakken-database/detail_query.html?filter=60)) as well as the right inset.

Figure 34. Uncorrected multibeam bathymetry image from campaign ST0502. a) Imagery of the southern part of the Oosthinder revealing very-large dunes. B) Imagery of the eastern flank of the Westhinder.

2.3.5. Surficial sedimentology

Video recordings

Video recordings have been performed during two campaigns in the swales bordering the southern part of the Oosthinder. The recordings in the swale between the southern parts of the Westhinder and Oosthinder show higher amounts of gravel and larger individual fragments. In one spot, fragments of at least one meter have been observed. In the swale east of the Oosthinder, video imagery shows higher gravel amounts in the southern part of this region and higher amounts of sand north of the scarp where, from acoustic seabed classification and sample results it is known to be a sandy region. Also, in between the barchan dunes in the northeastern part of the image, gravel has also been detected.

It is clear from all of the measurements that there is no continuous gravel seabed surface, but that the gravel spots are more or less isolated and the rest of the region consists of gravel covered by a sand blanket. The following images show some video frames of the recordings made during campaigns ST0424 (Figure 35) and during campaign ST0502 (Figure 36).
Figure 35. Video frames recorded during campaign ST0424 in the swale east of the Oosthinder.
As it is clear from the video imagery, samples taken with a Van Veen grab in the past gave erroneous high amounts of gravel as a large part of the finer fraction was washed away during recovery. Gravel stones blocking the valves of the grab caused this. The new Hamon grab highly increases the probability of successful sampling and provides a more confidential result.

According to Veenstra (1969), the gravel can be found in a layer at a uniform depth of 35m. This continuous gravel bed off the Belgian coast could represent an old beach plain, on which during the Flandrian transgression, sand ridges were built up by the sea (Veenstra, 1969). As the gravel is sometimes sub-rounded to angular, the pebbles might have a fluvial origin. Presumably Palaeogene
rivers that took up material from a weathering residue on the Ardennes transported the gravel. According to Veenstra (1969), the predominant rocks among the gravel are flint, sandstone, quartzite and limestone, including chalk (Figure 37). Most probably the large amount of flint pebbles finds its origin in the Cretaceous deposits outcropping in the Strait of Dover (Tytgat, 1989) whereas the more weathered light-coloured pebbles with a nucleus frequently occur in the Diestian formation and at the base of the Palaeogene. The sandstone pebbles are mostly well rounded and are either similar to those of the Diestian Formation or similar to those of the Mont-Panisel Formation (Tytgat, 1989). The smaller well-rounded quartz grains probably have a Rhine and/or Meuse origin. Igneous rocks are less important and account generally less than 5%. A remarkable feature is that flint occurs more as large fragments (>8mm), quartz occurs more as small fragments (1–4 mm) and limestone, quartzite and sandstone are equally distributed over the grain-size range.

Figure 37. Gravel fragments coarser then 16mm from Van Veen grabs taken during campaign ST0030. Rounded as well as angular fragments can be seen.

Side-scan sonar recordings during cruise ST0424 permitted to do a visual mapping of all the found objects. All of these objects are most probably stones. From the resulting map (Figure 38), it is clear that their distribution is random. Nevertheless the inset shows that there is a higher concentration in the middle and southern parts where the multibeam morphology clearly points to a gravel region and the side-scan images reveal that the largest objects were found here (Figure 39). The yellow polygons representing the Pleistocene/Holocene thickness less than 2,5m (Figure 38) mostly coincides where stones were found, but it is no necessity for gravel occurrence.
Figure 38. Overview of the stones detected on the one hand with the side-scan sonar (inset) and on the other hand by army divers. It should be pointed out that this is not a complete mapping as the divers only followed certain routes and also the side-scan sonar box was relatively small.
2.3.6. Acoustic seabed classification

For the acoustic seabed classification of the region of the Hinder Banks, classes were used which are defined by the Fund for Sand Extraction (FSE) (Roche, 2002). These classes represent relative large polygons with the purpose to use them in different areas. In total 4 classes are used in the region of the Hinder Banks based on 5 classes defined by FSE.

The backscatter signal is used to calculate five parameters. These are extracted each ping in four integrated sectors (first sector is from beam 1 to beam 28, second sector is from beam 29 to beam 56, third sector is from beam 57 to beam 84 and the fourth sector is from beam 85 to beam 112) (Figure 40). When 4000 backscatter values are recorded in one sector over successive pings (maximum 20), the values are integrated into a patch on which the five parameters are calculated (Roche, 2002). This often causes the image to have a linear striped pattern, as there is no correlation or compensation foreseen between adjacent sectors.
Figure 40. Presentation of the ‘patches’, i.e. the spatial units on which the 5 parameters are calculated (Kongsberg Simrad).

For this reason, it was decided to use three parameters, which don’t visualize this linear pattern. For the separate lines a spectral (Pace), a textural (contrast) and a statistical (quantile) parameter (Figure 42) is calculated. Lines, however which were recorded in a mosaic, proved to give better results with the use of quantile, contrast and standard deviation (Figures 41 & 43). Moreover the outliers were every time set to white to give a better visual result as the patches in the outlier class can never be interpreted.

Figure 41. Plots of the three used features: quantile, contrast and standard deviation.
Figure 42. Overview of the whole region of the Hinder Banks. Results are obtained from following campaigns: ST0025 and ST0030, based on Deleu (2001).

Table 4. Values of the four used parameters for class 1 to class 5 from Roche (2002).

<table>
<thead>
<tr>
<th></th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
<th>Class 4</th>
<th>Class 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantile</td>
<td>-27 dB</td>
<td>-33 dB</td>
<td>-29 dB</td>
<td>-41 dB</td>
<td>-35 dB</td>
</tr>
<tr>
<td>Pace</td>
<td>47</td>
<td>55</td>
<td>51</td>
<td>70</td>
<td>59</td>
</tr>
<tr>
<td>Contrast</td>
<td>7.7</td>
<td>7.0</td>
<td>7.5</td>
<td>5.2</td>
<td>6.6</td>
</tr>
<tr>
<td>STD</td>
<td>5.8</td>
<td>5.8</td>
<td>5.9</td>
<td>5.1</td>
<td>5.6</td>
</tr>
</tbody>
</table>

From the interpretations and the correlations with sedimentology of Roche (2002) (Table 4) it is clear that class 1 corresponds with coarse sand mixed with gravel and shells. This is also clear in the region of the Hinder Banks where it is known from previous sampling campaigns that the region around the southern parts of the Westhinder and Oosthinder are more gravelly then further up north (Deleu, 2001) (Figures 18 & 19). Especially the swales west and east of the southern part of the Oosthinder are characterized by sometimes large stones and these were seen in the Hamon grab samples and on the video images.
According to Roche (2002), class 4 corresponds with homogeneous fine sand. This is clear from the low BS value and from the low standard deviation and contrast values, contrary to those of class 1. This class flourishes most importantly on the top of the southern part of the Oosthinder, west of the kink of the Westhinder and further up north on top of parts of the Noordhinder, Bligh Bank, Oosthinder and Westhinder (Figure 42). This has been cross-correlated with sediment samples east of the Westhinder kink (Figure 43).

Class 3 has high backscatter, standard deviation and contrast values and seems to be relatively comparable to class 1, but characterized by finer sediments (as can be seen on the ellipses, Figure 41). This class can be seen as the transitional class between class 1 and classes 2 and 5, what becomes clear when looking at its spatial distribution (Figures 42 & 43). Probably the sediment corresponds with coarse sand, mixed with shell fragments.

The last two classes are class 2 and class 5 and when looking at the values of the parameters (Table 4), these classes are rather similar and can be taken together as class 2/5. The values of the 5 parameters make it logical that it is a transitory class between class 3 and class 4. It is located where dune structures are present as well in the swales as on parts of the banks. It correlates most probably with medium sand.

A quantitative correlation of the classes with the sedimentological results still has to be made, based on the samples recovered with the Hamon grab.

Figure 43. Automated seabed classification based on the EM1002 multibeam backscatter. Detail of, forming the study area. Results are shown for the southern region of the Hinder Banks and the data were obtained during the campaigns: ST0030, ST0404, ST0415, ST0424, ST0425 and ST0502.
2.4. Aggregate resource evaluation in view of the sustainable management of the new extraction zone at the western extremity of the Gootebank

An aggregate resource evaluation of the western extremity of the Gootebank has been carried out in the view of a sustainable management of this new concession zone (for a localisation see Figure 1, zone 1b). Field data were acquired by the Federal Public Service Economy, SMEs, Self-employed and Energy-Marine Sand Fund, using a multi-beam echosounder (EM1002, RV Belgica, March 2004 (GB0406), October 2004 (GB0423) and November 2004 (GB0426)). In addition, the Ministry of the Flemish Community, Sea Fisheries Department sampled the surficial sediments for biological purposes in September 2004 (RV Belgica ST0421, 25-30/09/2004) using a Van Veen grab sampler. Grain-size results were provided for this study. The very high-quality bathymetrical and backscatter data were processed into detailed morphological, backscatter and classification maps and were evaluated against the sedimentological information, the geological background and the present hydrodynamical and sediment transport regimes. Details of this research can be found in Delye (2005). The methodologies correspond to those described in the previous sections.

The study area is characterized by the presence of many asymmetric dune structures ranging from very-large dunes in the southern part (up to 6 m) to smaller dunes northwards or completely no dune structures in the northwestern and northeastern regions. The sediments forming the dune structures have mean grain-sizes ranging from 250 µm in the southwestern area up to 400 µm in the southeastern part, corresponding to medium grained sands. No high silt or clay percentages are found.

The extreme high resolution of the morphological chart allows studying the morphology of the area in detail. The asymmetry of the dune structures gives an indication of the main transport directions. This bedform-derived transport seems to be consistent with the results of hydrodynamical and sediment transport models. The bedform-derived transport directions suggest that most dunes are formed by a residual flood current, except for the western and eastern extremity where the ebb current dominates.

Backscatter results were compared with the morphological chart and the results of the sediment classification. Based on these results, four different areas can be distinguished. Three high-reflecting regions (No 1) in the north seem to correspond with the occurrence of gravel and coarse sands of 600-800 µm. Additionally, a weight percentage of gravel of almost 30 % is found. However, the lack of Holocene sediments combined with a weak current and relative low sediment transport in these regions, is not in favour of a sustainable aggregate extraction in these regions. The remaining region in the northern area (No 4) is characterized by intermediate backscatter values and the presence of mainly medium sands (mean grain-sizes of 275-375 µm). The hydrodynamics and sediment transport show a slightly higher regime compared to the adjacent northern regions, what could represent a more dynamic character.

It is put forward that the more interesting areas are present in the southern part. The southeastern area (No 2) is characterized by uniform low backscatter values corresponding with medium sands (275–325 µm), under the form of large dune structures. From the hydrodynamics and sediment transport it can be assumed that this converging region has the most dynamic character of the area, improving a fast regeneration and hence in favour of a sustainable aggregate extraction.

The most complex and interesting southwestern area (No 3) can be divided in a western and eastern part according to differences in the hydrodynamics and sediment transport. This area is characterized by high backscatter values along the large to very-large dunes combined with lower backscatter values in between the dune structures. Corresponding sediment classes suggest the occurrence of coarser sediments on the dune structures with coarse to medium sands in between. The sediment samples confirm a range of 400-600 µm in mean grain-size and locally slightly higher gravel percentages occur. Evidence of gravel dunes is not found.
Figure 44. Multibeam-based digital terrain model of the area showing the complex dune morphology in the area and less to no bedforms to the north. Dune heights are indicated and reach up to 6 m.

A weaker current regime in the western part of region No 3, results in less dune structures with broad interdune patches. This suggests that this is a less dynamic area. Both the more pronounced morphology and the hydrodynamics in the eastern part of region No 3, suggest a more dynamic character, making it less sensitive to the physical (and biological) effects of aggregate extraction and in line with a sustainable aggregate extraction approach.

Although the very high resolution and highly qualitative acoustic datasets, there is a need for a further quantitative sedimentological characterisation. Both sampling and video imaging are needed to confirm both the resource potential as the biological richness in the different regions.
Figure 45. Multibeam-based backscatter map showing clear differences in seafloor reflectivity, both morphology and sediment-driven. The lowest backscatter (light) values correspond to coarser sediments.

Figure 46. Automated seabed classification based on the multibeam backscatter data.
2.5. Set-up of environmental assessment tools and strategies

2.5.1. Set-up of acoustical evaluation tools

Results of the acoustical seabed classification, related to the Marebasse project, are being discussed in the paragraphs on the old dumping site of the Sierra Ventana, Hinder Banken, Goote Bank and on the Kwinte Bank. Some aspects and problems were discussed before in Van Nieuwenhove (2003) and Darras (2004). However, more work is needed before quantitative relations between acoustic classification and true seabed sediment nature over the shelf can be discussed in detail. The datasets that will allow a good evaluation are presently under compilation. Up till now, different aspects have been studied separately as also the biological nature (macrobenthos densities and species richness). This data will be coupled to the acoustic imagery to further elaborate the concept of an eco-morphological sonar interpretation as proposed by Van Lancker et al. (2003a,b).

The acoustical seabed classification based on multibeam backscatter is worked out in close cooperation with the Marine Sand Fund. This enables to define and validate seabed classes that are valuable for the range of seabed sediments types over the Belgian shelf. In this report, the results on the multibeam derived acoustic seabed classifications are based on seabed classes that were derived by the Marine Sand Fund (Roche 2002) in the areas of the concession zones. Apparantly, they are also very useful for the areas investigated within the Marebasse framework. As such, it is clear that common seabed classes can be derived that are spatially and temporarily valid. This research topic will be discussed with other scientists during the final Marebasse workshop.

Furthermore, the use of acoustic techniques in terms of habitat mapping are investigated in detail in the Interreg IIIb project MESH. The Marebasse datasets will provide valuable information in this perspective.

2.5.2 Set-up of sampling tools

One of the key investigation areas in the Marebasse project are those characterized by coarse sediments. Sampling these is difficult because, due to a washing out of the finer fraction, it is utmost difficult to obtain representative samples of the seafloor with a Van Veen grab. With the use of the Hamon grab, the loss of sample through ‘wash out’ is kept to a minimum, enabling to obtain a quantitative, representative sample.

The grab consists of a rectangular frame forming a stable support for a sampling bucket attached to a pivoted arm and can be deployed from a standard ship’s crane (technical details can be obtained upon request). The original design of the Hamon grab was suited for the sampling of areas of about 0.25m². However, more recently, CEFAS has introduced a smaller device with a sampling area of 0.1m² (mini Hamon grab). As 0.1m² is the conventional surface sample unit employed in most benthic surveys of continental shelf sediments, conformity with this size allows a better comparison of results with those from a wide variety of sources using a range of other sampling devices.

As mentioned in the 2nd scientific report (Van Lancker et al. 2004), it was proposed to both MUMM and VLIZ to consider the purchase of a Hamon grab that would enable a more quantitative sampling of coarser substrates. Subsequently, an official demand was formulated (see Annex A). Based on this document, VLIZ purchased the Hamon grab and made it available to the research community from February 2005 onwards.

Since then, the Hamon grab has been used successfully used on board the RV/Belgica. Gravel samples have been taken by UG-RCMG during campaign ST0502 close to the West- and Oosthinder and during campaign ST0512, offshore of Cadiz. The Department of Sea Fisheries (Ministry of the Flemish Community) also used the grab during campaign ST0504. The grab can also be used from the Zeeleew and this has been done during campaign 05-314 (UG-RCMG). The results were very satisfying and it
proved that the grab is a suitable instrument to sample gravely areas. Moreover the instrument is user-friendly and works also quite well with a rougher sea-state. 3 crew members and 3 scientists are needed.

Figure 47. Examples of Hamon grab samples as obtained during the Marebasse campaigns.

Figure 48. Side-views of the Hamon grab.

2.5.3 Set-up of modelling tools (hydrodynamic and sediment transport) (ref. 2nd scientific report)
3. ASSESSMENT OF AN ENVIRONMENTAL IMPACT (EIA)

An intensive integrated site surveying (WP3) is carried out on along the central part of the Kwiinte Bank. Marine aggregate extraction led to an elongated depression that is presently 5 m below the reference level. As such, exploitation was stopped since February 15, 2003 for 3 years. Cause and effect research is carried out to evaluate the true impact of this high level of exploitation and to study regeneration processes.

Detailed integrated fieldwork has been carried out (Task 3.1.1). This is in cooperation with the Federal Public Service Economy, SMEs, Self-employed and Energy, responsible for the follow-up of this area (Marine Sand Fund). Moreover, the fieldwork was complemented with experience and instrumentation related to the Fifth Framework Research Training Network EUMARSAND (European Marine Sand and Gravel Resources).

Basically, the environmental characteristics of the area of impact are studied using the techniques described in WP2 (Task 3.1.2). Supplementary, high resolution seismic investigations were carried out to study to what level the exploitation has taken place and to evaluate the resource availability in general. Ground-truthing (Task 3.1.3) included video imaging to optimally characterise the area of impact. Hydrodynamic and sediment transport measurements (Task 3.1.4) were also carried out using a.o. an instrumented tripod including CTD, OBS and LISST-100 instrumentation. Supplementary, a bottom-mounted ADP is used for current measurements over the vertical. The tripod is suited to measure intensively the processes on a specific site and is thus complementary to the sediment transport measurements at a larger scale.

3.1 Field experiments (ref. 1st and 2nd scientific report)

3.1.1. Acoustic measurements (ref. 1st and 2nd scientific report)
3.1.2. Ground-truthing (sampling) (ref. 1st scientific report)
3.1.3 Hydrodynamic and sediment transport measurements from a research vessel and through the use of a multisensor benthic lander (ref. 1st and 2nd scientific report)

3.2. Environmental characterisation of a site subdued to sand extraction: the Kwiinte Bank central depression (also ref. 2nd scientific report)

3.2.1. Physical study of the hydrodynamical regime, the wave climate and sediment transport patterns on the Kwiinte Bank: set-up of numerical models (Task 3.2.1.) (also ref. 2nd scientific report)

Hydrodynamical regime

OPTOS-FIN model
To model the currents and the water elevation on the Kwiinte Bank in detail, a three-dimensional hydrodynamic model with high resolution (273 m x 257 m) is used. The model is based on the COHERENS code (Luyten et al., 1999). The implementation of the model on the Belgian Continental Shelf was already discussed in Van Lancker et al. (2003) en Van Lancker et al. (2004). The validation of the model was executed using about 400 hours of current data of a bottom mounted Acoustic Doppler Current Profiler (ADCP) type Sentinel 1200 kHz Workhouse from RD Instruments. The validation showed that the Root-Mean-Square-Error (RMSE) of the norm of the currents usually is less then 15 cm/s and the relative error of the direction less then 15 % (Van Lancker et al., 2004).
TELEMAC model
To have better insight in the model results and the model performance, a separate numerical two-dimensional model was set up for the same area. This model is based on TELEMAC-2D release 5.5 (LNH/EDF) (see Appendix for model description). Due to the complexity of the geometry and the bathymetry of the North Sea the open boundary had to be shifted away from the shallow sea (Yu, 1993). Doing so, the number of tidal constituents is reduced to the number of astronomical tides only and, besides, the influence of the shallow water can be taken into account when the tidal wave propagates from open boundary up to the Belgian coast.
Four different bathymetric data sets (Table 5), have been used in order to build the computational mesh. A coarse mesh covers the northern part of the North Sea (Figure 49), the Irish Sea and part of the Atlantic Ocean (node distance ≈ 70 km); the southern part of the North Sea and particularly the Belgian coast have been further refined (node distance ≈ 800 m), as can be seen in Figure 50.

At the open boundary the tidal elevation has been regarded as the only external forcing to the model. Eight constituents (Q₁, O₁, P₁, K₁, N₂, M₂, S₂, K₂) have been considered sufficient to represent the complete tidal forcing for the modelled region. Atmospheric data (wind velocity component at 10 m height and atmospheric pressure) were obtained from the UK Met. Office (Van den Eynde et al., 1995). The data are available at 6-h interval, on 1.25° latitude/longitude grid; a spatial interpolation is then performed to obtain them on the computational mesh. A linear interpolation in time is made to calculate wind speed and pressure at each time step. For an accurate computation of the wind resistance a drag coefficient wind-velocity dependent has been implemented (see Appendix). Bottom friction has been calculated according Chezy formulation considering a water depth dependent friction coefficient (Verboom et al., 1987). Table 6 provides some of the physical and numerical parameters used for this model set-up.

Table 5. Geographical coverage and resolution of the bathymetric data set used for the Marebasse implementation of the TELEMAC-2D model

<table>
<thead>
<tr>
<th>Grid</th>
<th>Limits in latitude</th>
<th>Limits in longitude</th>
<th>Resolution in latitude</th>
<th>Resolution in longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>47.8333 N, 71.1667 N</td>
<td>12.25W, 12.25 E</td>
<td>0.333 deg., 0.5000 deg.</td>
<td></td>
</tr>
<tr>
<td>Local1</td>
<td>48.5000 N, 55.5000 N</td>
<td>2.75 W, 9.25 E</td>
<td>0.0667 deg., 0.1000 deg.</td>
<td></td>
</tr>
<tr>
<td>Local2</td>
<td>49.2333 N, 52.6333 N</td>
<td>0.05 E, 4.75 E</td>
<td>0.0222 deg., 0.0333 deg.</td>
<td></td>
</tr>
<tr>
<td>Bcp</td>
<td>51.0000 N, 51.3981 N</td>
<td>2.08 E, 3.20 E</td>
<td>0.0074 deg., 0.0111 deg.</td>
<td></td>
</tr>
</tbody>
</table>
Figure 49. Mesh used for the Marebasse implementation of the TELEMAC-2D model on the Northwest European continental shelf.

Figure 50. Mesh used for the Marebasse implementation of the TELEMAC-2D model at the Belgian continental shelf.

Table 6. List of parameters used during the Marebasse implementation of the TELEMAC-2D model.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spherical coordinates</td>
<td>Yes</td>
</tr>
<tr>
<td>Time step</td>
<td>60 s</td>
</tr>
<tr>
<td>Law of bottom friction</td>
<td>Chezy</td>
</tr>
<tr>
<td>Friction coefficient</td>
<td>Variable with water depth: $65 - 90 \text{ m}^{1/2} \text{ s}^{-1}$</td>
</tr>
<tr>
<td>Coefficient wind influence</td>
<td>Variable with wind speed: $0.565 - 2.513 \times 10^{-3}$</td>
</tr>
<tr>
<td>Turbulence model</td>
<td>Constant viscosity</td>
</tr>
</tbody>
</table>
Comparison with measurements
During two Belgica campaigns, measurements were taken with the bottom mounted ADCP. The sampling interval was 300 seconds. The profiles were taken with a vertical resolution of 0.5 m, with a maximum of 30 measurements over the profile. Information on the position and time of the measurements can be found in Table 7. An additional data set has been collected with an S4 directional wave current meter but, so far, these data have not been analysed.

Table 7. Measurements at the Kwinte Bank with bottom mounted ADCP. Lat.: Latitude in degrees North; Lon.: Longitude in degrees East; Dep.: Water depth referred to MLLWS; Dur.: Duration of the measurements

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2003/15</td>
<td>51°18'.</td>
<td>2°40.24'</td>
<td>17</td>
<td>11/06/03 16h30</td>
<td>25 h</td>
</tr>
<tr>
<td>2004/04-05</td>
<td>51°18'.</td>
<td>2°40.245'</td>
<td>02/03/04 12h45</td>
<td>9*24h</td>
<td></td>
</tr>
</tbody>
</table>

The two periods have been simulated with both models and compared with the available ADCP measurements. In Figure 51 to Figure 54 the depth-averaged current components and current speeds are presented for both periods and both models.

The root-mean-square-errors (RMSE) were calculated and are presented in Table 8. For the TELEMAC-2D model, only the minimum and maximum values of the U- and V-component are taken in account. As already found in Van Lancker et al. (2004), the RMSE of the models are less then 15 cm/s. For the March 2004 period, the RMSE for the norm of the currents even is around 7 cm/s. These results are clearly satisfactory.

Table 8. RMSE for the U-component, the V-component and the norm of the depth-averaged current for the OPTOS-FIN and the TELEMAC-2D model. For the TELEMAC-2D model only the extreme values are used to calculate the RMSE.

<table>
<thead>
<tr>
<th></th>
<th>#</th>
<th>OPTOS-FIN</th>
<th>TELEMAC-2D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RMSE U</td>
<td>RMSE V</td>
</tr>
<tr>
<td>2003/15</td>
<td>39</td>
<td>0.140</td>
<td>0.119</td>
</tr>
<tr>
<td>2004/04-05</td>
<td>421</td>
<td>0.069</td>
<td>0.083</td>
</tr>
</tbody>
</table>
Figure 51. Measured and modelled depth-averaged currents for the campaign 2003/15 with the OPTOS-FIN model. Top: u-component; middle: v-component; bottom: current speed.
Figure 52. Measured and modelled depth-averaged currents for the campaign 2004/04-05 with the OPTOS-FIN model. Top: u-component; middle: v-component; bottom: current speed.

Figure 53. Measured and modelled depth-averaged currents for the campaign 2003/15 with the TELEMAC-2D model. Top: u-component; middle: v-component; bottom: current speed.
Figure 54. Measured and modelled depth-averaged currents for the campaign 2004/04-05 with the TELEMAC-2D model. Top: u-component; middle: v-component; bottom: current speed.

Residual currents
Both models were finally used to calculate the residual currents during a spring-neap tidal cycle (14.8 days). These results are presented in Figure 55 and Figure 56.

Figure 55. Residual currents, as calculated by the OPTOS-FIN model.

The residual currents, calculated by the OPTOS-FIN model are very similar as the residual currents, which were calculated by the fine grid 2D hydrodynamic model and were presented in Van Lancker et al.
Also here a clockwise gyre can be found around the sand banks. On the western flank of the Kwinte Bank, the residual currents are following the bank, towards the northeast, while on the eastern flank of the bank the residual currents are in the opposite direction, to the southwest.

The residual currents, calculated by the TELEMAC-2D model show a more uniform residual current pattern with residuals to the northeast to northwest.

Figure 56. Residual currents, calculated by the TELEMAC-2D model.

Sediment transport pattern at the Kwinte Bank

Numerical models

The MU-SEDIM model was already described in detail in Van Lancker et al. (2004). Until now, two-dimensional hydrodynamic models drove the model. The MU-SEDIM model has been extended now, so be able to run with the results of the three-dimensional OPTOS-FIN model. The main characteristics of the model haven’t changed however and can be checked in Van Lancker et al. (2004).

Since the sediment transport models have still large uncertainties and the results of sediment transport model can vary over different order of magnitudes, it was found useful to implement another sediment transport model to the area. The results of the two models then could be compared to gain more insight in the sediment transport patterns. The SISYPHE (release 5.5) is a finite element morhodynamic model, part of the Telemac system models (LNH/EDF) and was implemented by KULeuven.

The model has been set-up on the same computational mesh used for the TELEMAC-2D computation. The total-load sand transport rate is calculated as a function of the hydrodynamic conditions, through internal coupling with the TELEMAC-2D model (see Appendix for model description). Where the MU-SEDIM model is based on the Ackers-White formula for total load, the SISYPHE models used the Engelund-Hansen formula. Some more characteristics and parameter values of the SISYPHE model are given in
Table 9. List of parameters used during the MAREBASSE implementation of the SISYPHE model.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment transport formula</td>
<td>Engelund-Hansen</td>
</tr>
<tr>
<td>Mean sediment diameter</td>
<td>200 µm</td>
</tr>
<tr>
<td>Hydrodynamic time step</td>
<td>60 s</td>
</tr>
<tr>
<td>Sediment transport time step</td>
<td>600 s</td>
</tr>
<tr>
<td>Coupling period</td>
<td>600 s</td>
</tr>
<tr>
<td>Porosity</td>
<td>0.37</td>
</tr>
<tr>
<td>Bottom friction</td>
<td>Strickler law</td>
</tr>
<tr>
<td>Strickler coefficient</td>
<td>55</td>
</tr>
<tr>
<td>Sediment density</td>
<td>2650 kg/m³</td>
</tr>
</tbody>
</table>

First results
As a first results, a simulation has been executed with the MU-SEDIM model for the period March 2\textsuperscript{nd} 2004 6h30 to March 17\textsuperscript{th} 2004 00h00, which comprises an entire spring-neap tidal cycle. For this first test, no influences of waves and meteorological conditions were taken into account. A constant grain size equal to 200 µm had been used as representative of the all domain. The residual total transport is presented in Figure 57.

Figure 57. Residual transport, calculated with the MU-SEDIM model, using the currents of the three-dimensional OPTOS-FIN model. On the background the bathymetry is shown.

The results are comparable with the results, obtained with the two-dimensional hydrodynamic model, which were presented in Van Lancker et al. (2004). Also here, the sediment transport is in the NE direction at the western flank of the bank, while along the eastern flank of the bank, the sediment transport is in the SW direction. The sediment transport clearly is higher on the western side of the bank, resulting in erosion at the western side of the sand bank and deposition on the eastern side. This is shown in Figure 58.
Figure 58. Erosion (blue) and sedimentation (red) patterns on the Kwinte Bank as simulated with the MU-SEDIM model, on the basis of the currents calculated with the three-dimensional OPTOS-FIN model.

For comparison, also with the SISYPHE model, the same first simulation has been executed. The simulation was run for the period 2 to 17 March 2004 and also here the flow velocity has been forced by tidal action only and a constant grain size equal to 200 μm has been used. Figure 59 shows erosion processes occurring to the west flank of the Kwinte Bank while sedimentation characterizes the eastern side. The results of both sediment transport models therefore are very similar, which is encouraging.

Figure 59. Bottom evolution from the simulation with the SISYPHE model for the period 2 – 17 March 2004.

Future work
To investigate more in detail the sediment transport on the Kwinte Bank, first of all, the effects of wind and pressure will be added to the tidal forcing in the hydrodynamic simulation in order to quantify the effects of meteorological factors on the Kwinte Bank morphodynamics. The effects of waves, superimposed to a mean current, will be also addressed. Higher bed evolution is expected due to an
enhanced shear stress in the bed boundary layer. Different wave conditions will be compared and their effect quantified in terms of bed evolution.

When a good insight in the sediment transport on the Kwinte Bank is obtained, different scenarios will be simulated to investigate the influence of massive extraction of sand on the sediment transport and the possible stability of the sand bank.

3.2.2. Characterisation of different sub environments on the Kwinte Bank

The present-day sandbank shows at its surface several bedforms ranging from small ripples to very-large dunes. On the side-scan sonar and the multibeam imageries, these bedforms sort in four areas around the central depression. Each area seems to have a particular sedimentary composition. In the following paragraphs, the different subenvironments are being described. Moreover, it has been investigated how these subenvironments link with the dominant current (flood or ebb).

The eastern part of the swale, in-between the Buiten Ratel and Kwinte Bank

The swale, west of the central depression, consists of heterogeneous sediments with mean grain-sizes in the range of fine to medium sand and with an admixture of a lot of shells and animals. The silt content is often higher than 5 % and large stones were sampled on the sea bottom. Locally, Tertiary clay can be found as also pre-Holocene stones (essentially flints) as the thickness of the Quaternary is minimal in this environment. At some occasions, strong currents may lead to the formation of erosional furrows eroding the underlying Tertiary clay and transport a variety of sediments in the direction of the sandbank. In fact, as the banks are generally oblique (up to 20°) to the tidal current, all the sediments eroded in the swale are likely transported towards the bank. When enough sand is available, ripple fields form in specific areas. Where the swale is in direct interaction with the central depression, a clear ripple field is observed witnessing a transport path from the swale to the central depression.

Western part of the sandbank: steep slope and top

This part of the sandbank is characterised by elongated large to very-large dunes. They consist of heterogeneous medium to coarse shelly sand. Flood currents also form with these large dunes structures also smaller ripples. Northward, the high height of the very-large dunes stops the formation of these ripples. The strong currents of this area provoke the erosion of the steep slope. The coarse fraction of the sediments has 2 origins: the gravel comes from the swale and can be transported into the central depression (Figure 60). The high content in shells is likely due to the high density of animals on the steep slope. Active transport of shells and coarse material, due to the strong flood currents and common along the erosive western flank, is now extended up to the depression (Figure 60). The eastern flank of the central depression seems to form a boundary for the progression of the coarse fractions. During this transport, the shells are destroyed and they finish-up accumulating in the northern area where abundant very-large dunes are present. A this location, the size of the shells is is quite homogeneous.

The central depression

In the central depression patches of fine to coarse sediments are found. In fact, it is an intermediate area between the heterogeneous and poorly-sorted sand of the west flank and the fine and well-sorted sand of the gentle slope. Before dredging, it had probably the same kind of sedimentation as along the west side. Remarkably, the size of the large to very-large dunes is less n height than the dunes surrounding the depression. This decreasing height leads to a higher mobility of the bedforms into the depression and can provoke disruptions in their morphology. The lack or the decreasing height of these bedforms make an easier passage of the currents and probably increase the erosion in this area. The depression also corresponds to an important volume to fill. The problem is the lack of coarse sand. The direction of the currents would indicate the need of a southern provenance. However, at present only fine to medium sand is supplied. Nevertheless there is a continuous supply in shells from the steep slope and the depression seems to act as a corridor for these shells (Figure 60). This is an important process as it could
initialise the filling-in of the depression by trapping sand.

A- Presence of whole shells in white. Bathymetry in the background

B- Size of gravel bigger than 3 mm. Bathymetry in the background

Figure 60. Repartition of the coarse fraction draped over a bathymetry digital terrain model. Crosses correspond to the sampling stations. A- Presence of whole shells (not destroyed). They are only present on the west part of the bank. B- Presence of gravel larger than 3 mm. The repartition is almost the same than for the shells.

Normally, only few silty or clayey sediments are found on the bank. When the samples have been taken during the flood, the silt and clay content was generally lower than 2 %. However, during the campaign of February 2005, the samples have been taken during the ebb and in remarkably, values of more than 2 % and even up to 5 % were found in the depression. Although, this needs further investigation, this...
could mean that during ebb, the central depression acts as a trap of fine sediment. These sediments correspond to a mobile layer of silt. During the flood, this layer is however eroded (Figure 61).

Figure 61. Percentage in fine sediments (< 75 µm) draped over a bathymetry digital terrain model. Crosses correspond to the sampling stations. In February 2004, the samples have been taken during the flood; there is no silty/clay layer on the top. In February 2005, the samples have been taken during the ebb into the central depression; a fine layer of mobile silt/clay is present on the top of the samples.

Eastern part
At last, opposite to the western part, the gentle slope is composed of homogeneous fine to medium sand. The large to very-large dunes are smaller and are covered by ripples. This slope is merely submitted to the ebb. The limit between the influence of the flood and the influence of the ebb is visible on the acoustic imagery (Figure 62): firstly, the bedforms of the western part have the same direction, towards the northeast and seems to be the influence area of the flood; secondly, the bedforms of the eastern part have 2 directions: the biggest bedforms seem always to follow the flood in this area, but the smaller ones
69 are due to the ebb.

Figure 62. Detail of multibeam backscatter imagery located around the elongated very-large dunes to the north of the central depression.

3.2.3. Conclusions on the differentiations of the subenvironments

Three major environments (channels, western part and eastern part of the sandbank) plus the central depression characterize the area of the Kwinte Bank. This differentiation is essentially due to the tidal currents which lead to different sedimentations (Figure 63):

The flood is a stronger, but short duration current. It erodes and transports the sediment, but the duration of this current does not allow to intensively sort the sediments. As such, a coarse sedimentation is present, but without a significant sorting. The content in shells is high. The ebb is a less strong, but longer duration current. It erodes with difficulty the sediments, but its longer duration allows a good sorting of the sand which is fine to medium and well-sorted. There is no supply in shell as the source area of shells is likely the western part of the bank.

The presence of the central depression has several influences. Firstly, it is located in the mobile part of the bank and close to the recess or kink area. It could be positive because there is a lot of transport and the depth differences could be levelled out. However, the problem is that it is also the instable part of the bank and the presence of the depression could destabilise this part.
The depth of the central depression should likely permit a trap of sediment, but it is submitted to the strong flood current which leads to the high mobility of the larger dunes which do have a smaller height than those in the other subenvironments. The dunes present can not slow down the current and so increase its erosive and transport effect. Moreover, there is no supply in coarser sand and the volume of the Kwinte Bank might continue to decrease. Nevertheless, there is a constant supply in shells coming from the steep slope. These shells could help the infill of the depression. In fact, they are able to trap fine sediment and protect fine sediment in their concave side.

The supply in coarse sand is the problem of the sand bank in equilibrium: it takes a lot of time before reaching again the previous shape. As such, it should be investigated whether the central depression can not be supplied with coarse sediments or shells, permitting a more important trap of the sediment and thus initiating the filing of the depression.

Figure 63. Scheme of the effects of the tidal currents on the four environments. At the top: flood. At the bottom: ebb. Env. = environment

4. RESEARCH INTEGRATION AND VALORISATION/EXPLOITATION OF RESULTS
4.1 Set-up of an integrated assessment framework for marine aggregates

4.1.1 GIS data management and mapping

Throughout the project, existing and newly acquired data is upgraded through its integration into a Geographical Information System (ArcGIS(8.3; 9)) (Task 4.1.1). Finally, the set-up of an integrated assessment framework (Task 4.1.3) is aimed at including a compilation of the knowledge of the different types of sedimentary systems. The main results will be synthesised cartographically.

Regarding data management and mapping issues, significant expertise is gained through the participation of UG-RCMG in the Interreg III b project MESH. MESH aims to produce seabed habitat maps for north-west Europe and to develop international standards and protocols for seabed mapping studies. The end products include a meta database of mapping studies, a web-delivered GIS showing the habitat maps, guidance for marine habitat mapping including protocols and standards, a report describing case histories of habitat mapping, a stakeholder database and an international conference with published proceedings. As such, the Marebasse datasets will be structured and represented according to international standards.

4.1.2 Mapping of marine sediments and their dynamic environment

On the level of the Belgian continental shelf, 3 new map deliverables have been produced that are highly valuable in terms of their usage for scientific, management and industrial purposes. They are respectively related to the depth, sedimentology and morphology of the Belgian shelf. They are unique in the sense that they are highly detailed and compiled using sound statistical methods. The end-user demand for these maps is high and they are an important input to a variety of modelling initiatives. As an example, Schelfaut (2005) has integrated the different GIS data layers to classify the Belgian continental shelf in terms of marine landscapes with ecological relevance, this in the context of the MESH project.

The maps are produced using GIS tools, sometimes in combination with more powerful statistical software packages. Special care is taken for a proper infill of the GIS attribute tables as this will allow a sound spatial analysis of the data and a quality control.

**New digital terrain model of the Belgian continental shelf**
The digital terrain model was compiled on the basis of bathymetrical data from the Ministry of the Flemish Community (Department of Environment and Infrastructure, Waterways and Marine Affairs Administration, Division Coast, Hydrographic Office) and was completed with data from the Dutch and English Hydrographic Offices. The map was compiled and interpolated in GIS software with a resolution of 80 m. For end-users’ needs a interpolation was also made at a 250 m resolution.

**New holistic sedimentological map of the Belgian continental shelf**
The mapping of the seabed sediments covering the whole of the Belgian continental shelf has resulted in a highly-detailed distribution map of the median grain-size. This deliverable is very important: due to an increasing need on the knowledge of the nature and distribution of marine aggregates (sensu stricto Marebasse aim), the need to evaluate anthropogenic activities with respect to the physical seabed (GAUFRE, Belspo), because of its potential to link up different ecosystem components that are substrate bounded (BwZee, Belspo and MESH, EU-InterregIIIb). As such, the mapping was procured taking into account different needs and will play a crucial role in the ecological valuing of shelf seas (for the rationale, see Van Lancker et al. 2004). The research has mainly been carried out by Els verfaillie, in the framework of her PhD (Institute for the Promotion of Innovation by Science and Technology in Flanders (IWT)). The interpolation of the map was done on a 250 m grid. Innovatively, the sediment dataset (sedisurf@database, hosted by Ghent University) was interpolated taking into account the bathymetry digital terrain model as described above.
New holistic bedform map of the Belgian continental shelf
The compilation of a holistic bedform map was at first based on the bedform map that was produced in the framework of the Belspo PODO1 project BUDGET (Lanckneus et al. 2001). The BUDGET map showed a compilation of all the dune structures derived from monitoring studies and as such the information was mainly restricted to the sandbank areas. The data was derived from individual single-beam measurements and was added with the available side-scan sonar and multibeam data that was available at that time. In the present framework, the BUDGET map was updated with newly acquired datasets. However, to arrive at a holistic map, the highly detailed digital terrain model was used to delineate the bedform zones outside the sandbank areas or where no previous data was available. The holistic digital terrain model was used to complete the bedform map. The areas that are attributed with 'no detailed information available' are likely devoid of major bedforms. The whole process was done in GIS in combination with sophisticated 3D software packages and allowed to attribute the different areas with details on the bedform heights, wavelengths and the data source. The latter is important for a further mapping in terms of mapping and data quality. More details are presented in Schelfaut (2005).

Figure 64. New holistic bathymetry digital terrain model covering the Belgian continental shelf based on a statistical analysis of bathymetrical datasets from the Belgian, Dutch and English hydrographic offices.
Figure 65. Spatial distribution map of the median grain-size, based on the sedisurf@database (hosted by Ghent University, Renard Centre of Marine Geology) and interpolated using the geostatistical method 'Kriging with external drift' (KED). Verfaillie et al. (in prep.) describe the methodology and results in detail. Caution is needed for the sediment distribution at the northern extremity of the Bligh Bank and the Fairy Bank due to a lack of samples (circles).
4.2 Valorisation/exploitation of results

4.2.1 Marebasse website

For the valorisation and exploitation of the results, the Marebasse website (Task 4.2.1) serves as the nodal point of information ([http://allserv.ugent.be/~vvlancke/Marebasse/](http://allserv.ugent.be/~vvlancke/Marebasse/)).

4.2.2 Discussion meetings with the advisory committee

The advisory committee has met 2 times (see Annex E; reports also consultable on the Marebasse website under Archive, [http://allserv.ugent.be/~vvlancke/Marebasse/archive.htm](http://allserv.ugent.be/~vvlancke/Marebasse/archive.htm)). These meetings help
in getting acquainted with the end-users’ needs and to translate and fine-tune the scientific results towards management or end-users in general.

4.2.3 Development of targeted EA tools and strategies

In this section, it is the purpose to translate and tune scientific results towards end-users’ needs. On the other hand, discrepancies of the techniques used, due to instrumental/physical restrictions, are being discussed. Following, is a discussion on the usage and experience of video systems within the project.

Video imaging (also ref. 2nd scientific report)

Underwater video measurements have been done during several campaigns using three different camera-types mounted in two different set-ups. The first system was hired from Simrad and consisted of a camera and lamp mounted in a frame and connected with a TV cable to a control unit. The second system was hired from the French navy (EPSHOM), but has not been used due to bad weather. The set-up was however more complicated as the system had its own winch, with a weight of 300 kg. The third system is a system owned by Ghent University, RCMG and has a set-up more or less the same as the Simrad system. Video measurements have been performed on the Belgica (5 campaigns until now) and on the Zeeleeuw (1 campaign).

A description of the Simrad and EPSHOM systems can be found in the Marebasse report (Van Lancker et al., 2004). The RCMG system consists of a colour zoom camera (Inspector from ROS Inc.), a 250 W light (MV4000 from ROS Inc.) and both are mounted in a little inox frame from Magelas. The electrical connection to the control unit ship is made by a Mini TV Cable of 100 m (MacArtney). The control unit is a Seatools system. Measurements are recorded on Mini DV tape with a Sony Handycam and are digitized afterwards into MPEG video files and TIF snapshots.

Measurements have been successful in areas with a low suspension amount and hence at offshore locations. Video recordings closer to the coast, as have been performed near the Ostend and S1 dumping site had no visibility. Probably this is due to the high suspension amount that is continuously in circulation regardless neap tide and/or slack water.

Table 10. Overview of the video measurements.

<table>
<thead>
<tr>
<th>Ship</th>
<th>Campaign</th>
<th>Period</th>
<th>Region</th>
<th>System</th>
<th>Remarks</th>
</tr>
</thead>
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<tr>
<td>RV Belgica</td>
<td>ST0317</td>
<td>23-27/06/2003</td>
<td>Kwinte Bank</td>
<td>Simrad OE1366/7 MkII</td>
<td></td>
</tr>
<tr>
<td>RV Belgica</td>
<td>ST0325</td>
<td>6-10/10/2003</td>
<td>SHOM-system</td>
<td>Not used</td>
<td></td>
</tr>
<tr>
<td>RV Belgica</td>
<td>ST0405</td>
<td>8-12/03/2004</td>
<td>Kwinte Bank, Ostend area</td>
<td>Simrad OE1366/7 MkII</td>
<td>No visibility</td>
</tr>
<tr>
<td>RV Belgica</td>
<td>ST0424</td>
<td>18-22/10/2004</td>
<td>Hinder Banken</td>
<td>ROS Inc. Inspector</td>
<td></td>
</tr>
<tr>
<td>RV Belgica</td>
<td>ST0502</td>
<td>7-11/02/2005</td>
<td>Hinder Banken, Sierra Ventana</td>
<td>ROS Inc. Inspector</td>
<td>No visibility</td>
</tr>
<tr>
<td>Zeeleeuw</td>
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<td>16-17/06/2005</td>
<td>Hinder Banken</td>
<td>ROS Inc. Inspector</td>
<td></td>
</tr>
</tbody>
</table>
4.2.4. Organisation of 2 workshops (firstly on environmental assessment tools and strategies, secondly on the project results)

It has been decided to couple the 2 workshops and hold them at the end of the project.
REFERENCE LIST


ANNEX A. MOTIVATION FOR THE USE OF A HAMON GRAB ON THE BELGIAN CONTINENTAL SHELF

Vera Van Lancker
Ghent University, Renard Centre of Marine Geology

Introduction and motivation

In the framework of the Belspo SPSDII project Marebasse, the investigation of sedimentary systems is aimed at including those comprising coarse mixed sediments. These include gravel or large fragments and due to a washing out of the finer fraction, it is utmost difficult to obtain representative samples of the seafloor with a Van Veen grab. A boxcorer might be useful, though this is largely unfavourable given the risk of damage.

Boyd et al. (2003 (CEFAS, The Centre for Environment Fisheries and Aquaculture Science)) puts forward that the Hamon grab can be regarded the standard sampling device for coarse sediments. With the use of this grab, the loss of sample through ‘wash out’ is kept to a minimum, enabling to obtain a quantitative, representative sample. The grab consists of a rectangular frame forming a stable support for a sampling bucket attached to a pivoted arm and can be deployed from a standard ship’s crane (technical details can be obtained upon request). This device is employed, as it has been shown to be particularly effective on coarse substrata (Kenny & Rees 1994, 1996, Seiderer & Newell 1999). The original design of the Hamon grab was suited for the sampling of areas of about 0.25m² (Oele 1978). However, more recently, CEFAS has introduced a smaller device with a sampling area of 0.1m² (mini Hamon grab, see Boyd 2002). As 0.1m² is the conventional surface sample unit employed in most benthic surveys of continental shelf sediments, conformity with this size allows a better comparison of results with those from a wide variety of sources using a range of other sampling devices.

Also in the other neighbouring countries (France, The Netherlands), the Hamon grab is regarded the standard tool for the sampling of marine aggregates (ref. Ifremer (FR), NITG-TNO (NL)) and for sampling benthic macrofauna in sands and gravels as recommended by CEFAS.

Ideally, the Hamon grab would be fitted with a video camera that would allow a more sound ground-truthing especially for eco-morphological investigations (ref. CEFAS mini hamon grab). Depending on the possibilities of financing, this might be envisaged in the future.

Related to the Belgian shelf, it is worthwhile mentioning that there is an increasing interest in the Hinderbanken area that is known for its coarser sediments and a high probability of finding gravel in the swales (Deleu 2001). Projects with a present interest in the Hinderbanken area are mentioned in the section ‘potential users’. Moreover, in the framework of the exploitation of marine aggregates, a large exploration zone has been opened in which sampling will be an important component for the estimation of the resource potential.

More information on the standard operating principles can be found at:
‘Procedural Guideline No. 3-9: Quantitative sampling of sublittoral sediment biotopes and species using remote-operated grabs’ (http://www.jncc.gov.uk/marine/mmh/Pg%203-9.pdf)

Information on experiences with the mini Hamon grab can be obtained from a.o. CEFAS (David Limpenny, D.S.Limpenny@cefas.co.uk), the Scottish Association of Marine Science (SAMS; Craig Brown, craig.brown@sams.ac.uk).
The CEFAS mini hamon grab fitted with a video camera

References
See also http://www.cefas.co.uk; http://www.jncc.gov.uk/marine/mmh/Contents.htm
Interested parties and potential users

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Especially, in the framework of the Marebasse project (*Management, Research and Budgeting of Aggregates in Shelf Seas related to End-users*, Belgian Science Policy, SPSDII (2004-2006)) a clear need was defined to enable an appropriate sampling of coarse mixed sediments. In Marebasse, techniques and strategies are being evaluated for an optimal characterisation of the seabed habitat of the Belgian continental shelf. In this, a full-coverage mapping of the seafloor is of primary importance and as such state-of-the-art geo-acoustical tools (a.o. multibeam, side-scan sonar) are being used. This comprises the testing of automated classification systems for seafloor characterisation including the relation with benthic diversity and community localisation. Especially related to the latter, the validation in terms of ground-truthing remains of utmost importance. For the fine-tuning of the different techniques and approaches, areas are chosen that are representative for a typical mud, sand and gravel environment. For the gravelly sediments, a Hamon grab was proposed as most suitable sampling device.

Partners involved: Ghent University, Renard Centre of Marine Geology; Management Unit of the North Sea Mathematical Models; Catholic University of Leuven, Hydraulics Laboratory; Magelaas and Ghent University, Section of Marine Biology.

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Macrobenthos research of the Marine Biology Section of Ghent University at the Belgian shelf already resulted in a good ecological knowledge of the macrobenthos of mobile soft substrates. Unfortunately, because of the lack of appropriate sampling gear, no scientific information on the benthos of gravel beds within the area exists. Yet, based on information on the benthos of gravel beds in surrounding North Sea areas, the ecological importance of this habitat is stressed (cf. doubling of species richness, compared to mobile soft substrates). Therefore, the Marine Biology Section of Ghent University is since a long time interested in the quantitative biological sampling of coarse substrates.

For the nearby future, the availability of a Hamon grab will be of increasing importance in the framework of the BELSPO project BWZee (*A Biological Valuation Map of the Belgian continental shelf*, Belgian Science Policy, SPSDII (2004-2006)). Here, a full-coverage and integrated view on the biological value of the Belgian continental shelf is aimed at, mainly based on the ecosystem components macrobenthos and seabirds. Detailed, quantitative knowledge of the spatial distribution of macrobenthos is crucial and it is highly expected that supplementary information will be needed in the areas with coarse substrates. As such dedicated sampling campaigns will be designed to fulfill the gaps in knowledge. The Hamon grab would be most suitable to enable a quantitative sampling of the coarser beds.

Partners involved: Ghent University, Section of Marine Biology; Institute of Nature conservation; Ghent University, Renard Centre of Marine Geology and the Ministry of the Flemish Community, Agricultural Research Centre, Sea Fisheries Department.

Ministry of the Flemish Community, Agricultural Research Centre, Sea Fisheries Department
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The Sea Fisheries Department performs various routine research and monitoring programmes on the possible repercussions of man-made perturbations and contaminants on the marine ecosystem. Particular emphasis is put on the monitoring of aggregate extraction areas and dredge spoil disposal sites. In these areas, and on several reference sites, regular biological monitoring surveys are carried out to investigate the mid- and long-term effects of aggregate extraction and dredge disposal, on the benthic fauna. Generally for this biological monitoring, but also in the framework of the BELSPO project BWZee (see above) and for the monitoring of new exploration (Hinderbanken) and exploitation zones (e.g. Gootebank, Thorntonbank), the Sea Fisheries Department recognises the lack of a suitable sampling device for coarse mixed sediments.

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In the framework of the BELSPO project (The Hinder banks : yet an important region for the Belgian marine biodiversity ?, Belgian Science Policy, SPSDII (2004-2006)) there is a particular interest to deploy the Hamon grab to validate the seabed habitat along areas of the seafloor where a dredge or beamtrawl will be used. The beamtrawl will be operated in a way to comply with the historic dredge tows of Gilson (collection 1900-1910). The operation of a Hamon grab on the beamtrawl path would allow to characterise discrete habitats brought together in the net. The epibenthic cover of collected stones will also provide data to compare with the historic samples of Gilson. Operating different instruments including the Hamon grab would provide a complete (sedimentological and biological) characterisation of "stony" heterogeneous sites, which is presently not possible using the available sampling techniques.

Partners involved: Royal Belgian Institute of Natural Sciences

Federal Public Service Economy, SMEs, Self-employed and Energy – Marine Sand Fund
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Tel. +32 2 206 52 56

Referring to the new exploration zone in the Hinderbanken area, the Marine Sand Fund is presently mapping the whole area with multibeam. They intend to produce a geomorphological and sedimentological map of the Hinderbanken area and complete the mapping of the exploitation zones on the Kwintebank, Buiten Ratel, Oostdyck, Thorntonbank and Gootebank. The Hamon grab is likely to provide a good ground-truthing for the acoustical seabed classification results and the backscatter image and could facilitate the sedimentological mapping of the large gravel areas.
ANNEX B. DATA DESCRIPTION AND IMPLEMENTATION OF WAM FOR WAVE CHARACTERISATION OF THE KWINTE BANK AREA

Jesus Portilla & Jaak Monbaliu
Hydraulics Laboratory K.U.Leuven

Wind data description

The wind field from the UKMO centre

The wind field data from the UKMO meteorological centre has been used to drive the wave generation models. Wind field is provided in ASCII format. The file consist of different blocks with three variables (given at 10m height): atmospheric pressure (P), wind speed in the abscise axes (U) and in the ordinate axes (V). The domain covers the North Sea from 32.5ºN to 75.0ºN in latitude and from 70.0ºW to 35.0ºE in longitude and its grid resolution is 1.25º. Wind field data are available every 6h. It is known that UKMO wind speeds predictions are systematically low; therefore wind speeds are corrected by a factor of up to 10% prior calculations.

Wind measurements

Wind measurements are available through the Monitoring Network of the Flemish Banks, Afdeling Waterwegen en Zeewezen (AWZ) at the locations of:

<table>
<thead>
<tr>
<th>Denomination</th>
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<tbody>
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<td>3º02'50&quot;</td>
</tr>
<tr>
<td>MP7</td>
<td>51°23'28&quot;</td>
<td>2º26'29&quot;</td>
</tr>
<tr>
<td>ZMP</td>
<td>51°20'07&quot;</td>
<td>3º12'06&quot;</td>
</tr>
</tbody>
</table>

Namely wind speed, direction and pressure. Wind measurements consist of time series of wind speed and direction with a time step of 10min taken at 25m height. A factor of 0.9 has been used to approximate wind speed measurements $U_{25}$ to $U_{10}$.

Buoy measurements

Spectral wave measurements and time series (of HM0, HM1, HMM, GTZ, E10, GEM, RHF, RLF, SEM, TM2, TPE) are available through the AWZ from directional buoys. Wave spectra consist of wave energy density, mean direction and directional spreading as a function of frequency. Frequency ranges linearly from 0.005 Hz to 0.5 Hz in steps of 0.005 Hz.

<table>
<thead>
<tr>
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</tr>
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<tbody>
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<td>BVH</td>
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</tr>
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<td>KWI</td>
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<td>2.68º</td>
</tr>
<tr>
<td>AWZ</td>
<td>51.41º</td>
<td>2.77º</td>
</tr>
</tbody>
</table>

The data set for the locations of WSH, BVH and AWZ is fairly continuously available for the year periods of 2003 and 2004. Data for the Kwinte Bank (KWI) from this source is available from June to December 2003.

In the framework of the EU-FP5 RTN Eumarsand, the University of Dunkerque deployed an S4 current meter on the Kwinte Bank (51°17.640’N 2°40.0508’E). Data is available from March 2, 2004 15:00 (Belgian local time) to March 11, 14:09.
WAM North Sea Spherical Grid WLABLAB Version

The current implementation of the WAM-Cycle 4 model (WAMDI GROUP, 1988), corresponding to the WLABLAB version (Anonymous, 2003), consists of four nesting levels on a spherical system coordinates starting with a coarse grid covering the North Sea and part of the Norwegian Sea from 47.83ºN to 71.17ºN, and from 12.25ºW to 12.25ºE, with a resolution of 1/3º in latitude and 1/2º in longitude (~32 km spacing).

The finest grid covers the Flemish coast from 51.10ºN to 51.60ºN and from 2.38ºE to 3.60ºE, with a resolution of 1/450º in latitude and 1/240º in longitude (~300m). The two-dimensional wave energy spectrum consists of 25 frequencies (ranging from 0.04177 Hz to 0.41145 Hz in logarithmic scale) and in 12 directions. The following are the characteristics and the set-up conditions for the nested grids run in the WAM model.

![Figure 1. North Sea nested grids.](image_url)

Information on the grid coordinates, resolution and the set-up information are given in the following tables.
Table 1. The grid coordinates, resolution and the set-up information.

<table>
<thead>
<tr>
<th></th>
<th>North Sea</th>
<th>Local1</th>
<th>Local22</th>
<th>BCP Fine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RESOLUTION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latitude resolution</td>
<td>1200</td>
<td>240</td>
<td>40</td>
<td>8</td>
</tr>
<tr>
<td>Longitude resolution</td>
<td>1800</td>
<td>360</td>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td><strong>COORDINATES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Most Northern Latitude</td>
<td>256200</td>
<td>199800</td>
<td>18948</td>
<td>185104</td>
</tr>
<tr>
<td>Most Southern Latitude</td>
<td>172200</td>
<td>174600</td>
<td>17724</td>
<td>183600</td>
</tr>
<tr>
<td>Most Eastern Longitude</td>
<td>44100</td>
<td>33300</td>
<td>17100</td>
<td>9900</td>
</tr>
<tr>
<td>Most Western Longitude</td>
<td>-44100</td>
<td>-9900</td>
<td>180</td>
<td>7500</td>
</tr>
<tr>
<td>Propagation time step (s)</td>
<td>600</td>
<td>200</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>Source term time step (s)</td>
<td>600</td>
<td>600</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>BC output time step (s)</td>
<td>10800</td>
<td>10800</td>
<td>10800</td>
<td>10800</td>
</tr>
<tr>
<td>Grid Size</td>
<td>50x71</td>
<td>121x106</td>
<td>283x307</td>
<td>161x189</td>
</tr>
<tr>
<td>Number of wet points</td>
<td>2592</td>
<td>5164</td>
<td>35787</td>
<td>161x189</td>
</tr>
<tr>
<td>Simulation period</td>
<td>12h</td>
<td>12h</td>
<td>12h</td>
<td>12h</td>
</tr>
<tr>
<td>Running time (hh:mm)</td>
<td>00:01</td>
<td>00:04</td>
<td>00:45</td>
<td>01:04</td>
</tr>
</tbody>
</table>

Simulation periods
The simulation periods correspond to the months of June 2003 and March 2004 for which data is available and significant wave activity was present.

SWAN nested run
The simulation with the SWAN model (Booij et al., 1999) has been performed for the finest grid domain. The resolution and extension of the SWAN grid are basically the same as the one implemented in the WAM model. The version used is SWAN 40.31ABCDE, third generation option with JONSWAP formulation for bottom friction. The runs were carried out in non-stationary mode with stationary computations.

References
Management, research and budgeting of aggregates in shelf seas related to end-users  
Scientific Report Year 3
WIND 6.64 320.97
COMPUTE STATIONARY 20040225.090000
WIND 6.64 320.97
COMPUTE STATIONARY 20040225.100000
WIND 6.64 320.97
COMPUTE STATIONARY 20040225.110000
WIND 6.90 315.04
COMPUTE STATIONARY 20040225.120000
WIND 6.90 315.04
COMPUTE STATIONARY 20040225.130000
WIND 6.90 315.04
COMPUTE STATIONARY 20040225.140000
WIND 6.90 315.04
COMPUTE STATIONARY 20040225.150000
WIND 6.90 315.04
COMPUTE STATIONARY 20040225.160000
WIND 6.90 315.04
COMPUTE STATIONARY 20040225.170000
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COMPUTE STATIONARY 20040225.180000
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COMPUTE STATIONARY 20040225.190000
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COMPUTE STATIONARY 20040225.200000
WIND 6.70 313.66
COMPUTE STATIONARY 20040225.210000
WIND 6.70 313.66
COMPUTE STATIONARY 20040225.220000
WIND 6.70 313.66
COMPUTE STATIONARY 20040225.230000
WIND 6.41 289.51
COMPUTE STATIONARY 20040226.000000
WIND AND COMPUTE
STOP
ANNEX C. RESULTS COMPARISON AMONG DIFFERENT WAVE MODELS
WAM, SWAN, TOMAWAC AND HYPAS

Dries Van den Eynde¹, Alessio Giardino², Jesús Portilla²
¹Management Unit of the North Sea Mathematical Models (MUMM)
²Hydraulics Laboratory K.U.Leuven

Locations

<table>
<thead>
<tr>
<th>Location</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Westhinder</td>
<td>51.38N</td>
<td>2.44E</td>
</tr>
<tr>
<td>Kwinte Bank</td>
<td>51.35N</td>
<td>2.68E</td>
</tr>
</tbody>
</table>

Results Time series

JUNE 2003, KWINTE BANK

[Graphs showing wave data for June 2003 at Kwinte Bank]
Results RMS $H_m0$ (m):

### JUNE 2003, KWINTE BANK

<table>
<thead>
<tr>
<th>MODEL</th>
<th>rms</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYPAS</td>
<td>0.27060</td>
<td>57</td>
</tr>
<tr>
<td>Tomawac</td>
<td>0.25995</td>
<td>1247</td>
</tr>
<tr>
<td>WAM</td>
<td>0.21220</td>
<td>1343</td>
</tr>
<tr>
<td>SWAN</td>
<td>0.22916</td>
<td>696</td>
</tr>
</tbody>
</table>

### MARCH 2004, WESTHINDER

<table>
<thead>
<tr>
<th>MODEL</th>
<th>rms</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYPAS</td>
<td>0.36240</td>
<td>129</td>
</tr>
<tr>
<td>Tomawac</td>
<td>0.26128</td>
<td>1476</td>
</tr>
<tr>
<td>WAM</td>
<td>0.29906</td>
<td>1004</td>
</tr>
<tr>
<td>SWAN</td>
<td>0.27526</td>
<td>577</td>
</tr>
</tbody>
</table>
ANNEX D.  2D HYDRODYNAMIC MODEL TELEMAC-2D: MODEL DESCRIPTION.

Alessio Giardino & Jaak Monbaliu
Hydraulics Laboratory K.U.Leuven

TELEMAC-2D (LNH/EDF) solves the shallow water equations using finite element or finite volume method on a computational mesh of triangular elements (Hervouet et al. 1996):

\[
\frac{\partial h}{\partial t} + u \cdot \nabla (h) + h \text{div}(\rho \frac{\partial \bar{u}}{\partial t}) = S_h
\]
\[
\frac{\partial u}{\partial t} + \rho \frac{\partial \bar{u}}{\partial t} = -g \frac{\partial h}{\partial x} + S_x + \frac{1}{h} \text{div}(h \nu \frac{\partial \bar{u}}{\partial x})
\]
\[
\frac{\partial v}{\partial t} + \rho \frac{\partial \bar{v}}{\partial t} = -g \frac{\partial h}{\partial y} + S_y + \frac{1}{h} \text{div}(h \nu \frac{\partial \bar{v}}{\partial y})
\]
\[
\frac{\partial T}{\partial t} + \rho \frac{\partial \bar{T}}{\partial t} = S_T + \frac{1}{h} \text{div}(h \nu \frac{\partial \bar{T}}{\partial x})
\]

The source terms \((S_x, S_y)\) include wind influence, atmospheric pressure, bottom friction, Coriolis force and eventual source or sink of momentum. The wind resistance is calculated according equations (5) and (6):

\[
F_x = \frac{1}{h} \rho_{\text{air}} a_{\text{vent}} U_{\text{vent}} \sqrt{U_{\text{vent}}^2 + V_{\text{vent}}^2}
\]
\[
F_y = \frac{1}{h} \rho_{\text{air}} a_{\text{vent}} V_{\text{vent}} \sqrt{U_{\text{vent}}^2 + V_{\text{vent}}^2}
\]

The coefficient of wind drag \(a_{\text{vent}}\) has been implemented in the Marebasse project according to a wind-velocity dependent formulation used by the Institute of Oceanographic Sciences (United Kingdom):

\[
\begin{cases}
0.565 \cdot 10^{-3} & \text{if } |\bar{U}_{\text{vent}}| < 5 \text{ m/s} \\
-0.12 + 0.137 |\bar{U}_{\text{vent}}| \cdot 10^{-3} & \text{if } 5 < |\bar{U}_{\text{vent}}| < 19.22 \text{ m/s} \\
2.513 \cdot 10^{-3} & \text{if } |\bar{U}_{\text{vent}}| > 19.22 \text{ m/s}
\end{cases}
\]

Atmospheric pressure \((P_a)\) is taken into account by expression:

\[
-\frac{1}{h} \text{grad}(P_a)
\]

Bottom friction has been calculated according to a Chezy law. For the Marebasse implementation a variable Chezy coefficient has been defined according to the following equation (Verboom et al., 1987):

\[
C = \begin{cases}
65 & , \text{if } H < 40 \text{ m} \\
65 + (H - 40) & , \text{if } H > 40 \text{ m and } H < 65 \text{ m} \\
90 & , \text{if } H > 65 \text{ m}
\end{cases}
\]
The components of the Coriolis force are calculated as follow:

\[
\begin{align*}
FU &= FCOR \times V \\
FV &= -FCOR \times U
\end{align*}
\]  

(10)

being FCOR the Coriolis force coefficient variable according to the latitude.

### List of symbols

#### Latin alphabet

- \(a_{\text{vent}}\) : coefficient of wind drag
- \(C\) : Chezy coefficient \([m^{1/2}s^{-1}]\)
- \(F_{x}, F_{y}\) : source terms due to the single action of wind, pressure, bottom friction \([m/s^2]\)
- \(FCOR\) : Coriolis force coefficient \([s^{-1}]\)
- \(FU, FV\) : components of the Coriolis force \([m/s^2]\)
- \(g\) : acceleration due to the gravity \([m/s^2]\)
- \(h\) : water depth \([m]\)
- \(S_{n}\) : source or sink of fluid \([m/s]\)
- \(S_{T}\) : source or sink of tracer \([g/l/s]\)
- \(S_{x}, S_{y}\) : source or sink terms in dynamic equations \([m/s^2]\)
- \(t\) : time \([s]\)
- \(T\) : non-buoyant tracer \([g/l]\)
- \(u\) : depth mean velocity in the \(X\) direction \([m/s]\)
- \(U_{\text{vent}}\) : wind speed \([m/s]\)
- \(v\) : depth mean velocity in the \(Y\) direction \([m/s]\)

#### \(X, Y\) : HORIZONTAL SPACE COORDINATES \([M]\)

#### \(Z\) : FREE SURFACE ELEVATION \([M]\)

#### Greek alphabet

- \(\nu_{t}, \nu_{T}\) : momentum and tracer diffusion coefficients \([m^2/s]\)

### Reference List

ANNEX E.  2D SEDIMENT TRANSPORT MODEL SISYPHE: MODEL DESCRIPTION.

Alessio Giardino & Jaak Monbaliu
Hydraulics Laboratory K.U. Leuven

General features

SISYPHE (release 5.5) is a horizontal two dimensional morphodynamic model that computes bed-load and suspended transport induced by current and wave-current interaction. The model solves a bed-evolution equation (1) and an advection-diffusion equation for suspended load concentration (2) with a finite element or finite volume method:

\[
(1 - n) \frac{\partial Z_f}{\partial t} + \text{Div}(Q_{SC}) + (E - D)_{z=a} = 0
\]

(1)

\[
\frac{\partial C}{\partial t} + U \frac{\partial C}{\partial x} + V \frac{\partial C}{\partial y} = \frac{1}{h} \left[ \frac{\partial}{\partial x} \left( h \varepsilon_s \frac{\partial C}{\partial x} \right) + \frac{\partial}{\partial y} \left( h \varepsilon_s \frac{\partial C}{\partial y} \right) \right] + \frac{(E - D)_{z=a}}{h}
\]

(2)

being:

\( n \) = bed porosity
\( Z_f \) = bottom elevation
\( Q_{SC} \) = bed load transport rate
\( (E-D)_{z=a} \) = net erosion minus deposition flux of sediment at the interface between suspended-load and bed-load layer
\( C \) = depth averaged sediment concentration
\( U, V \) = depth averaged flow velocities
\( h \) = water depth
\( \varepsilon_s \) = sediment diffusivity coefficient

The model is internally coupled to the hydrodynamic model TElemAC-2D (LNH/EDF); a wave field produced by the TOMAWAC (LNH/EDF) model can also be included.

Marebasse implementation

A preliminary implementation has been set-up within the framework of the Marebasse project. This set-up considers only bed-load sediment transport with a constant grain size (equal to 200 \( \mu m \)) uniformly distributed over the whole domain. This means that equation (2) is not considered while equation (1) assumes the following form:

\[
(1 - n) \frac{\partial Z_f}{\partial t} + \text{Div}(Q_{SC}) = 0
\]

(3)

The solid transport is calculated according to the Engelund-Hansen (Engelund et al. 1967) formulation valid for fine sediment in the range (0.2mm\(<D_{50}<1\) mm) in the implementation modified by (Chollet et al. 1980):

\[
\Phi_s = 0.05(\mu \theta)^{5/2}
\]

(4)

being \( \Phi_s \) the non-dimensional induced transport rate (5), \( \theta \) the total dimensionless shear stress (6) and \( \mu \) a parameter related to the quadratic friction coefficient \( C_D \) (7):
\[ \Phi_S = \frac{Q_S}{\sqrt{g(s-1)D^3}} \]  \hspace{1cm} (5)

\[
\begin{align*}
\theta &= 0 & \text{if } \theta_p < 0.06 \text{ (flat bed regime - no transport)} \\
\theta &= \sqrt{2.5(\theta_p - 0.06)} & \text{if } 0.06 < \theta_p < 0.384 \text{ (dune regime)} \\
\theta &= 1.0650^{0.176} & \text{if } 0.384 < \theta_p < 1.08 \text{ (transition regime)} \\
\theta &= \theta_p & \text{if } \theta_p > 1.08 \text{ (flat bed regime - upper regime)}
\end{align*}
\hspace{1cm} (6)

\[ \mu = \left[ \frac{1}{C_D} \right]^{2/5} \] \hspace{1cm} (7)

The friction coefficient is calculated as function of a Strickler coefficient \( S_t \):

\[ C_D = \frac{2g}{S_t^2 \frac{1}{h^{1/3}}} \] \hspace{1cm} (8)

while the dimensionless skin friction according to relation:

\[ \theta_p = \frac{\tau_0}{(\rho_S - \rho)gD} \] \hspace{1cm} (9)

**List of symbols**

**Latin alphabet**

- \( a \): reference elevation \hspace{1cm} [m]

**C**

- \( C_D \): quadratic friction coefficient \hspace{1cm} [-]
- \( D \): flux of sediments in deposition \hspace{1cm} [m s^{-1}]
- \( E \): flux of sediment in erosion \hspace{1cm} [m s^{-1}]
- \( g \): acceleration due to the gravity \hspace{1cm} [m s^{-2}]
- \( h \): water depth \hspace{1cm} [m]
- \( n \): bed porosity \hspace{1cm} [-]
- \( Q_{SC} \): bed load transport rate \hspace{1cm} [m^3/s]
- \( S \): relative density \((\rho_S/\rho)\) \hspace{1cm} [-]
- \( S_t \): Strickler coefficient \hspace{1cm} [m^{1/3}s^{-1}]
- \( t \): time \hspace{1cm} [s]
- \( U \): depth mean velocity in the \( X \) direction \hspace{1cm} [m s^{-1}]
- \( V \): depth mean velocity in the \( Y \) direction \hspace{1cm} [m s^{-1}]

**X,Y**: HORIZONTAL SPACE COORDINATES \hspace{1cm} [M]

**Z_F**: BOTTOM ELEVATION \hspace{1cm} [M]
Greek alphabet

$\varepsilon$: sediment diffusivity coefficient [m$^2$/s]

$\phi$: non dimensional induced transport rate [-]

$\theta$: total dimensionless shear stress [-]

$\phi_P$: dimensionless skin friction [-]

Reference List


ANNEX F. END-USERS MEETING 4 & 5 - PODOII PROJECT MAREBASSE

Report: End-users meeting 4 - OSTC PODOII project Marebasse
Venue: Ghent University, Geological Institute, Renard Centre of Marine Geology

Agenda:

14:00 Welcome, approval of agenda

Status and framework of the project

Overview of the second scientific report.

Complementarity of Marebasse with other projects, nationally (Belspo projects Speek, Gaufre, BWZee, Momo, Mocha) and internationally (EU-FP5 RTN Eumarsand, EU-Interreg IIIb, Mesh).

Overview of the main results: modelling set-up and results; environmental characterization of the depression in the Kwinte Bank, of the Ostend dumping site and of the S1 dumping site region.

Round table discussion on how the results can be translated to meet end-users’ needs

Conclusion

17:00 Close of meeting

List of participants (18)


Vera Van Lancker, Valérie Bellec, Samuel Deleu, Els Verfaillie, Isabelle Du Four (Ghent University, Renard Centre of Marine Geology); Michael Fettweis, Dries Van den Eynde, Frederik Francken, Brigitte Lauwaert (Management Unit of the North Sea Mathematical Models); Jaak Monbaliu (Katholieke Universiteit Leuven); Steven Degraer (Ghent University, Marine Biology Section); Jean Lanckneus (Magelas); René Desaever, Luc Van De Kerckhove (Zeegra vzw); Guido Dumon (Ministry of the Flemish Community, Waterways Coast Division); Frederik Mink (European Dredging Association); Frans Van Hulle (3E nv); Stella Kortekaas (Université de Dunkerque (EU-FP5 RTN Eumarsand))

1. Welcome, approval of agenda

2. Complementarity of Marebasse with other projects, nationally (Belspo projects Speek, Gaufre, BWZee, Momo, Mocha) and internationally (EU-FP5 RTN Eumarsand, EU-Interreg IIIb, Mesh) (Vera Van Lancker, UG-RCMG, coordinator)

3. Overview research activities MUMM (Dries Van den Eynde, MUMM)

Sediment transport measurements and modelling are presented. Reviews of Environmental Impact Assessments (EIA) on a European level have been made.

For the first task of the project related to an overall characterisation of the BCS, several models are used. There is a hydrodynamical model on a 250m grid, a sand transport model with a dominating direction towards the NE and a mud transport model. This last model points to a division of the incoming mud
through the Channel in two directions. One flows towards Belgium and The Netherlands and the other flows towards the UK.

The second task focuses on evaluation techniques. The model results are checked here by a.o. 13h-cycle measurements using ADCP, OBS and Rosette measurements, ... The correlation between ADCP-measurements and the hydrodynamical model results reveals an error of 5-15cm/s. Through the whole water column there is a relative error of 10 to 20%. The 3D sediment transport model is more or less ready; results are expected in a later phase.

The third task sets up an EIA of the Kwinte Bank area. LISST-measurements over a period of 10 days show that the median floc size is largest during slack water and becomes smaller during stronger currents.

4. Environmental characterisation of the Kwinte Bank central part (Valérie Bellec, UG-RCMG)
Seismic profiles were recorded over the depression and internal structures are studied. There is a good correlation between the internal structures of the Kwinte Bank and the Middelkerke Bank, which has been studied in the past (EU-MASTII). The lower part of the bank consists of different units with a Tertiary or Pleistocene age. The internal part of the bank consists of Holocene deposits. 17 boxcores have been taken on the basis of the multibeam results, corresponding to different acoustic facies. A seabed classification reveals a large shell content in the depression (25%) and on the steep slope north of the depression.

5. Environmental characterisation of the Ostend dumping site (Samuel Deleu, UG-RCMG)
The old dumping site causes the region to be very shallow with depths up to only 4m. The region of the old dumping site gradually rose whilst the channels north and south of the site deepened. Most of the dumped sediment is mud, which is largely taken away by the currents. The amount of shells is rather low, but nevertheless a small band stretches from north to south over the old dumping site. The eastern part of the study area is sandy well-sorted sediment whereas the western part consists of poorly sorted muddy sediments.

The eastern part is overlain by more seafloor structures than the western part, but these remain rather scarce over the whole area. The old dumping site is covered by distinct dredge spoils; the new dumping site by less distinct spoils. The acoustic seabed classification based on the multibeam backscatter values is not straightforward. Some links exist with the sediment distribution, but this is not straightforward. The MEDUSA classification, based on the natural radioactivity of the sediments, corresponds better with the sedimentology as it easily distinguishes between the sandy and muddy sediments and the band with shelly material.

6. Environmental characterisation of the Sierra Ventana region (Isabelle Du Four, UG-RCMG)
Studying the S1-dumpsite, it is clear that sand piles have formed on the edges except for the northeast, and more or less a depression in the centre. Moreover, there is a clear depth reduction and the grain-size decreases towards the northeast. After the closure in 1999, small and large dunes were formed. The sediments of the old dumping site are coarser than those of the new dumping site. A correlation can be found between the morphology and the surficial sediments due to hydraulic sorting processes.

The medium to fine sand of the investigated part of the centre of zone 3 tends to have a good combination of silt-clay fraction and shell fragments for the use as fill- and replenishment sand. Concentrations of PAH’s, mineral oil, PCB’s and heavy metals in the 7 analysed samples are lower than the standards for the re-use of waste as a construction material.

7. Density measurements in the Oostende area (Frederic Francken, MUMM)
The boxcores of the Ostend area have been investigated using bulk density measurements. This non-destructive technique is used to study the erosion characteristics of the muddy sediments. It is also used
to measure gamma-ray photons and radioactive sources (Americium-241). An instrumental set-up has been made and the system is calibrated with samples consisting of 100% mud and of 100% sand. The results for the muddy samples show values of 1088 – 1425 kg/m³. Those of the sandy sediments lie between 1806 – 2230 kg/m³. Sand/mud mixtures have an average value of 1802 kg/m³.

The erosion characteristics are studied by looking at the critical erosion shear stress, which takes amongst others the average bulk density of the top layer into account. The shear stress is important because it is the force that one should exercise to "take" a layer away. This aspect is of interest to the dredging industry to tune better the type of dredging equipment needed. The critical erosion shear stress becomes higher for coarser sediments.

8. Macrobenthos analysis of the different regions (Steven Degraer, UG-Marine Biology Section)

To have a complete coverage of biological information, three methodologies can be followed. The best one is to take lots of samples, but this is very time- and cost-consuming. A second method is the rough and dirty method and takes samples on an irregular basis; however, the objectiveness of the method is rather low. The third method is the habitat approach (ref. Habitat projects) This approach is based on (1) habitat modelling investigating the relation between physical and biological variables; (2) linking remote sensing techniques to the distribution of macrobenthos (i.e. macrobenthic interpretation of sonar imagery). Throughout the Marebasse project, datasets have been acquired that will enable a further refinement and validation of this concept.

For the Marebasse project, all of the samples of the Ostend region, the Kwinte Bank, the Sierra Ventana and Zeebrugge area are analysed for their macrobenthic content. The Ostend area is characterized by a high amount of *Abra alba – Mysella bidentata*. The Kwinte Bank and Sierra Ventana areas are mainly characterized by *Nephtys cirrosa*, corresponding to fine sand without mud. The *Abra alba – Mysella bidentata* community, corresponding to fine sand with mud enrichment, characterises the Zeebrugge area.

9. Round table discussion on end-users needs

Only limited extra information is provided.

10. Varia

No varia

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**Report**: *End-users meeting 5 - OSTC PODOII project Marebasse*

**Date**: Wednesday, December 22, 2004. 14:00 – 17:00

**Venue**: Ghent University, Geological Institute, Renard Centre of Marine Geology

**Agenda**:

14:00 Welcome, approval of agenda

- Status and framework of the project
- Latest results of the MU-SEDIM sand transport model (application Belgian shelf)
- Status on the Kwinte Bank scientific results
- Overview of measurements carried out in the Hinder Banken region
  - from the Marebasse project: multibeam, video, ADCP
Presentation of Jean-Sébastien Houziaux related to a biodiversity study in the swale, west of the Westhinder sandbank (*Royal Belgian Institute of Natural Sciences*)

Presentation of Marc Roche related to a gravel site survey in the Buiten Ratel swale (video from divers) (*Federal Public Service Economy, SMEs, Self-employed and Energy*)

Round table discussion on how to approach a ‘Targeted resource mapping according to end-users’ needs’

Varia

Conclusion

17:00 Close of meeting

**List of participants (19)**

**Excused:** Jean Lanckneus (Magelas), Geert Moerkerke (Magelas), Frans Van Hulle (3E)

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**Welcome, approval of agenda**

Introduction of the participants of the meeting and welcoming of new participants.

1. **Status and framework of the project (Vera Van Lancker, UG-RCMG, coordinator)**

   It is highlighted that the project has reached a phase during which integration of data and valorisation of results become important. The end-users in particular are invited to express their views and to formulate suggestions how the research results can be presented.

2. **Latest results of the MU-SEDIM sand transport model on the Belgian shelf (Dries Van den Eynde, MUMM)**

   Hydrodynamic and sediment transport modelling results on a 250*250 m grid are presented. The status of the 3D model (based on the COHERENS model) is outlined. Regarding wave modelling, MUMM works with the HYPAS model on a 50*50 km grid for the whole of the North Sea and with a 5*5 km grid for the southern North Sea. In the framework of Marebasse, a cooperation is worked out with the Catholic University of Leuven to refine the wave modelling related to the Belgian shelf and to apply it for the Kwinte Bank area.

   Applications of the modelling are presented for 2 cases: the Westhinder and the Kwinte Bank.

   In the framework of a cooperation between the Renard Centre of Marine Geology and MUMM, sediment transport modelling results have been combined with bedform analysis based on multibeam imagery.
Related to the Kwinte Bank, old single-beam profiles (900) have been digitised and the volumetric evolution analysed from which the creation of the central depression becomes clear. Moreover, the profiles have been interpolated to obtain a digital terrain model of the sandbank. For different periods, these results were used in combination with sediment transport calculations and the evolution of erosion and deposition areas is shown.

Comparing the volumes of extracted sediments (from black box data) versus the evolution of the volume of the Kwinte Bank, it seems that the volume reduction is larger than the amount extracted. Prior to further validation, this may question whether the sandbank is still in its dynamic equilibrium.

In the future, the available single-beam profiles from the Oostdijck (300), Buiten Ratel (500), Goote Bank (1000) and Middelkerke Bank (500) will be digitised and analysed in the same way as for the Kwinte Bank.

It is remarked (Marc Roche), that care is needed with the statistical analysis of the evolutionary trends on the basis of the single-beam profiles. Moreover, some of these profiles are not corrected for the heave and may induce significant volume differences. The quality of the profiles can best be verified in the swales where the topography is more stable.

3. Status on the Kwinte Bank scientific results (Valérie Bellec, UG-RCMG)

Results are presented related to the internal structure of the Kwinte bank based on seismic profiling. It is shown that the sandbank is composed of 5 units of which the oldest unit is likely of Pleistocene age. Profiles crossing the central dredged depression show that the extraction has nearly reached an older geological unit.

New results have been obtained related to the correlation of multibeam backscatter with the true seabed nature. Apparently, only a poor relation can be derived with the sediment nature and it is merely the morphology and especially that of the dune structures and their complexities that drive the backscatter differences.

The sedimentological nature of the area of the central depression is followed-up in time based on a dense sampling grid. From this, several regions can be distinguished amongst which the central depression itself. Comparing the results of 2 sampling campaigns, a trend can be derived for the major sedimentological parameters. However, this trend is merely seasonally driven and likely not related to a recovery of the area. From the monitoring work of the Marine Sand Fund, no volumetric differences are being observed since the closure of the site for extraction.

Up till now, there are no scientific arguments that the former area of extraction will evolve towards a new equilibrium.

4. Gravel site survey in the Buiten Ratel swale (Marc Roche, Federal Public Service Economy, SMEs, Self-employed and Energy) (invited presentation)

To validate multibeam derived acoustical seabed classification with video imagery, the Federal Public Service Economy, SMEs, Self-employed and Energy developed a project together with scientific divers.

On the basis of an extensive multibeam coverage over several sandbanks and swales, an area was selected with the highest backscatter that normally should correspond with a gravel-dominated seafloor. During 2 dives (with GPS positioning), 2 track lines were followed where gravel was suspected. The video imagery confirmed the presence of boulders, though it also showed that the gravel is merely found in patches and that most of the time the gravel is covered with a veneer of rippled sand that can be 30-40
cm in thickness. This could lead to the assumption that the EM1002 does not ‘see’ the fine layer of sand. Though, it should be further investigated to what extent the typical hillhocky morphology of gravel beds is responsible for the high backscatter values.

5. Overview of measurements carried out in the Hinder Banken region (Samuel Deleu, UG-RCMG)
An overview is shown of all the multibeam data that has been acquired during the last campaigns. The area was chosen to be representative of gravely sediments. A typical hillhocky morphology is seen in the swales and indeed corresponds with a seafloor where gravel likely occurs. Grab sampling with a Van Veen grab sampler has been performed though with very limited success. From this, it could be deduced that gravel is omnipresent. However, video imaging has shown that the occurrence of gravel is very patchy and that sand is dominating. Several video sequences are shown of which the quality is very satisfactory.

A good sampling is likely to become possible since a Hamon grab will be available in 2005. The Flanders Marine Institute (VLIZ) is thanked for this purchase and for organising a future training for the use of the equipment.

6. A biodiversity study in the swale west of the Westhinder sandbank (Jean-Sébastien Houziaux, Royal Belgian Institute of Natural Sciences) (invited presentation)
The objectives of the project ‘The Hinder banks, yet an important region for biodiversity’ are presented. It is clear that the seabed of the Hinder Banken region is least known in terms of biodiversity. This is partly due to a lack of good sampling devices to obtain a good and representative view of the biological nature of the seabed.

The basis of the study is the Gilson collection (early century) comprising numerous samples of epi- and endobenthos that were most rich and diverse along the southern part of the Hinder Banken. It is put forward that this is likely due to the presence of stony grounds.

During the present project it is the purpose to investigate the same areas of Gilson and hence to verify the changes that have occurred since then. Preliminary observations seem to show that those rich areas are hardly existing anymore. It was preferred to work with a modern 2 m beam trawl and not with a copy of the trawl of Gilson. As such, the data will be compliant with nowadays surveys and can be better exchanged.

The Marebasse project is end-user of this project and as such complementarities are sought and research results can be combined.

7. Round table discussion on ‘Targeted Resource Mapping’
End-users are invited to express their views on how the mapping of resources can be approached to suit better the needs of a wider community. A discussion could be hold whether an integrated mapping should be envisaged combining various variables in a synthetic way. On the other hand users may prefer to keep the themes per map simple and provide multiple maps according to the amount of variables. It is clear that the Marebasse group will proceed anyhow and make choices, but input/comments are welcome.

It is put forward (Toon Verwaest) that some end-users are most interested in having the digital data themselves and that maps can be combined individually, at least if good metadata is available. As such, the importance of delivering digital data is highlighted.

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