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QUantification of Erosion/Sedimentation patterns to Trace the natural versus anthropogenic sediment dynamics (QUEST4D)

SCIENCE FOR A SUSTAINABLE DEVELOPMENT

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Reference to this report:
# TABLE OF CONTENTS

ACRONYMS, ABBREVIATIONS AND UNITS ..................................................4

1. EXECUTIVE SUMMARY ...........................................................................5

2. INTRODUCTION ..........................................................................................7

   2.1 Context ......................................................................................................7

   2.2 Objectives ..................................................................................................7

   2.3 Expected outcomes ..................................................................................7

3. SCIENTIFIC METHODOLOGY .................................................................8

4. INTERMEDIATE RESULTS .........................................................................13

5. PRELIMINARY CONCLUSIONS AND RECOMMENDATION .................20

6. FUTURE PROSPECTS AND PLANNING ...............................................22

7. FOLLOW-UP COMMITTEE .........................................................................24

8. REFERENCES .............................................................................................25

9. PUBLICATIONS ..........................................................................................26

   9.1 Publications of the teams .......................................................................26

      9.1.1 Peer Review .....................................................................................26

      9.1.2 Others ..............................................................................................26

   9.2 Co-publications ......................................................................................26

      9.2.1 Peer Review .....................................................................................26

      9.2.2 Others ..............................................................................................27
<table>
<thead>
<tr>
<th>Acronyms</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCMG:</td>
<td>Ghent University, Renard Centre of Marine Geology</td>
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<tr>
<td>MUMM:</td>
<td>Royal Belgian Institute for Natural Sciences, Management Unit of the North Sea Mathematical Models</td>
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<tr>
<td>K.U.Leuven:</td>
<td>Hydraulics Laboratory K.U.Leuven</td>
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<td>WL:</td>
<td>Flanders Hydraulics Research</td>
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<tr>
<td>MARBIO:</td>
<td>Ghent University, Marine Biology Section</td>
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<td>RBINS:</td>
<td>Royal Belgian Institute for Natural Sciences</td>
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<tr>
<td>BMDC:</td>
<td>Belgian Marine Data Centre</td>
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<td>VLIZ:</td>
<td>Flanders Marine Institute</td>
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<tr>
<td>VUB:</td>
<td>Vrije Universiteit Brussel</td>
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<tr>
<td>TNO:</td>
<td>Netherlands Institute of Applied Geoscience</td>
</tr>
<tr>
<td>DGPS:</td>
<td>Digital global positioning system</td>
</tr>
<tr>
<td>GIS:</td>
<td>Geographic information system</td>
</tr>
<tr>
<td>DTM:</td>
<td>Digital terrain model</td>
</tr>
<tr>
<td>POC:</td>
<td>Particulate organic carbon</td>
</tr>
<tr>
<td>SPM:</td>
<td>Suspended particulate matter</td>
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Sustainable development requires the quantification of human impacts, against the seafloor’s ecological value. Recent impact studies have shown localised effects only, though indications of a longer-term and broader-scale degradation of the seafloor exist. This is due possibly to cumulative anthropogenically-induced effects, but the natural evolution and the response of the seafloor due to sea-level rise are poorly known. Nonetheless, it is likely that changing wave climate and an increased storminess induce different erosion/sedimentation patterns. Such evolution needs to be disentangled against the impact of dredging, aggregate extraction, fisheries and beach replenishment on the ecosystem’s physical functioning.

To investigate in more detail the sedimentation/erosion processes and the sediment transport system of the Belgian part of the North Sea (BPNS), site-specific measurements were performed during several RV Belgica campaigns. A multisensor benthic lander was used for longer-term measurements to determine the current structure and near-bed dynamics, as also the particle size distribution, volume concentration, the density of the suspended particulate matter and the fall velocity of mud flocs. At locations with a persistent erosion or sedimentation history, measurements on the erodibility of the sediments were performed. All of these parameters are important as input to numerical modelling. The models themselves are being upgraded with the development of integrated 2D sand/mud transport models with extension of a flocculation model. Wetting/drying schemes have been set-up to include the shallow coastal strip. Further, the spectral wave model WAM is being dynamically coupled to the COHERENS flow model and test runs are being made. Meanwhile, data is being acquired to support case studies that will be used to model the impact of the natural versus anthropogenically-induced sediment dynamics along the BPNS. In particular, the area north of the Vlakte van de Raan was targeted, as with the dumping ground Br&W S1, it is one of the main sedimentation areas. Data from very-high resolution acoustic surveys, grab sampling and vibrocoring are being analysed and their results will be integrated to quantify erosion/sedimentation trends along this area.

Biological data has been gathered also; their role in local sedimentation processes will be investigated. Meanwhile, a historic reference framework is being set-up, based on the sediment and macrobenthos dataset of Gilson (~1900). In addition, long-term datasets are compiled and their analyses will be integrated, both physically and ecologically. Historical hydrographic charts are digitised to study the long-term bathymetry changes, whilst the quantification of long-term sediment volume changes is envisaged, based on repetitive surveys along fixed tracklines covering the major sandbank areas. Sediment datasets are extended to allow trend analyses of sediment changes of the past 100 years. The changes in mud content will be supported by the results of clay mineralogy analyses that are performed to study the potential mud sources. For the impact of climate change, a literature study has been performed and relevant cooperation is being sought. The impact of human activities on the seabed is mostly visible from very-high resolution acoustic data. Where relevant, the data coverages have been extended with new and external data. Together with data on the major human activities (e.g. from Electronic Monitoring Systems), this will allow evaluating the spatial extent of the impacts and to extrapolate some of the findings. Most of the seabed data is managed in GIS allowing simplified integrations of spatially diverse datasets.

Year 1 has concentrated mainly on data acquisition, laboratory analyses and preparatory work for further exploration of existing datasets. Only limited conclusions and recommendations can be formulated. Still, significant results have been obtained on a better parameterisation of the sediment and sediment transport system; this was shown necessary for the improvement of model output. The importance of the temporal variability of suspended particulate matter with varying hydro-meteorological conditions and in particular storms has been highlighted. Results from the area, north of the Vlakte van de Raan, indicate varying sedimentation patterns that can be correlated to both naturally and anthropogenically-induced sediment dynamics.

In the following phases of the project, the research results will be validated and further refined in the view of the sustainable management and exploitation of the EEZ. With the integration
and synthesis of all results, it is aimed at distinguishing the natural from the anthropogenically-induced sediment dynamics. From this, the adaptation of the marine ecosystem on changes will be derived, including the impact of different sea-level rise scenarios.

For the valorisation of the project results, a website and a leaflet have been designed. The follow-up committee has provided technical, managerial and scientific support to the partnership.
2. INTRODUCTION

2.1 Context

Op (inter)nationale niveau

Seabed, living and non-living resources are exploited increasingly: sand and gravel is needed for beach nourishment and for construction purposes, the accessibility of harbours requires regular dredging and dumping operations, offshore windmills contribute to our future energy supply and pipelines and cables transport gas and electricity to the mainland. The interaction of these activities with the seabed nature and processes needs careful consideration. However, present-day impact studies remain often inconclusive because of: the lack of a ‘non-disturbed’ reference situation, the interference of both naturally and anthropogenically-induced changes and, the hitherto unknown, role of climate change on seabed processes. Moreover, the range of human activities may result in cumulative effects affecting the magnitude and extent of the impact on the seabed. A sustainable management, based on an overall marine environmental status and its possible degradation, is therefore needed. Setting-up environmental targets and well-balanced monitoring programs have become timely. These will help in protecting and preserving the marine environment and safeguard our seas for future generations.

2.2 Objectives

Quest4D targets the Belgian part of the North Sea (BPNS) to reconstruct seabed ecosystem changes in the past 100 years. This becomes feasible since extensive data have become available on the seabed nature and processes. The datasets are unique in Europe and allow going beyond traditional research. Throughout the reconstruction, case studies will be built and impacts will be modelled, relating seabed changes to both naturally and anthropogenically-induced sediment dynamics. Furthermore, climate change scenarios will be modelled and their consequences on the management of the seabed will be estimated. A significant increase in knowledge on the sediment and sediment transport system is thus expected, which is key to any ecosystem or impact study. Final results will contribute to the development of more sustainable exploitation strategies of non-living seabed resources.

2.3 Expected outcomes

A Geographic Information System and databases containing multidisciplinary information on the seabed of the Belgian Continental Shelf, including the various human impacts of the last 100 years and a historic reference situation of 1900.

Models, in which the nearshore-shelf is coupled to the coast and Scheldt-estuary to address the sand and mud balance and idealised models to be used in impact assessments;

Parameters to be used in climate change studies;

Case studies on the effect of fisheries, aggregate extraction and long-term dumping on the seabed;

Management tools (e.g. indicators) for a sustainable development / exploitation, including recommendations.

The main results will be published in peer-reviewed journals and presented at dedicated fora; for the public at large, leaflets, a set of animations and posters will be produced.
During the last year the Quest4D partners MUMM, RCMG and WL participated in 6 RV Belgica campaigns. An overview table, representing the cruise data, gathered in the framework of the QUEST4D project (1.1.1, 1.1.3, 2.2) and the cruise reports, can be found on the QUEST4D website (http://www.vliz.be/projects/Quest4D/news.php).

Work Package 1: Process studies and modelling (MUMM)

Task 1.1: Defining the physical system in the space, time and depth domain (4D) (Ph1-2)

Task 1.1.1: Definition of the sediment- and sediment transport system and the whole range of processes having an impact on these systems (Ph1/Yr1-2)

A literature review on sediment transport process studies is underway (MUMM, WL and K.U.Leuven). It deals with 1) influence of sand-mud mixtures on the erodibility of the sediments; 2) flocculation and its associated parameters, e.g. turbulence, particulate organic carbon (POC), aggregation time, floc break up; and 3) Influence of biota on the erodibility of the sediments.

Large-scale approach (Ph1/Yr1-2)

On the large-scale modelling results on erosion and sedimentation over the entire Belgian part of the North Sea are being analysed against existing physical, geomorphological and biological datasets.

Small-scale approach (Ph1/Yr1-2)

To investigate in more detail the sedimentation/erosion processes and the sediment transport system, several measurements were performed on specific areas during RV Belgica campaigns.

RCMG’s activities concentrated on the area north of the Vlakte van de Raan, including the dumping ground Br&W S1, as it is one of the main sedimentation areas on the Belgian part of the North Sea (BPNS). During the Belgica campaigns ST0703b, ST0725 and ST0728, multibeam measurements with the EM1002S echosounder and side-scan sonar measurements (Klein3000 series) were performed to characterize the area. Van Veen grab samples were taken to characterise the sedimentological and biological environment. The density of the tube-building worm Owenia fusiformis was counted; dense colonies of these species form small-scale sedimentation patches. It is aimed at deriving their habitat preferences, to extrapolate these findings to similar environments and to gain more insight in sedimentation areas.

MUMM carried out sediment- and sediment transport measurements with a benthic lander (tripod) during longer time periods (a few weeks). Together with previously collected measurement data, they acquired: (1) very-high resolution PC-ADP measurements to determine the current structure and near-bed dynamics; and (2) LISST measurements, together with SPM concentration measurements to determine the particle size distribution, the volume concentration, the density of the SPM and the fall velocity of the mud flocs.

Task 1.1.2: Definition of a reference framework, based on the historic Gilson sediment and macrobenthos dataset (1899-1939) (RBINS)

The historic data on sediment and benthos are gathered from the historic collection of G. Gilson, held at RBINS. This collection has been described in Van Loen et al. (2001) and Houziaux (2007). Sediment data, derived from Gilson’s field descriptions, have been processed, mapped and analysed in the aforementioned projects; in Fettweis et al (2006) and in Houziaux et al (in prep), they are available now for further analyses. In this dataset, the considered parameters are: sand median grain-size, mud content, shell content and gravel occurrence. For the sand median grain-size, the accuracy of the estimated values assigned to the categories of Gilson (e.g. “fine sand”, “coarse sand”) remains doubtful, due to the low amount of control samples analysed. To solve this problem, grain-size analyses of 74 sub-samples of the original samples have been carried out (MUMM). All samples originate from the surroundings of the Westhinder sandbank and are accurately geo-referenced.

For the benthos, the invertebrates from the infauna (with priority to bivalves and amphipods, later polychaetes) were targeted. The arrangement of samples in the RBINS repositories, based on taxonomy, imposes a specific approach to digitisation, i.e. samples are digitised following taxa, rather than station codes. This constraint involves that total species lists of stations cannot be reconstructed unless the whole collection is digitised. Given the amount of data to digitise, an exhaustive inventory of the data is made first,
rather than revising the taxonomy of the specimens. However, wherever possible, a “taxonomic upgrade” is performed on the basis of best available taxonomic sources, using the valid names of “Marinespecies.org” as “current name” where possible. Digitisation of benthic invertebrates is carried out in the ‘Darwin’ database of the RBINS, created to archive all digital information of the RBINS collections of specimens. Specific fields were created in this database to enable meaningful digitisation of Gilson’s data.

The digitisation of data in the frame of “Quest4D” is performed thanks to an agreement with the Belspo project “DIOGIT05”. One encoder of DIOGIT05 is dedicated fully to digitisation of Gilson’s data. We expect the bivalves and amphipod data to be fully digitised by 2008; for Polychaetes, it is likely that a selection of some species will be necessary, given the timeframe and available man-power.

The sampling information has been checked and processed at the RBINS since 2001 for two main sampling gear of Gilson: the “dredge” (benthos, ~900 validated sampling events) and the “ground-collector” (sediments; ~2,200 validated sampling events with field descriptions). The sampling information is available in field logbooks and inventories for every sampling station, identified by a unique station code. This station code is written down on labels of specimens, archived in the repositories. We expect a large number of specimens to originate from the aforementioned sampling gears, for which the largest part of sampling information could be verified. However, it is likely that a yet undetermined proportion of samples have been collected with other gears (there are more than 14,000 sampling events and measurements recorded in Gilson’s sampling inventories). Depending on results of digitisation, additional verification and validation will be performed to enable e.g. meaningful mapping of the distribution of certain species or species association analysis.

Task 1.1.3: Quantification of changes and trends, based on long-term datasets and sampling within the depth and time domain (Ph1-2/Yr1-2-3)

Large-scale approach (Ph1/Yr1-2)

Based on historical hydrographic charts (ranging from ~150 years ago up till now), the long-term bathymetry changes will be studied. A selection is made out of the charts available from the Flemish Hydrography. The selection should span a large spatial scale (BPNS) and time (last century) scale. The selected charts are digitised, and by chart differencing (ArcGIS), the dynamic zones of the BPNS will be identified. Special attention will be given to the morphological evolution in the zones surrounding the navigation routes and to the ports of Oostende and Zeebrugge, in order to investigate the influence of human activities (dredging and dumping) on the morphology.

The long-term volume changes are studied in cooperation with the Fund for Sand Extraction (FPS Economy, SME’s, Self-Employed and Energy). Volume changes are being calculated from across-bank bathymetry profiles and spread over the entire area of the Flemish Banks (fixed tracks). In the same area, RCMG performed additional measurements (February and November); as such temporal variations will be investigated (task 2.1.1). RCMG covered also the profiles along the Hinder Banken (July), but these cannot be used due to technical problems. The long-term sediment changes will be studied by performing trend analyses comparing the present and Gilson sediment datasets (see above). Part of the data has been incorporated in GIS and some maps have been made. The sediment database (@sedisurf), hosted at RCMG, is being updated. Apart from the median grain-size, silt-clay and gravel percentage, all data from the sediment distribution curve is added, when available.

Small-scale approach (Ph1-2/Yr1-2-3)

At locations with a persistent erosion or sedimentation history, a more sound sampling strategy has been adopted in the depth domain using a boxcoring. An essential strength of the applied strategy is that various analyses have been carried out on the same sample. From each boxcore, 3 subsamples were taken for sediment characterisation and erosion measurements.

MUMM’s activities have been focused on sediment characterisation through grain-size, bulk density and POC analysis of samples, whilst WL has focused on the erodibility measurements. These measurements were planned originally with an erosion flume, already present at the WL. However, given the difficulty to retrieve enough sediment sufficient for the large dimensions of this flume, alternative methods were sought to measure $e_{crit}$: (1) the SETEG-system (Strömungskanal zur Ermittlung der tiefenabhängigen Erosionsstabilität von Gewässersedimenten); and (2) the CSM (cohesive strength meter).

The SETEG-system is a rather unique erosion flume, developed at the University of Stuttgart (Universität Stuttgart, Institut für Wasserbau). This system consists of a flume with an opening in the bottom, to which a cylindrical sediment sampling tube (diameter: ~13.5 cm) can be connected. The sediment in this tube can be pushed upwards through the opening into the flume, while water flows through the flume with increasing velocity until erosion is observed. The SETEG-system has several advantages: it requires only a limited
amount of sediment, and it allows measuring a depth profile of $\tau_{\text{crit}}$ (when a sediment layer has eroded in the flume, the sediment can be pushed further upwards, allowing to perform a measurement of $\tau_{\text{crit}}$ of the underlying layer). Moreover, the SETEG-system is equipped with an optical device that measures the volume of sediment eroding per time unit, from which the erosion rate can be derived. WL has set-up cooperation with this University group. The CSM is a small and portable device for in-situ measurement of $\tau_{\text{crit}}$. It consists of a small cup (diameter: ~3cm), which has to be placed upside down on the sediment surface. The CSM creates water jet pulses with a stepwise increasing pressure in the cup, until a built-in optical device detects erosion. The VLIZ has acquired a CSM recently, which WL can use. Besides the erodibility measurements, also sediment measurements will be performed at WL. Correlations between the parameters will be sought and the results of WL and MUMM will be compared. Finally, a literature study of the existing devices to measure the critical shear stress for erosion will be made. This will eventually result in a general overview, in which the existing erosion devices will be categorised, according to their field of application, working principle, etc. At this point, several articles on this subject have been collected and read, but this has not yet resulted in a review.

RCMG deployed seismic sources to investigate the recent regional sedimentation at the old and present dumping ground of dredged material Br&W S1, one of the study areas in QUEST4D (task 2.2.2). In April, a sparker (centipede) source (20 kHz) was used, whilst in July seismic data was recorded with the X-star chirp (0.5-4.5 kHz) of TNO.

Finally, mud samples from the North Sea area and the Scheldt estuary have been analysed for their clay mineralogy (K.U.Leuven) to study the mud sources along the BPNS. The method is based on extensive chemical pre-treatment and separation on size. The analysis incorporates a qualitative and quantitative determination of clay mineral content with additional polytype analysis, 060-analysis, species determination and general bulk mineralogical analysis.

Task 1.2: Modelling of processes

Task 1.2.1: Development of models to describe and predict the response of the ecosystem on changes (Ph1/Yr1-2)

During the first year, MUMM started the development of integrated 2D sand/mud transport models with the extension of the 2D sediment transport model with a flocculation model and the development of a wetting/drying scheme in order to include the shallow coastal strip and other inter-tidal areas. Prof. Toorman of K.U.Leuven will assist the modelling team by its know-how on the effect of fine cohesive sediment on flow behaviour.

Task 1.2.4: Coupling/interaction of different models (Ph1/Yr2)

K.U.Leuven investigates the dynamic coupling of the spectral wave model WAM with the COHERENS flow model, developed at MUMM. A parallel version of the wave model WAM, a semi-open source code, has been implemented on the High Performance Computer of the K.U.Leuven. At the moment the model is being calibrated. A parallel version of the COHERENS flow model is currently being implemented on the High Performance Computer of the K.U.Leuven. Test runs are being made. There is strong cooperation between MUMM and K.U.Leuven for this task.

Work Package 2: Impact of natural and anthropogenic pressure (RCMG)

Task 2.1: Natural evolution of the seabed and impact of climate change

Task 2.1.1: Natural evolution (Ph1/Yr2)

Hydro-meteorological data from the Flemish Hydrography is being compiled and will be analysed statistically against sediment volume changes (see above). The impact of storms will be evaluated on the basis of literature.

Task 2.1.2: Climate change (Ph2/Yr3)

K.U.Leuven has performed a literature study and has established cooperation with other Belgian Science Policy projects, in particular CLIMAR and CCI-HYDR. Furthermore, international contacts have been made through the SEAMOCS workshop (see publications).
Task 2.2: Impact of (cumulative) human activities on the ecosystem with respect to the executed or planned monitoring programmes

Task 2.2.1: Evaluation of the spatial extent (2D) and intensity of the human impacts (Ph1/Yr1)

The impact of human activities on the seabed can be revealed from very-high resolution multibeam or side-scan sonar imagery (Van Lancker et al., 2007). However, to evaluate the spatial extent of the impacts and to extrapolate some of the findings (e.g. % of fisheries impact), these data are needed over wide areas. As such, the newly acquired data and the existing very-high resolution multibeam data from RCMG and the Fund for Sand Extraction have been incorporated into ArcGIS (RCMG); additional multibeam coverages were sailed to bridge gaps between the datasets. These datasets will be compared with data on the major human activities (e.g. Electronic Monitoring Systems).

Task 2.2.2: Evaluation of erosion/deposition rates (4D) with the impact of human activities: case studies of impact assessments (Ph1-2/Yr2-3)

Regional impact assessment of long-term dumping in the Sierra Ventana region (Ph2/Yr3)
The sedimentation patterns on the present and old dumping ground Br&W S1 were investigated based on the analyses of vibrocores. Density plots were obtained by analysing the cores with a GEOTEK multi-sensor core logger. Afterwards, a lithological description was made and photographs and subsamples for sedimentological analyses were taken. To characterise the morphology of the present dumping site Br&W S1 and its surroundings, multibeam data was collected with the EM1002S multibeam sonar on the RV Belgica in November. The vibrocores were obtained through cooperation with TNO in the framework of the InterregIIIb project MESH (‘Mapping European Seabed Habitats).

Work Package 4: Data management and valorisation (RCMG/MUMM)

Task 4.1: Data management (Ph1-2/Yr1-4)

Task 4.1.1: GIS data management (RCMG)
Relevant information from the partners is compiled in a GIS. The basis is the GIS@SEA Information System, developed in a previous project (Van Lancker et al., 2007).

Task 4.1.2: Database management (BMDC)
BMDC has carried out the necessary preparatory work to import the expected measurements into the QUEST4D database. This includes the inventory of potential datasets and the adaptation of the database where necessary (e.g. time series of CTD and LISST100C data).

Task 4.2: Valorisation (Ph1-2/Yr1-4)

Task 4.2.1: Valorisation of results (VLIZ)
A project website with a public and private domain was created. The public website includes general information on the background and aims of the project, the partners, activities and a literature database. The illustrative part is an active photogallery. Partners can upload pictures with a short description or copyright note. The website centralizes information on the project, but acts also as a communication tool between the partners. On the restricted pages, a thematic message board will be created. Documents can be transferred using a FTP-server or by making them available on the restricted pages.

A project leaflet was designed. This outreach product summarizes the core of the project using text and illustrations. Partners on symposia, meetings, will use the leaflet,.....

A digital newsletter of VLIZ, the VLIZINE, will devote short articles on the activities and aims of the Quest4D project.

VLIZ is partner in the foundation “Zee in Zicht”, a Dutch initiative involving different research groups such as NIOZ, NIOO, Stichting Noordzee, ECOMARE,..... With this bilingual website, the foundation aims to bring the natural value of the North Sea under the attention of the public and politicians. A lot of information and links concerning Quest4D will be incorporated in the website (www.zeinezicht.nl).
Task 4.2.2: Follow-up committee (RCMG)

An external advisory group has been established to provide recommendations and guidance over the practicality of all project aspects. A balance was sought between governmental organisations (Flemish/Federal), industrial groups and the main users of the EEZ.
4. INTERMEDIARY RESULTS

Work Package 1: Process studies and modelling (MUMM)

Task 1.1: Defining the physical system in the space, time and depth domain (4D) (Ph1-2)

Task 1.1.1: Definition of the sediment- and sediment transport system and the whole range of processes having an impact on these systems (Ph1/Yr1-2)

Sediment- and sediment transport system

The Belgian near shore area is a trap for fine-grained cohesive sediments. Existing long-term measurements (between 0.5 and 51 days), which have been collected between 2003-2006 in the Belgian coastal zone, at different locations, have been analysed. A benthic lander (tripod) was used, equipped with CTD, OBS, LISST 100C, ADV and PC-ADP sensors. The SPM concentrations show that – beside the typical tidal (ebb-flood) influence – the wind velocity and direction (SW or NW) has a major impact on SPM concentration variation and that the meteorological and hydrodynamic history has often a more important influence on SPM concentration than neap-spring tidal cycles. Moreover, it was found that a high SPM concentration layer (>3g/l) is formed regularly near the bed and that this relates often with the occurrence of high SPM concentrations from previous stormy periods. This layer can remain present during a few tidal cycles after a storm (Figure 1). The SPM concentration in the coastal zone is reflected also by the origin of the water masses in the southern North Sea; salinity can be used as a clue. The salinity displays often big and sudden variations. High salinity values are an indication of an Atlantic origin of the water and occur during SW winds. The influence of the Scheldt and other fresh water sources is dominating during low salinity periods, which can be related to NE-NW winds.

Figure 1: Measurements near Zeebrugge during November 2005 (SPM1: 0.2 m and SPM2: 2.0 m above the bottom). The sudden increase in SPM1 concentration at day 2.5 is caused by a storm with significant wave heights of more than 3 m. Remark that the SPM1 concentration remains high during the following days.

Settling of mud flocs is controlled by flocculation and determines the transport of cohesive sediments. Flocculation is the process of floc formation and break-up and has a direct impact on settling velocity. The settling velocity is a function of the particle size and effective density. Because the SPM consists of a population of flocs with heterogeneous sizes, densities, and shapes, the settling velocity of mud flocs in natural environments may vary. Direct and indirect methods exist for the sampling of settling velocity. Direct methods are carried out, typically, in-situ (or even in the lab); the LISST100 has become a standard measuring instrument for particle size spectra and volume concentrations for applications at sea and in estuarine waters. The effective density and the settling velocity cannot be measured using this instrument; therefore an indirect method has been used to calculate the fall velocity based on LISST 100 data, together with SPM concentration data. The measurements have been carried out between 2003 and 2005, during 8 tidal cycles (Figure 2). The effective density was calculated based on a fractal description of mud flocs and using floc and water density data. The water density was derived from CTD measurements and the floc density was calculated using SPM concentration, particle volume concentration and water and primary particle densities. The fractal dimension has been derived from the empirical relation between effective
density and floc size (Kranenburg, 1994). The settling velocity for flocs with fractal structure was calculated after Winterwerp (1998).

Experimental observations are always subject to uncertainties that can be typically attributable to random measurement errors (lack of precision), systematic errors (lack of accuracy), human error, and intrinsic variable stochasticity. Within the field of flocculation of cohesive sediment dynamics, stochastic uncertainty is of primary importance as recently recognised by e.g. Khelifa and Hill (2006) and Maggi (2007). Based on the theory of error propagation, the error of the effective density and the settling velocity of mud flocs have been estimated using the measurement data of OBS, SPM filtration, LISST100C, CTD and Sedigraph. The results show that the relative standard deviations for effective density and settling velocity are about 10% and 100%, respectively. These uncertainties should rather be regarded as lower limits of the real error, because the errors due to the lack of accuracy of the OBS, LISST and Sedigraph have been omitted, as they are unknown. From the results, it was found that the statistical error of effective density was dominated by uncertainties of SPM concentration and primary particle density and for fall velocity by uncertainties of primary particle and floc sizes, respectively. These statistical uncertainties will always be high when dealing with natural flocs or particles and cannot be reduced by increasing the accuracy of the instruments.

Figure 2: Example of particle (floc) size distribution of the SPM measured by the LISST as a function of volume concentration measured during 2 tidal cycles near Zeebrugge.

Sedimentation patterns
RCMG focussed on the area north of the Vlakte van de Raan; including the dumping ground Br&W S1, as it is one of the main sedimentation areas on the BPNS. A digital terrain model (DTM), based on multibeam data (RV Belgica campaign ST0728), reveal different sedimentation and erosion patterns originating from natural processes and human-induced activities. Figure 3 shows the spatial extent of the measurements. Sedimentation occurs on the dumping ground of dredged material, resulting in the formation of dredge spoils. Further eastwards, small-scale sedimentation patches, formed by dense *O. fusiformis* aggregations, are present. This tube-building worm occurs in aggregations of up to 6000 tubes per m². Side-scan sonar and multibeam images reveal that the patches have different sizes and shapes (Figure 4). Their surface area ranges between 10 and 220 m². The high-resolution images demonstrate also that the patches occur in between large to very large subaqueous dunes; these form sheltered conditions to the tubeworms. Van Veen samples were taken to define the preferred sedimentological environment of the macrobenthos and densities of the tubeworms were calculated. Up to 6000 *O. fusiformis*/m² were found (Figure 3). Furthermore, bedforms of different sizes occurring in this area have been used to deduce the sediment transport directions. A dominance of SW-directed bedload transport is derived. Finally, various erosion patterns are observed, due to intensive beam trawling.
Figure 3: Map showing the area north of the Vlakte van de Raan, including the dumping ground Br&W S1, with the densities of *O. fusiformis* and the spatial extent of the multibeam measurements (red rectangle).

Figure 4: Details of a) side-scan sonar images and b) multibeam image showing individual patches formed by *O. fusiformis* aggregations. The red lines are 10 m apart from each other.

Task 1.1.2: Definition of a reference framework, based on the historic Gilson sediment and macrobenthos dataset (1899-1939) (RBINS)

**Sediment data**

Selection of sediment samples for further grain-size analysis was performed initially accordingly with previous and ongoing research on the Westhinder area. Samples have been processed by MUMM and the results will be interpreted in the course of 2008.

**Benthos data**

Bivalves: Gilson’s specimens represent about 80 % of the “Belgian” marine bivalves of the collections of the RBINS and contain dry specimens (shells, valves) and fluid-preserved animals (ethanol). From the dry collection, about 4000 “lots” (boxes, mini-bags, ...) should exist, representing ~30 families. So far (01/10/2007), about 30 % (1125 “lots”) of this material has been successfully digitised; 10 families and 24 species have been recorded. 23% of the specimens are not determined at the species level. Up-to-date, 320 specimens in the form of “bi-valves” (290 “fresh” or “collected alive”), 210 shells of Gastropods (family Calyptraeidae e.g. *Crepidula fornicata*, *Calyptra chinensis*), and more than 95,000 loose valves, of which 370 only are flagged “fresh” have been recorded. This indicates that a large part of the dry material will not be representative of the actual distribution of living bivalves at the time of collection. This information might
however prove useful, i.e. to compare distributions of loose valves and actually living bivalves and evaluate whether loose valve occurrence can be used as a “proxy” to track species occurrence in a given habitat. The whole collection of fluid-preserved specimens was digitised. 3145 tubes representing 20 families and 57 species are recorded. 21% of the material is not determined at the species level.  ~89,000 specimens are in the form of “bi-valves” (88,000 flagged “collected alive”), 750 in the form of “valves” (30 “collected alive”, 450 “fresh”). This material is thus most suited to track the historic distribution of species actually living in the area at the time Gilson carried out his sampling programme. The geographic distribution of species within the dredge-sampling grid can be tracked using “fresh” records; counts of specimens can be considered after appropriate processing of data.

**Amphipods**: about 1000 tubes that have been digitised represent the whole collection of Amphipods from the Belgian marine area. 63 different “taxa” (genus or species) are recorded (old names) belonging to 24 families. 517 tubes with a total of 1938 specimens are from Gilson and were gathered at 199 sampling stations, of which only a small fraction can be geo-referenced at this stage; dredge and sediment samples are, indeed, very little represented in these data. Overall, the data set is considerably reduced for the Amphipods as compared to other taxa. It seems likely that under sampling explains this observation, probably due to the small size of most Amphipod species; most records occur in “plankton” nets.

Task 1.1.3: Quantification of changes and trends, based on long-term datasets and sampling within the depth and time domain (Ph1-2/Yr1-2-3)

**Large-scale approach (Ph1/Yr1-2)**
Based on historical hydrographic charts, the long-term bathymetry changes will be studied. A number of charts have been selected for digitisation, and WL is now digitising this selection.
The long-term volume changes will be studied based on the bathymetric measurements along fixed tracklines covering the Flemish Banks. The multibeam data surveyed still need processing. Long-term sediment changes will be studied when the sediment databases are fully populated.

**Small-scale approach (Ph1-2/Yr1-2-3)**
At the University of Stuttgart erodibility measurements were performed on 8 subsamples of boxcores (ST0717 campaign). A typical result is showed in Figure 5: the graphs give the variation of the bulk density and of $\tau_{e, crit}$ with depth in the sediment sample. All 8 samples show a similar pattern: at the surface, the critical shear stress for erosion $\tau_{e, crit}$ is rather low, and lies between 0.3 and 1.0 Pa. However, $\tau_{e, crit}$ increases rapidly with depth, up to values of several Pa (with a maximum of 13 Pa), suggesting that the underlying layers are more consolidated. Some of the samples seem to indicate a positive correlation between the bulk density and $\tau_{e, crit}$, although some other samples seem to show no correlation at all. However, $\tau_{e, crit}$ will probably also depend on other parameters, among which the grain size distribution and the POC-content. These possible correlations still have to be investigated, which will be done once the grain size distribution and POC analyses have been carried out. None of the planned analyses at WL have been performed up till now, since the gammadensimetry at the VUB could not be carried out yet. This is due to the fact that the gammadensimeter needed recalibration, since the dimensions of the sampling tubes were different from those of the tubes used in the past. This recalibration has been done recently, and the density profiles will be measured in the very near future. It must also be noted that the CSM, recently acquired by VLIZ, is under repair; it is still unsure when the instrument will be available again.
Figure 5: Graph representing the variation of the bulk density and of \( \tau_{e,crit} \) with depth.

Two seismic sources were used (RCMG) to investigate the recent sedimentation at the old and present dumping ground Br&W1 of dredged material. The resulting seismic profiles show that the sources are not suitable for the investigation of the sedimentation patterns. Due to ringing, a seismic disturbance by which a strong reflector masks the underlying structures, and the limited resolution, only the seabed reflector and the base of the Quaternary reflector could be detected, while the sedimentation patterns in the first 5 meters are not visible.

For the provenance study of the North Sea muds (K.U.Leuven) using (clay) mineralogy, over 180 samples were collected and analysed. 24 additional bottom and suspension samples of the BPNS were taken (RV Belgica) to further characterize and compare the muds. The rest of the sampling was focused on characterizing the potential source areas of the muds: 16 bottom and suspension samples were taken from the Scheldt Estuary, between the harbour of Antwerp and its mouth (RV Belgica). 10 more samples were taken of river sediments, further upstream, and from the Scheldt tributaries. 60 samples, covering the relevant stratigraphic range of the Eocene and Oligocene were taken from (on land) drill cores. A total of 40 Quaternary samples were collected, including 10 Holocene clays from the Belgian coastal area and 30 from Pleistocene samples consisting of cover sands from Flanders and clay sediments from the Campine basin and the Roer valley in The Netherlands. Beach sediments were sampled on the French coast, between Dunkirk and the Somme Estuary (14), and on the English Coast between Folkestone and Portsmouth (7). From the Atlantic Ocean (off the Spanish and French coast) and The Channel, 7 suspension samples were taken (RV Belgica). To estimate the variation in the mineralogical composition of marine bottom samples, also 4 samples from more distant locations (up to Bergen, Norway) were collected (RV Belgica). Over 90% of the analyses have been carried out and interpretations of the results are currently underway.

Task 1.2: Modelling of processes

Task 1.2.1: Development of models to describe and predict the response of the ecosystem on changes (Ph1/Yr1-2)

Flocculation model

In literature, different flocculation models can be found; these models calculate the fall velocity of mud flocs in an empirical, theoretical or heuristic way. Different models have been implemented and validated against the fall velocity data, which have been collected by the tripod. The models are: constant fall velocity, power function and tidal model. The conclusion so far is that simple models cannot represent correctly the measured fall velocity and that more complicated models; combining microbiological and mineral components of mud flocs, have to be used to obtain a good representation of the measurements.
Wetting/drying scheme

A new grid has been developed to set-up a detailed model of the Zeebrugge area. The model grid has a resolution of about 50 m × 50 m. The hydrodynamic COHERENS model (Luyten et al., 1999) has been adapted to allow grid points to become dry or wet during simulation. This “wetting-drying” scheme gives a better representation of bathymetry in shallow areas, because no minimum depth has to be used for numerical reason. The implemented scheme is based on the work of Uchiyama (2004). The scheme has been validated for 2D as well as 3D applications of the Scheldt estuary, between Vlissingen and Antwerp, where many intertidal areas occur, and for a detailed model of the Zeebrugge area, see Figure 7.

Figure 7: Wetting/drying scheme applied to a detailed model of the area around Zeebrugge. Left is shown the total water depth at high water; right at low water during spring tide.

Task 1.2.4: Coupling/interaction of different models (Ph1/Yr2)

There are no results yet from the dynamic coupling of the spectral wave model WAM with the COHERENS flow model, as the models are being calibrated and tested.

Work Package 2: Impact of natural and anthropogenic pressure (RCMG)

Task 2.2: Impact of (cumulative) human activities on the ecosystem and with respect to the executed or planned monitoring programmes

Task 2.2.2: Evaluation of erosion/deposition rates (4D) with the impact of human activities: case studies of impact assessments (Ph1-2/Yr2-3)

Regional impact assessment of long-term dumping in the Sierra Ventana region (Ph2/Yr3)

The sedimentation patterns on the present and old dumping ground Br&W S1 were investigated based on the analyses of vibrocores. The photographs of Figure 8 and the density plots show that the vibrocore, taken on the present dumping ground, is characterised by fine to medium sand with intercalations of clay and clay lenses, whilst the one on the old dumping ground is characterised by fine to medium sand with intercalations of silt. The difference in sedimentation patterns between the two vibrocores is mainly due to the difference in morphological setting, which implies different hydro dynamical conditions and the type of dredging works.
To characterise the morphology of the present dumping site Br&W S1 and its surroundings, full-coverage multibeam data was collected in the swale, north of the Vlakte van de Raan. The resulted DTM (2x2m) clearly shows the impact features of the dumping process (Figure 9).

**Work Package 4: Data management and valorisation (RCMG/MUMM)**

**Task 4.1:** Data management (Ph1-2/Yr1-4)

Data will be imported into the Belgian Marine Data Centre in the course of 2008.

The first data will be expected during the next year.

**Task 4.2:** Valorisation (Ph1-2/Yr1-4)

A project website with a public and private domain was created and a project leaflet was designed.
Year 1 has concentrated mainly on data acquisition (incl. field surveys), laboratory analyses and preparatory work for further exploration of existing datasets. Only limited conclusions and recommendations can be formulated.

**Work Package 1: Process studies and modelling (MUMM)**

**Task 1.1: Defining the physical system in the space, time and depth domain (4D) (Ph1-2)**

**Task 1.1.1: Definition of the sediment- and sediment transport systems and the whole range of processes having an impact on these systems (Ph1/Yr1-2)**

The long-term sediment- and sediment transport measurements with the tripod have shown that a high SPM concentration layer (>3g/l) is formed regularly near the bed and that this often relates to the occurrence of high SPM concentration from previous stormy periods. The knowledge of the presence of such a persistent near-bottom high SPM concentration layer in the Belgian near-shore area is new. Further research has to be carried out in order to understand the dynamics of this near bed SPM layer and its influence on the high siltation rate in the ‘Pas van het Zand’ navigation channel and in the port of Zeebrugge.

An important part of our understanding of flocculation and cohesive sediment dynamics (deposition and erosion) is based on measurements. The uncertainties associated with indirect (or direct) settling velocity measurements are very high due to their statistical nature; the total error will be even higher because systematic errors, due to a lack of accuracy of the measuring instruments, have not been included. Our results underline that the statistical nature of flocculation processes and settling velocity must be taken into account when modelling cohesive sediment transport by at least a standard deviation of settling velocity, based on measurements or by introducing a floc size (and settling velocity) distribution in numerical models.

It has been proven that the area north of the Vlakte van de Raan is a good study area to investigate different sedimentation processes, both occurring naturally as well as human-induced. Secondly, the suitability of multibeam and side-scan sonar measurements, for the mapping and characterisation of sedimentation and erosion features, has been demonstrated (RCMG).

**Task 1.1.2: Definition of a reference framework, based on the historic Gilson sediment and macrobenthos dataset (1899-1939) (RBINS)**

The historic data of Gilson are probably unique for this period, as it provides data on benthos and sediments within a large, homogeneous and high-resolution sampling grid. Contrary to the expectations, bivalves of the collection have been collected mainly with a dredge, which will lower the power of long-term analysis. On the one hand, this implies that sampled benthic communities have been aggregated along dredge tows; on the other hand, sediment parameters must be averaged for each tow to examine correlations with the macrobenthic data. However, for Amphipods, results are worse than expected as most sampling stations can at this stage not be geo-referenced. Selected species will be examined more closely in the next stages of the project. At this stage, bivalve data tend to indicate high biomasses and high species richness values, north of the Scheur channel, off Zeebrugge. Surprisingly, the high densities, observed recently along the western Coastal Banks, do not appear in the Gilson dataset. Reasons for this observation still have to be clarified. Further analyses will be necessary to evaluate the limitations of this data-set for interpretations on the long-term evolution of macrobenthos in the Belgian waters. Meanwhile, digitisation will be pursued to complete the dataset for bivalves and to obtain preliminary data on Polychaetes.

**Task 1.1.3: Quantification of changes and trends, based on long-term datasets and sampling within the depth and time domain (Ph1-2/Yr1-2-3)**

No conclusions can yet be made as the analyses are still performed on the boxcores. The seismic investigation of the recent sedimentation on the dumping ground Br&WS1, has demonstrated that higher resolution sources, like a parametric sub-bottom profiler, should be used to detect the different sedimentation structures, caused by successive dumping events.
Task 1.2: Modelling of processes

Task 1.2.1: Development of models to describe and predict the response of the ecosystem on changes (Ph1/Yr1-2)

Classical flocculation models, based on an empirical approach, are not able to reproduce satisfactorily the measurement data. A comprehensive understanding of SPM dynamics and its implications in coastal morphodynamics must include the mineral, as well as the microbial fraction. Because the mineral and organic constituents are correlated strongly to the site, a calibration of flocculation models will be site-specific largely. It is therefore important to have data on the suspended matter and the organic concentration at the same moment.

Work Package 2: Impact of natural and anthropogenic pressure (RCMG)

Task 2.2: Impact of (cumulative) human activities on the ecosystem and with respect to the executed or planned monitoring programmes

Task 2.2.2: Evaluation of erosion/deposition rates (4D) with the impact of human activities: case studies of impact assessments (Ph1-2/Yr2-3)

Regional impact assessment of long-term dumping in the Sierra Ventana region (Ph2/Yr3)

The analyses of vibrocores demonstrate a clear difference in sedimentation patterns between the old and the present dumping ground of Br&W S1. A difference in morphological setting is important, but also the type of material that has been dumped. Still, the dynamics of this area need to be investigated to get a better insight in the driving processes on both dumping grounds.
### Work Package 1: Process studies and modelling (MUMM)

#### Task 1.1: Defining the physical system in the space, time and depth domain (4D) (Ph1-2)

- **Task 1.1.1:** Participation in publication and literature review by all the modelling partners. MUMM’s activities will focus mainly on sediment transport measurements and data interpretation. Three long-term measurements with the tripod (2 weeks to 3 months), near Zeebrugge, as well as tidal cycle measurements from the RV Belgica are planned. In particular, the interpretation of PC-ADP data and the near-bed current and sediment transport dynamics will be focused on.
- **Task 1.1.2:** RCMG will further investigate the sedimentation processes in the area north of the Vlakte van de Raan: 10 vibrocores, with an average length of 4.5 m, will be analysed; the results will be compared and interpreted in function of the naturally versus anthropogenically-induced sedimentation.
- **Task 1.1.3:**

#### Large-scale approach (Ph1/Yr1-2)

- The further digitalisation of the selected bathymetric charts (WL) is planned for January/February. The results will be used to study the morphological evolution of the North Sea bed (March/April/May). If necessary, the selection of bathymetric charts can be further extended, in the course of the study.
- During the next year, RCMG will survey fixed tracklines covering the Hinder Banks, both in Spring and Autumn; the seasonal variability will be investigated. However, it must be noted that the M2 tidal reduction method for the Belgian coastal zone (Van Cauwenberghe et al., 1993) is not yet applicable for the northern part of the BPNS. It is not yet clear when it will be possible. In a later phase, the data will be compared with previous data series to investigate long-term volume changes.
- The remaining sediment samples of the Gilson collection (mainly coastal area). The Marine Biology Section volunteered to analyse the grain size distribution of a selection of these samples, relevant for QUEST4D, using their Malvern Mastersizer.
- The long-term changes of macrobenthos, based on the MACRODAT database (1976-2006) has been worked out in the project “Long-term changes in the macrobenthos of the Belgian Continental Shelf (SPSDI, 2001-2003). MARBIO will partly revisit these results, interpret and couple them to the changes in the physical habitat.

#### Small-scale approach (Ph1-2/Yr1-2-3)

- In January, the density profiles of the WL samples will be measured using the gamma-densimeter at the VUB. Depending on the availability of the instrument and taking into account the duration of the measurement (minimum 1 day/core), it is possible that only a selection of samples will be done. Afterwards (February/March), the grain size distribution and the POC content will be determined at different depths in the cores. The critical shear stress for erosion will be measured also, using the CSM of VLIZ, when available.
- The cooperation with the University of Stuttgart will continue and supplementary boxcores will be collected during the next RV Belgica campaigns. Bulk density and erosion resistance analysis (the latter by WL) will be performed. Radiometric analysis will be carried out on some of the boxcores in order to determine the age and accumulation rate of the sediments. In cooperation with the Belgian Navy, it is planned to perform free-fall penetrometer tests along the case study areas (RCMG). The instrument is under purchase.

#### Task 1.2: Modelling of processes

- **Task 1.2.1:** MUMM will finalise the flocculation model development during the second year and a numerical scheme will be set-up to integrate sand-mud mixtures in the simulation.
- **Task 1.2.2:** K.U.Leuven will investigate the feasibility to incorporate detailed flow-sediment interaction into the QUEST4D modelling.
MUMM will carry out a validation of the 2D sediment-transport model using existing and newly collected data.

Task 1.2.3: Model validation, see also 1.2.2. MUMM will start with the development of a sediment-transport module for the COHERENS model.

Task 1.2.4: Coupling of the parallel codes of the spectral wave model WAM and the hydrodynamic model COHERENS. Implementation, validation and first simulations on High Performance Computer of K.U.Leuven will be finished by the end of 2008.

**Work Package 2: Impact of natural and anthropogenic pressure (RCMG)**

Task 2.1: Natural evolution of the seabed and impact of climate change

Task 2.1.1: Further compilation and analyses of hydro-meteorological database.

Task 2.1.2: First proposal for climate scenarios in close collaboration with other partners and with international contacts through SEAMOCS.

Task 2.2: Impact of (cumulative) human activities on the ecosystem and with respect to the executed or planned monitoring programmes

Task 2.2.1: The spatial extent of the fishing impact will be estimated based on the analysis of available multibeam and side-scan sonar data. The impact of dredging, dumping and coastal engineering works will be based on the analysis of the historical nautical maps (task 1.1.3).

Task 2.2.2: Case studies

**Investigation of the cumulative impact of fisheries and aggregate extraction on the maintenance processes of tidal sandbanks (Ph1/Yr2)**

Boxcoring and free fall penetrometer tests will be performed to study the spatial variability of the seabed over some sandbank areas. Several methodologies will be worked out, partly based on literature.

**Regional impact assessment of long-term dumping in the Sierra Ventana region**

The dynamics of the study area will be investigated by performing ADCP measurements during one of the RV Belgica campaigns, by analysing already collected multibeam data (sediment transport direction can be deduced from the dunes) and by comparing dumping intensity maps with difference maps over several years. Based on these results insight will be gained on the cause of the difference in sedimentation patterns between the old and present dumping ground Br&W S1. Finally, from the time reconstruction of the Sierra Ventana time slices of physical data, the Marine Biology Section will feed these data into their macrobenthic community and species-specific habitat suitability models. From this, it will be attempted to derive thresholds of changes and the influence of turbidity on the occurrence of macrobenthos.

**Work Package 4: Data management and valorisation (RCMG/MUMM)**

Task 4.1: Data management (Ph1-2/Yr1-4)

Task 4.1.1: Various partner contributions will be integrated into the central GIS (RCMG). This will include the digitised bathymetrical data of WL, dumping intensity data, modelling data, …. GIS models will be created to incorporate the data in an efficient way.

Task 4.1.2: BMDC will import the data delivered by the partners.

Task 4.2: Valorisation (Ph1-2/Yr1-4)

A workshop will be organised to discuss the research result in a multidisciplinary context. At the end of year 2, the development of an animation is foreseen illustrating the seabed evolution during the Holocene.
The follow-up committee consists of the following members: Balcaen Nathalie, Mertens Tina (Flemish Authorities, Agency for Maritime & Coastal Services, Coastal Division); Dupont Yves (Belgian Navy, DGRM); Roche Marc, Degrendele Koen (FPS Economy, SMEs,Self-employed and Energy, Marine Sand Fund); Bonne Wendy (FPS Health, Food Chain Safety and Environment, Department of Marine Environment); Hostens Kris (Institute for Agricultural and Fisheries Research, Fisheries); Scory Serge (RBINS, MUMM); Stalpaert Lisbeth (Flemish Environment Agency, MIRA); Roose Frederik (Flemish Authorities, Department of Mobility & Public Works, Division Maritime Entrance); Desaever René, Zeegra vzw

More specific cooperation has been established:

Cooperation has been established with the Division Maritime Entrance (Flemish Authorities, Department of Mobility & Public Works), to obtain dredging intensity data.

The Hydrographic Office, Flemish Authorities, provides time-series of soundings needed to study the long-term bathymetry changes. They showed a high interest in the temporal variation of the seabed, in the view of tuning future hydrographic charting to the variability in seabed dynamics.

An active cooperation is established with the Belgian Navy. They are interested in the approach adopted to study sediment transport processes and in the data that will be acquired; this in the view of setting-up probability risk maps of mine burial. In 2008, the Belgian Navy will start with high frequency seafloor observations, some of which on a weekly basis. Quest4D can provide a framework for these measurements and MUMM’s tripod will be deployed in one of the targeted areas. Moreover, they acquired recently a suite of very-high resolution acoustic tools and a free fall penetrometer, which is of interest to the Quest4D group.

There is an active cooperation with the FPS Economy, SMEs,Self-employed and Energy, Marine Sand Fund, especially towards the processing and evaluation of the multibeam data covering fixed tracklines over sandbank areas. Their extensive multibeam datasets and time-series of the BPNS, are available for further analyses.

Useful comments were given by all the end-users during the first end-user meeting, which took place on 19/11/2007.
8. REFERENCES

**Overzicht van max. 1 pagina**

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<th>Author(s)</th>
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<td>Uchiyama, Y.</td>
<td>2004</td>
<td>Wetting and drying scheme for POM and its application to San Francisco Bay</td>
<td>Proc. 6th Int. Conf. on Hydrodynamics, Perth, Australia.</td>
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9. PUBLICATIONS
Gedetailleerde chronologische bibliografische lijst. Kopie van de publicatie toe te voegen in bijlage!

9.1 Publications of the teams
Ordenen per partner van het netwerk

9.1.1 Peer review

RCMG
Du Four, I. & Van Lancker, V. Physical impact of dredged material disposal sites and their recovery after cessation of dumping: a case study in the Belgian coastal zone. Submitted to Marine Geology in October 2007. (no copy is provided, since the paper is not accepted yet)

MUMM
Fettweis, M. Uncertainty of effective density and settling velocity of mud flocs derived from in situ measurements. Submitted to Estuarine, Coastal and Shelf Science in December 2007. (no copy is provided, since the paper is not accepted yet)

9.1.2 Others

RCMG

MUMM

KUL

9.2 Co-publications
Specificeeren betrokken ploegen

9.2.1 Peer review

RCMG

MUMM

(*) publication of Marebasse project, finalised during Q4D

(**) publication of Mocha project, finalised during Q4D

KUL


(*)

9.2.2 Others