Three years of bedform evolution on the Flemish banks, based on successive multibeam surveying of 2 monitoring areas.

K. Degrendele [(1)], M. Roche[(2)] and P. Schotte[(3)]

(1, 2 and 3) FPS Economy, SMEs, Self-employed and Energy, Fund for Sand Extraction,
NG III, Avenue Roi Albert II, 16, B-1000 Brussels, Belgium
(1) Koen.Degrendele@mineco.fgov.be
(2) Marc.Roche@mineco.fgov.be
(3) Patrik.Schotte@mineco.fgov.be

Abstract
The Fund for Sand Extraction evaluates the impact of the marine aggregates extraction on the environment. From November 1999 to December 2002, using a multibeam echosounder, we have carried out 7 surveys on 2 reference areas situated on the Flemish Banks complex. This time-series provides valuable information on the spatial evolution and mobility of the large dunes on this part of the Belgian Continental Shelf. This set of data emphasises the strong impact of the extraction on the bathymetry. However, the extraction doesn't affect the morphology-relief itself. A migration of the dune crests can be quantified and related to hydrodynamical and meteorological conditions. Our results are in accordance with previous publications.

1. Introduction and context
Numerous tidal sandbanks characterise the Belgian continental shelf. Each year, around 2 million cubic meters of aggregates are extracted from these sandbanks. The Fund for Sand Extraction, as a subdivision of the FPS Economy, SMEs, Self-employed and Energy is responsible for all activities that concern the granulate extraction on the Belgian Continental Shelf.

An important part of our assignment is to evaluate the impact of the extraction on the marine environment. This is performed by frequently conducting surveys on reference areas using a multibeam echosounder. Our two main The zone KBMA (0.92 km^2) on the Kwintebank is subjected to a dense extraction. Before February 2003, around 15 % of the total extracted volume has been dredged in this restricted area (Degrendele et al., 2002a). The zone R2 (0.34 km^2) on the Middelkerke Bank is outside the concession area.

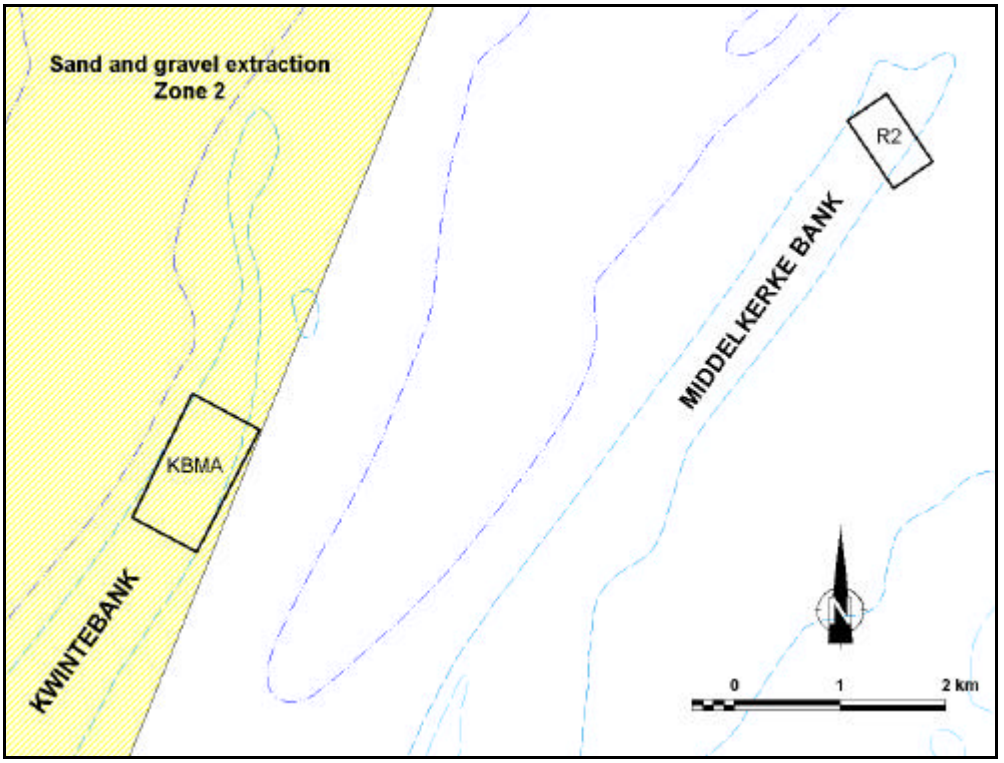

Fig. 1 – Location of the monitoring areas
Hydrographic survey isobaths of 5, 10 and 20 m are drawn.
The limits of the sandbanks can be defined by the 10 m isobath.

From November 1999 to December 2002, we have carried out 7 surveys on the KBMA and R2 areas. This time-series provides information on the spatial evolution and mobility of the large dunes on this part of the Belgian Continental Shelf. The repartition in time of the surveys (table 1) allows a medium range (yearly basis) evaluation of the morphological and bathymetrical evolution. However, based on the proximity of certain surveys, we can estimate the variation over a shorter time period.

	SURVEYS						
	9925	**0023**	**0104**	**0131**	**0203**	**0219**	**0229**
KBMA	16/11/1999	28/09/2000	21/02/2001	27/11/2001	12/02/2002	05/09/2002	12/12/2002
R2	16/11/1999	29/09/2000	22/02/2001	30/11/2001	13/02/2002	06/09/2002	12/12/2002

Tab. 1 – Date of the surveys on the 2 monitoring area KBMA and R2.

The goal of this contribution is to present these factual results. The correlation with meteorological and hydrodynamical data is currently in progress and will be presented at the workshop.

2. Methods

Since November 1999, we use a Kongsberg – Simrad EM1002 multibeam echosounder installed on board the federal research vessel Belgica. The EM1002 provides 111 beams of 2° width. It works at a nominal frequency of 95 kHz and with ping-rate of around 4 Hz. The data are real-time corrected for roll and heave using a Seatex MRU 5 motion sensor. The geographic co-ordinates are provided by a DGPS positioning system. According to the manufacturer, the depth measurement accuracy of the EM1002 is up to 10 cm RMS or 0.2% of depth. Post-processed data of successive surveys on a stable target (wreck) indicate a global error of 20 cm (Degrendele et al., 2002b).

Multibeam data are processed with Kongsberg – Simrad post-processing softwares : Neptune for the bathymetric correction, Poseidon and Triton for the backscatter strength cartography and seabed classification. The soundings are tide-corrected and referenced to the MLLWS-datum.

For each survey, a digital terrain model (DTM) of 2 X 2 m resolution has been computed using an inverse distance type algorithm. Each DTM reflects the bathymetrical-geomorphological state of the seabed at the time of surveying. The comparison of the successive DTMs allows to evaluate the mobility of the large dunes (change in the XY plan) and the bathymetrical evolution (change in Z values). Comparison of cross-sections from each DTM allows the quantification of the shifts of the large to very large dune crests in the horizontal plain (figure 2). Histograms and statistical analysis of the Z values of each DTM provide additional information on the bathymetrical evolution.

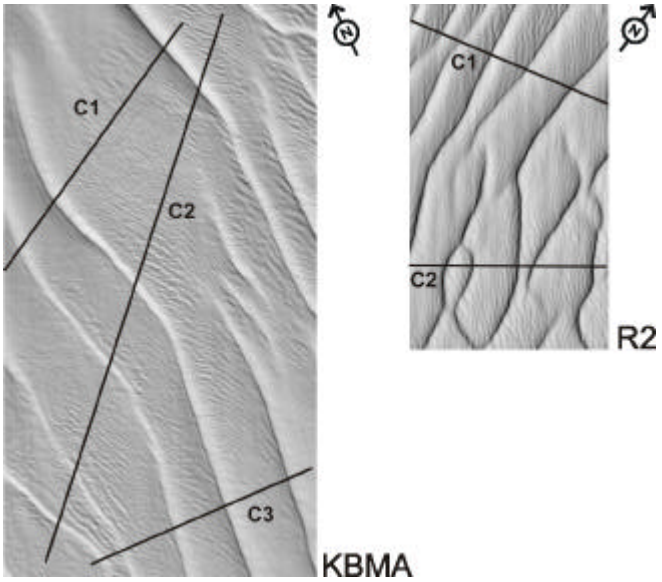

Fig. 2 – General morphology of the monitoring areas (Surveys 9925) and location of cross-sections

3. Results

Bathymetrical and geomorphological evolution

Monitoring area KBMA:

The sandwaves in this area have a height that varies between 2 and 6 meters, with a wave length of more then 100 m. They are orientated N-S and are asymmetric with the steepest slope directed to the east. Within the 3 years of monitoring, the KBMA area shows a drastic decrease of the bathymetry and a clear shift of the location of the dunes crests (figure 3). The statistics (table 2), calculated for each survey, establish that the bathymetric evolution is not continuous. The maximal differences between the mean bathymetric values are observed between November 1999 and September 2000 (-0.39 m) and between September and December 2002 (-0,28 m).

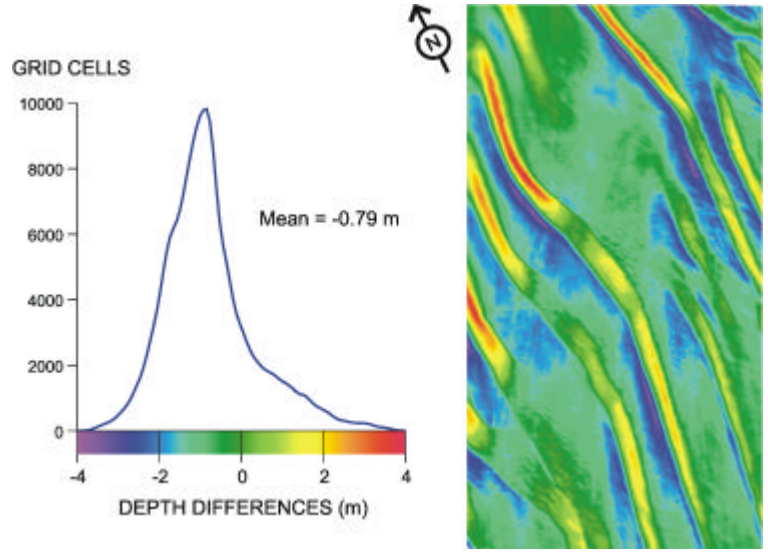

Fig. 3 – KBMA: difference between Survey 0229 – December 2002 and Survey 9925 – November 1999.

	9925	0023	0104	0131	0203	0219	0229
Minimum	-17.376	-17.945	-17.769	-17.855	-17.87	-17.957	-18.26
Maximum	-7.68	-7.271	-6.919	-7.997	-7.851	-6.572	-7.805
Mean	-13.394	-13.775	-13.663	-13.741	-13.794	-13.899	-14.181
Delta mean	0	-0.381	0.112	-0.078	-0.053	-0.105	-0.282
Std. Dev.	1.963	2.016	2.097	2.092	2.109	2.129	2.143

Tab. 2 – KBMA: Statistics of the bathymetry for the successive surveys

Overall the mean bathymetry of the area has decreased by 0.79 m between November 1999 and December 2002 indicating a clear deficit of the sedimentary budget. The highest depth differences are observed in the Northwest area of the zone, near the western slope (limit W of the bank, see figure 3). They are the result of a shift of the largest dunes of the area to the Northeast.

Based on the location of the different sand dune crests, we calculated a mean north-eastern shift of 11m/year in the northern part (figure 4) and 7.5m/year in the southern part of the zone. If we compare the last survey of each year (figure 4) the shift seems fairly constant.

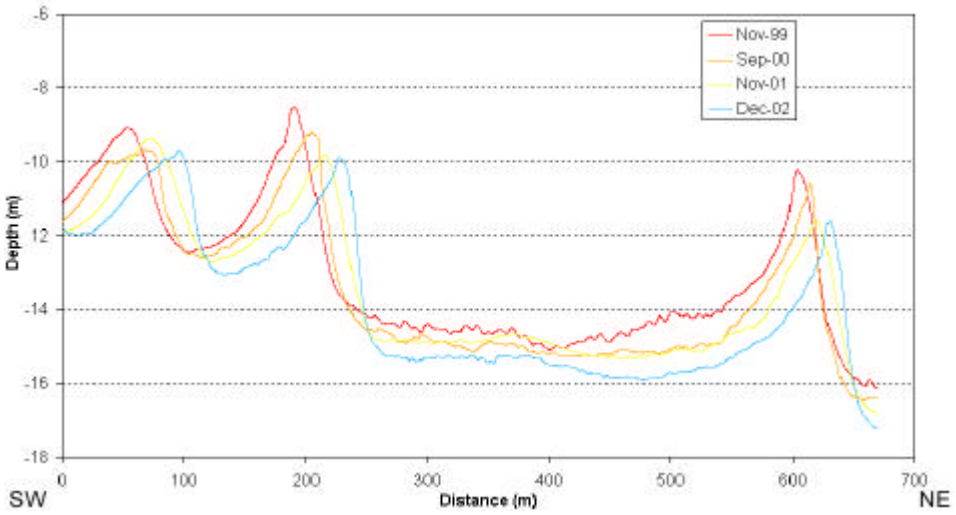

Fig. 4 – KBMA: Cross-section (C1) of selected surveys.

Monitoring area R2:

The height of the sandwaves varies between 1 and 4 meters, with a variable wave length (between 50 and 150 m). To the west of the area the dunes are asymmetrical with the steepest slope orientated to the east, to the east the steepest slope is orientated to the west, and in between the dunes are symmetrical. Opposed to the KBMA area, the R2 area doesn't undergo a significant global deepening. The difference between the mean depths measured over a 3 year interval is virtually null, suggesting a balanced sedimentary budget. The map of the depth differences (figure 5) shows a strong heterogeneity between the western part of the zone with strong variation related to a large shift of the dune crests and the eastern part which is quite stable.

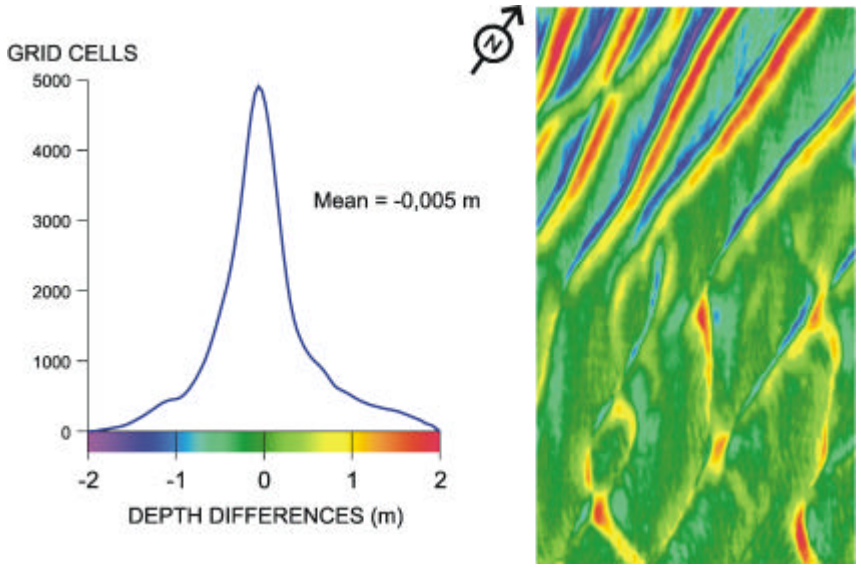

Fig. 5 – R2: difference between Survey 0229 – December 2002 and Survey 9925 – November 1999.

	9925	0023	0104	0131	0203	0219	0229
Minimum	-14.688	-14.803	-14.595	-14.526	-14.436	-14.589	-14.68
Maximum	-7.863	-7.791	-7.575	-7.891	-7.81	-7.327	-7.785
Mean	-11.114	-11.305	-11.114	-11.037	-10.956	-11.036	-11.109
Delta mean	0	-0.191	0.191	0.077	0.081	-0.08	-0.073
Std. Dev.	1.433	1.414	1.423	1.409	1.407	1.424	1.424

Tab. 3 – R2: Statistics of the bathymetry for the successive surveys

The dunes on the western part of the area, near the western slope of the Middelkerkebank, have a mean shift of 4.8 m/year in Northeast direction. The other sand dunes (figure 6), on the eastern slope, are stable or have a light shift (1.3 m/year) in the opposite direction. Their asymmetry (figure 6) confirms this tendency.

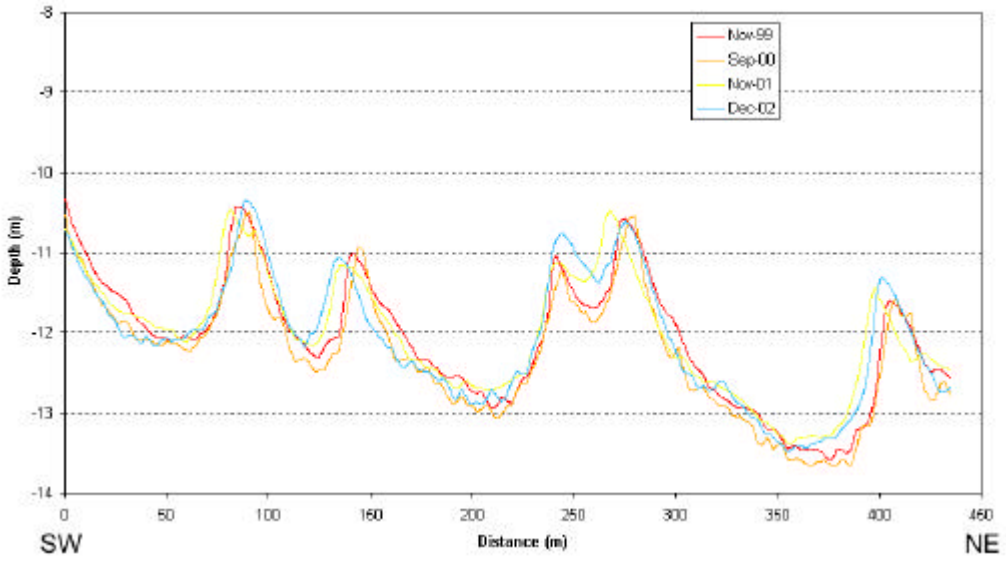

Fig. 6 – R2: Cross-section (C2) of selected surveys.

4. Interpretation and Conclusion

The morphology of both zones is more or less unchanged, as witnessed in earlier studies in adjacent regions on the Belgian Continental Shelf (eg Van Lancker et al., 2000). The shape and asymmetry of the sand dunes is stable (on a medium time scale). In the non-extracted area the bathymetry (Z-value) hasn't changed, the sediment budget is balanced. In the extracted zone on the Kwintebank (KBMA) we see a global deepening. This deepening is correlated with the high extraction density in this area. There is no differentiation between the dunes and the swales, the bathymetry changes are evenly spread across the zone. Since 1999, the morphology is apparently unaffected by the extraction of sediment.

On a medium time scale the evolution on both zones is dominated by tide. The horizontal shift of the dune crests takes place in the direction of the steepest slope. The symmetrical dunes are stable. On the flood dominated western part of the sandbanks (KBMA and western part of R2), the shifts have the same orientation as the flood, to the northeast. The eastern part of the zone R2 is located on the central part and eastern slope of the Middelkerkebank and shows a shift in the opposite direction. These results coincide with the circular maintenance model for sandbanks as described by several authors.

As pointed by Le Bot et al. (2000), the short term fluctuations on this global trend are the result of punctual meteorological conditions (storms). The study of the correlation between the successive surveys and meteorological and hydro-dynamical data is currently in progress.

5. Acknowledgements

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6. References

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