NUMERICAL DATA ABOUT PRESENT DAY SEDIMENT DYNAMICS ON THE FLEMISH BANKS (SOUTHERN BIGHT, NORTH SEA)

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NUMERICAL DATA ABOUT PRESENT DAY SEDIMENT DYNAMICS ON THE FLEMISH BANKS (SOUTHERN BIGHT, NORTH SEA)

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ABSTRACT

The paper analyses present day residual morpho-dynamics and sediment dynamics on the Kwintebank, partly on ground of volumetric monitoring and partly of visual bank profile comparison, departing from geomorphological techniques, requiring sequential detailed bathymetric profiling, high precision navigation and positioning, and profile normalization, uniformization and equalization. It aims at a quantified approach of shape and location change and of sediment migration problems. It presents numerical data about volumetric evolution trends on the bank and advances a dynamical subdivision of the bank and the existence of different sand transportation mechanisms.

INTRODUCTION

Large sandbanks occur in most of the shallow clastic tidal shelf seas. They have attracted much scientific attention, especially because of their genesis, morphology and evolution. The Flemish Banks and the East Anglian banks in the Southern Bight of the North Sea became classic reference zones for the North Sea area.

Moreover many of the bank systems, especially in the Southern Bight and on the belgian platform, are situated in areas of strategic nautical importance as they border important shipping lanes and approach routes and recently became the seat of important sand and gravel extraction or mobile passageways for submarine oil- and gaspipes and for telecommunication cables.

Those uses raise numerous questions about the present day sea floor morphology and especially about the bank stability ; about possible maintenance of the banks by a sand supply coping with the demands of the extraction ; about the origin, the pathways and the supply mechanisms of sand supplies ; and about repercussions of the aggregate extractions upon the bank height, volume, shape and location, upon the wave climate, the tidal currents and the surficial, sweep and therefore upon fisheries and coastal erosion.

It is clear that many of the scientific problems and much of the economic and technical questionning meet each other, especially in the field of residual morphodynamics and sediment dynamics, the changes of morphology and the related sediment displacements ensuing increasing lenghts of wave activity and of cycles of tidal wave passages and tidal current cycles.

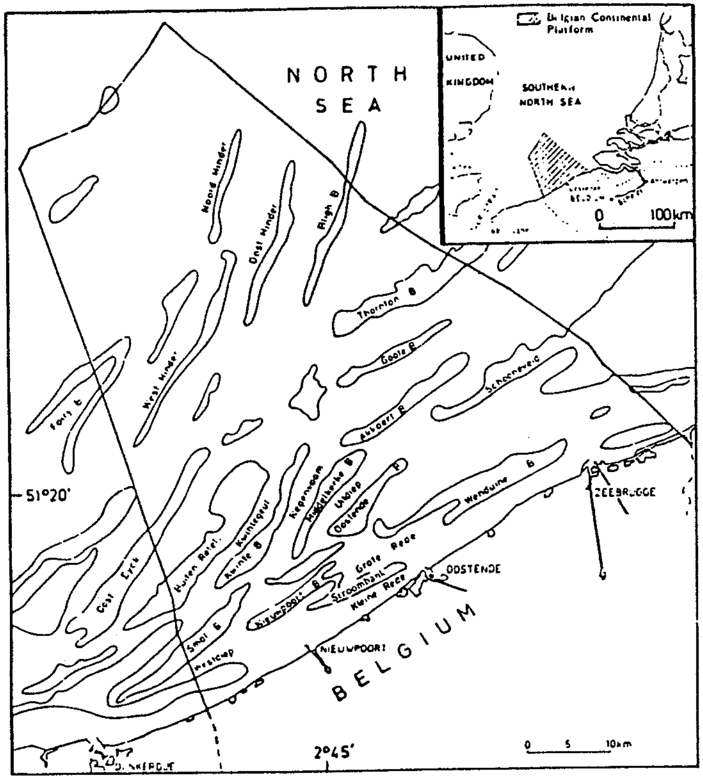

Fig. 1: The Belgian Continental Platform and the different sand banks

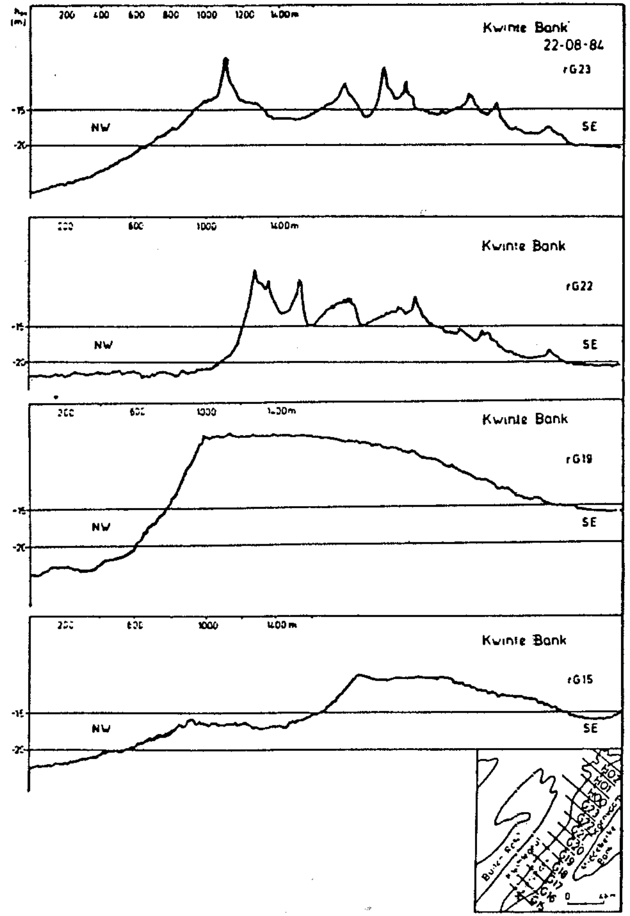

Fig. 2: Summer transverses of the Kwintebank on 22 August 1984 from the northern part (rG23, rG22) over the central part (rG19) to the southern part (rG15). The northern part is characterized by high asymmetric sandwaves climbing both bank sides; the central part shows a flattened top zone; the southern part presents a western bankside terrace. Remark the general asymmetry with a steeper residual erosive western side, as well as the depth difference between the western Kwinte Swale and the eastern Negenvaam

A better knowledge of present day changes in bank volume, shape and position and of the related sediment transport processes will not only interest the dynamical geomorphologist, the coastal hydrographer, the off shore engineer, the marine biologist, the economist, the fishery and so many others involved in the exploitation and management of the shelf sea floor and the coast, but possibly could help as well to find some clues for the interpretation of the banks interior structures and for a better understanding of their long term evolution and genesis, and possibly yield elements for testing of existing genetical theories.

In order to understand landforms, geomorphogenic processes and evolutions it is essential to distinguish short, medium and long term components as well as local and regional, instantaneous and residual aspects and to take in account the megatidal environment with its semidiurnally rotating currents, presenting velocities continuously changing between more or less opposite, unequal and varying eb and flood peaks and slack minima, as well as the impact of the wave characteristics.

PURPOSE AND GENERAL METHODOLOGY

It is not the purpose of this paper to deal with a more detailed bathymetric mapping, nor to focus on the geological structure of the banks and their origin and age, but to obtain quantitative data about the present day short term residual morphodynamics and sedimentdynamics by using geomorphological techniques in monitoring the basic volumetric variations and the related shape and location changes, and in evaluating the sediment migrations in ground of their morphological repercussions. Hereby the attention is more directed towards the quantified description of the present day phenomena and especially towards present day short term evolution trends, than upon their explanation, which undoubtely will require detailled hydrodynamical data.

Within that geomorphological and quantitative approach the fundamental way to tackle the problem of present day short term residual morphodynamics and sediment dynamics consists in comparing qualitatively or quantitatively successive total or partial crosssections along representative reference transverses of the bank, and in inferring transport pathways either from bedform characteristics indicating the residual migration direction of the bottom load transport or from the geographical distribution of the sediment losses and grains.

Qualitative evaluation of volume, shape, dimension and position changes of a bank transverse can be obtained by superposition and visual comparison of successive comparable cross-sections along a reference transverse. A posteriori the changes in profile can be expressed quantitatively.

Evaluation of changes in the total volume can be approached quantitatively by computing the differences between unit-volumes of the total cross-section along a reference transverse and above a reference level obtained at different dates (total unit-volumes).

The unit-volume corresponds to the area of the vertical cross-section times a width of 1 m. Unit- volumes are only computed above reference levels cutting the profile at least on both sides of the bank and bankwards of the bank's base-concavity.

Quantitative evaluation of shape and position changes of the bank can be obtained by comparing successive unit-volumes for total or partial reference slices delimited by reference levels and by reference positions, or by comparing unit-volumes for reference columns delimited by reference positions verticals (partial unit-volumes).

The Kwintebank, one of the Flemish banks, has been chosen as testing area, especially because it is, since 1978, an area of continuous sand extraction at a more or less controlled rate of about 400.000 m^3/year, mainly localised on its northern off shore part.

BASIC OPERATIONS AND RESULTS

Navigation and positioning

Monitoring of bank profile variations departs from sequential bathymetric profiles, sailed within a very short time in successive campaigns exactly along fixed representative reference transverses in a sufficiently dense network, as much as possible at constant bottom speed, and recorded with high depth and position accuracy and geographical reliability, and with high vertical and areal resolution.

The reference transverses correspond to loxodromic lines between fixed extreme W-Points situated along red Decca lines of the 5 B Decca network. Navigation has been worked out using radioelectronic hyperbolic systems : before 1984 Decca Navigator, since 1984 video track plotter aided Decca Navstar, since 1987 with simultaneous video track plotter assisted Syledis support. Positions have been taken every 60 seconds on Decca Navigator before 1984 ; afterwards every 30 seconds simultaneously on Decca-Navstar, on Decca Shipmate and on Toran, using the belgian Toran pattern, and since 1987 on a belgian Syledis chain. Positionings have been attended by on line data aquisition of the different system coordinates and other nautical parameters such as ship's longitudinal bottom velocity and ship's heading, by their monitor display, by on line video track plotting, by immediate control of geographical reliability of the hyperbolic positionings, and by data storage by HP 1000 ship's mini-computer, and followed up by data transfer, by position fix mapping by compatible laboratorium HP 600A minicomputer and by further laboratory evaluation of the geographical reliability by logical analysis of the position fix plots.

No profile sections have been used situated at more than 100 m away from the reference track.

Bathymetric profiling

Depth profiling has been worked out with Atlas Deso X echosounder before 1984 and, since 1984 with Atlas Deso XX echosounder. The vertical resolution is about 10 cm. and the digital reading error 10 cm. The profiles have been sailed at a ship's bottom velocity of 10 kts.

In order to obtain normalized and comparable profiles usable for morphological analysis, for volumetric computation and for visual comparison by superposition, several corrections are introduced on the bruto echosounder record : (1) tidal reduction every 10 minute for vertical tidal movement during the profile recording ; (2) time/length scale transformation ; (3) length scale uniformization for varying ship's bottom speed ; (4) possibly course correction for real but short course deviations ; (5) length scale equalization on sequential profiles ; (6) drawing of reference levels and reference position marks. No profiles have been used for visual comparison when wave amplitude exceeded 1 m because of interferency. Use of profiles for volumetric computation has been stopped at wave amplitudes of 2 m.

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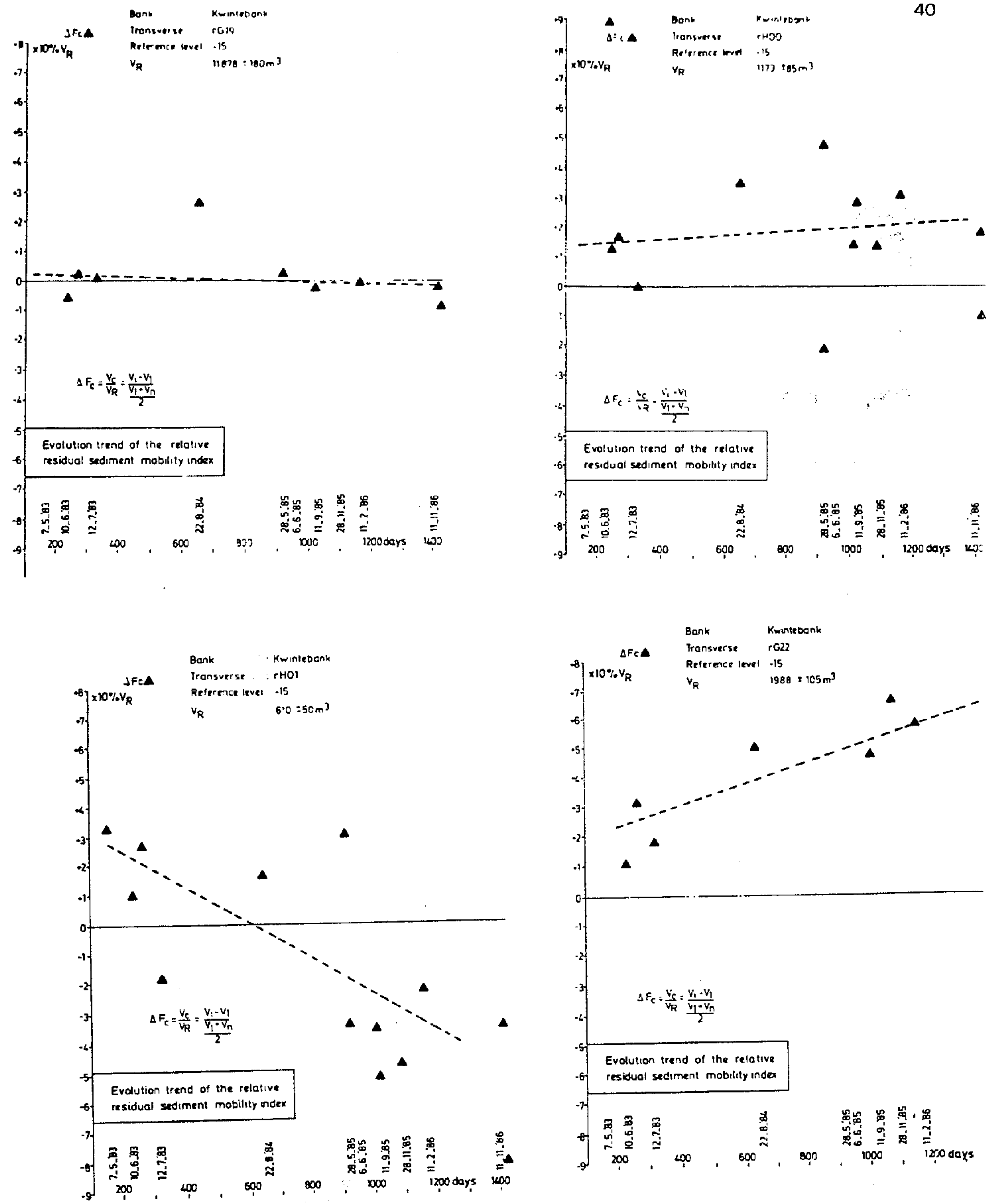

Fig. 3: Kwintebank: Evolution trend of the relative residual sediment mobility index along different reference transverses for the period November 1982 - November 1986

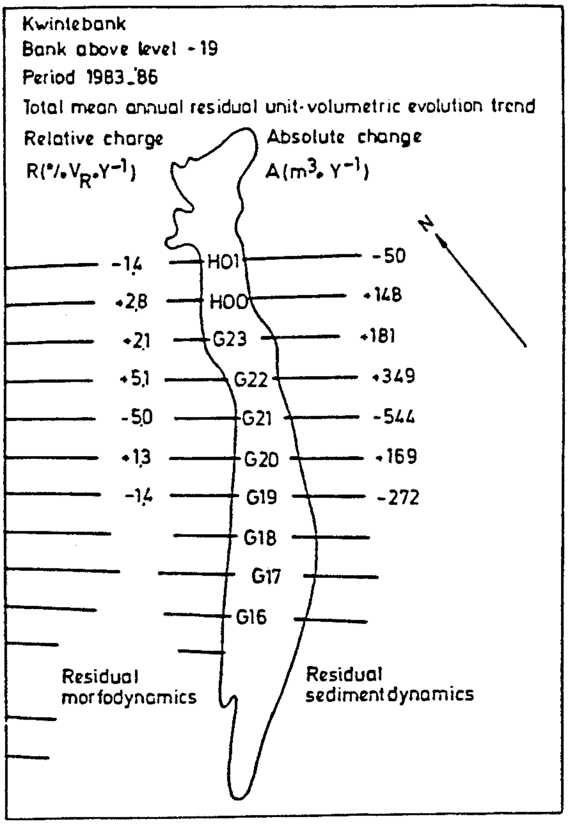

Fig. 4: Kwintebank. Geographical differenciation of the total annual mean residual unit-volumetric evolution trend above level -19 (MLLWS) along several reference transverses on the Kwintebank for the period November 1982 - November 1986

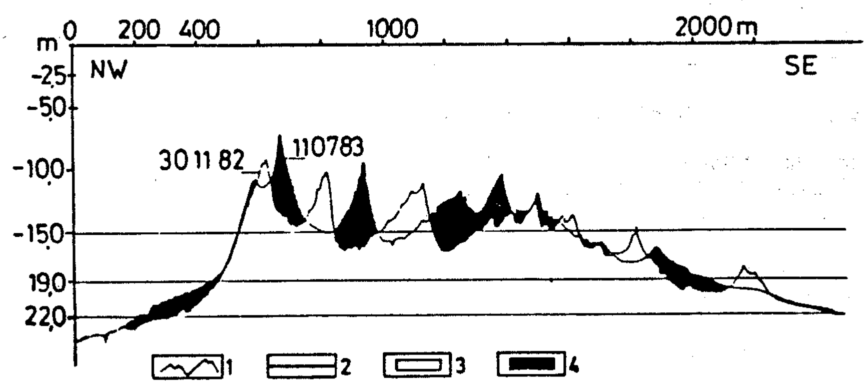

Fig. 5: Kwintebank. Visual comparison of sequential depth profiles along reference transverse rG22 on the Kwintebank; 1. profile, 2. reference depth, 3. losses, 4. gains

Volumetric computations

The residual unit-volumetric change (ΔV_c) provides the volumetric change between the unit-volume at any sailing in a series and the initial unit-volume at the beginning. With periods of increasing length this parameter expresses more and more the residual change.

Geographical comparison is hampered by the differences in dimensions and in shape-factors of the transverses. Geographical normalization is possible by relating the unit-volumes or the unit-volumetric changes to a reference unit-volume V_R specific for the transverse and the level.

Such a reference volume, provisionally used here, is the arithmetic mean of the unit-volume at the initial date (V_1) and that of the last of the measurements.

A quantitative and geographical evaluation of morphodynamics and sedimentdynamics is obtained using the residual mobility index ΔF_c for periods of equal length and date.

$$\Delta F_c = \frac{\Delta V_c}{V_R} = \frac{V_i - V_1}{V_R}$$

Residual volumetric evolution trend

To get a numerical expression for the evolution trend of the present day short term residual morphological change and residual sediment mobility along transverses, and which at the same time allows geographical comparison, ΔF_c/time graphics are drawn for each of the total or partly reference transverses above a same reference level and at identical successive data.

Figure 3 shows the ΔF_c/time graphics for the total cross section above level -15 for 4 different transverses on the Kwintebank over the period 1983-86. These graphics illustrate distinctly the existence of different evolution types along the Kwintebank.

Using the graphic distribution a correlation line can be inferred.

Using this correlation line a trend for the residual mobility index, hence for the annual mean relative residual unit-volumetric change, can be deduced (ΔF_c = R in % of V_R). As it corresponds to a percentage of the reference volume at expresses morphological change.

Knowing the specific reference volume for each reference transverse and reference level, the trend of the relative annual mean residual unit-volumetric change can be recalculated into a trend for the absolute annual mean (A in m^3/ year) for the considered period. This value is more indicative for the amount of residual sediment displacement.

Figure 4 shows distinctly the geographical differenciation of the total present day short term residual morphodynamics and sediment dynamics along the Kwintebank (above level -19).

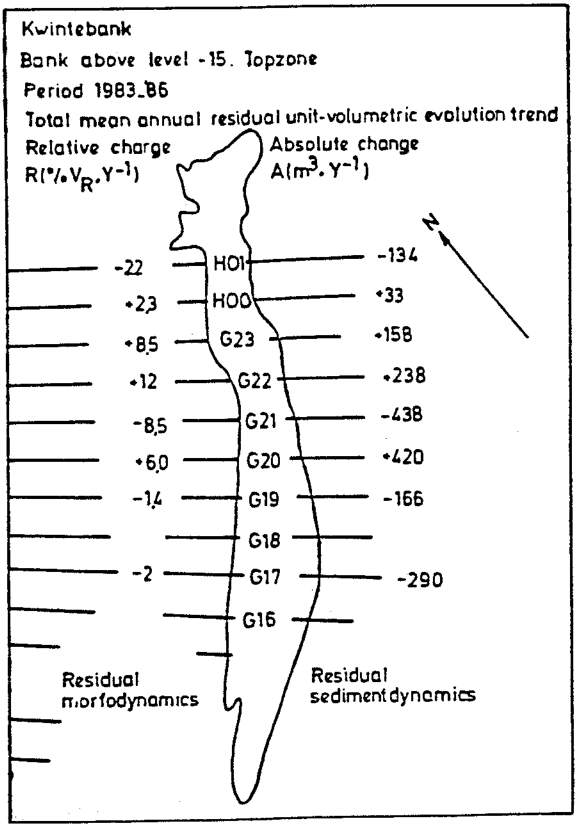

Fig.6: Kwintebank. Geographical differenciation of the annual mean residual unit-volumetric trend on the top zone (above level -15) along several reference transverses for the period November 1982 - November 1986

Evaluation of shape and position changes and of sediment exchange

Residual changes in shape and in location and related residual sediment displacement can be approached by visual comparison of comparable sequential depth profiles.
Figure 5 shows an example of such superposition of two successive depth profiles along the reference transverse rG22 on the Kwintebank between November 1982 and July 1983. Most remarkable are the strong changes in shape, due to the migration of large sandwaves, especially from the western top convexity toward the slight eastern slope, where westwards upslope climbing sandwaves are encountered. This is a first indication for a bank maintenance mechanism by sand uppiling.

A numerical approach towards an evaluation of the shape evolution and the location changes of the bank, giving simultaneously indications about the sediment migrations involved, is provided by monitoring partial unit-volumetric changes of morphological sections, of slices between two successive reference levels, especially if they are computed separetely for both bank halves, or of colums.

Figure 6 shows the geographical differenciation of the present day short term morphodynamics and sediment dynamics on the top zone (above level -15) of the Kwintebank.

A FEW CONCLUSIONS

a. A detailed quantitative monitoring of residual present day short term morphodynamics and sediment dynamics - especially changes in volume, shape and location of sandbanks - on a geomorphological basis becomes possible now. Qualitative approach by visual comparison remains necessary.

b. The present day morphodynamics and sediment dynamics - at least on the Kwintebank - are quite complex.

There are different types of evolution trends varying not only from one place to another along the bank (over distances in the 1 NM range) but as well in the different hypsographical zones of the bank).

Chronologically the period 1983-86 shows at least 4 types of evolution trends on the Kwintebank, as they are indicated on figure 3. These trends can not be used for long term prediction, as the evolution of the evolution trend itself is unknown.

These trends should not be projected to other areas.

Geographically, during the period 1983-86, the Kwintebank was characterised by different dynamical zones, which are morphographically different as well :

the northern edge with intense residual breakdown in the top zone above -15 but relatively important accretion on the lower bank sides.

the northern part is relatively low and sand mobility is indicated by sandwave migration. The top zone shows a trend to accretion, increasing gradually southward.
That top zone accretion is remarkable as most of the sand dredging is done on that section.

This certainly proves the existence of a proces of maintenance due to a residual sand supply, mainly caused by uppiling.

the central part which is a higher, flatter and more voluminous part of the bank. The evolution trend in the top zone varies largely at short distances (1 NM) between relatively important losses and moderate gains, pointing at a longitudinal wavelike sediment passage or possibly at some transversally preferential sand migration. The morphodynamics are less important than the sediment migration, because of the greater available sand volume. Remarkable is that here the lower parts show an inversed evolution trend.

the southern part, is still massive and shows some sandwaves. Its western side presents an erosional terrace on the lower bankside. Top and banksides show a trend of moderate unit-volumetric decrease. The low short term morphological change corresponds to important sand migration. On longer term erosion seems to affect the top zone of the western side while the eastern side seems to know accretion as indicated by the threshold crossing the adjacent Negenvaam Channel.

c. There are different mechanisms of sand transportation : (1) residual sand uppiling on both sides from the lower parts and from the swales ; (2) internal longitudinal wavelike sand transport ; (3) internal vertical sand exchanges between top zone and lower sides probably by wave truncation and by renewed uppiling.

d. On somewhat longer terms the present day short term sediment dynamic's pattern seems to indicate a geographical alternation of periods of local upbuilding by heightening and probably asymmetric broadening, of bankparts using sand simultaneously and at least partly eroded from other parts and transported at least partly eroded from other bank parts and transported at least partly by intrabank mechanisms. Therefore we assume that locally sand deposits within the bank can greatly differ in age laterally at short distances.

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