7. Presentation of surveys

7.1 Preliminary evaluation of the accretion-erosion pattern in the beach and offshore

Now after two years, some considerations can be done regarding the behavior of the beach.

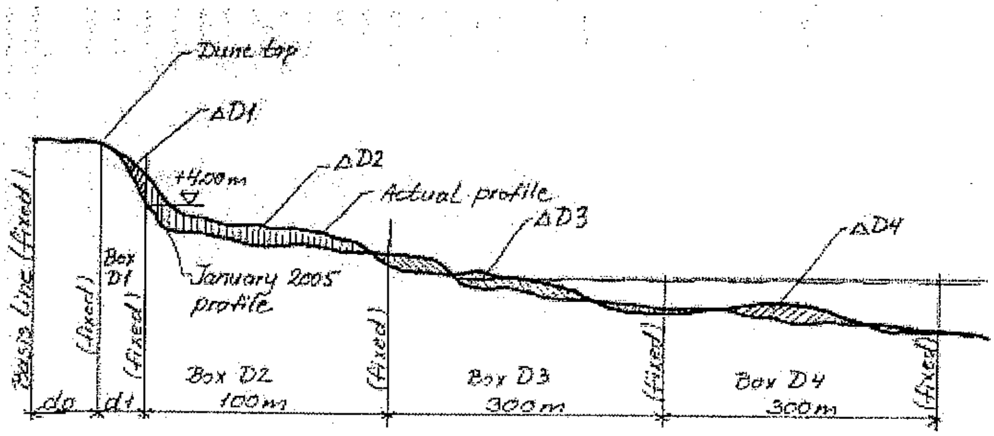
As described in the chapter 3, the idea behind the system is to improve the drainage and hereby get less erosion from the waves.
It must here be mentioned, that if the beach is more well drained, it will be drier, and thus more exposed to wind erosion. Eventually more sand will be accumulated in the upper part of the beach and in the dunes, so it can have a positive effect.

In this chapter we look at the erosion-deposition as measured since the experiment started in January 2005.

It was finally agreed to separate the profile in four fixed boxes and study the volume changes in these boxes. Moreover, it was decided to use parameters which makes it possible to follow the changes in positions of the dune foot and the coastline, and study the volume changes in dune and beach. For convenience the parameters used for the fixed box study are denoted D-parametres while the parameters used for the study of changes in the dune foot and coastline positions as well as dune and beach volume are denoted E-parametres. Both the D- and E-parametres are agreed upon in a project meeting.

Positions of the four fixed boxes of specific widths and fixed positions are related to the positions of the level +4.00m intersection with the first surveyed profile of January 2005, figure 7.1. The changes in sand volumes in each box $\Delta D1, \Delta D2, \Delta D3$ and $\Delta D4$, are calculated. Besides this is calculated the mean surface level denoted MBL in the 100m wide box as well as the changes in this level, Δ MBL. All measured values of D and MBL are included as an appendix after this section.

Professor Hans Burcharth wanted to follow both the changes in the position of the dune foot (dunes are the natural protection against violent storm erosion) as well as the changes in the coastline portion and dune and beach volumes. As the D-parametres do not provide this information it was necessary to supplement with additional parameters, here named E-parametres. The more detailed comments on beach changes are based on the E-parametres, and this is presented in section 3 of this chapter. Since SIC and also one of the consultants feel most familiar with a fixed system of reference, section 2 of this chapter is a very short description of what can be said about the beach behaviour based on the D-profiles. There are some overlap in between section 2 and 3, each section been made by the individual consultant. This only demonstrates the agreements in the evaluation in between the two experts.



Volume changes ΔD within each box are calculated positive in case of accretion and negative in case of erosion.

The mean surface level in Box D2 is denoted MBL. The changes in MBL from January 2005 is denoted ΔMBL

Fig 7.1: Definition of D-parameters.

7.2: Changes in the beach-box (100 m box D2) based on the D-parameters.

The profiles are described in figure 7.1. In section 3 the total figures on volumetric changes for the all individual reaches are given, so tables 7.1-7.3, which are based on the measurements provided in appendix 4, instead provides figures on what have happened per unit length in the separate section with and without tubes ("rør") along the coast.

	Reference 1	Rør 1	Reference 2	Rør 2	Reference 3
Beach-box	1.25	45	-22	140	77
Offshore-box	-31	26	2.2	34	12

Table 7.1: Deposition(+) or erosion (-) in cbm/m from January 2005 till January 2006.

	Reference 1	Rør 1	Reference 2	Rør 2	Reference 3
Beach-box	-49	-34	-80	-93	32
Offshore-box	72	-21	55	9	23

Table 7.2: Deposition (+) or erosion (-) in cbm/m from January 2006 till January 2007.

	Reference 1	Rør 1	Reference 2	Rør 2	Reference 3
Beach-box	-48	11	-102	47	104

Offshore-box	41	5	57	43	35

Table 7.3: Deposition (+) or erosion (-) in cbm/m from January 2005 till January 2007.

Since the "beach-box" actually covers everything from the dune foot and 100-meter seawards (see fig 7.1), the average change in "beach-box"-height is found from the data in the row "beach-box" by dividing by 100 m.

7.3 . Method of presentation of surveys based on E-parametres

The E-parameters shown in Fig. 7.2 separates the beach profile in three parts: The dune defined by levels higher than the dune foot at level +4.00m, the beach defined by levels between +4.00m and 0.00m (coastline), and the foreshore which is the zone from the coastline to a line in the sea 400m from the dune foot in January 2005.

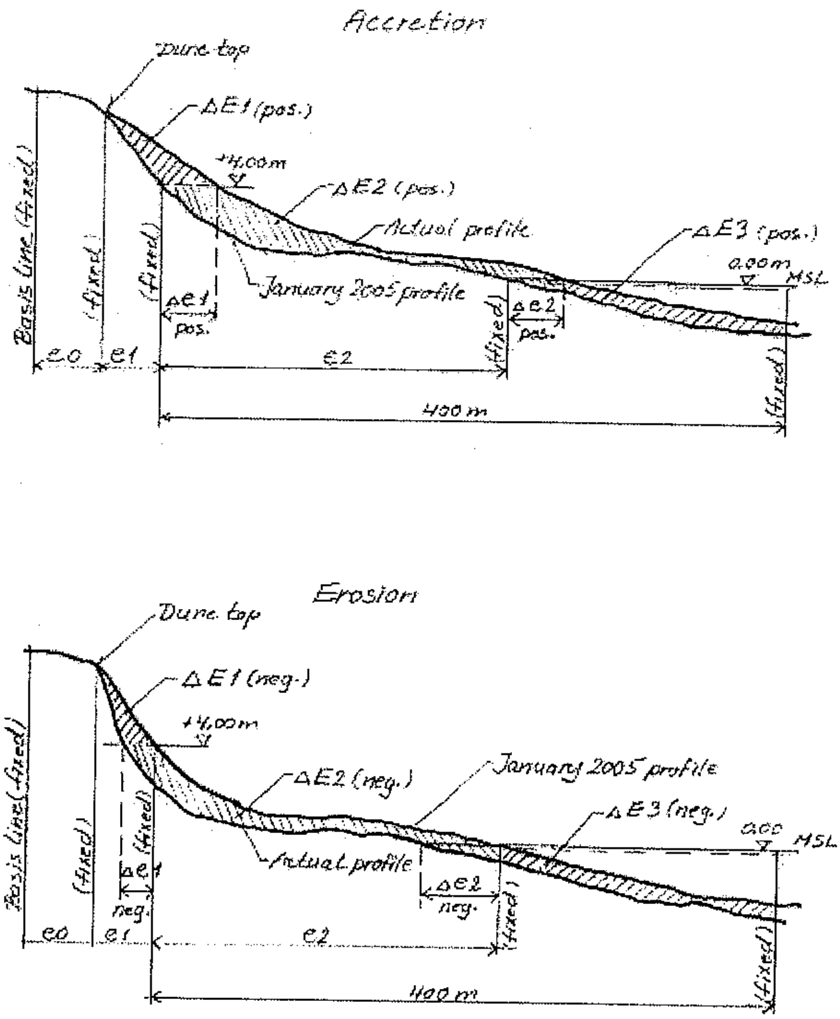


Figure 7.2 Definition of E-parametres

The changes in the position of the dune foot, $\Delta e1$, and the changes in the position of the coastline, $(\Delta e1 + \Delta e2)$, are identified as well as the changes in the dune volume, $\Delta E1$, and the beach volume, $\Delta E2$. Moreover, the changes in volume of the foreshore, $\Delta E3$, is calculated as $\Delta D1 + \Delta D2 + \Delta D3 - \Delta E1 - \Delta E2$.

Because the dunes over level +4.00 m were not fully surveyed in January 2007 it has not been possible to estimate ΔE_1 with high accuracy, as exterpolation has to be made between the highest measured point and the January 2005 measured top of the dune front face. As a consequence Δ MBL is not so well defined. However, the bias introduced by this omission is not very significant and does not change to picture of the development of the coastal profile.

Results of surveys January 2005 – January 2007

7.3.1. Changes in dune foot positions

Seaward changes in dune foot positions are due to transport of sand by the wind from the beach plane to the dunes.

The changes in the dune foot position (defined at level +4.00m) are shown in Fig. 7.3. A shoreward movement is observed for all stretches after the first year. Between October 2006 and January 2007 a considerable retreat of the dune foot took place in Ref. I and Ref. II and in the boundaries of Rør I. In the middle of Rør I and in the entire Rør II there was shoreward movement of the dune foot.

7.3.2 Changes in coastline positions

The evolution in coast line position calculated as the changes in e_2, i.e. Δe_2 observed in the two-year period is shown in Fig. 7.4.

Very large changes are observed in some stations. For example in Rør I a total shift in some lines are app. 80m. After the two-years period there are consistent coastline retreat in Ref. II and retreat in a large part of Rør I. Ref. I and Rør II show both retreat and seaward growth. More consistent seeward growth is seen in Ref. III. In conclusion there is not a clear correlation between movements in coastline position and positions of drains.

The initial beach width e_2 as surveyed January 2005 is shown in Fig. 7.5 together with the beach width e2+ Δe_2 in April 2005.

Fig. 7.6 shows the beach width in October 2006 and January 2007. From these two figures it is seen that the variation in beach width along the test site is more or less maintained from the initial survey in January 2005 until October 2006. Only hereafter there has been a change resulting in a more even beach width distribution along the site, but still with the more narrow beaches in parts of Ref. I and Ref. II although limited stretches of narrow beach also exist in Rør I and Ref. III.

7.3.3 Changes in dune and beach volumes

The approximate changes in dune volumes ΔE_1 are shown in Fig. 7.7. After one year there was accumulation in all stations with few exceptions. In the April 2006 survey was seen very large accumulations in the northern part of Rør I and southern boundary of Ref. I. Erosion was only seen in two stations in Rør I and one in Ref. I. After two years the large accumulations were still in the same locations, but erosion was seen in some stations within all five stretches, most severely in Ref. II.

Fig. 7.8 and 7.9 show the changes in beach volume. The first survey in April 2005 showed mainly accretion in Rør I, Rør II and Ref. III. Dominant erosion was seen in Ref. I and Ref. II, but also in the northern part of Rør I. By April 2006 the picture was very different in that deposition was in the middle of Rør I and Rør II and most pronounced in Ref. III, whereas almost no changes from the initial situation in January 2005 were seen in Ref. I and Ref. II. By July 2006 erosion had again taken place in a part of Ref. I and in Ref. II. Fig. 7.10 shows the further development in which the October 2006 situation corresponds closely to the April 2006 situation, but by January 2007 we see a picture of significant erosion in the southern part of Ref. I, in the northern part of Rør I, and in Ref. II. A large deposition in Ref. III is also noted.

Fig. 7.11 shows the total changes in dune + beach volumes, i.e. $\Delta E_1 + \Delta E_2$. By April 2005 there was significant accumulation in most of Rør I, Rør II and Ref. III, but more pronounced erosion in parts of Ref. I and Ref. II. This picture is more or less maintained in the later surveys and is also seen in the July 2006 survey. The only exception is that very pronounced deposition took place in Ref. III. The survey in January 2007 revealed that over the two-years period erosion took place in a part of Ref. I and in Ref. II, while in Rør I and Rør II a more variable picture of erosion/deposition (mainly deposition) is seen. Moreover, a very significant deposition took place in Ref. III.

Table 7.4 shows the approximate volume changes averaged over each of the five stretches. It should be noted that averaging over a stretch is a significant simplification because large variations occur within each of the stretches.

Table 7.4. Approximate average dune plus beach volume changes ($\Delta E_1 + \Delta E_2$) from January 2005 to January 2006 and January 2007. Positive values are deposition.

Stretch	**m^3/m coastline**		**Total m^3 over stretch**	
	Jan 05-Jan 06	Jan 05-Jan 07	Jan 05-Jan 06	Jan 05-Jan 07
Ref. I	1	-0.2	2.578	-427
Rør I	44	0.1	205.998	494
Ref. II	-23	-101	-41.543	-171.580
Rør II	126	44	113.793	436.300
Ref. III	80	115	143.317	207.160

For the two years period Jan 05 – Jan 07 it is seen that significant net deposition has taken place in Rør II, but mainly in Ref. III whereas both erosion and deposition - almost equalizing each other - have taken place in Ref. I. and Rør I. Ref. II shows a significant erosion. The net increase in beach and dune volumes over the total length of the test site amounts to app. 1.100 m^3 in total.

From Table 7.4 it is also seen that for the first year period Jan 05 – Jan 06 the deposition were larger and the erosion smaller. This is because the first-year period was relative quiet with no significant storms. In the second year however, four storms occurred, three of which took place in January 2007.

7.3.4 Dune, beach and nearshore volume

The changes in volume of the near shore zone as defined in Fig. 7.2 (calculated as ΔD1+ ΔD2+ΔD3 –ΔE1-ΔE2) are shown in Fig. 7.6. As expected for this very dynamic zone there are many shifts between deposition and erosion along the test site and no correlation with drained and non-drained stretches. The only persistent configuration is a deposition in Rør I app. 1 km South of the northern border, seen in all the surveys.

7.3.5 Changes in mean level of a 100 m wide beach zone measured from position of level +4.00 m in the January 2005 profile

The initial values of MBL, in January 2005, shown in the top diagram of Fig. 7.7, are not evenly distributed over the test area. Large values of MBL $\geq$ 2.0 m existed only in Ref. II near the border to Rør II. Values larger or equal to 1.5m were present mainly in Rør I and Ref. II. It is important to notice the extremely low MBL value of app. zero at the border between Rør I and Ref II, as this "hole" is more or less maintained in the two years period as seen in Figs. 7.7 and 7.8. Thus this initial weakness of the beach was never repaired although accumulation took place until October 2005 in the southern part of Ref. II.

The initial "hole" in the northern part of Ref. III was repaired as significant accumulation took place in Ref. III. The changes in MBL, i.e. Δ MBL, are shown in Figs. 7.9 and 7.10. It is seen that after the two years the MBL increased mainly in the northern part of Ref. III and the southern part of Rør II as well as in the middle part of Rør I and northern part of Ref. I. Lowering of the MBL took part mainly in Ref. II and northern part of Rør I and southern part of Ref. I.

7.3.6. Influence of the bar nourishment on the morphological changes in the test area.

With the data in hand it is not possible to analyze the influence of the bar nourishment on the beach development in the test area. Only it can be said that the dumped sand will be transported mainly towards South. The uncertainty it causes for the analysis of the effect of the drains has been known and discussed from the stage of selection of the tests site, cf. §2.1.

7.3.7. Summary of observations including impacts of the storms

In the period January 2005 to January 2006 no significant changes have taken place in the beach planform as the coastline undulations have more or less maintained their positions except that in the southern part of Rør II and the northern part of Ref. III the coastline has significantly moved seaward and there seems to be a tendency that the undulations are moving southwards. It can be

observed that significant accumulation of sand has taken place within the two areas with drains, Rør I and Rør II, i.e. the beach level has been raised. The same or even stronger development is however observed in Ref. III with no drains, whereas Ref. I also with no drains exhibit both erosion and accretion. Ref. II generally shows erosion.
This observed development took place in the first year period with no severe storms and extreme high water levels after the very severe storm around 8 January 2005. At that occasion large quantities of sand was probably eroded from the beach. Usually part of this sand will be transported back to the beach in periods with milder wave climate, normally occurring in the spring and the summer. Also sand nourishment might contribute to the accretion of the beach. Actually, the migration pattern of the nourishment sand is not clear, it may go on-, off- or long-shore. However, twice as much sand was nourished as what was accumulated on the beach in the one-year period.

The second year was quiet with no storms until the occurrence of a moderate storm in October 2006 and three more severe storms in January 2007. Until the occurrence of these storms there was no significant changes shown in the beach morphology compared to the end of the first year. In order to investigate the effect of the storms are shown in Figs. 7.6 the conditions/strength in July 2006 of the stretches given by the beach width e2, and the mean level MBL of the 100 m width of beach, together with the erosion of dune and beach (EΔ1+EΔ2) between July 2006 and January 2007 (just after the storms).

From Fig. 7.6 it is seen that severer erosion (say ≥ 90 m^3/m) took place over limited distances in all stretches. It is also seen that - as expected – there is a correlation between low strength of beach (low values of e2 and MBL) and larger erosion, but this correlation is not very strong. This points to fact that also other conditions than beach strength influence the erosion in storms. The most likely factor is the nearshore bar formation, as explained in §3.2. The difficulty in dealing quantitatively with the effect of the bars is not only related to lacking information in more quiet periods but indeed to the rapid changes in bar topography during storms.

In order to see if there is correlation between beach erosion and nearshore deposition (assumes that the sediment transport is only in the cross-shore direction which – for sure – is not the case) are depicted in Figs. 7.7 and 7.8 the values of the changes in the box volumes (ΔD1, ΔD2, ΔD3 and ΔD4) averaged over each stretch. The boxes cover beach and sea to a distance of 700m from the foot of the dune, cf. Fig. 7.1. It seems that there is no stringent correlation as expected. Table 7.5 shows the total volume changes in the boxes at different times for each stretch. Although it should not be taken as a good measure of performance it is seen that Ref. III, Ref. I andf Rør I have the best performance and Ref. II and Rør II the worst.

Table 7.5. Total volume changes in Boxes 1, 2, 3 and 4 in m^3.

Period from Jan 05 to	Ref. III	Rør II	Ref. II	Rør I	Ref. I
Apr 05	26	21	16	23	65
Jul. 05	60	67	25	39	35
Oct. 05	86	157	8	37	16
Jan. 06	92	137	-68	34	47
Jul. 06	128	54	-31	41	87
Jan. 07	192	-43	-141	39	102

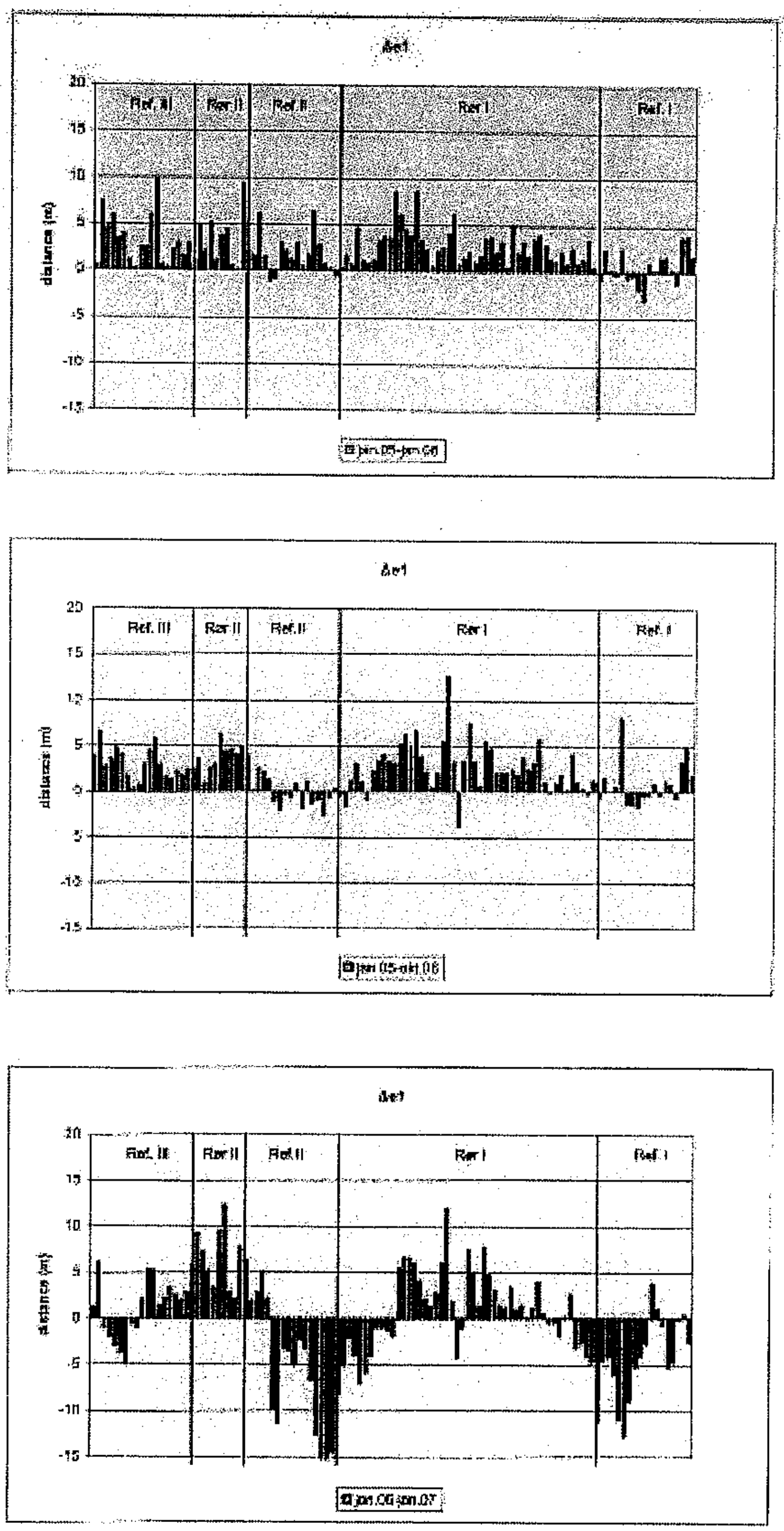
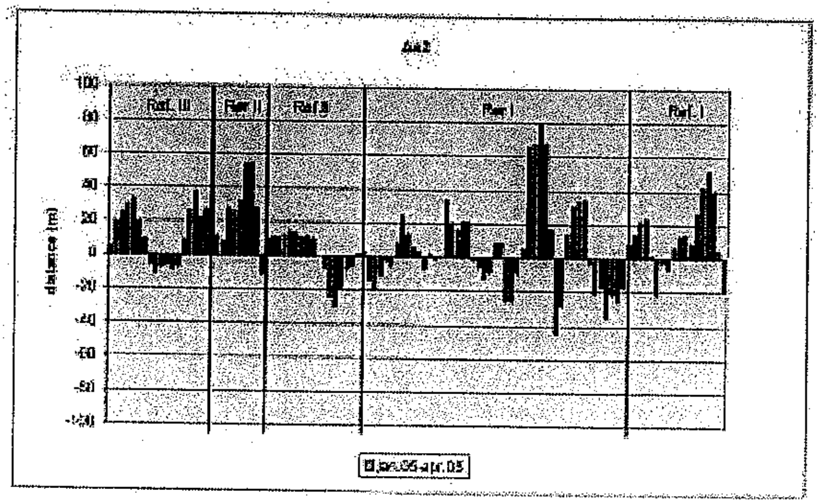
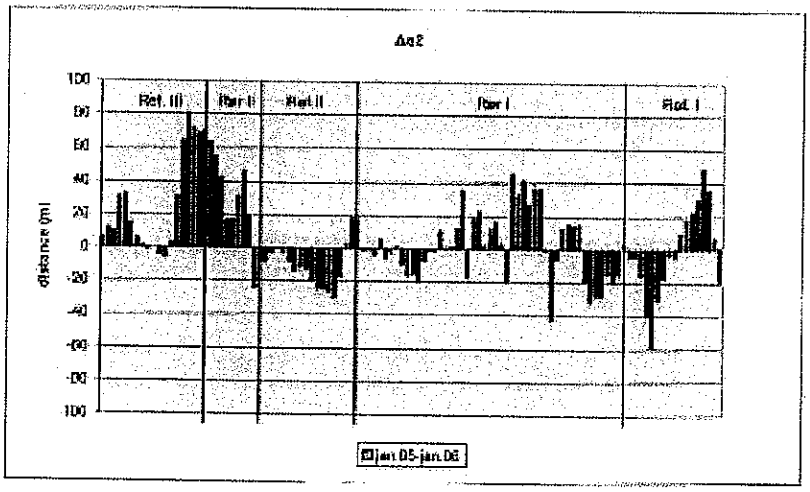


Fig. 6. Changes in dune foot position

Figure 7.3. Changes in dune foot position





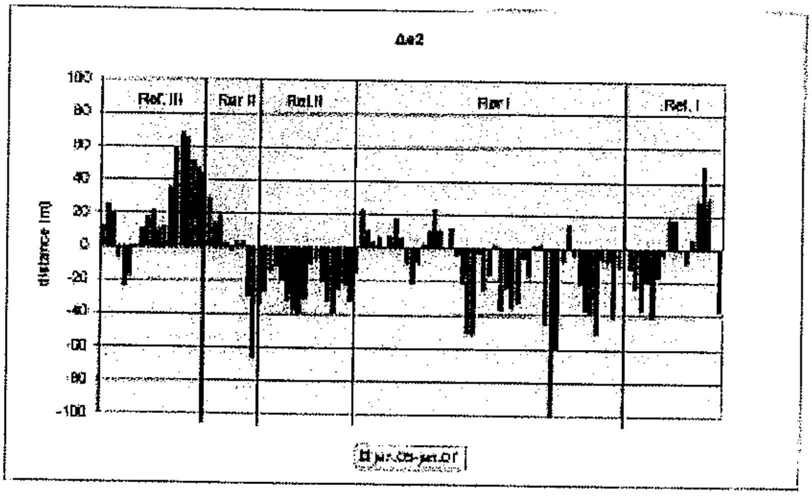
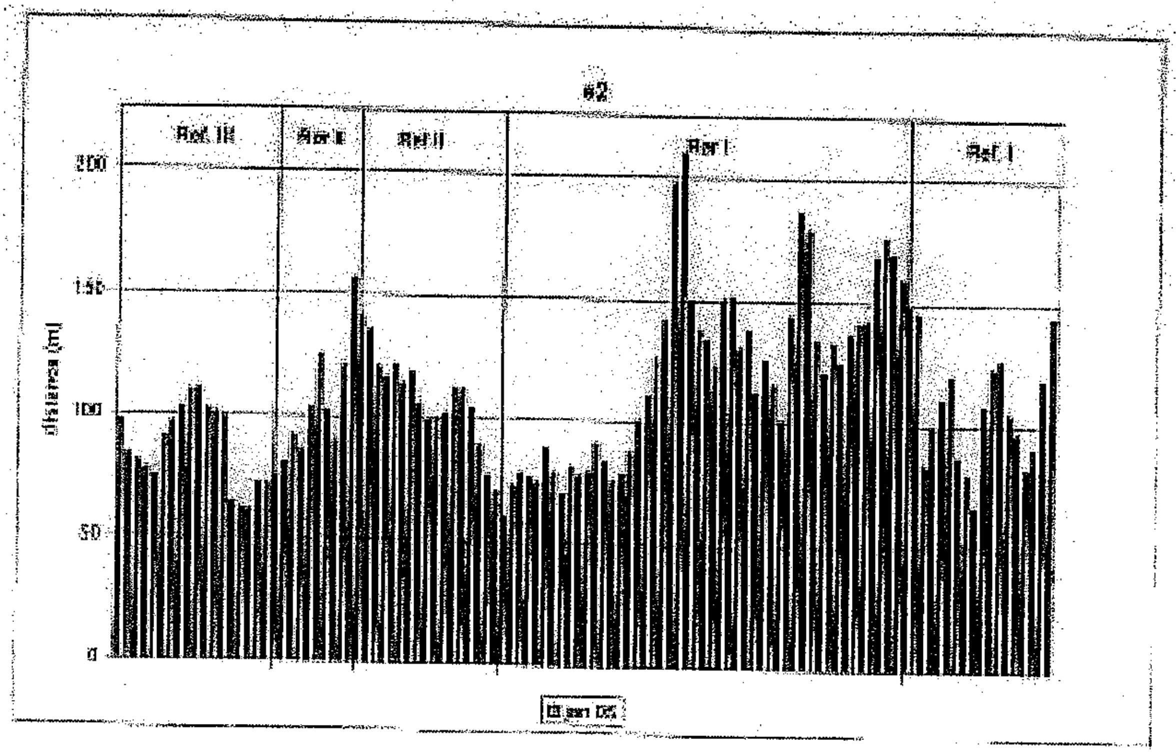


Fig. 7. Changes in position of shore line (level 0.00m)

Figure7.4 Changes in position of shore line (level 0.00m)



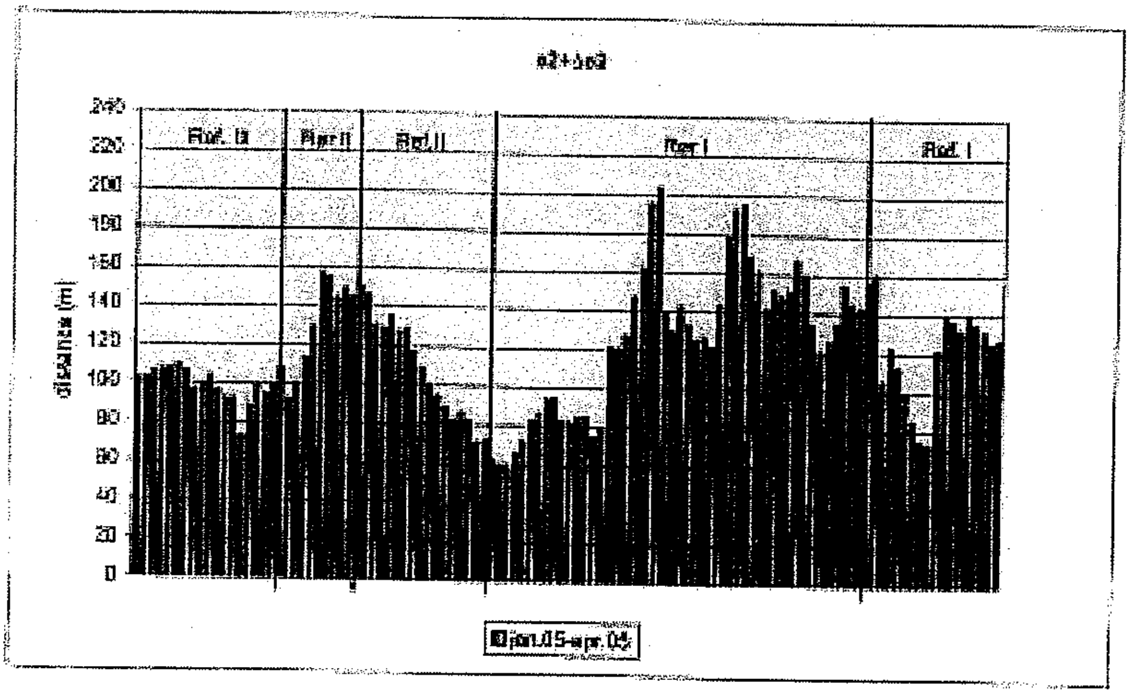


Fig. 8. Beach widths January 2005 and April 2005.

Figure 7.5. Beach widths January 2005 and April 2005

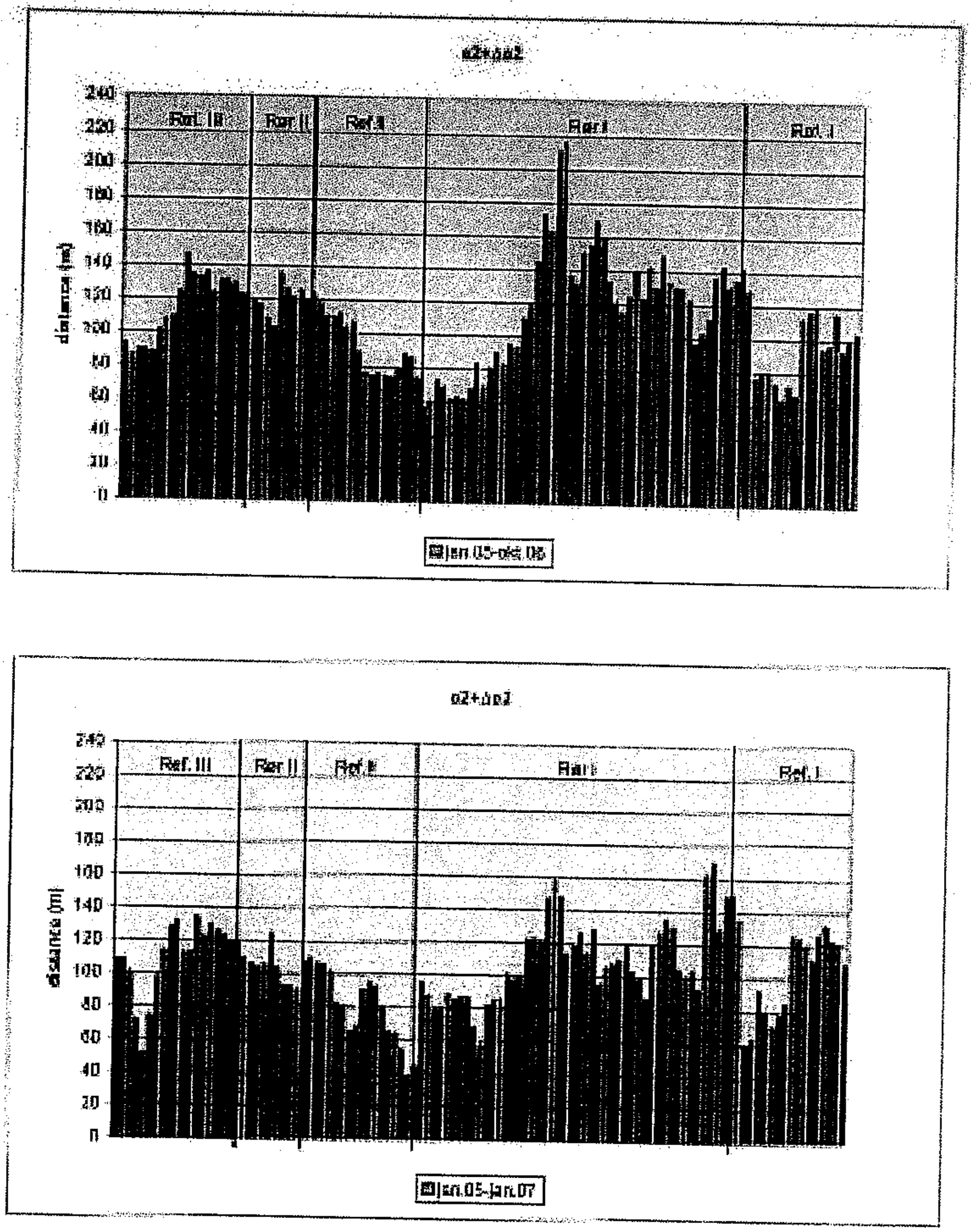


Fig. 9. Beach widths October 2006 and January 2007

Figure 7.6. Beach widths October 2006 and January 2007

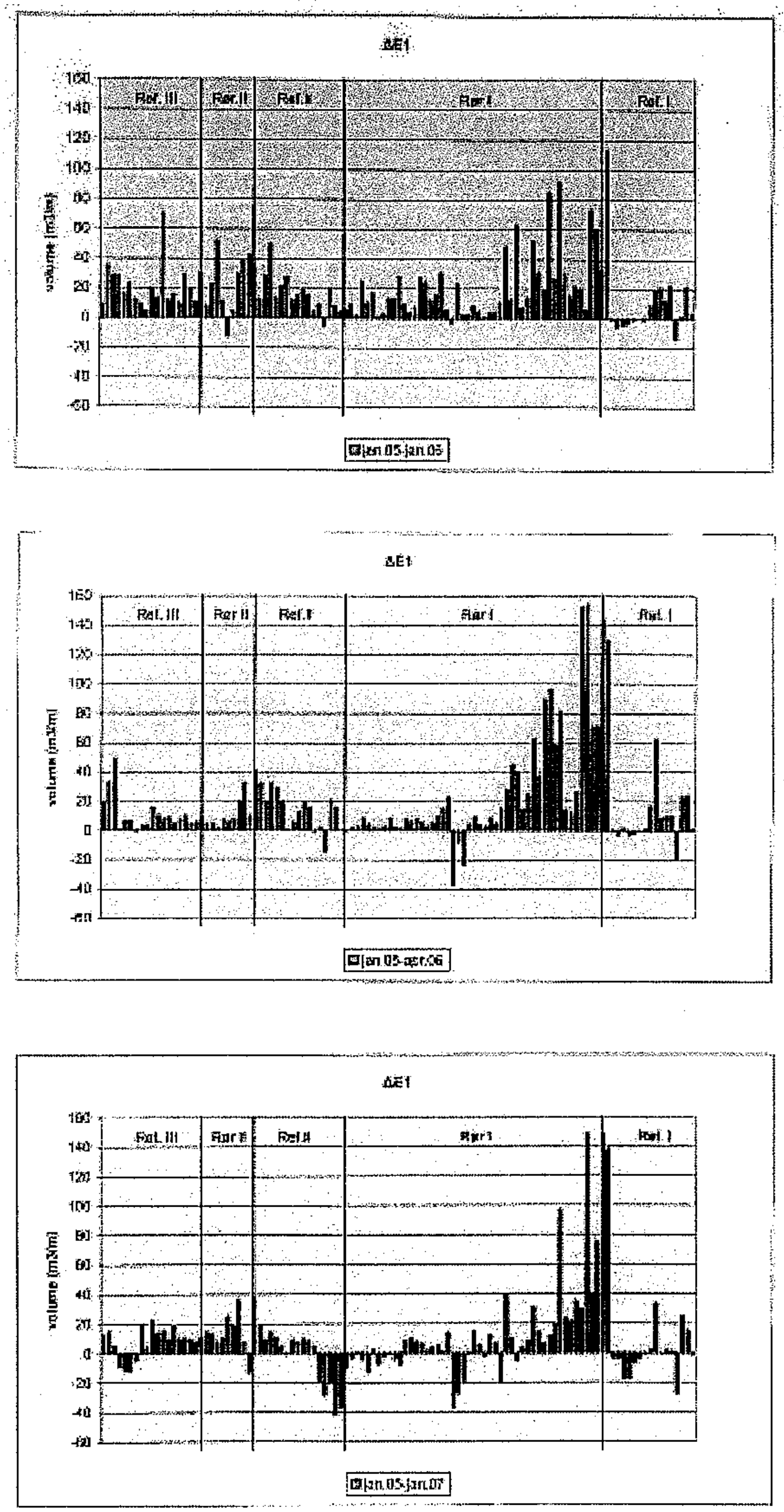
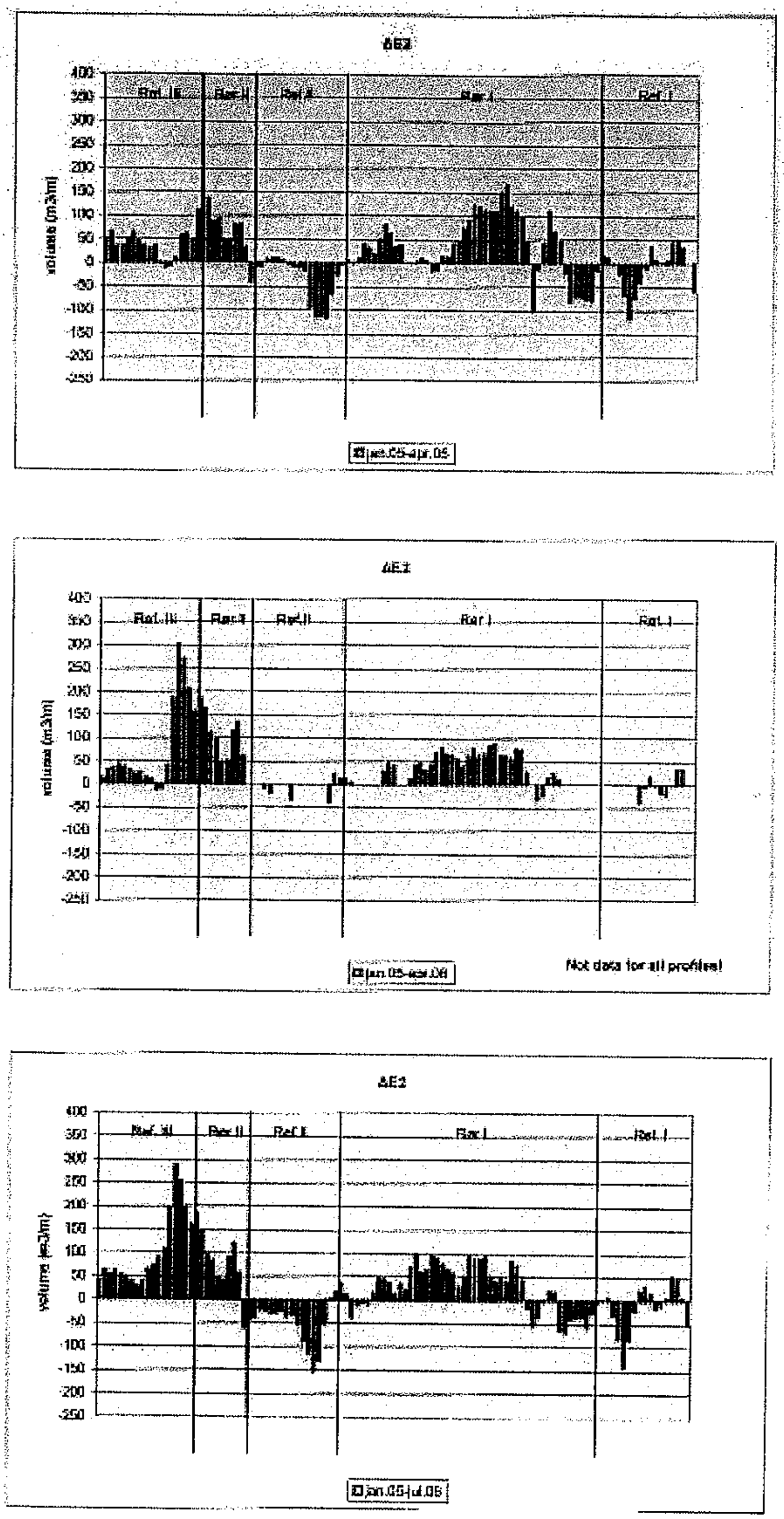


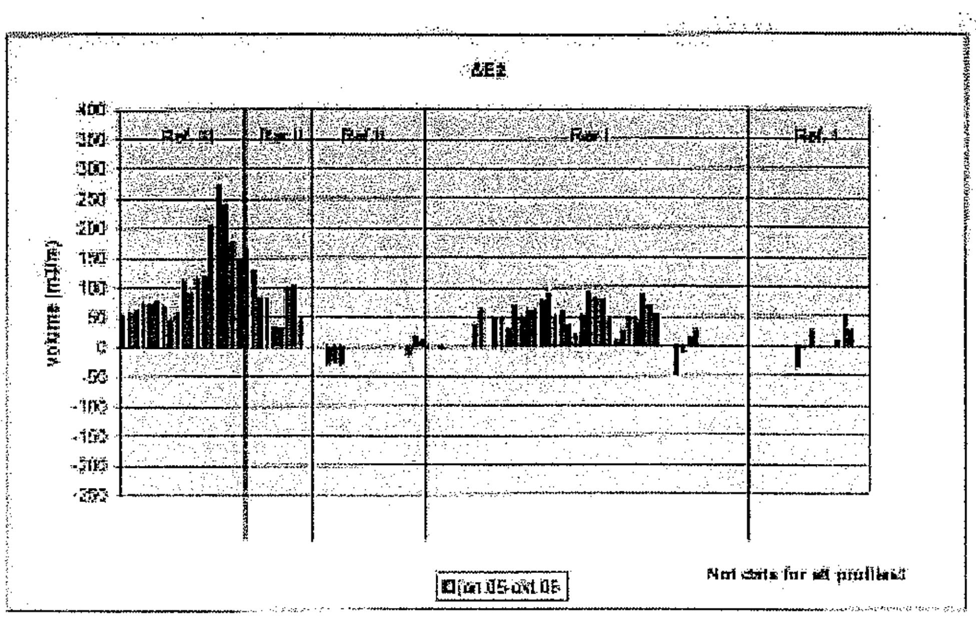
Fig. 10. Changes in dune volumes

Figure 15 Changes in dune volumes



Changes in beach volume from January 2005 to April 2005, April 2006 and July 2006.

Figure 7.7. Changes in beach volume from January 2005 to April 2005, April 2006 and July 2006



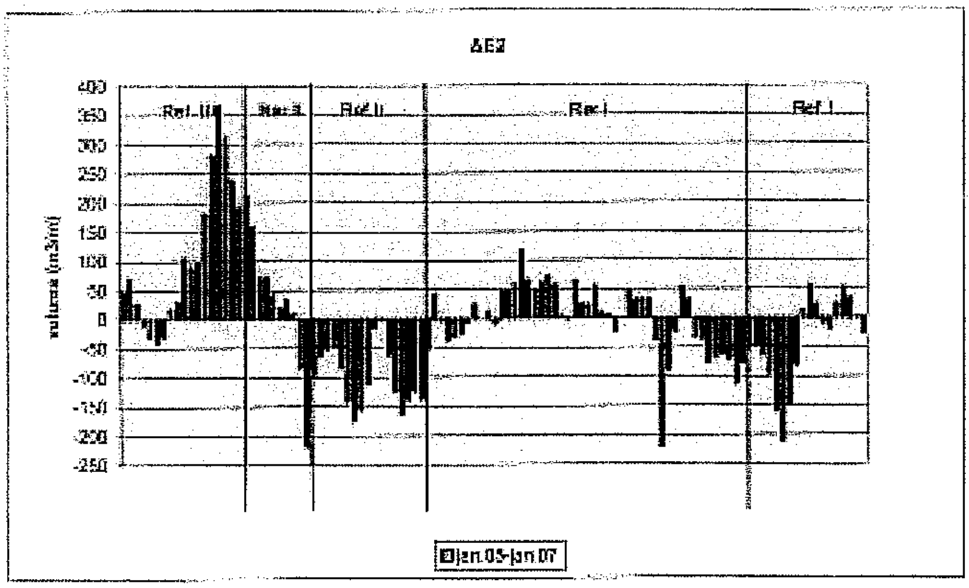
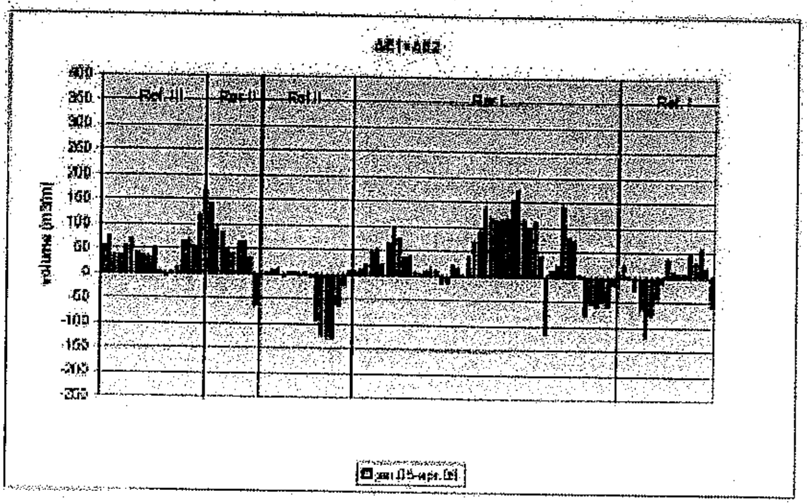
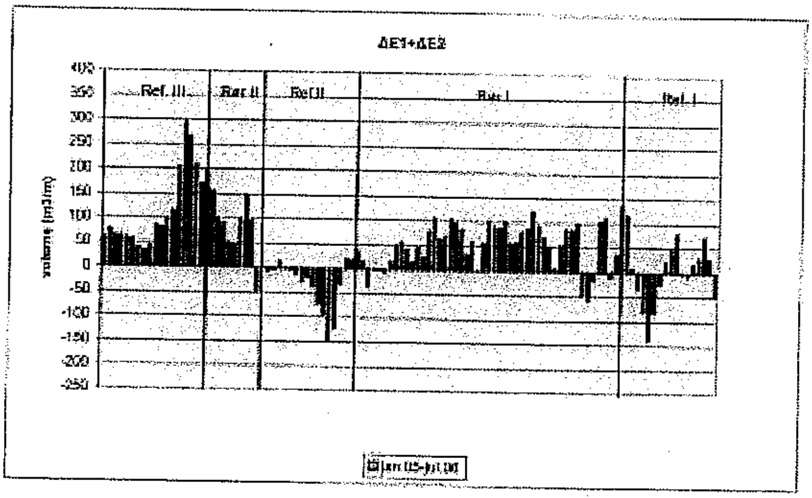


Fig. 12. Changes in beach volume from Janaury 2005 to October 2006 and January 2007.

Figure 7.8 Changes in beach volume from January 2005 to October 2006 and January 2007.





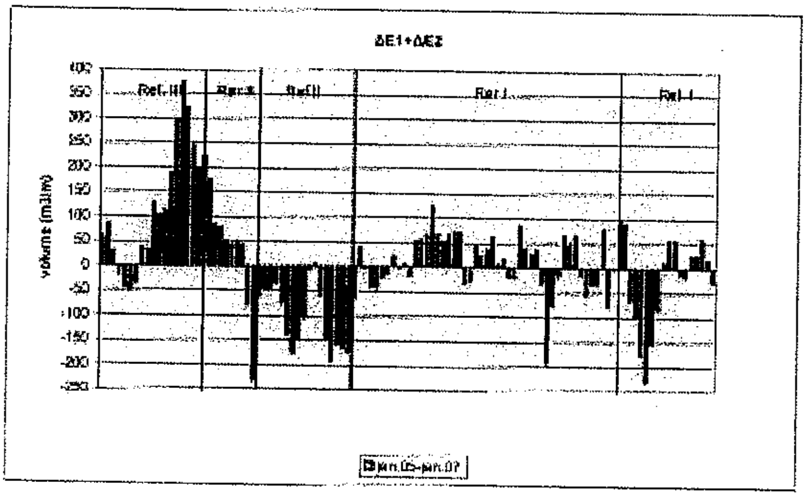


Fig. 13. Changes in total volumes of dune plus beach.

Figure 7.9 Changes in total volumes of dune plus beach.

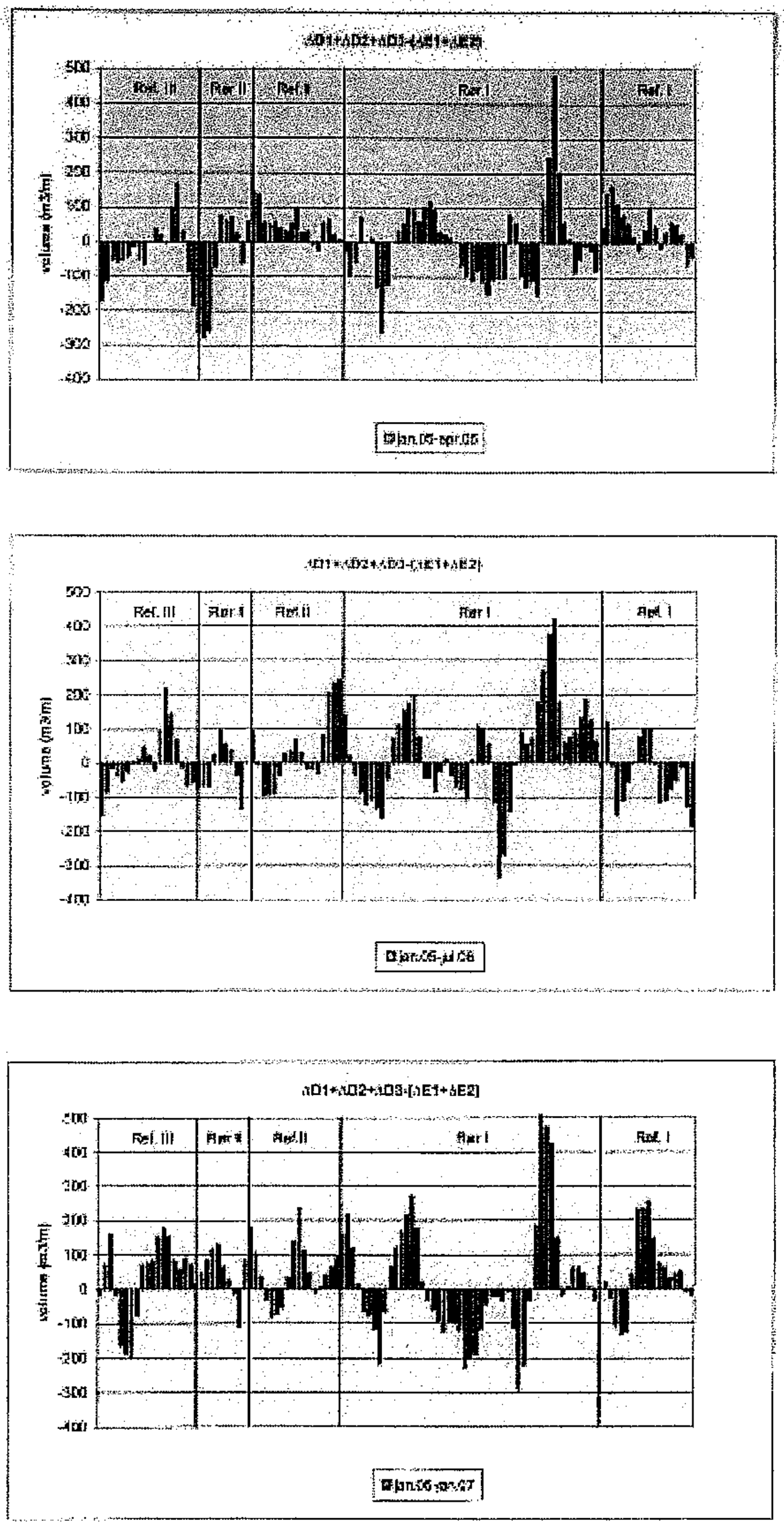


Fig. 14. Changes in volume of the near shore zone.

Figure 7.10 Changes in volume of the near shore Zone.

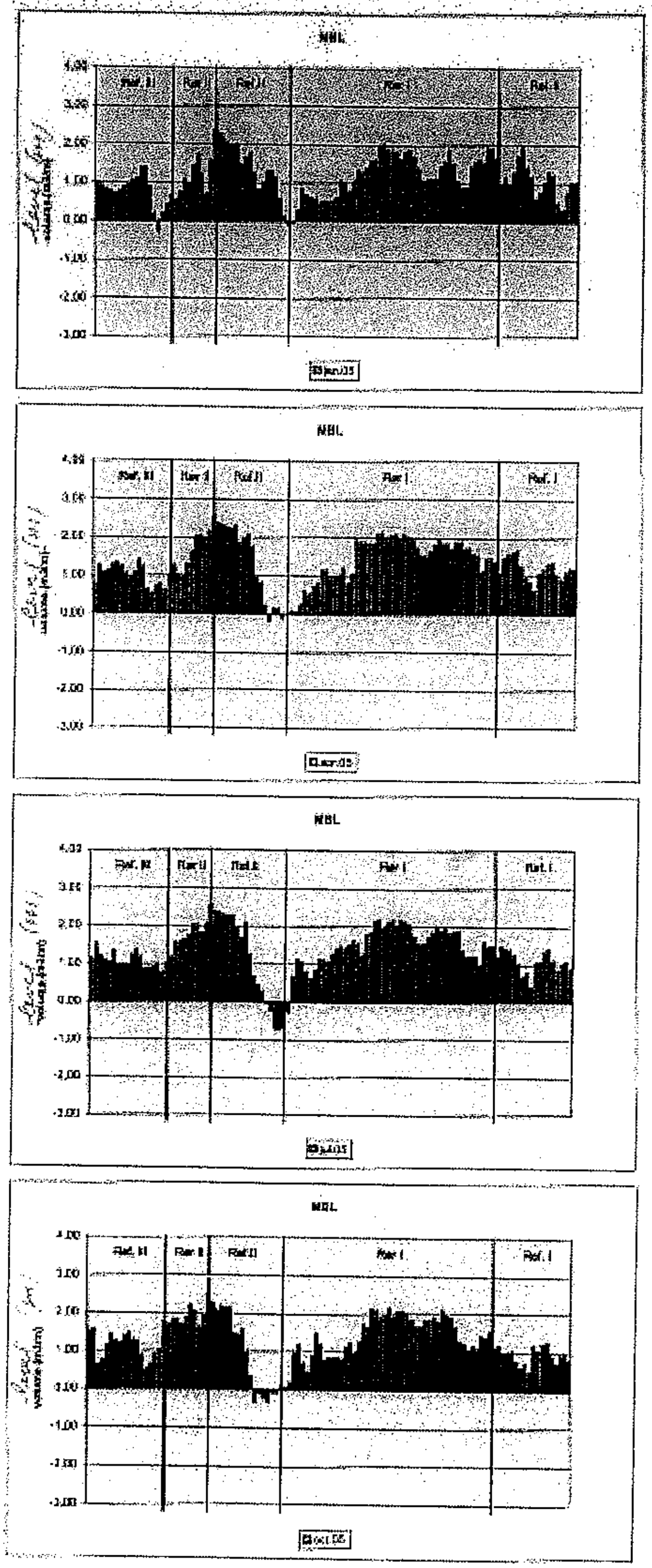
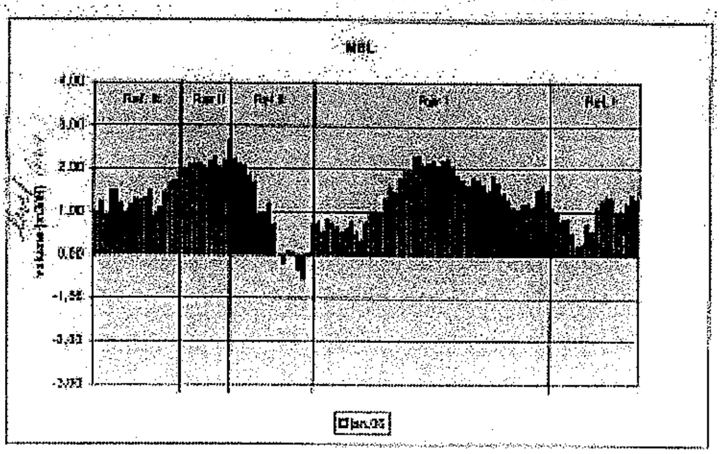
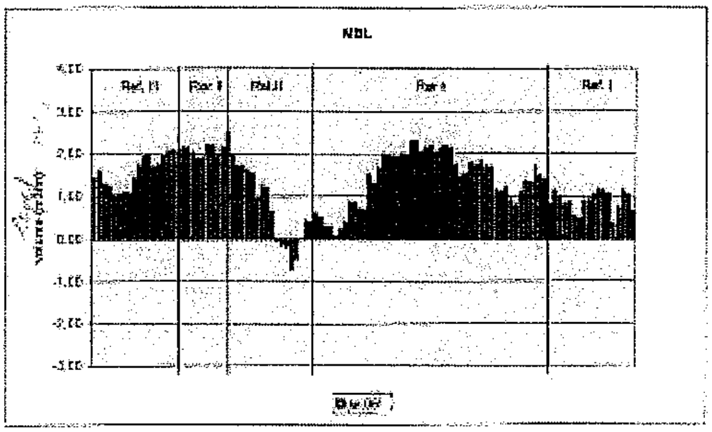


Fig. 15. Average beach level, MBL, of a 100 m wide zone seaward of the dune foot position of January 2005. January, April, July and October 2005.

Figure 7.11 Average beach level, MBL, of a 100 m wide zone seaward of the dune foot position of January 2005. January, April, July and October 2005.





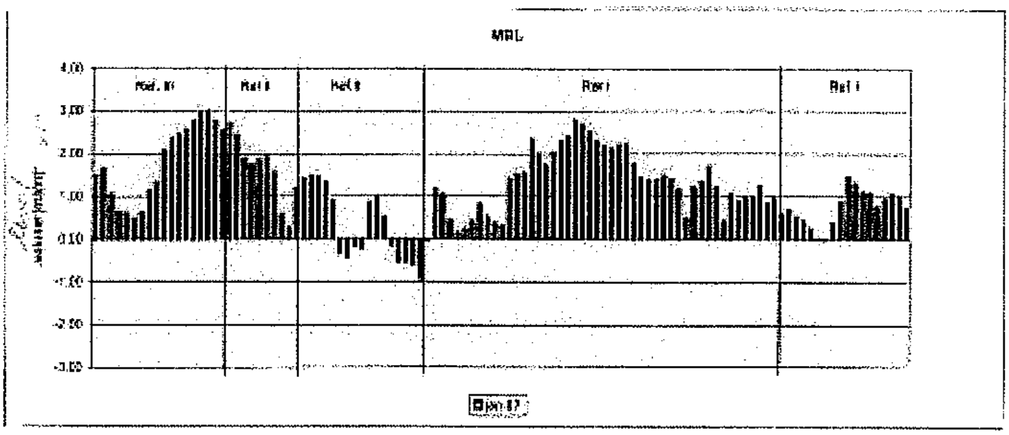


Fig. 16. Average beach level, MBL, of a 100m wide zone seaward of the dune foot position of January 2005. January and July 2006, and January 2007.

Figure 7.12 Average beach level, MBL, of a 100 m wide zone seaward of the dune position of January 2005. January and July 2006, and January 2007.

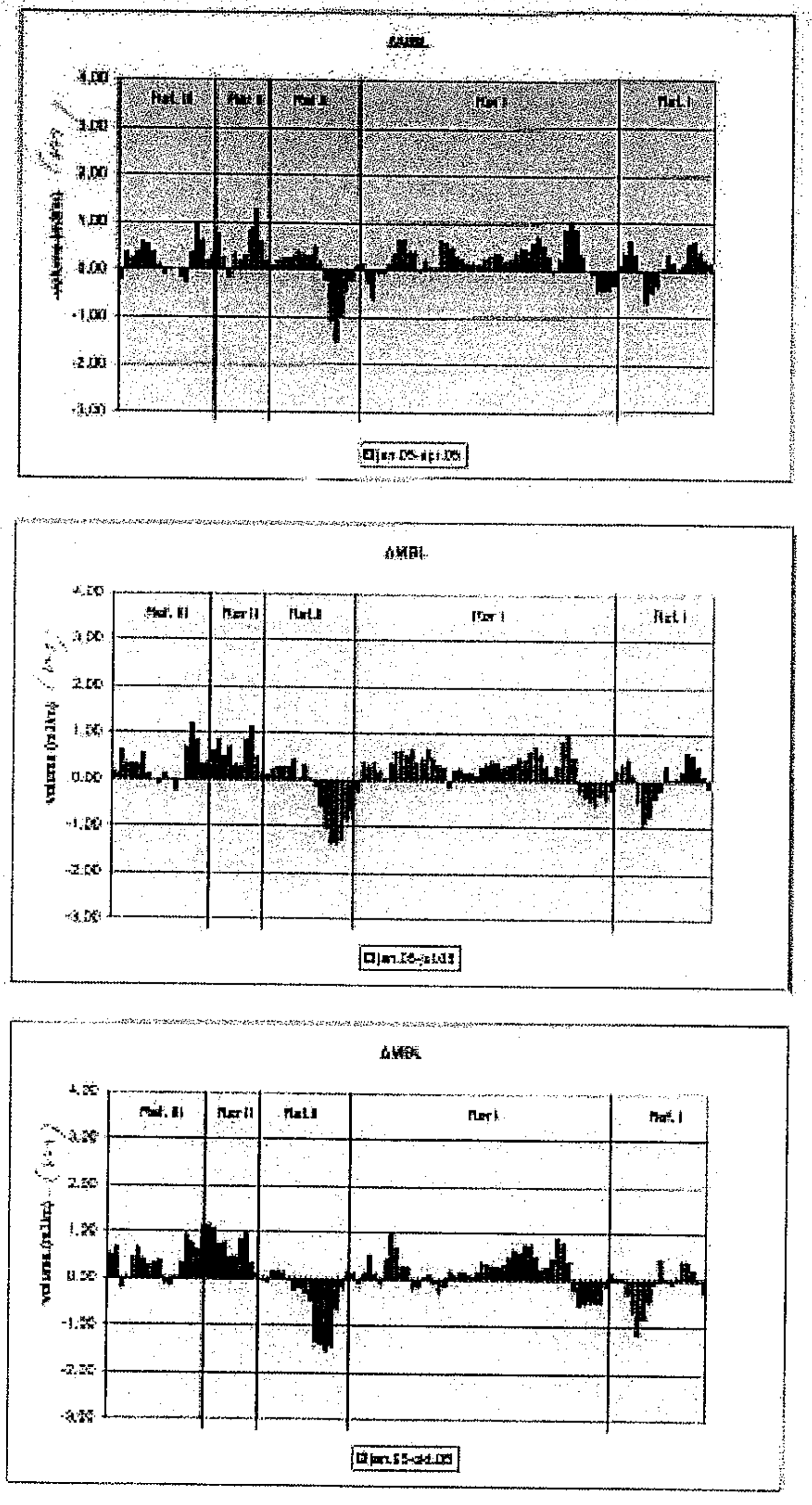


Fig. 17. Changes in MBL, ΔMBL, from January 2005 to July and October 2005.

Figure 7.13 Changes in MBL, ΔMBL, from January 2005 to July and October 2005.

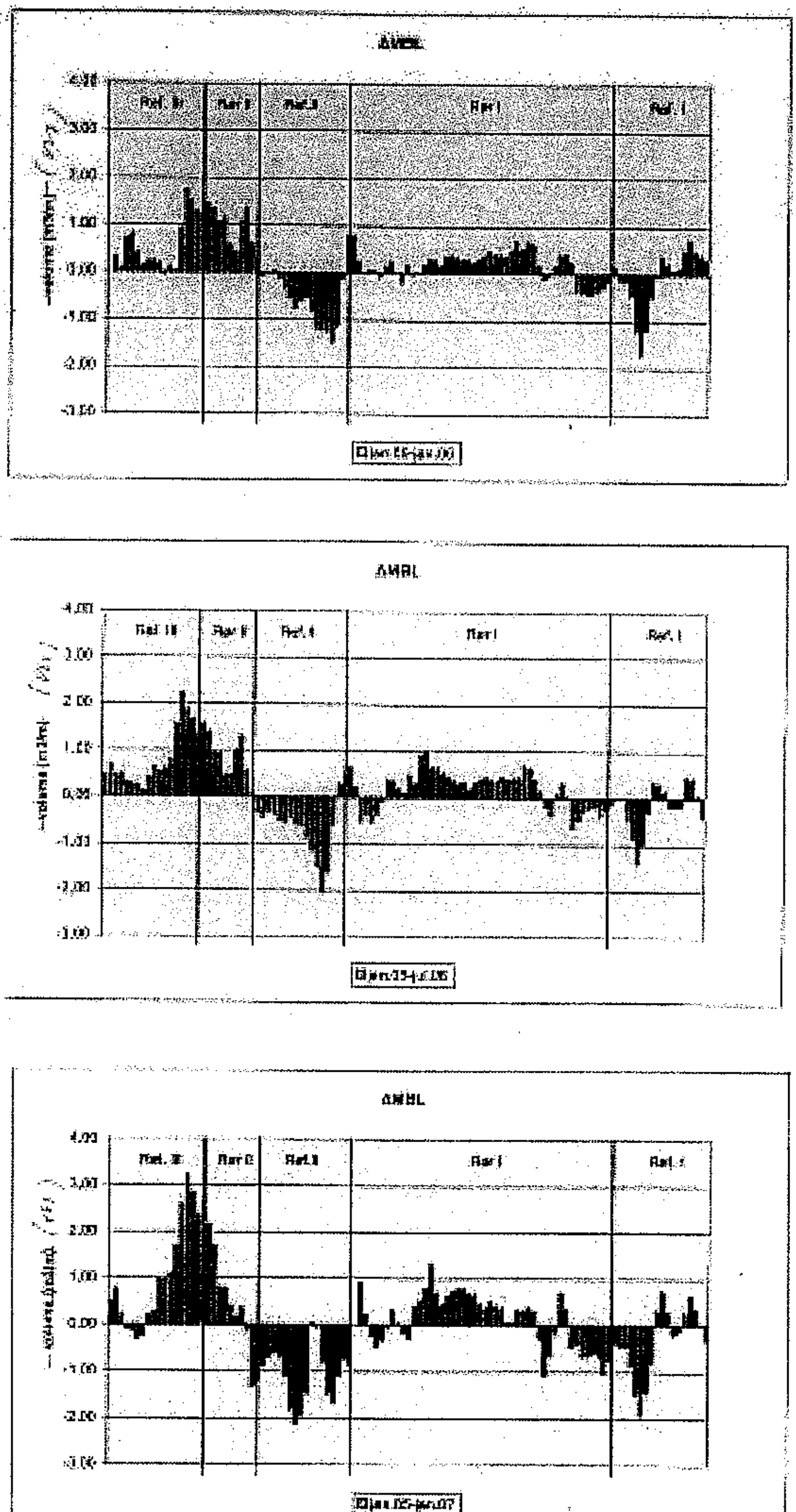


Fig. 18. Changes in MBL, ΔMBL, from January 2005 to July 2006 and January 2007

Figure 7.14 Changes in MBL, ΔMBL, from January 2005 to July 2006 and January 2007.

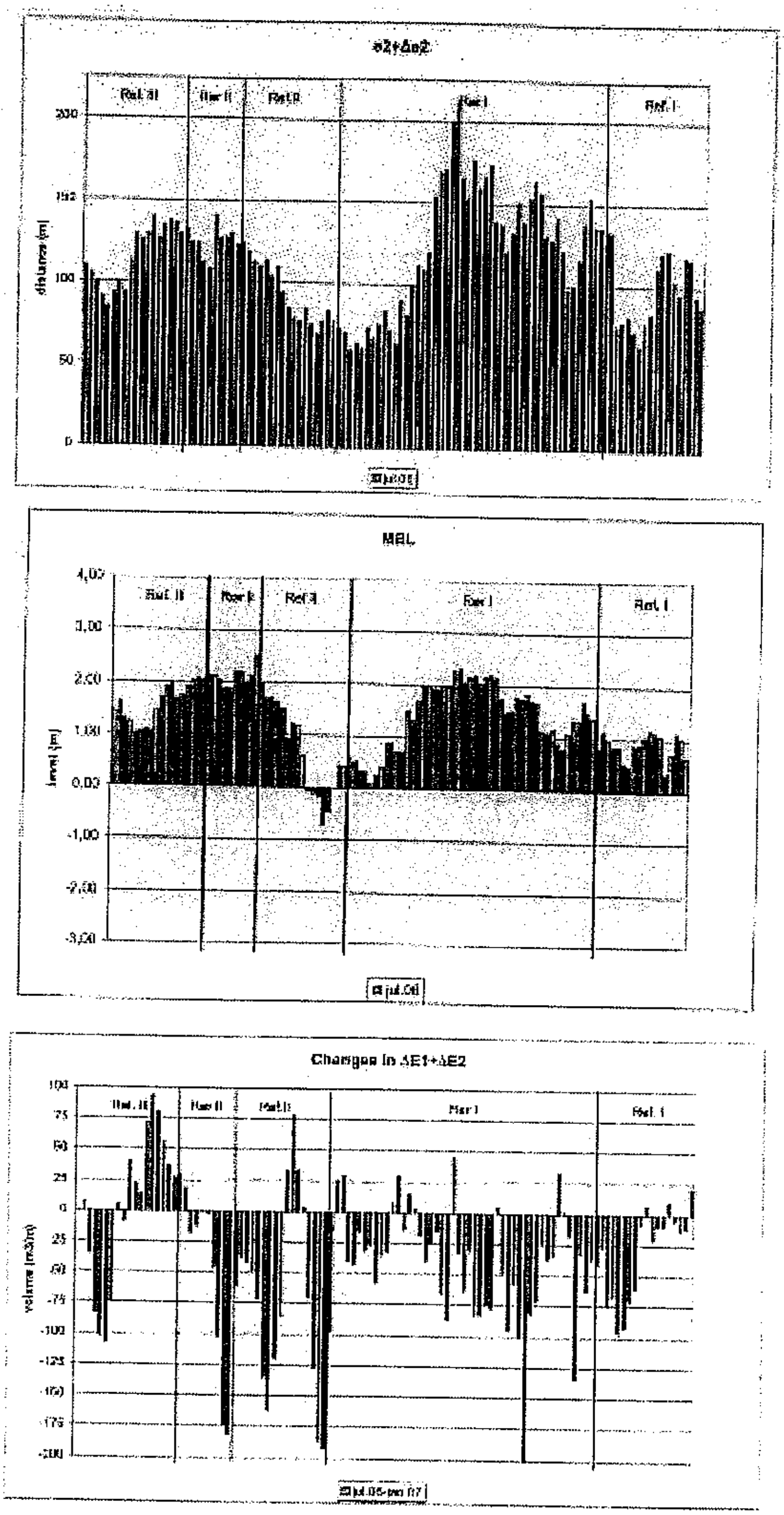
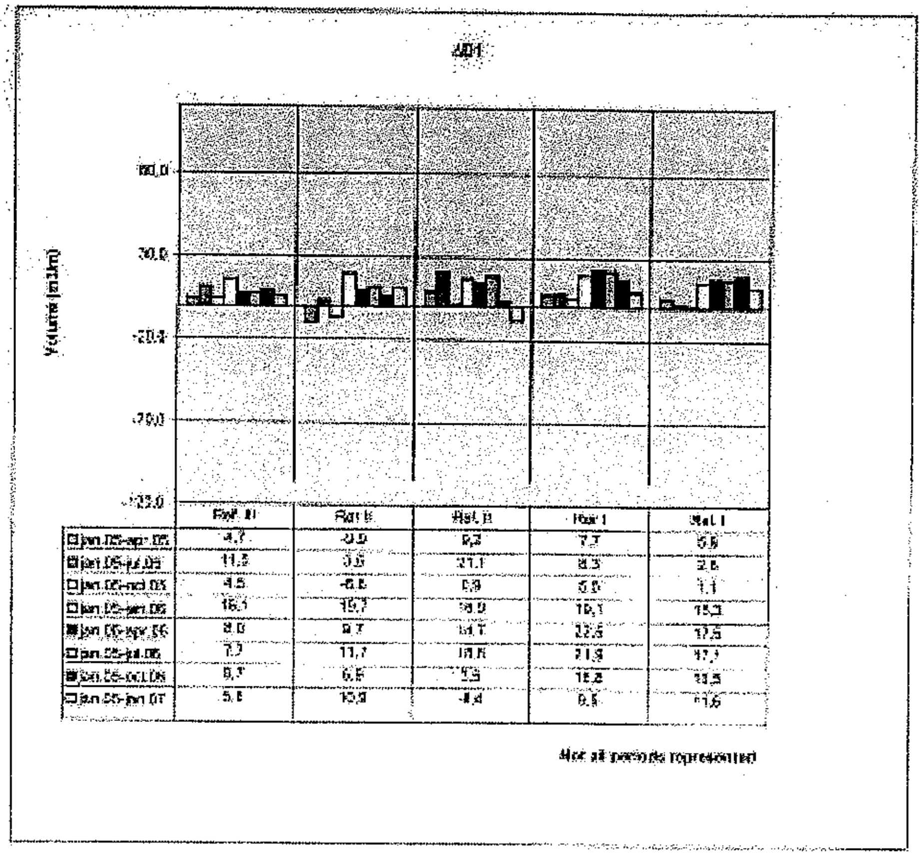


Fig. 19. Relative strength per July 2006 of the stretches and effect of the storms October 2006 and January 2007 in terms of dune and beach erosion.

Figure 7.15 Relative strength per July 2006 of the stretches and efect of the storms October 2006 and January 2007 in terms of dune and beach erosion.



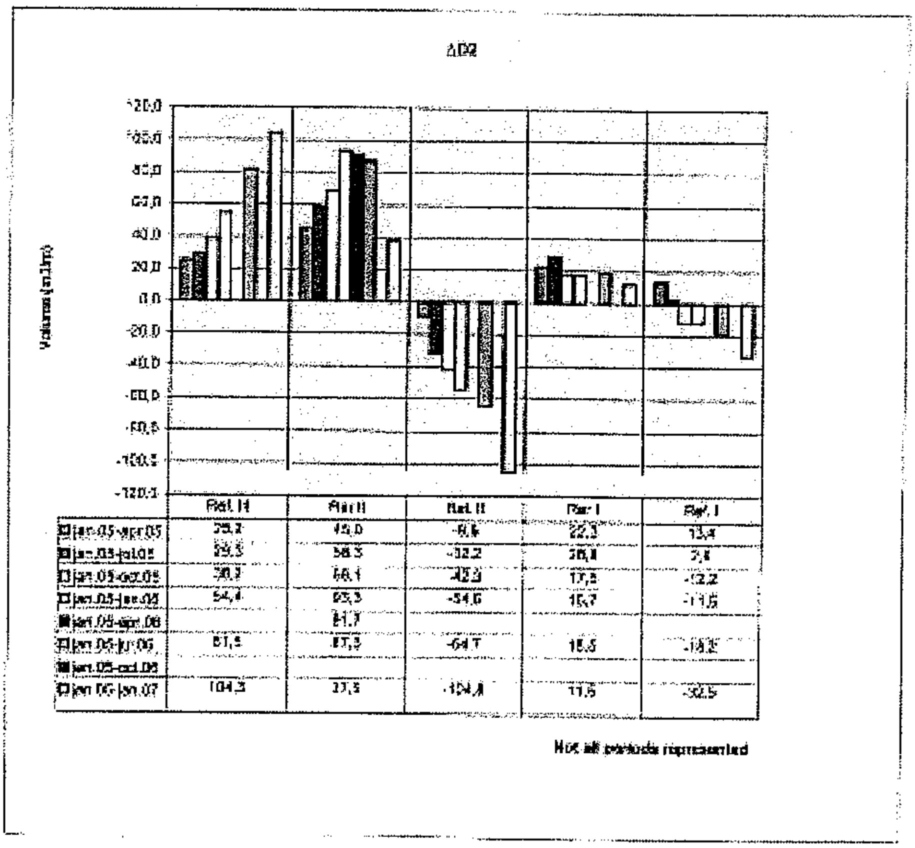
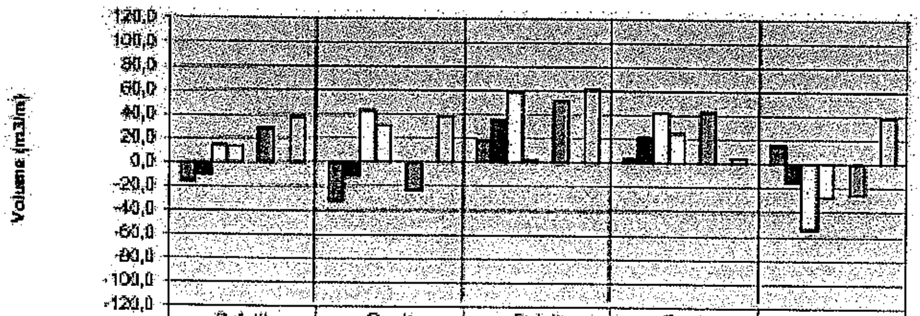


Fig. 20. Averaged volume changes in Box I and Box 2.

Figure 7.16 Averaged volume changes in Box 1 and Box 2.

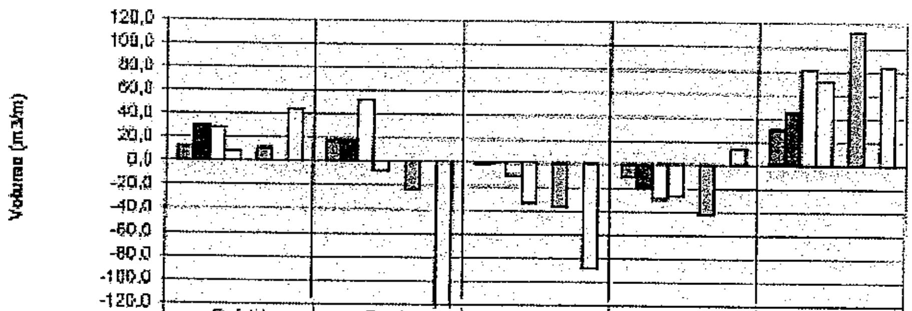
ΔD3



	Ref. III	Rer II	Ref. II	Rer I	Ref. I
jan.05-apr.05	-15,7	-32,1	18,0	3,6	15,6
jan.05-jul.05	-10,9	-12,2	35,7	21,6	-14,7
jan.05-oct.05	14,1	43,5	58,9	42,6	-54,3
jan.05-jan.06	13,4	30,8	2,8	25,3	-27,9
jan.05-apr.06					
jan.05-jul.06	27,8	-22,9	51,5	43,2	-26,6
jan.05-oct.06					
jan.05-jan.07	37,4	38,7	61,3	4,4	38,3

Not all periods represented

ΔD4



	Ref. III	Rer II	Ref. II	Rer I	Ref. I
jan.05-apr.05	11,8	17,5	-1,5	-10,6	30,1
jan.05-jul.05	30,3	17,6	0,5	-20,2	44,3
jan.05-oct.05	27,9	52,1	-9,9	-29,1	81,0
jan.05-jan.06	8,5	-7,4	-33,6	-26,8	70,6
jan.05-apr.06					
jan.05-jul.06	11,1	-22,0	-36,9	-42,4	113,4
jan.05-oct.06					
jan.05-jan.07	44,7	-130,3	-88,0	13,8	83,8

Not all periods represented

Fig. 21. Averaged volume changes in Box 3 and Box 4.

Figure 7.17 Averaged volume changes in Box 3 and Box 4.

7.4 Observed trends.

Only the upper part of the first page is related to D-parametres.
The observed trends are general observations not specifically related to parameter definitions. In table 7.1 it is not defined what are beach and offshore. It should be noted that Box D2 is not equivalent to what is the meaning of beach.

A. The beach.
After the first year (remembering that a large storm took place January 8th 2005, just before the system was implemented) we had significant accumulation in the beach in Rør 1 and 2 and in Ref 3. We had erosion in the Ref 2, located in between the two reaches with tubes, while ref 1 was neutral(neither erosion or deposition).

In the second year we had significant erosion in all stretches except in Ref 3. In this year severe storms occurred in January 07.

Over the two years we get the picture that we –with one exception – would have anticipated: Erosion at the northern part of the site, and more and more sedimentation as we move south: as mentioned in the introduction, we usually have erosion in the northern part, and accretion in the southern part, see also the sketch figure 7.9.

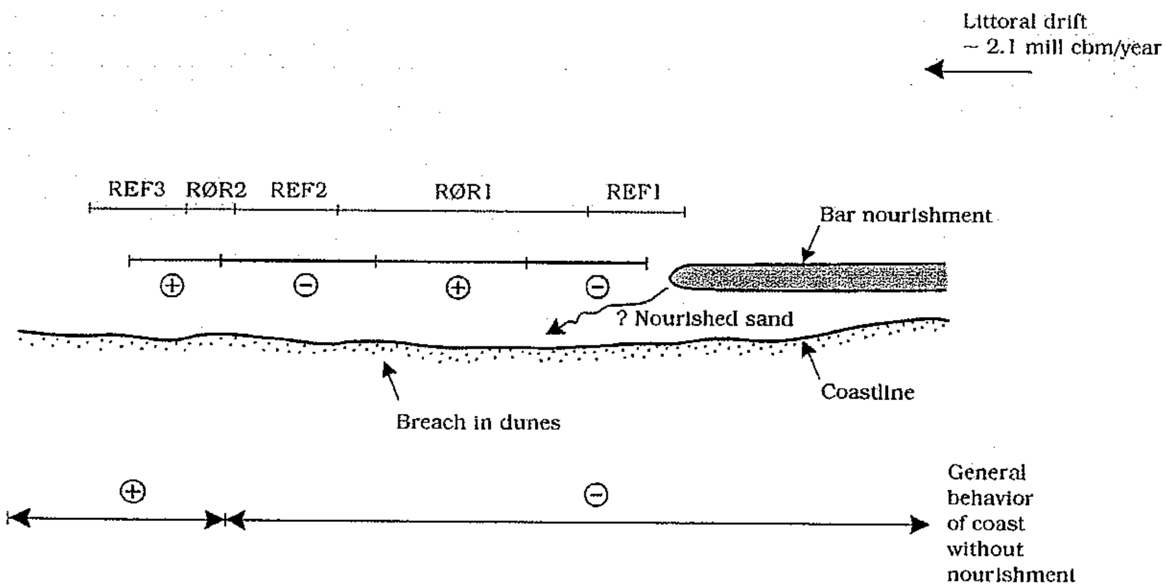


Figure 7.18: General behaviour at the site. Minus means erosion, plus deposition.

The exception is the large erosion at reference 2. It could be a proof of a positive impact from the tubes, since the erosion is so large at a location, where there are no tubes.
The question is whether it could be explained otherwise.
We would like to mention at least 4 things

1. Even though Ref 2 in average was quite robust (MBL=1.2In Jan 05), it was very thin and vulnerable in the transition in between Rør 1 and Ref 2, where MBL approximately was zero over more than 100 meters. Here the waves could attack the foot of the dunes and create a breach in the dunes (which actually happened). Such a lowering in the dune ridge will create a concentration of wind during storms, and this wind will transport a lot of

windblown sand landwards and hence accelerate the erosion of the beach locally as sketched in figure 7.20.

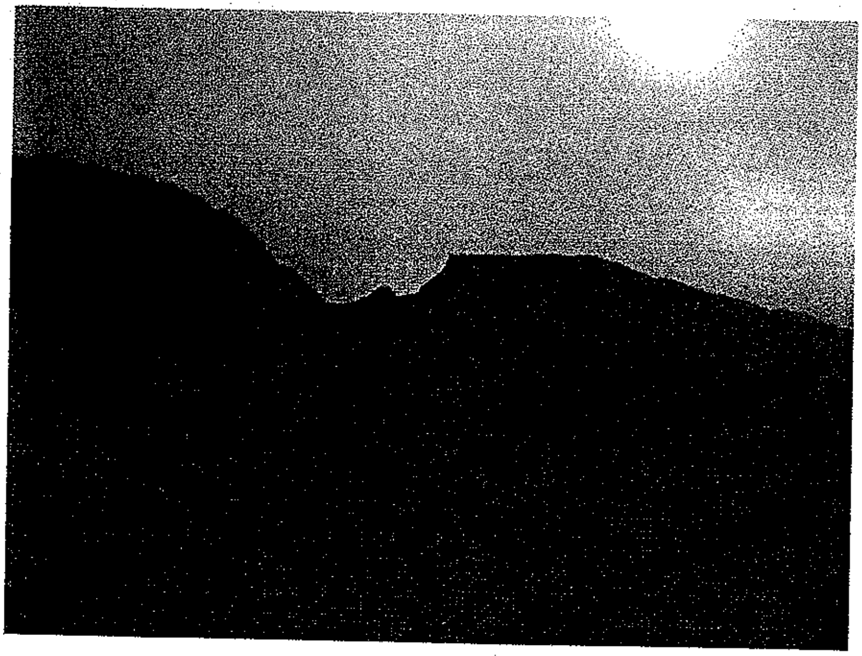


Figure 7.19: Observed breach in the dune close to the position between Rør 1 and Ref 2.

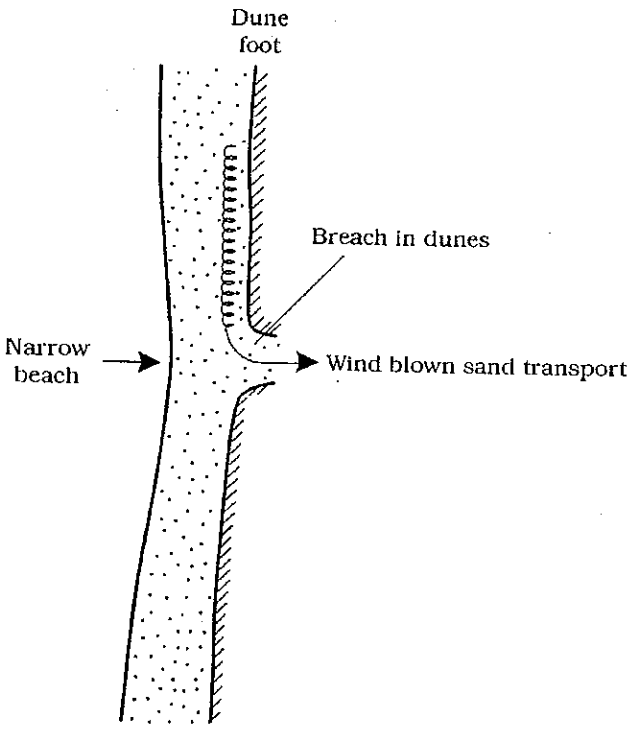


Figure 7.20: A breach will accelerate the wind born sediment transport through the dune system and will result in a narrowing of the beach.

2. The outer bar around 3-400 meter offshore seems to stop just outside the location, where the beach becomes narrow, see figure 7.21. The bar-behaviour in the entire region can be quite

strange because of the large nourishment on the bar just north of ref 1, see figure 7.18. A hole in the outer bar or termination of the bar can imply, that waves can penetrate more onshore without breaking (on the bar), and hence be the cause to the narrower beach, see the sketch figure 7.22. Figure 7.23, 7.24 and 7.25 illustrate other possible mechanisms which might be responsible for getting narrow beaches on some locations: concentration of the long shore current behind the bars, presence of rip holes in the bars, and migrating long shore undulations. These possible mechanisms will be studied in more detail during the last year of the project.

MIKE21 ved Skodbjerge

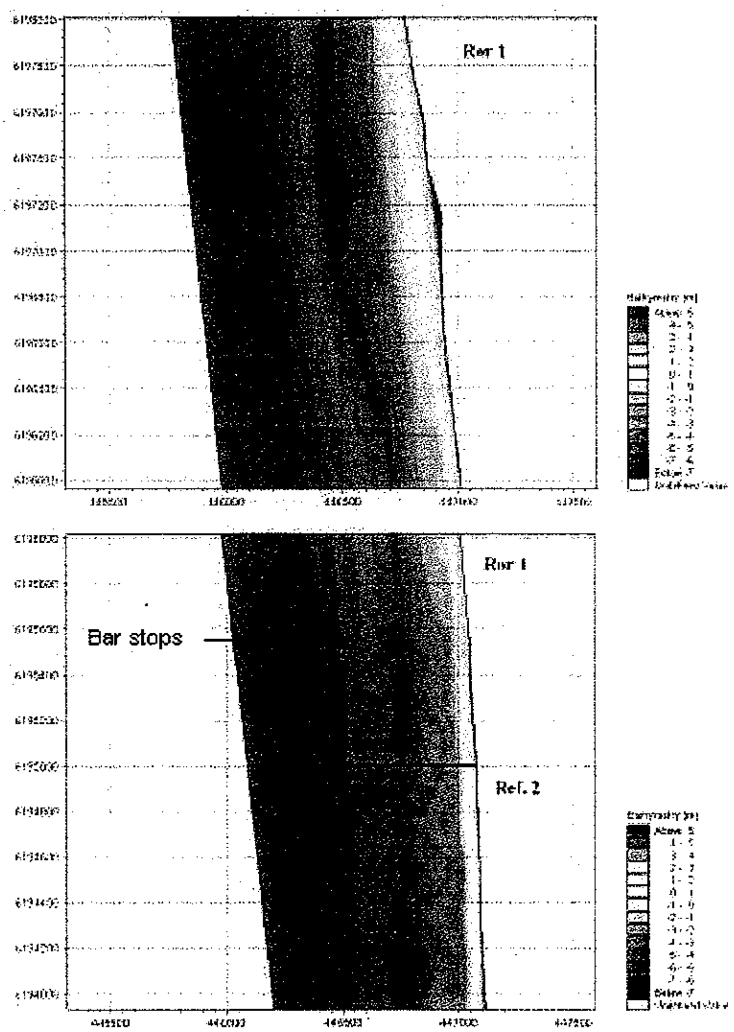


Figure 7.21: The bathymetry indicates that an outer bar disappear just in the transition in between Rør 1 and Ref 2. A more detailed survey will be performed this summer (2007).

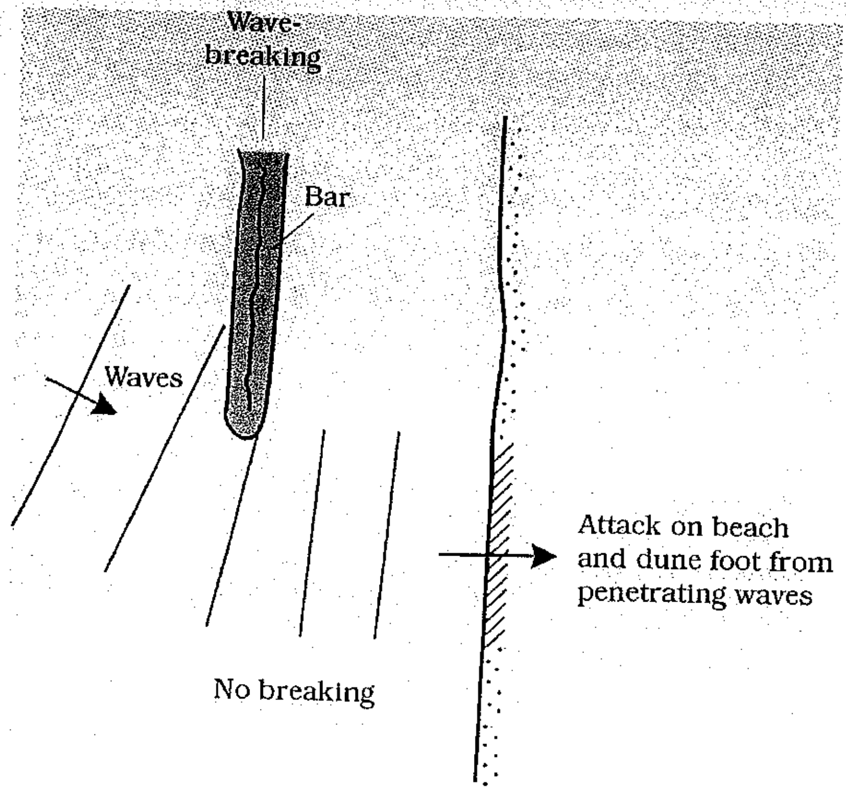


Figure 7.22: If the bar really disappears, the beach will be exposed to a larger wave attack.

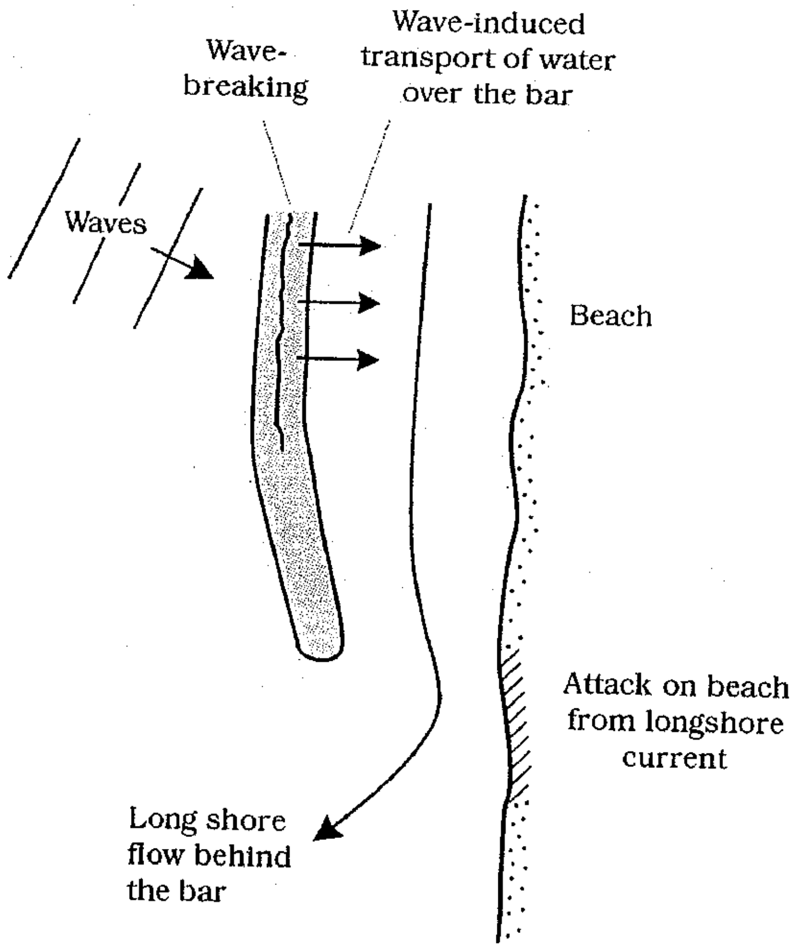


Figure 7.23: Another possible mechanism for a local narrowing beach is a concentration of the long shore current behind a crescendic long shore bar (originally suggested by Søren Knudsen, KDI).

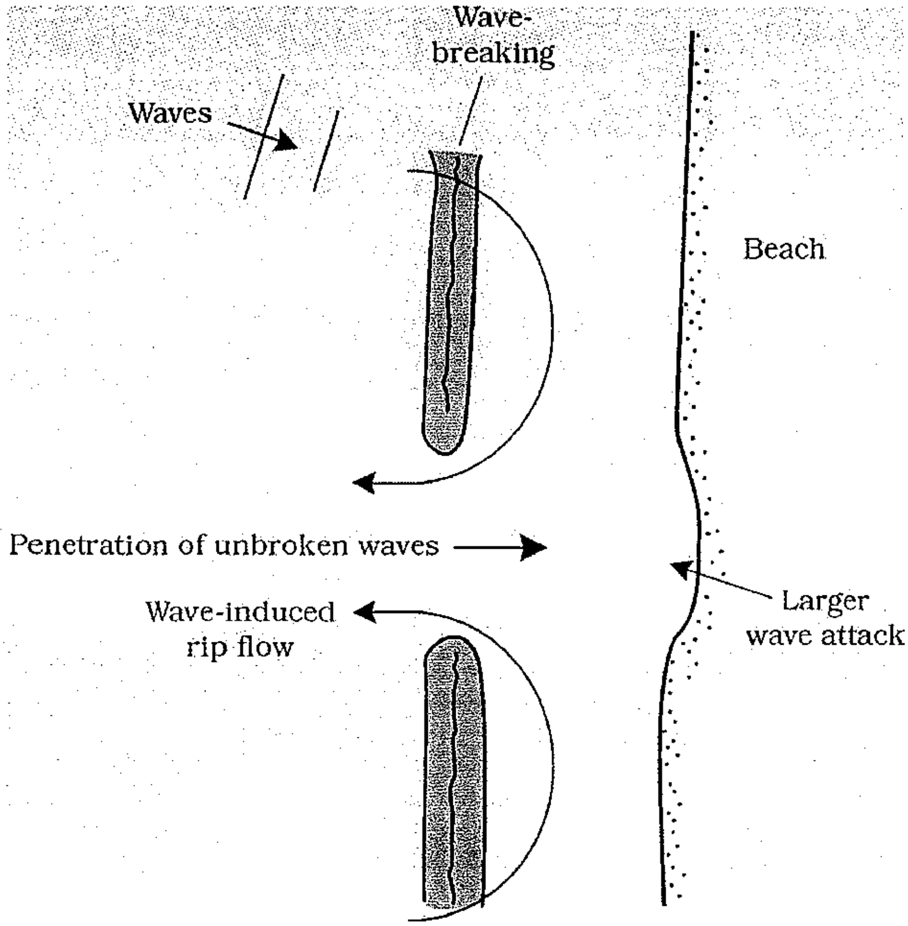


Figure 7.24: Also rip holes allow waves to attack the beach locally.

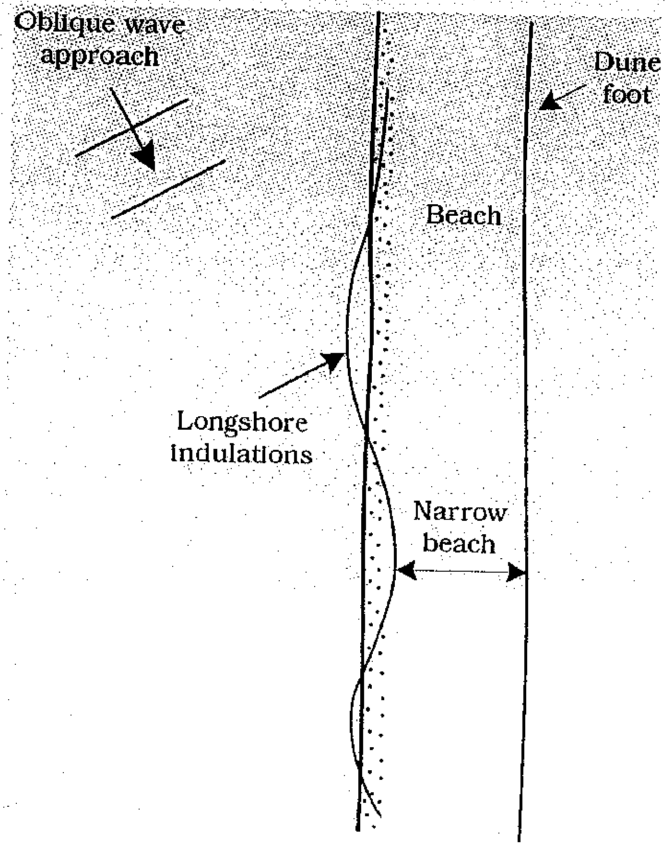


Figure 7.25: Obliquely approaching waves will form long shore undulations as described in the appendix 5.

3. The erosion in the beach is not only significant in Ref2 but also in several places where the tubes are located, see the sketch figure 2 and next section
4. There is no sign of erosion in Ref 3, on the contrary it grows and grows. SIC claims this is due to "washed sand", but then you can ask why is the sand not washed in ref 2, located down drift of more than 5 km tubes!!

8. List of appendices.

1: Comments on the infiltration into the beach by Peter Nielsen (taken from his homepage).
2: The drainage capacity of a tube in homogeneous sand and exposed to a vertical pressure gradient (by Jørgen Fredsøe)
3: A field study at the site on the flow in the beach (By Peter Engesgaard, KU).
4: D-profiles
5: Undulations along the shore (by Jørgen Fredsøe)