CHAPTER 166

PERMEABLE PILE GROINS

Thomas Trampenau[1], Frank Göricke[2], Arved J. Raudkivi[3]

ABSTRACT: Permeable pile groins have been built on the southern shores of the Baltic Sea in large numbers for the past century and a half, yet no detailed literature has been written on how these structures function. The study of the groin system at Warnemünde, has shown that this type of groin causes a reduction of the littoral current and elimination of the local rip currents. This, in turn, causes underwater profiles to raise, a widening of the beach and a seaward movement of the shoreline.

INTRODUCTION

Groins are one of the oldest forms of coastal protection structures used in a multitude of forms and types of material the world over. Their expected effects, however, are still only loosely predictable. Groins are generally solid structures extending from the shoreline into the surf zone. These may be short or long, high or low groins, where the latter are frequently overtopped by waves. There are also groins that slope from the beach or revetment down to the sea bed at the seaward end. Groins may also be classified by the type of construction and materials used. Rubble-mound, concrete, steel or wood are examples of materials used in construction. Many groins are permeable, but mainly as a result of leakage rather than intention. For example, rubble-mound groins may become less pervious as sand and slit block the voids.

The following discussion is restricted permeable pile groins. These are pervious by nature and built using piles rammed with predetermined spacing that may vary along the groin. Such a groin is illustrated in Fig. 1.

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1) Dipl.-Ing., Leichtweiß-Institut, Techn. Univ. Braunschweig, Beethovenstr. 51a, 38106 Braunschweig, Germany.

2) Dipl.-Ing., Staatl. Amt für Umwelt und Natur Rostock, Parkstr. 46, 18119 Warnemünde, Germany.

3) Em. Prof., Dr.-Ing. Univ. Auckland, New Zealand, 7 Coates Road Howick, Auckland 1705, New Zealand.

Figure 1. A permeable pile groin field in the test area Warnemünde during low water (caused by wind set-down)

The use of pile groins has been primarily confined to the southern coast of the almost tideless Baltic Sea, where over 900 pile groins have been built along the German coastline since 1843 (Weiss 1991) and about 950 along the Polish shores (Basinski 1963; Onoszko 1984). The permeabilities (the ratio of the pile diameter to the pile spacing) vary up to about 50%.

Frequently, the food of the groin has been rammed tight (permeability = 0%). The groins typically protrude 0.5 m above the sea level. Unlike non-permeable groin fields which cause a saw-tooth shoreline to form, permeable pile groins fields reatin a continous, straight shoreline (Fig. 2).

Consequently, the explanations of performance of groin, as expounded in literature, are not directly applicable to permeable pile groins. A discussion of the functioning of the permeable pile groins was published by Raudkivi (1996). The primary effect of permeable pile groins is the slowing down of wave induced longshore current in the groin fields and an elimination of rip currents along the groins (Fig. 3). This results in the raising of the profile within the reach of groin field and the development of a terrace. The following is a representation of field data from the groin system Warnemünde near Rostock, Germany.

Figure 2. Typical shoreline alignment of a permeable groin field at low water

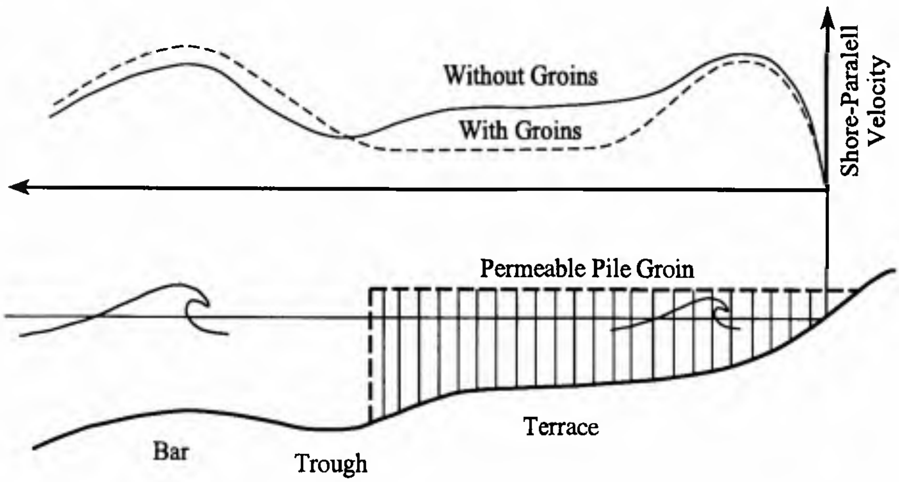

Figure 3. Schematic beach profile and wave-induced longshore current distribution with and without permeable pile groins

THE TEST AREA

The coastline of the test area faces northward. The predominant wind direction is from west to northwest thats leads to a net eastward component of annual energy flux. An aerial view of the groin system is shown in Fig. 4.

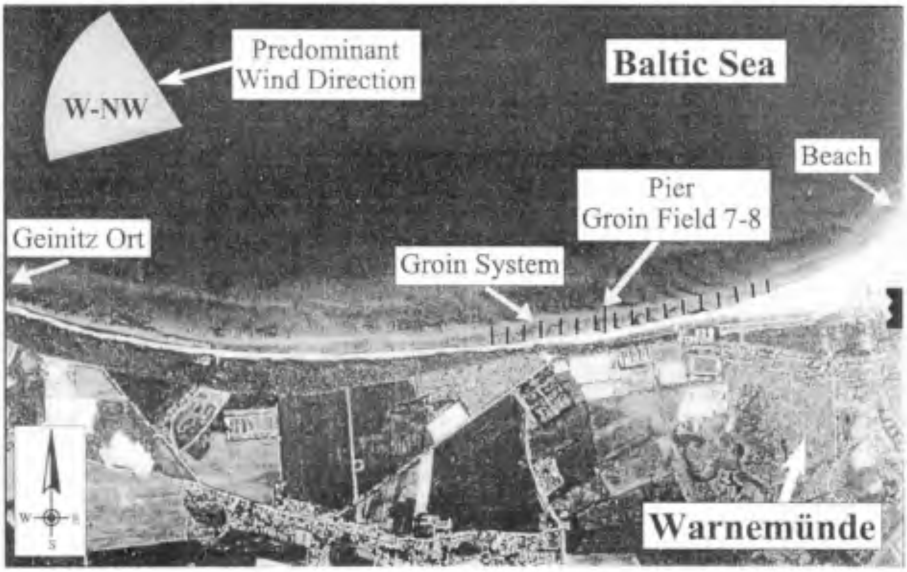

Figure 4. Aerial view of the groin system at Warnemünde

Although typical fluctuation of the water level due to wind setup/setdown is less than ± 0.5 m, storm tides up to 2.8 m above MSL have been recorded. Severe storm tides are associated with weather systems of lows in the North Atlantic or Mediterranean that move to the Baltic area and meet with Northern European high pressure systems. This leads to severe winds from the northeast. These have a mean return period of about 6 years. The frequency of significant wave heights H_S higher than 1.0 m is approximately 5%. The predominantly fine-groinded sediment of the coastline has a narrow swash zone, followed by an upward concave slope (terrace) that ends with a steeper slope down to the trough landward of the first shore-parallel bar. The term "first bar" is used because in the tideless Baltic Sea frequently more than one shore-parallel bar is present (Fig. 5).

Temporary bar-trough features (inner bar) occur on the nearshore slope due to local breaking of waves. In the swash zone the middle and coarse fractions of the local sand dominate. On the terrace about 90% are finer than 0.2 mm. The sand grain diameters increase down to the trough (0.35-0.63 mm). On the bar, though, about 90% of the sand is finer than 0.2 mm.

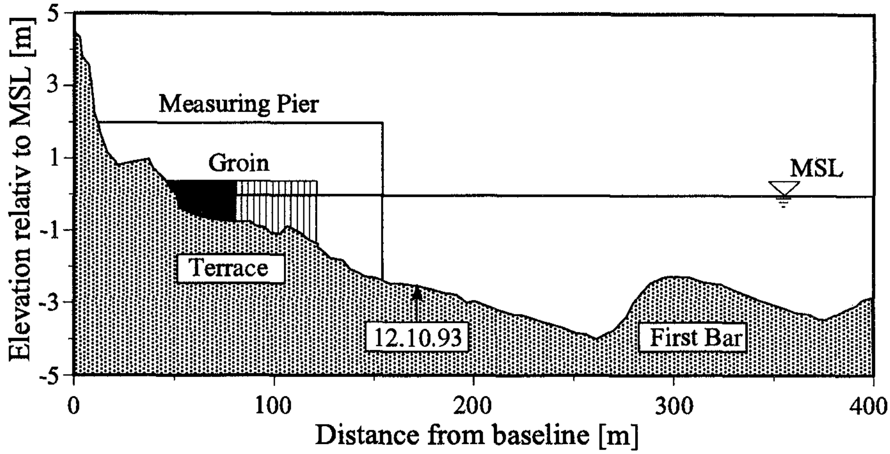

Figure 5. Typical shoreline profile in the test area

Field data has been collected from the Warnemünde test area since 1989. 17 pile groins were installed during 1991-92 and extend 120 m seaward from a baseline that is about 20 m landward from the water's edge. They are spaced 80 m apart. The top of the piles are 0.5 m above mean sea level. The groin system Warnemünde is shown in Fig 6.

The permeability (P) of the groins varies. The groins in the centre of the groin system are rammed tight for the first 80 m of their seaward reach. The permeability of the remaning 40 m displays an increase of spacing between the piles. The permeability of the groins also decreases between groins in the field. The groins furthest east and west exhibity the lowest mean permeabilities. Groin 8 and 9 have the highest permeabilities. The dotted area on Fig. 6 delineates the area where the groins are rammed tight. Groins 2 and 3 have pile spacings up to 0.25 m compared with pile diameter of 0.22 m. Permeability increases from 30% up to 55% with a mean over the groin length of 40%. The groins 5 and 6 have permeabilities from nominal zero up to 40% with an average of 20%, and groins 7 and 8 have permeabilities up to 40% with a mean of 13%. To verify the effecicacy of the permeable groin field after construction, a profile 140 m westward of the first groin was used for reference. Regular surveying along this profile as well as within the groin fields between groins 2-3, 5-6 and 7-8 have been carried out since 1991.

RESULTS

The bands of annual wave-induced profile variations at the groinless reference station are shown in Fig. 7 for the year 1990/91 superimposed onto the bands of the years 1992 up to 1995. Other years depict an essentially identical picture of small profile changes dependent on sea conditions. Changes between the underwater profile in the groin field 2-3, (of relatively high permeability) from that before the installation of groins, is illustrated in Fig. 8.

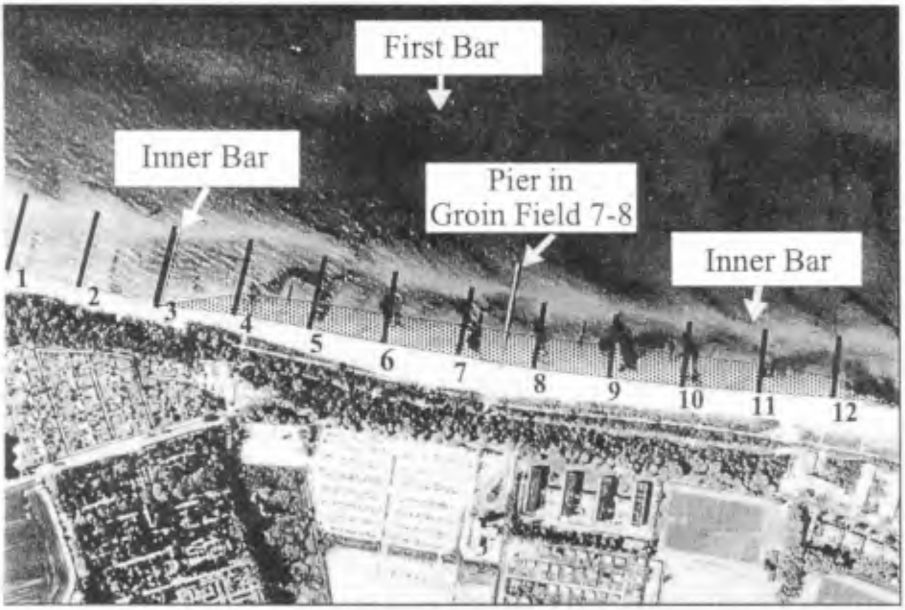

Figure 6. Aerial photo of the test area Warnemünde (enlargement)

A time span of almost two years past before a change of the profile become noticable. In 1995 a significant widening of the beach and development of an underwater terrace is apparent. It is also noticeable that the terrace now extends beyond the end of the groins. The underwater profile development in the groin field 5-6 is shown in Fig. 9. Also to be noted is the seaward shortening of the terrace, a rise of the underwater profile near the shoreline and a widening of the beach about 20 m in seaward direction.

The changes of underwater profile in the permeable groin field 7-8, with the lowest permeability (P=13%) over their entire length, is shown in Fig. 10. The comparison of the annual profile bands, before and after groin installation, were is informativ. The diferences in band variation (1990 and 1991) before groin installation are relatively small and comparable with those at the reference station that shows no trends. After installation of the groins in autumn 1991, 1) the shoreline has moved steadily in seaward direction, 2) the terrace has narrowed considerably, 3) the beach level has been raised, 4) the underwater profile in the groin field has lifted 0.5 m and 5) its slope at the groin toe has become steeper.

At the reference profile (groinless coast) only small profile changes have been recorded. The results show that permeable groins with relatively high permeability over their entire length lead to a shift of the shoreline seaward (note groin field 2-3). A further reduction in permeability and a tighter inshore segment lead to a raising and seaward shift of the underwater profile, as seen in groin fields 5-6 and 7-8.

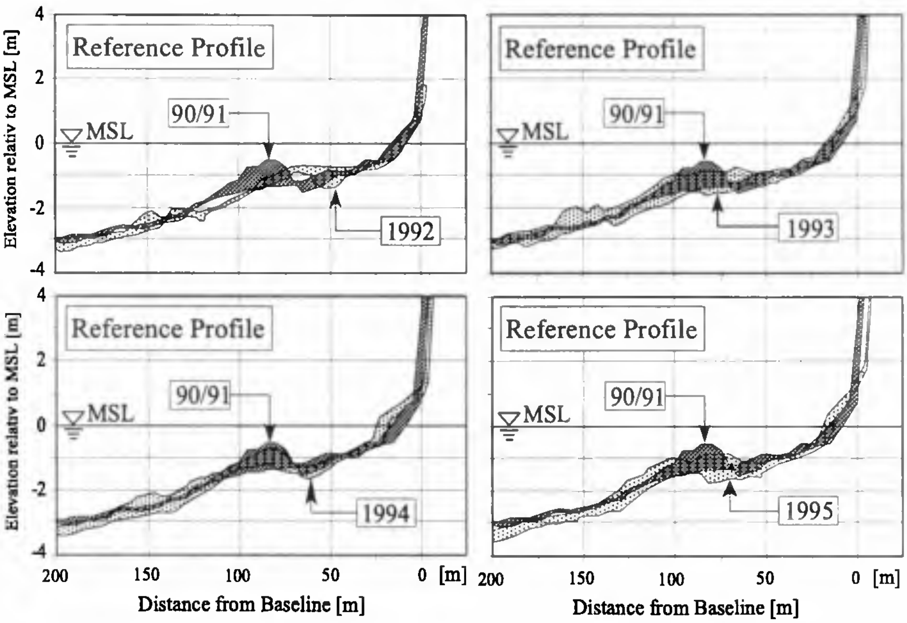

Figure 7. Bands of profile movements at reference station from 1992 up to 1995 compared with the band from 1990/91

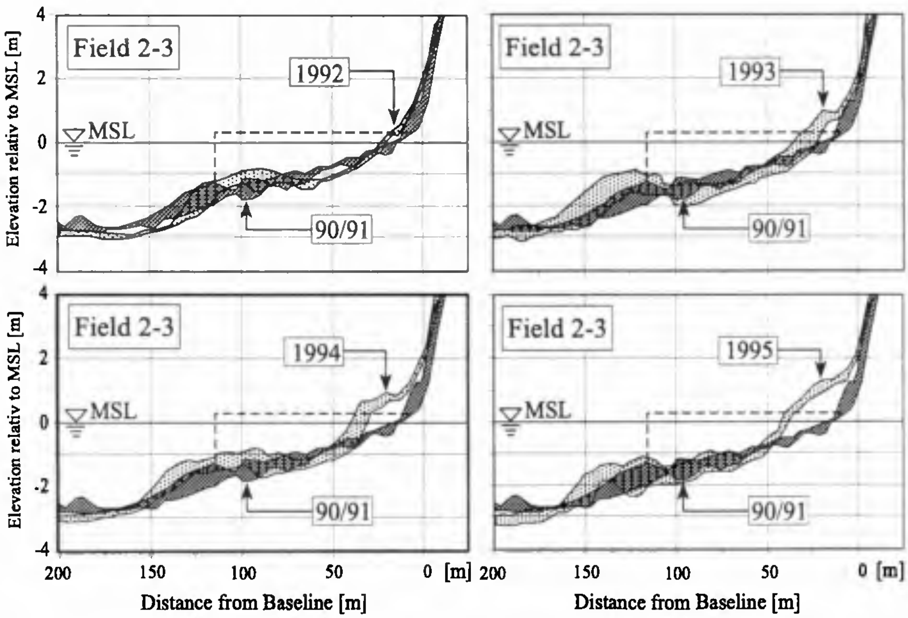

Figure 8. Bands of profile movements in groin field 2-3 from 1992 up to 1995 compared with the band from 1990/91 before groin installation

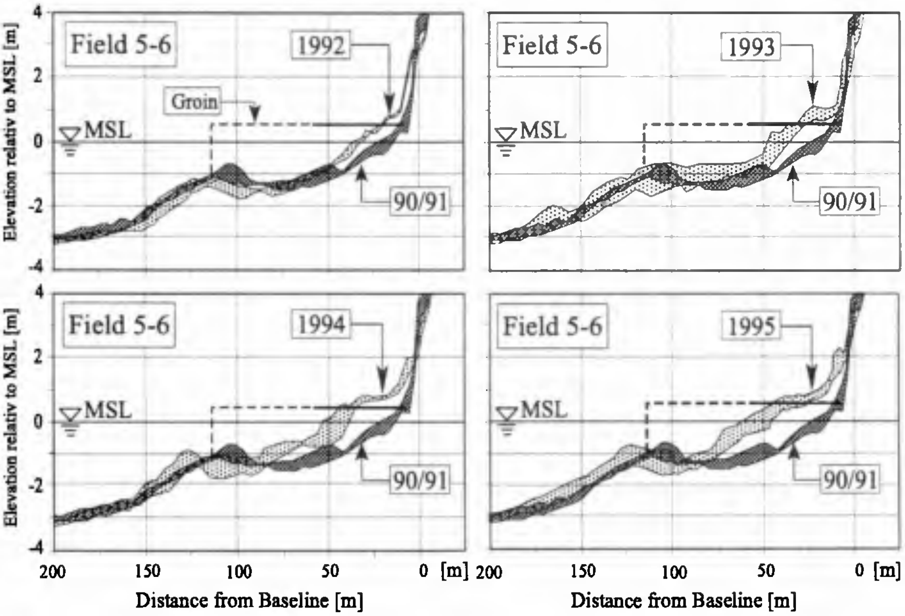

Figure 9. Bands of profile movements in groin field 5-6 from 1992 up to 1995 compared with the band from 1990/91 before groin installation

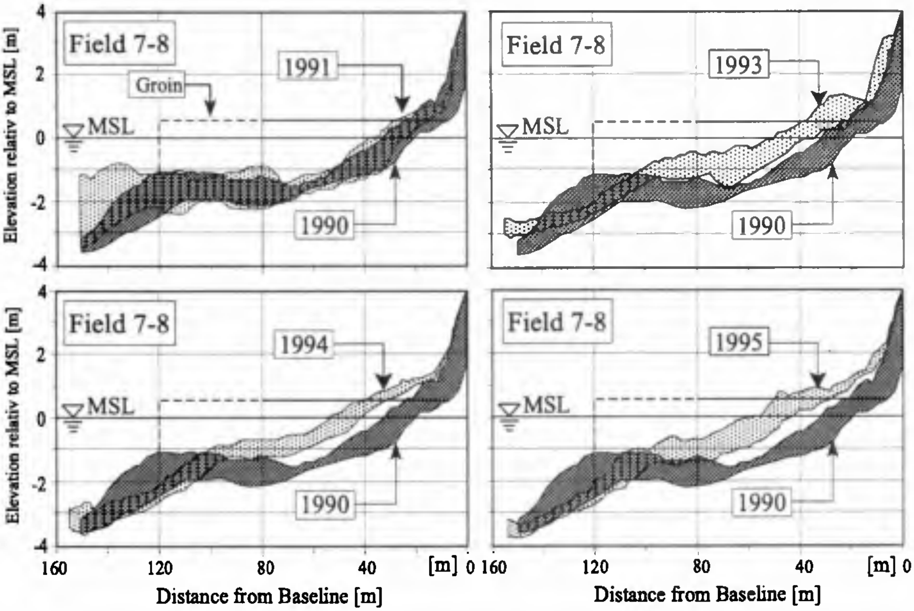

Figure 10. Bands of profile movements in groin field 7-8 from 1991 up to 1995 compared with the band from 1990 before groin installation

Significantly low permeability at the seaward end appears to concentrate the longshore current and erode the slope as seen from comparison of profiles of groin field 7-8.

The development of the shoreline over the time is illustrated in Fig. 11. No changes in the location of the depth contours are indicated at the reference location (Fig. 11 A) since 1990. No trends are recognizeable in the groin fields before construction of the groin field.

Response to groin construction was slow in groin field of relatively high permeability (e.g. 2-3). However, a slow movement of the shoreline and the -2 m contour line is apparent after installation of the groins (Fig. 11 B). In groin fields 5-6 (Fig. 11 C) and 7-8 (Fig. 11 D) the shoreline and the -1 m contour line started moving steadily seaward soon after installation of the groins, whereas at 7-8 the -2 m contour line moved landward.

Tests with tracer sands showed that sand placed at the edge of the seaward limit of the terrace moved predominantly along the slope to the trough. A small amount of the sand was carried in the direction of wind into the groin field. Tracer sand placed in the swash zone was transported partly into the corner of the groin field. However, the sand suspended in the swash zone was transported in a narrow band seaward normal to the beach. The width and alignment of this transport path indicate that the sand was transported in suspension by the return current.

DISCUSSION

It is apparent from the field data that pile groins have reduced the wave-induced longshore current without creating rip currents. This has lead to two beneficial effects:

- widening of the beach, and
- raising the level of the terrace.

The more gradual slope of the underwater profile and the shallower water over the terrace distributes the conversion of wave energy over a broader area and reduces the energy loading per unit area. This leads to a reduction of the erosion potential of the shoreline breakers and hence increases the stability of the beach. Groins with insuficient permeability, cause increased velocities past the ends of the groins and erosion of the seaward slope from the terrace to the trough. The groins should, therefore, be accordingly permeabile (even in the swash zone) to eliminate local rip currents.

ACKNOWLEDGMENTS

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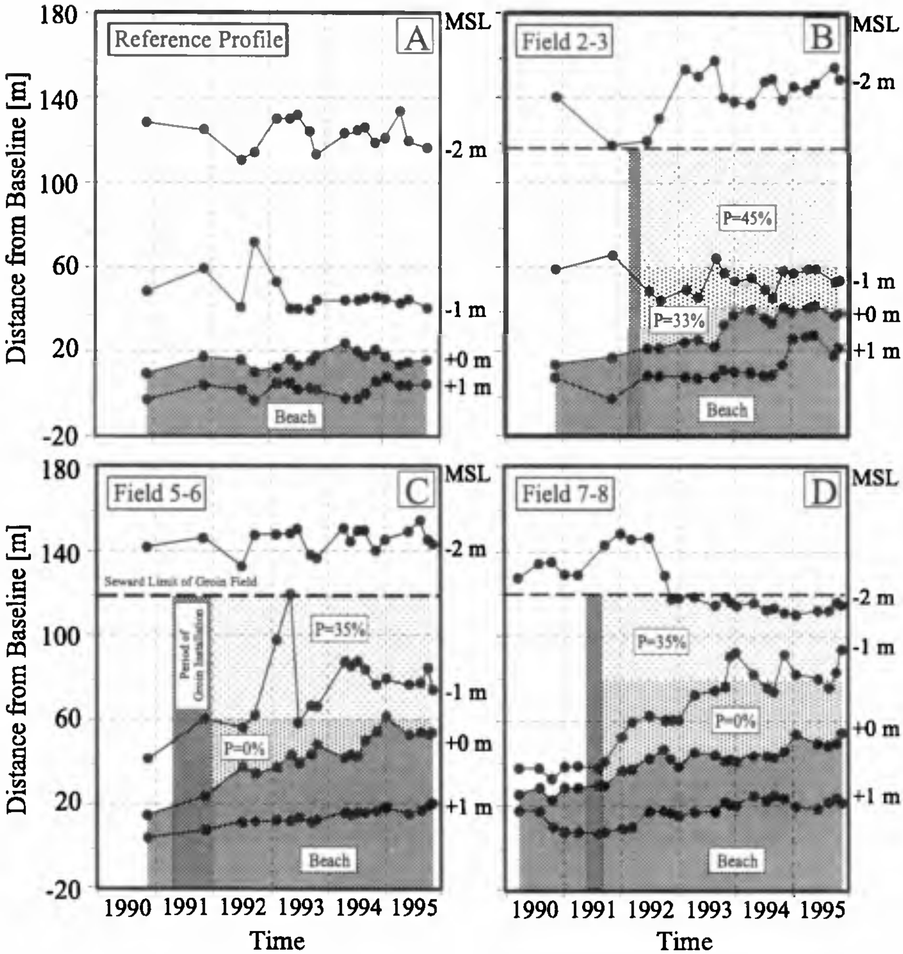

Figure 11. Changes in the location of contour lines during the period of observations

REFERENCES

BASINSKI, T. (1963) Budowle ochronne na poskin wybrzezu Baltyku, [w:] Materialy do monografii polskiego brzegu morskiego, PWN, Gadansk-Poznan, Poland (in Polish).

RAUDKIVI, A. J. (1996) Permeable pile groins. Journal of Waterway, Port, Coastal and Ocean Engineering, Vol. 122, No. 6.

ONOSZKO, J. (1984) Ochrona brzegu morkiego w minionym 40-leciu, Inzynieria Morska No. 5, Poland (in Polish).