CHAPTER 165

Groynes on the East Frisian islands: History and experiences

Hans Kunz [1]

Abstract

Groynes can be a valuable shore-protection structure. An example for this fact are the 'Strombuhnen' ('stream groynes') which have been constructed on most of the East Frisian islands throughout the last hundred years. These groynes are integrated in an engineering coastal protection system, which includes seawalls, dune revetments, 'Strandbuhnen' ('beach groynes') and artificial beach-restoration. The modern approach of society in Germany (and many other countries) towards nature preservation and integrated management of the coastal zone discourages use of 'hard' constructions. However, there are several demands of society, for which we have to concede, that properly designed 'stream groynes' can function effectively and economically; under certain conditions; this can also be the case for 'beach groynes'. According to the stated demands, these constructions have, more or less, the target to govern natural processes; hence they are principally objectable from an environmental point of view.

Introduction

The seven East Frisian islands extend along the North Sea in the western part of Germany (Fig. 1). The chain of barrier-islands is broken by inlets and separated from the mainland by a tidal flat system (Fig. 2). The semi-diurnal tides and wave action generate a net littoral drift from West to East. With respect to hydrodynamical boundary conditions and sediment transport, the islands experience both, erosion and accretion. The processes at the spits of the islands are governed by the tidal inlet, associated with the sediment transport processes in the ebb delta-shoals and the tidal

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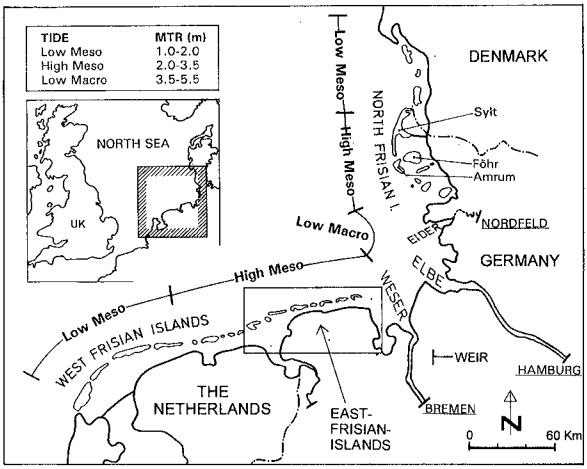

Fig. 1: The German, Dutch and Danish Waddensea - North Sea coast.

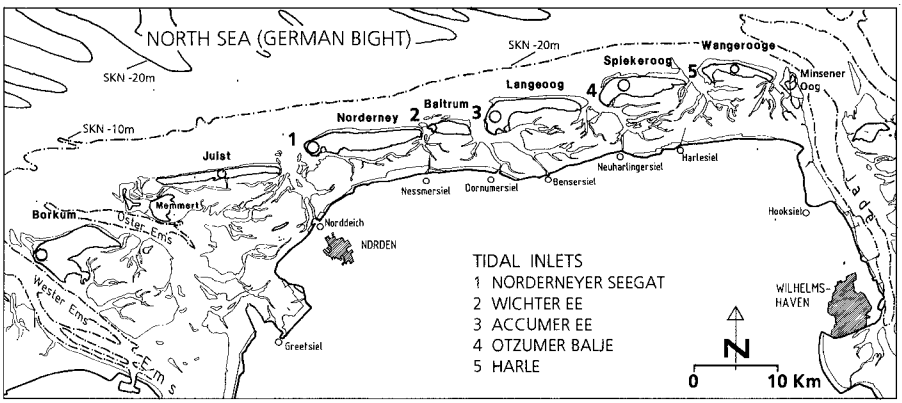

Fig. 2: The East Frisian islands and tidal inlets.

basin. The inlets are the most active part of the system; in the past they permanently changed their location as a reaction on structural changes within the sea/inlet/basin-system (naturally or man made). A migrating inlet can lead to erosion of an island, by the strong currents in the tidal channel and by effects on the ebb-delta shoals ('reef bow') which decrease the sand supply from the littoral system (negativ sand budget). The morphological development of the East Frisian islands is well recorded since 1650 (e.g. Homeier, 1962).

Groynes on the East-Frisian islands

Groynes are shore-perpendicular (normal) constructions. Professional terms in German literature distinguish 'Strandbuhnen' ('beach groynes') and 'Strombuhnen'

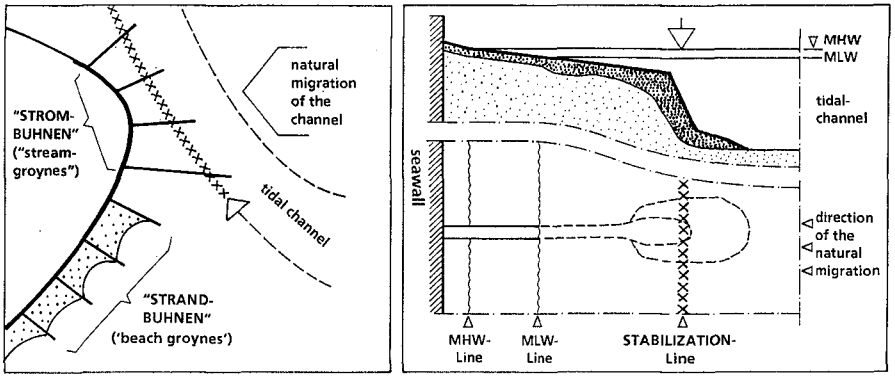

Fig. 3: Groyne-types (left). Stream-groyne (right).

('stream groynes') - see Fig. 3. The definition of 'beach groynes' has stated the purpose, quite similar to SPM (1984), as trapping littoral drift, building a beach, defending the removal of sand from the beach. 'Stream groynes' are structures to withstand and to govern the eroding forces (currents) of migrating tidal channels - e.g. KFKI (1993), TAW (1995).

The first solid construction (groynes, revetments) on the East Frisian islands were directed against dune and beach erosion. They failed in the beginning, because they could not stop migration of the inlets and they did not trap sand. The effects of scouring in front of the revetment and lee-erosion, prompted the extension of the protection means (expansion, displacement of the problems). Later on, the functional purposes of the groynes had been focused on the stabilization of the tidal inlet, leading to controversial discussions on the extension of groynes into deep water. The extreme high expenses for these 'Strombuhnen'finally had been justified by different targets (e.g. Witte, 1970):

- protection of the settlements (residential, recreational, commercial purposes).
- Preservation of the existing coastal protection constructions.
- Stabilization of the Ems- and Jade-waterway (Borkum- and Wangerooge-island).
- Stabilization of the tidal inlets and by this maintenance of the wadden-waterways to small harbors and of drainage channels.
- Protection of the mainland (dikes, foreland) against the impact of stormfloods.

The construction of 'stream groynes' started around 1900 and had been carried out on the western spits of four East Frisian islands. In every case these groynes had been constructed by extending existing 'beach groynes' into the deep water of the channel (response to the fact that the implemented groynes failed to stop erosion). Hence, these groynes are a combination of both types, depending on the crest-height; the lower part is addressed as 'underwater-groynes'. Since 1951/52 the technique of beach restoration has frequently applied to compensate sand losses by maintaining beaches within the groyne fields, which are heigh enough to protect the structures against failure caused by stormfloods.

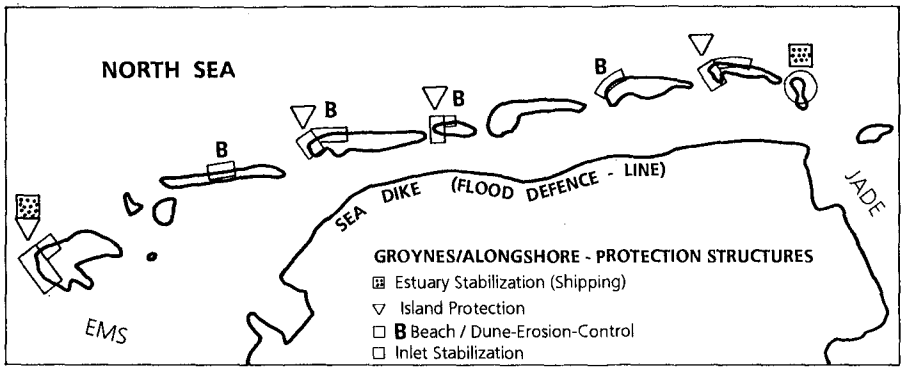

Fig. 4: Groynes on the East Frisian islands and their different targets.

The development of the groynes as part of the engineering coastal protection systems on the East Frisian islands is well known and described (e.g. Fülscher (1905), Gaye & Walther (1929), Kurzack et al. (1950), Witte (1970)).

Fig. 4 displays the groynes of the East Frisian islands (124); all are incorporated in protection structures (about 20 km length in total) which include shoreparallel constructions (seawalls, revetments). The different main targets with respect to the island/inlet are marked by signatures. The islands, tidal flats, forelands (saltmarshes), sea dikes (flood defence line) form one unit; hence the areas behind the islands benefit from the island protection means. The construction of groynes has rather based on a 'guidance on functional design', (e.g. Kraus et. al., 1994) than on 'roles of thumb'; adaptions derived from 'lessons learnt from experience' and from changing hydrographic and morphological boundary conditions. The effects of groynes had been studied in physical models, especially for Norderney-island (hydrodynamical preinvestigations go back to the end of the last century; in the fourties of this century they had been combined with morphodynamics (movable bed using amber grains) - Pr. Versuchsanstalt, 1940.

Examples

Fig. 5 shows, as an example, the actual situation of Baltrum-island: the western spit is totally armored, the inlet (Wichter Ee) has been fixed by 'stream groynes', the shoals (littoral drift) feed only areas eastward of the exposed spit. This situation is comparable with Norderney-island (e.g. Fig. 2 in Kunz, 1993a) and the problems are principally the same (e.g. Luck 1976, Kunz 1987).

The migration-history of the Wichter Ee inlet is shown on Fig. 6 by the development of: the Wichter Ee itself (ΔWI), the watersheds of the Wichter Ee tidal basin (to the West (ΔN) and to the East (ΔB)), the shore-line of Baltrum West. The definition of the terms is illustrated on Fig. 7. The construction of 'beach-groynes' started earlier on Norderney than on Baltrum (see (N) and (B) on Fig. 6); the exten-

Fig. 5: Aerial view of Norderney (left), Accumer Ee-inlet, Baltrum (right). Situation 1966, low water.

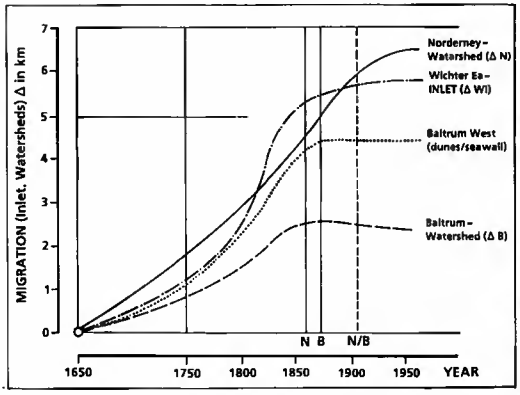

Figure 6

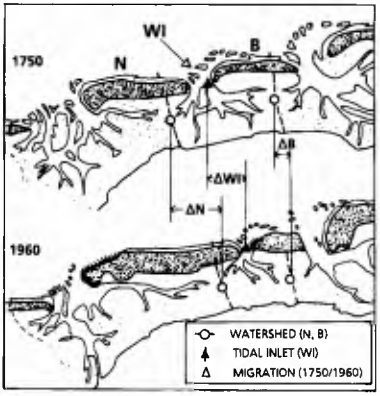

Figure 7

Fig. 6: Migration of the Wichter Ee-inlet (ΔWI), of the watersheds (ΔN, ΔB), of the Baltrum-spit. Data from Homeier (1962), Luck (1975).

Fig. 7: Situation of Norderney (N), Baltrum (B), Wichter Ee-tidal inlet (WI) arround 1750 and in 1960. Illustration of the terms ΔWI, ΔN, ΔB (see fig.6).

sion of the existing beach groynes into the tidal inlet (conversion into 'stream groynes') is marked by (N/B). The stabilization-effects are obious: the system lost it's dynamic behavior and became static. This happened to the East Frisian islands as a whole, as three more inlets (see Fig. 4) had been stabilized (e.g. Luck 1976). Society

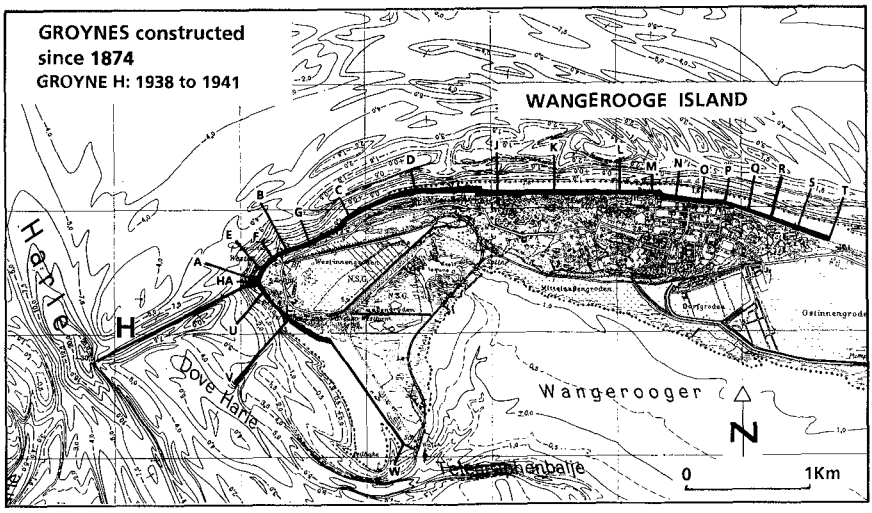

Fig. 8: Groynes on Wangerooge-island. Forschungsstelle (1980).

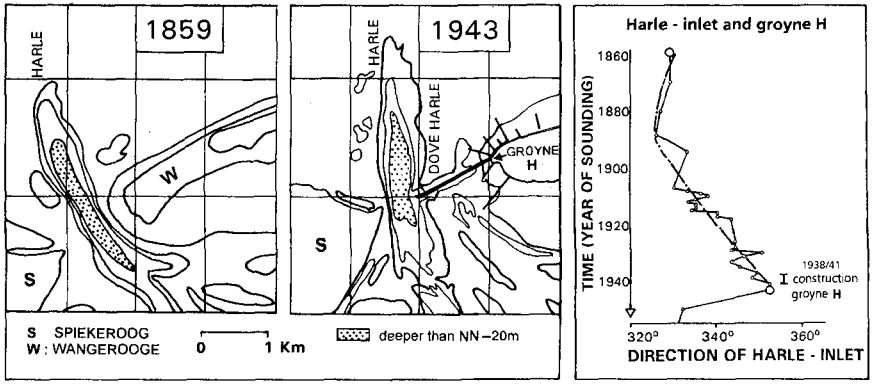

Fig. 9 : Harle inlet and Wangerooge island in 1859 and 1943. Turning of the Harle-inlet-direction before and after the construction of groyne H - Lüders (1952).

valued this result as a success; nowadays there are complains arising from the new targets of nature conservation, which society has more and more agreed on throughout the last decades (e.g. Kunz, 1993b).

The western spit of Wangerooge-island and additionally about four more kilometers of the shoreline to the East are protected by groynes (Fig. 8). The history of the island-protection is closely associated with the Jade-waterway and the harbor of Wilhelmshaven (e.g. Krüger 1911, Witte 1970). The Harle-inlet migrated to the East and turned clockwise (Fig. 9), a trend which can be explained by natural and by man made reductions of the attached catchment area 'Harle tidal basin' - Homeier (1973).

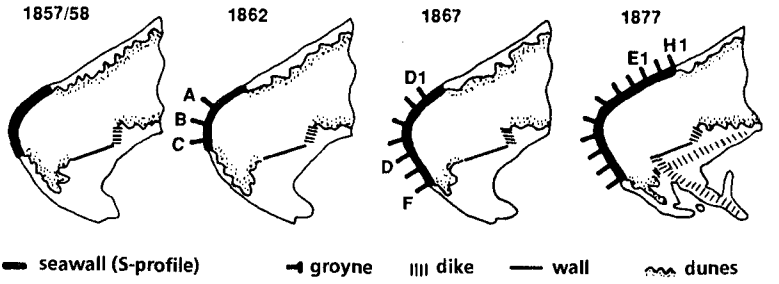

Fig. 10: Development of the protection on Norderney west (1857 to 1877).

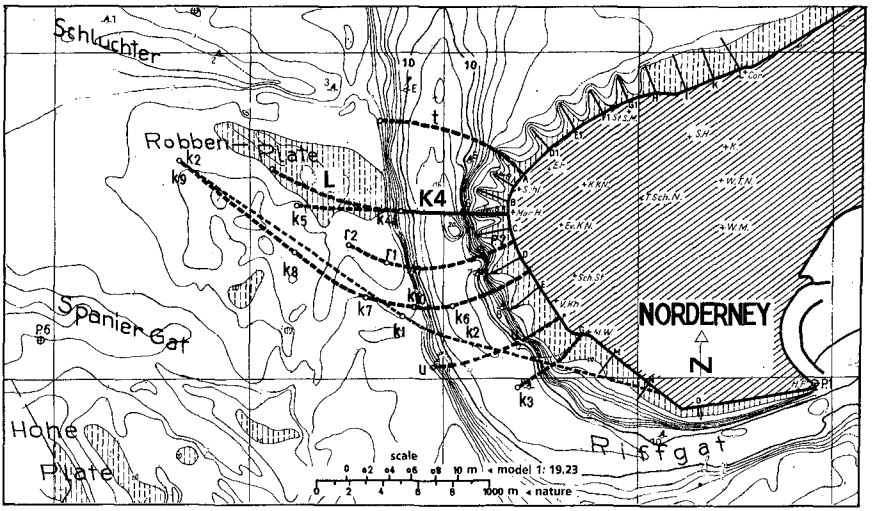

Fig. 11: Proposed groyne-extensions and training dams into the Norderney-inlet: physical model with movable bed (Pr.Versuchsanstalt, 1940).

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The groynes and shore-parallel structures on the East Frisian islands have been implemented 'step by step' since the middle of the last century. In each case the first

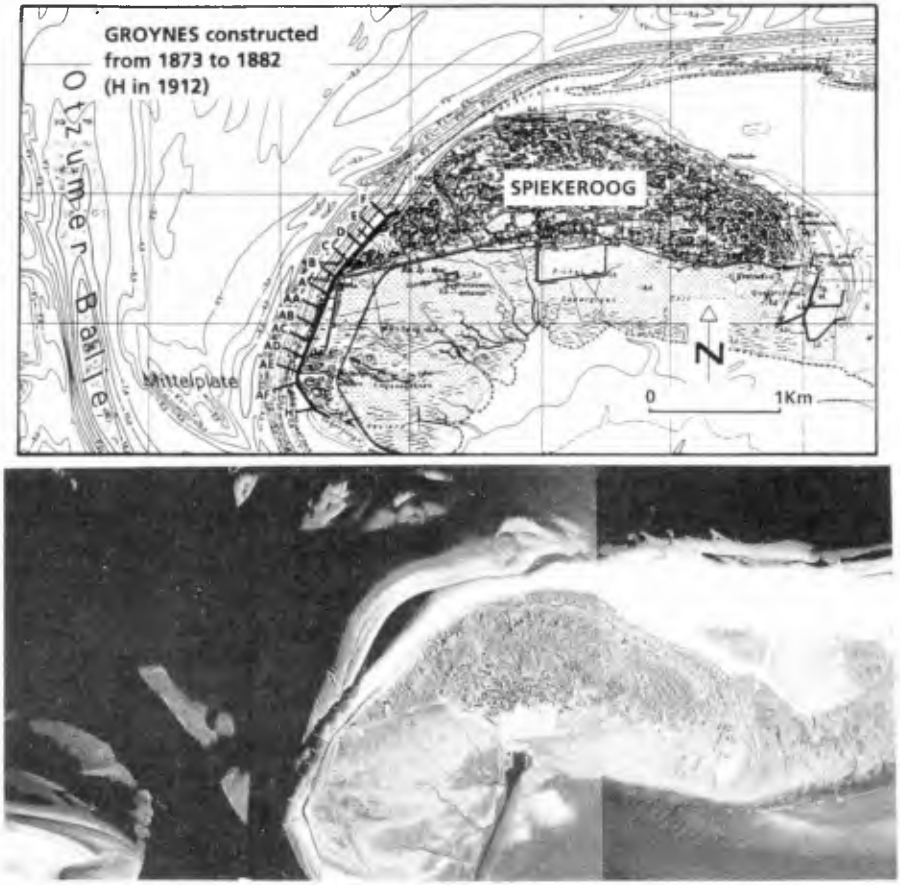

Fig. 12: Spiekeroog West. Above: groynes and dune revetment. Below: Aerial view, May 1989, shortly before landing of an accumulated shoals.

step had been a technical response to the respective problem: short stretch of dune revetment against dune-losses; a few short 'beach groynes' against beach-scouring; extensions against effects of lee-erosion etc.. Thus, the first 'volunteery step' had been followed by further steps which had been determined by the natural processes in interaction with the coastal defence-constructions (man made boundary conditions). This history is especially well documented for Norderney (e.g. Fülscher (1905), Gaye & Walther (1929), Kurzack et al. (1950), Peper (1956), Witte (1970)). Fig. 10 describes this history for the first two decades after a short solid seawall had been constructed in 1957/58 (still in place!). Under the existing conditions (tidal channel is migrating towards the island, lack of sand supply by cross-shore transport, unfavorable balance between net and gross longshore transport, bypassing) the construction had to be adapted or given up. The adaptation by 'stream groynes' stopped the inlet movement, but it didn't solve the erosion-problems. Therefore the question had been investigated, how the morphological and hydrographical boundary condi-

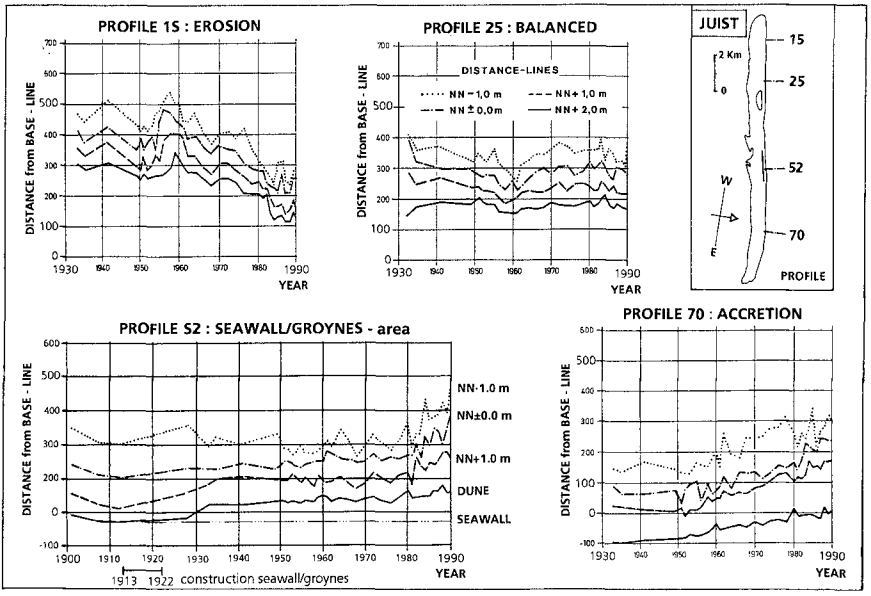

Fig. 13: Time-Distance-Lines for profiles on Juist island. Profile 52: construction of groynes with seawall from 1913 to 1922. Data: Archive CRS, Norderney.

had been investigated, how the morphological and hydrographical boundary condi tions could be changed by groynes and training dams in such a way, that a new tidal inlet (displacement to the West, anticlockwise turning of the direction up to 45°) could be established and maintained - Pr. Versuchsanstalt (1940), Kurzack et al. (1950). Fig. 11 gives an idea about the enormous dimensions of the discussed plans. Fortunately an especially established expert-group worked out an alternative (Küstenausschuß, 1952) and the decisionmakers followed their recommendations. Subsequently the first large scale beach nourishment in Europe (1.25 Mio m^3) had been carried out on Norderney-island in 1951/52 (see Fig. 14).

The morphological development of Spiekeroog-island since the Middle Ages had been substantially affected by natural sedimentation in the related tidal basin (Harle-bay) and by land reclamation means (poldering): persevering recession of the coastline in the West, accretion in the East - Homeier (1961). This let to a break through of the foredunes in 1832. The following construction of dikes (embankments) failed; consequently a solid construction work (groynes and dune revetment) had been implemented between 1873 and 1884, with supplements in 1912 and 1936/37 (Fig. 12, above). The construction works were successful; the large scale morphological features fluctuated around a generally stable stage and, in average, the natural sand supply from the 'reef bow' (merging shoals) has been sufficient. Critical situations occur when approaching shoals accumulate in front of the shore line, creating a shore-parallel channel (last phase before merging). In this phase the groynes combine more or less stabilization functions of beach- and stream-groynes (Fig. 12, below).

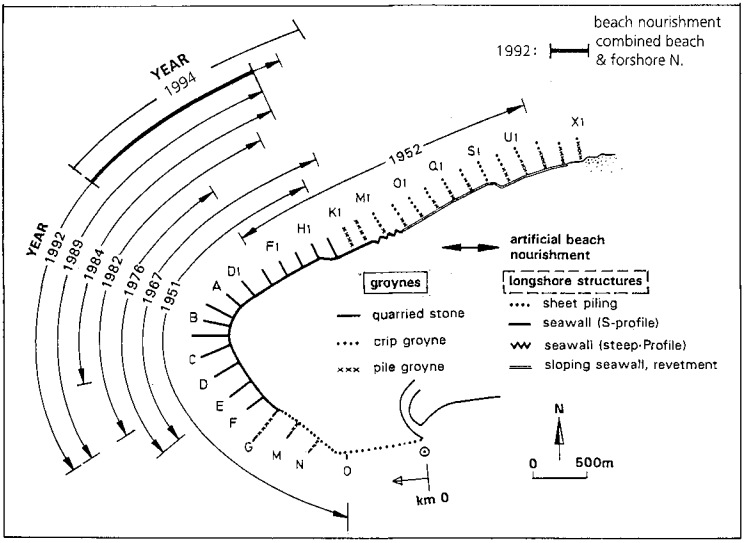

Fig. 14: Combined coastal protection system on Norderney-island.

The last groyne-seawall system on the East Frisian islands had been constructed on Juist between 1913 and 1922. Fig. 13 demonstrates long term trends of shore line developments: erosion in the West (prof. 15), accretion in the East (prof. 70), intermediate stages inbetween (prof. 25 & 52). The general trends are overlapped by short term aviations. The displayed trends can not be extrapolated without taking into account the possibility, that there may be a kind of cycle with a very long time-period (see prof. 52). Unfortunately we have only a few records on profile mapping available, which reach far enough back into the past, to work on this question. On Juist the settlement seemed to be endangered by dune-erosion in the first decade of this century. The construction of the protection-system coincidenced with the transition from an erosive to an accretional trend (see prof. 52). Subsequently the groynes and the seawall had been buried under sand (up to 10 meters).

Groynes as part of a coastal defence strategy

The groynes on the East Frisian islands are incorporated into an engineering coastal defence system. This system has been successful in stopping the migration of tidal inlets and it preserved endangered parts of the island. The groynes were not effective in reducing beach erosion; but they can stabilize artificially restored beaches, if approriately designed. Beach restoration is carried out as part of the maintenance. Fig. 14 demonstrates the strategy by the Norderney-example:

- Stream Groynes to stop the eastward directed migration tendency of the tidal inlet.
- Beach Groynes to stabilize the beaches in front of the shore-parallel structures.
- Shore-parallel Structures to protect the fordunes against erosive forces.
- Artificial beach nourishment of groyne fields to protect the existing structures against damage during storm floods.

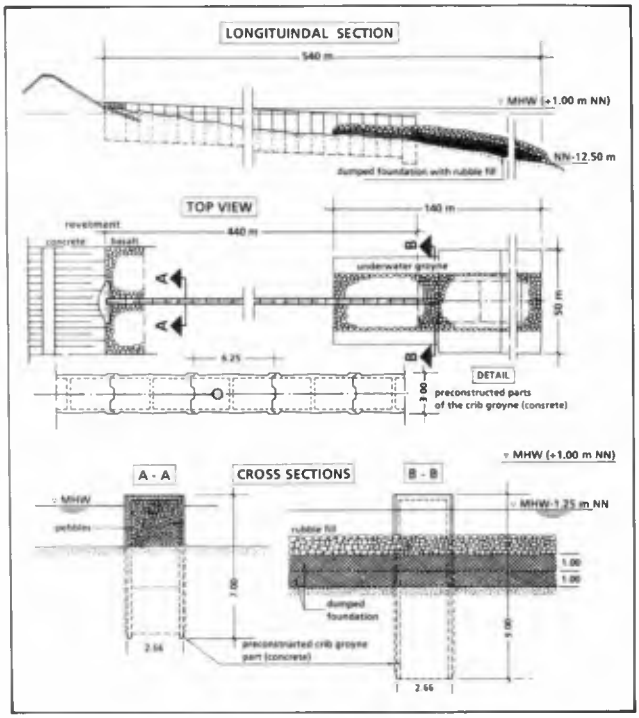

Fig. 15: Crib groyne No. 33 on Borkum island. Aster et. al. (1989), KFKI (1993).

The groynes need to be maintained and restored. A restoration-example is shown on Fig. 15 to give an idea about the dimensions - e.g. Aster et al. (1989), KFKI (1993).

The existing coastal defence systems on the East Frisian islands demonstrate, that they are sound tools to fix the shoreline. On the other hand they show, how expensive these systems are and how strongly they interfere with nature. There is an increasing demand by the island population to defend shoreline retreat with the 'hard' technique which has been proven as successful in the past. Fig. 16 deals with actual problems on Borkum-island. The western spit has been protected since the middle of the last century - e.g. Witte (1970), Aster et al. (1989). The north-eastern part of the island reacts (erosion, accretion) on structural developments of tidal channels and the foreshore (e.g. Kunz et al. 1996). The existing erosional trend and the expected development in future (szenario 2045) makes it understandable, that protection demands arise. However, if we take into account the aspects of an integrated coastal zone management, we should learn from history, that society has to take into account the problem as a whole, including the large scale processes (time & space). She also has to remember the fact, that an armoring of the existing intermediate stage is not favorable. The displayed hydro-morphological situation explains, together with the other examples, why proposed 'head-land' solutions (e.g. Silvester, 1978) provide no realistic alternatives for the East Frisian islands.

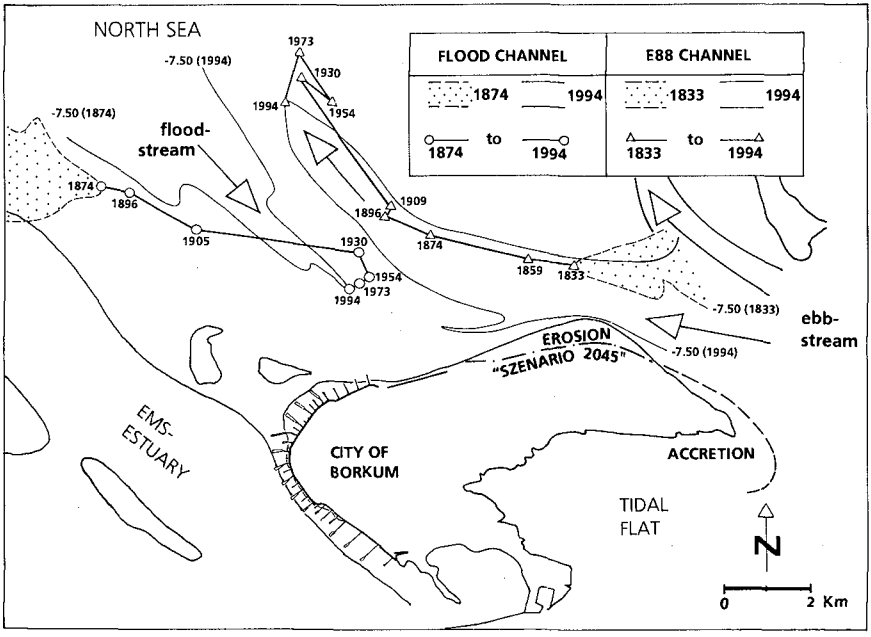

Fig. 16: Development (1874 to 1994) of the flood- and ebb-stream channels which impact the northern part of Borkum-island. "Szenario 2045" for erosion. Existing groyne-sea-wall system arround the western spit.

Conclusions

Man started to protect the islands against erosion by solid structures since the middle of the last century. Groynes had been proven as an essential part of the coastal protection systems. The groynes are incorporated into a system which consists of different types of groynes, seawalls & dune-revetments and of artificial beach/foreshore-nourishment. The system had been successful in stopping the migration of tidal inlets and it preserved endangered western parts of the islands. The groynes were not effective in reducing beach erosion - but the existing groynes can stabilize artificially restored beaches, if the restoration is approriately designed.

The existing groynes have to be maintained and enhanced, as far as they are essential to protect the historically developed situation. Beach groynes may be given up, instead of beeing reconstructed. This has to be investigated sitespecifically.

If we combine the lessons learned from the groyne-history with the recently developed demands of society (environmental issues & cost-benefit-ratio) we can not recomment to continue with the strategy of the past. Future strategies for the coastal-protection of the East Frisian barrier-islands should not include the construction of groynes, except in special cases, where no shore-line-retreat is acceptable and no solutions are possible, which are less static.

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