LAND RECLAMATION ALONG WEST GERMANY'S NORTH SEA COAST,
WITH PARTICULAR EMPHASIS UPON NORTH FRIESIA

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INTRODUCTION

The North Sea coast of West Germany can be divided into a North Friesian and an East Friesian sector, separated by the "corner" of the German Bight that merges with the estuaries of the Elbe and Weser Rivers (Fig. 1). Both areas are characterized by a gently-sloping offshore and a relatively high tidal range (about 2.4 m, increasing toward the corner of the bight). In both areas, wide mainland coastal plains--formerly marsh but now almost entirely reclaimed for agriculture--are relatively protected by sets of barrier islands and sand banks. It is the origin of the barrier islands that provides the greatest distinguishing difference between the two sectors. The East Friesian Islands are a true barrier island chain, nourished by eastward-trending drift composed of sands eroded from the Pleistocene/Holocene Rhine delta in Holland. The North Friesian Islands, on the other hand, are largely remnants of a formerly-extensive marsh area interspersed with chunks of coarse Pleistocene outcrops that were left behind following the last major period of glaciation. The outer (seaward) barrier nature of these islands has resulted primarily from a marine reworking--northward and southward--of the coarse Pleistocene (and some Tertiary) deposits.

In an examination of the role of coastal land reclamation in Germany, I have decided to focus primarily upon the North Friesian sector, owing to the more dynamic changes that have occurred there during the historic time framework. The protective role of the sand barrier has been less in North Friesia (comparatively), and man's attempts at marsh reclamation have repeatedly been set back by the forces of nature, particularly in the area of the marsh-remnant islands (halligen). In addition, source material for reclamation research is more readily available for the North Sea coast of Schleswig-Holstein, especially in the many detailed scholarly volumes written and edited by Dr. Otto Fischer (1955a, 1955b).

GEOLOGY

The geology of North Friesia has much of its origin in the Pleistocene period. Glaciers moving south and west from Scandinavia scoured much of the land surface yet also deposited extensive terminal moraines. Large amounts of sand resulted from the Ice Age, in the form of near-surface sand sheets (Fig. 2) and also deeper-lying sand layers. Fluvial processes of the Pleistocene carved out many of the northern German Rivers (i.e. the Elbe) with the result that today they function almost as large inland tidal channels. On the coast, morainal deposits make up the cores of the islands of Sylt, Amrum, and Foehr. During low water stands (interglacial) substantial marsh developed, which subsequently became buried by marine clays and silts during rising water stages, and eventually formed into peat. The Holocene sea level rise (Flandrian transgression) was also characterized by irregular rates of rise, and geological cores reflect alternating horizons of marine sediments and peat. The Holocene rise also accounted for the
marine deposition of sands on the coastal nearshore, in the form of sand banks in the North Friesians and barrier islands in the East Friesians. Between the sand barriers and the marsh shoreline a tidal flat (watt) evolved, comprised mainly of sands though increasing in fineness to silts and clays shoreward.

CLIMATE

The climate of the German North Atlantic region is temperate maritime, characterized by cool summers and mild winters. The Gulf Stream exerts a moderating influence on water and air temperatures. Precipitation is almost entirely in the form of drizzle and mist, and cloud-free days are rare (and appreciated). Rainfall is about 30 in/year—Bremen averages 693 mm (Dickinson 1953). Storms are of the temperate cyclonic variety, sweeping out of the North Atlantic, and are most pronounced during the winter months. Particularly severe storms result when low-pressure cells moving toward Europe from the Azores region collide with cold Arctic air. The configuration of the German coast makes it particularly vulnerable to storm surges, as these become funnelled into the "corner" of the German bight, raising water levels substantially.

EARLY SETTLEMENT

Early coastal settlement, dated to 3000-4000 B.C. through shell middens, was limited to Pleistocene outcrops and was of a hunting-gathering nature. The post-Neolithic Bronze Age has yielded much information through archeological investigation, though habitations were still restricted to the safer Pleistocene core areas, such as Foehr and Amrum (Terlouw 1976). Many tools were excavated, and it was inferred that livestock were grazed on island forelands.

The first real impact of man upon the marsh environment is credited to Friesian settlers, who spread northward along the coast from a Holland core area. In Holland, evidence for moulding habitations in a marsh setting has been dated at 300 B.C., and archeological excavation on the lower Weser in Germany indicates a small moulded village dating to 300 A.D. (Terlouw 1976). This practice of moulding—creating a hillock called warf—became more apparent in North Friesia about 400 to 800 A.D. during a phase of sea level rise (Fig. 3). Large-scale Friesian immigration into the North Friesian coastal area did not commence until rising sea level had peaked, at about 900 or 1000 A.D. It was a stable or falling sea level that set the stage for the initiation of land reclamation and the introduction of dikes.

The early dikes, only 1 to 1.5 m in height, were represented by "connecting dikes" which connected two or more warfs much like an elevated walkway, and "ring-dikes" which enclosed several warfs or large areas of marsh. These polders, or koogs, became useful for agriculture and grazing land, and also as sites of peat removal. Under a thin surface layer of silts, peat horizons of about 0.9 m in thickness (Fischer 1955a) were excavated for the purpose of boiling and extraction of salt. Salt was a valuable trade item well into the Middle Ages, and it provided a livelihood for many of the early coastal dwellers.
The oldest documented reclaimed marsh dates to 987 A.D., and by 1300 A.D. practically all of the North Friesian marshland from the Dithmarschen Peninsula north into present-day Denmark had been poldered (KFK 1978). It is not known, however, exactly what were the respective roles of agriculture vs. peat-cutting for salt extraction in the early-poldered marshlands.

ENVIRONMENTAL RESPONSES TO MARSH RECLAMATION

Physically, several major changes resulted from man's reclamation activities. The first of these was the lowering of the surface level of the newly-reclaimed land. This occurred because of removal of the 0.9 m thick peat layers and the withdrawal of water from the upper soil horizons. A study conducted in Holland found that 80 to 90 per cent of total subsidence took place above the water table, and of the total subsidence, 30 per cent was due to settlement, 20 per cent to oxidation, and 50 per cent to shrinkage of the soil sediments (Stephens & Speir 1969).

Rates of subsidence vary throughout the German coast, depending on underlying soil types. Substantial sections of North Friesia are underlain by Ice Age sands (which do not collapse as a result of water withdrawal) and fine marine clays (which are not very water-saturated). Both help retard subsidence. The organic layers are quite susceptible to subsidence, and around Jade Bay, a rate of 35 cm/century was calculated (Fischer 1955a). This rate cannot be considered representative, however. The areas of Eiderstedt and Dithmarschen are underlain by substantial layers of Pleistocene sands, and total subsidence (since the early Middle Ages) has been on the order of 1 meter. On the "older marsh," i.e. the marsh that existed around 500 A.D., subsidence has been measured as approximately 1.5 to 2 m total (Fischer 1955a). The highest subsidence rate reported was 2.5 m total (since the early Middle Ages) in marshlands near the mouth of the Elbe and in formerly-important peatlands of North Friesia where clay layers at a depth of -2.5 m effectively inhibited subsidence.

A second effect that reclamation had upon the coastscape was the restriction of water flow, particularly during high spring tides and storm surges. Wave energy was no longer able to be dissipated over large expanses of marsh (i.e. sheet flow and tidal channel bank-overtopping), but was instead concentrated into the tidal channels and rivers between the impoundments (Fig. 4). This process resulted in water levels in the streams and rivers being raised during storms, and even under normal tidal range, the salt-water wedge was extended much further upriver.

The above-mentioned physical changes coupled with the low heights of the early dikes set the stage for devastating impacts by storm surges. Several severe storm surges struck North Friesia in the 12th and 13th centuries, and the worst storm catastrophe ever—the 2nd Marcellus flood of Jan. 16, 1362—destroyed practically all land reclaimed to date, caused water levels to lap up onto the Pleistocene terrace of the mainland, and was responsible for the deaths of what the chroniclers estimated at 100,000 people (KFK 1978). Because of the lowered surface levels within the dikes, the conversion of land to water was greatly accelerated. The greatest impact was felt in the marsh remnant islands, which were greatly reduced in area. Today, in the tidal flats around the halligen,
traces of medieval plow furrows can still be identified (KFK 1978). The 1362
storm was also responsible for the demise of the city of Rungholt, which was
situated between what are now the islands of Pellworm and Nordstrand on what
was then the "natural levee" of a tidal channel. Over the centuries following
the storms, this city became a part of the North German coastal folklore and its
size and importance became greatly exaggerated. Archeological investigations by
Andreas Busch early in the 20th century did indeed confirm the existence of
Rungholt, which was estimated to have been populated by over 2000 people...a
sizeable urban area for that time (Hagemeister 1979).

In regions where the mainland coastline was fairly straight, the storm
surges of 1362 and later years broke through the dikes, occupying low-lying
peatbog areas. This created the embayments such as the Dollart, the Jade, and
the smaller Meldorfer Bay north of the mouth of the Elbe. (The Zuiderzee in
Holland was also formed in this fashion.) Following the opening up of these
embayments, they acted as sediment traps with high rates of sedimentation and
accretion (KFK 1978). This made conditions quite favorable for renewed
reclamation activities, which have been historically-reconstructed for the
Dollart Basin (Homeier 1977) and the Jade Basin (KFK 1978--see Fig. 5).

LAND RECLAMATION 1362 TO PRESENT

With the exception of a few koogs on the Eiderstedt peninsula, all
reclaimed land was lost in the 2nd Marcellus flood, and the year 1362 is generally
regarded as the beginning date of modern reclamation. Many of the 15th and 16th
century koogs were removed by further severe storm surges and a renewed rise in
sea level (25 cm/century up to the present). Hardest hit once again were the
vulnerable halligen, many of which were reduced to just the higher-standing warfs
and surrounding forelands. In the 1634 flood, 8400 people lost their lives and
the island of Strand was split into the islands of Pellworm and Nordstrand. After
the 1717 Christmas flood, 6000 sq km were inundated, 11,000 people died, 100,000
animals were lost, and 5,000 homes were destroyed (KFK 1978).

A modern map of coastal North Friesia (Fig. 6) outlines the many koogs and
the dates of their embanking (Quedens 1978). By planimetering the area of the
koogs reclaimed for each century since 1400, I was able to construct a graph
showing the rate of reclamation through time (Fig. 7). The observed trends show
a high rate of reclamation early in the period (indicating efforts to "re-claim"
lands lost in 1362), and a gradual slowing of the reclamation rate up to about
1800. The 19th century showed almost no increase in reclaimed land, but by the
20th century a sharp upswing had begun. This reflects the shift to governmental
control over all land reclamation and coastal protection activities.

A more detailed analysis of reclamation on the mainland of North Friesia
(Fig. 8 after Fischer 1955b) breaks down each koog into the year and number of
hectares diked, and the trend reflects the graph shown on Fig. 7. In addition,
this analysis details hectares lost as a result of storm surges and dike breaks.
For the area shown on Fig. 8, between 1362 and 1954 a total of 47,284 ha were
diked, of which 690 ha were lost to storm surges (half of them following the
1634 storm). For the most part, the relatively small portion of land lost reflects
the increasingly-higher and better-constructed protective dikes, many of which
were adopted upon the advice of Dutch engineers in the 17th century (Quedens 1978).
One can identify at least five major environments in which land reclamation activities are presently active: 1) open mainland shoreline, 2) estuarine areas such as the Elbe and Eider river mouths, 3) the halligen and along the flanks of the many connecting dams between them, 4) embayments, such as the Dollart and Jade, and 5) the back-barriers in the lee of the East and North Friesian barrier islands. Land reclamation in these zones is not necessarily intended to expand the area of useful land, but often to provide a protective buffer between the sea and older koogs. Such is the case in many sections of exposed open shoreline and in the halligen, where the series of connecting dams and undiked reclaimed forelands are primarily coast protection measures. In the back-barrier environments, reclamation is conducted for both land-gain (by diking) such as on Norderney and also for merely making marginal marshlands useful for grazing (by ditching and de-watering...but not diking).

THE PROCESS OF LAND RECLAMATION

It was probably realized very early that sediments carried in suspension were often deposited on coastal forelands following the ebb of the tide. Deposition occurred naturally and the foreland built up and out until storm surges removed the deposited fine sediments (fine silts and clays). It was also realized at an early date that by simply digging ditches (grueppen) perpendicular to the shore, the sedimentation process could be sped up. By adding small earthen barriers, also perpendicular to the shore, lateral wave action could be diminished and increased sedimentation encouraged. Thus the forerunner of today's reclamation technique became developed. The present method of platting out fields into the intertidal zone was developed in the early parts of the 20th century (Terlouw 1976).

Presently, the first step in land reclamation entails the building of small "dams" (lahnungen) perpendicular to the coastal foreland (Fig. 9). Sometimes, additional sections of lahnungen are constructed parallel to the shore at a given distance offshore (lahnungsfields in Holland generally enclose 16 ha, but in Schleswig-Holstein the size is usually smaller and varied). These lahnungen are built by driving two lines of sticks (about 30 cm apart) into the mud and stuffing straw or reeds between the parallel fences. Wire is often added to help keep the lahnungen together. This step reduces the impact of wave action and accelerates sedimentation.

After sedimentary processes have built up the surface levels within the platted field, the grueppen are dug out, also perpendicular to the shore and at intervals of from 6 to 10 m. These ditches have the dual purpose of allowing the land between them (beete) to dry out more and compact (increasing the land's resistance to potential storm surge erosive forces) and also to trap sediments. As the grueppen fill in with fine clays, they are dug out (formerly by hand, now by machine) and the sediment is piled ridge-like in the center of each beete. The excavated clays piled on the beete serve to further stabilize, as well as build up, the sediments. Repetition of this process can raise surface elevations 10 cm per year (KFK 1978).

Vegetative stabilization of the sediments occurs under natural conditions by the colonization of the pioneer Salicornia, the succulent (naturally) ubiquitous throughout the German tidal flat environment. While its roots serve to stabilize the sediments already laid down, Salicornia is not an effective trapper of
newly-introduced fine sediments. Another intertidal marsh species--Spartina townsendii--which had been first identified in the Thames estuary in the 1870s, was found to be an effective sediment trapper. It was introduced into British tidal flat environments in the late nineteenth century and into the continental North Sea area early in this century. Spartina was introduced into Germany in 1927 (Lueders & Luck 1976) and was incorporated as another step in the land reclamation process, though mainly in East Friesia and the Dollart area. Recently, however, it was found that the increased benefit incurred by planting Spartina was not really economically justifiable, and the mineral and nutrient gains in the underlying sediment not that high (Michaelis 1974).

Neither Spartina nor Salicornia exhibit any grazing value because of their high salt content. One plant--the grass-like Andel (Puccinellia sp.)--which could tolerate salinities of up to 30 ppt and still taste sweet to sheep and cattle, was held in high regard. So, following the sediment build-up, the next step in the process is to introduce Puccinellia, which today probably covers over 90 per cent of the mainland littoral. Once the Puccinellia becomes established, sheep are let onto the newly-reclaimed land to graze it. Both sheep and cattle graze on Puccinellia, but on the newly-reclaimed forelands cattle can foster compaction and localized subsidence.

On those parts of the coast vulnerable to erosive forces, this may be the end step of the land reclamation process. A buffer zone between the sea and land planted in wheat or other crops often consists of a foreland, a summer dike, a cattle pasture, and a winter dike. The winter dike is the major dike, protecting inland koogs, especially during severe winter storms. Summertime meteorological conditions are not as severe, and the lower summer dike adequately protects the grazing land between the dikes. (Storm surges continue to break through winter dikes, and the height, width, and shape of dikes have been evolving for a millenium. Fig. 10 shows dike evolution since 1600.)

On those parts of the coast where seaward expansion of agricultural land is feasible, it is determined by engineers whether the foreland and newly-reclaimed land (built up perhaps 1 m by sedimentation) is "dike-ripe." It is only feasible to build a summer dike and push the whole land reclamation seaward if the strip of coastfront land is at least 250 or 300 m wide, or if for each hectare of potential agricultural land, less than 0.1 ha is covered by a dike (Lueders & Luck 1976). Via these methods, the land can migrate ribbon-like into the tidal flats. In some cases, forelands or littoral marsh areas are first enclosed by dikes and reclaimed by gradual de-watering and the introduction of Puccinellia. (See Fig. 11 for examples of both trends in North Friesia.)

POLITICAL PARAMETERS

Early diking and land reclamation was conducted on a communal basis, as was the subsequent farming (and/or peat-cutting). The concept of private enterprise began to take hold early in the Middle Ages. While much of the land became held by large landowners who oversaw the creation of their own private koogs, the need for central authority soon became apparent. In 1557, several landowners on the island of Nordstrand (at the time still the eastern extension of Strand) banded together to form a local central control (Quedens 1978). Each farmer was expected to maintain his section of dike and assist in overall maintenance. This gave rise
to the expression "De nich will dieken, mutt wieken" (loosely "If you don't dike, leave"), and non-compliance resulted in expropriation of land. These local authorities became more common through the centuries, although private enterprise (by large individual landowners and companies) played an important role into the early 20th century. Schleswig-Holstein began to exert state control in about 1870, and in the early 1900s the Federal government recognized the need for governmental supervision of reclamation, diking, and coastal protection activities.

Today, the Federal government assumes control over all projects related to navigation, and the four coastal states (Schleswig-Holstein, Lower Saxony, and the city-states of Bremen and Hamburg) assume control over coastal protection and land reclamation (KFK 1978). This state control is normally delegated to the individual political units that are directly affected by the given project.

Reclamation and coastal protection projects have expanded in the 20th century as a result of this increased governmental authority. The severe depression of the 1920s and early 1930s inhibited reclamation, but Hitler with his ideas of a self-sufficient Germany encouraged a renewed upswing in land reclamation for the purpose of increased food production. This was in turn followed by a relapse during the World War II period.

PRESENT TRENDS

Today, the seaward expansion of agriculture has diminished in importance. Land reclamation projects maintained for coastal protection are widespread, particularly in the halligen of North Friesia and along exposed coasts. One government goal has been to shorten the line of embankments between the Danish and Dutch borders as a protective measure and this has spawned reclamation projects such as the closing off of the Eider estuary (by sluice-gates). The line of embankments has thus been reduced from 1430 to about 970 km (KFK 1978). Even in areas where reclamation for land gain is quite feasible, such as in the Jade Basin, an increase in agricultural land would encourage sedimentation at Wilhelmshaven, the main oil port for West Germany. Dredging costs would probably exceed the benefits derived from additional agricultural land.

Due to the high costs of oil and labor, economics plays a large role in the reduction of reclamation projects. The benefit-cost ratios are today not as favorable as they once were. Also, in regard to increased food production, agriculturalists are focusing more on improving yields than on expanding acreage. The costs of increased runoff (which needs to be pumped out) resulting from increased diked land are also considered uneconomical. An ecological awareness is also on the increase in Germany, as environmentalists are increasingly pointing out the value of the tidal flat habitat for wildlife as well as the fishing industry. Excessive diking/reclamation, industrialization, and urbanization (for seasonal tourism) are taking their toll on nature (anon. 1980), and popular acceptance of this is small but growing.

As a summary statement, one can say there were two major periods during which land reclamation was greatly accelerated: following the great 1362 flood and following government intervention about 1900. Reclamation as coastal protection will surely continue until the overall plans are accomplished, at which point a man-dominated equilibrium will be reached.

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Fig. 1. Location of Study Area