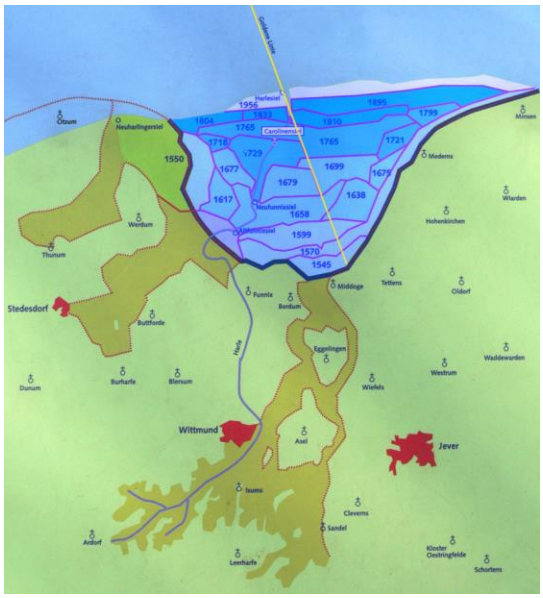
Dike Solutions Dike reinforcement with clay

Along the Wadden coast longer sea dikes exist for circa a millennium. Roughly, three types of dikes can be distinguished: those for static, eroding and static coasts. Older dikes often consist -nearly completely- out of clay. Modern dikes may have a sand core and a clay and stonework cover. Over time, sea dikes have become considerably higher and broader, as population and net values behind the dikes grew, whereas land levels dropped, and sea-levels rose. In the Netherlands, an increasing technical approach resulted in high standards for the clay that could be used in dikes and, in the 20th Century, often river clays were used. In the other Wadden Sea countries mostly local clays are used. New approaches involving different dike profiles make the use of local clays possible.

The earliest dikes in the Wadden area, which we know of, were built as early as the first Century BC. Larger continuing dikes were built since the 10th-11th Century. To understand the built up of dikes three central factors should be considered:

1) *<u>The morphological development of the area</u>*

Roughly speaking: three types of morphological development can be distinguished:

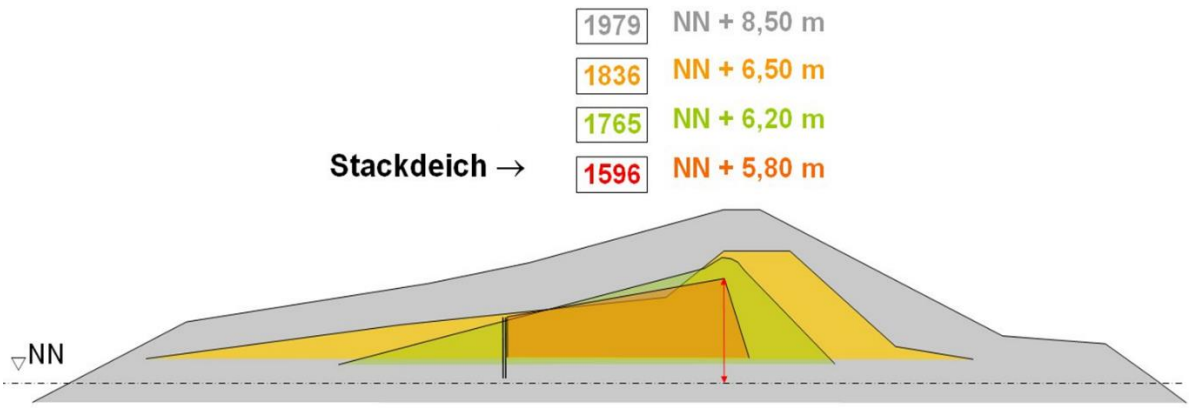


Prograding coast and poldering history of the Harle Bay (Wikipedia, after Homeier, 1979). Yellow line is newly established border between Jeverland and Ostfriesland.

1a) *A prograding coast* where the deliverance of sediment outpaces sea-level rise and erosion by storm surges. In such coasts new tidal marshes may form in front of the sea dike, either fully natural or with human help. Such developments mainly occur in embayments where mud deposition is often strong but may also be encountered along straight stretches of the mainland coasts. Once the tidal marshes

became high enough they were often poldered. This often happened via an upgrade of the summer dike seaward from the winter dike. In such prograding coasts mostly series of seaward increasingly younger dikes are present. Due to their young age the built-up of such dikes may be consisting of only a few "dike improvement layers". Examples of prograding coasts can be found in embayments such as Harle Bucht, Leybucht, Jade Busen, Dollart etc. Also, where foreland tidal marshes enhancement was successful, new land could be diked, e.g. along the Groningen coast and at the Hamburger Hallig.

1b) *A static coast* where the deliverance of sediment is more or less in balance with sea-level rise and erosion by storms or where dike improvements made a static coastline possible. Depending on the period over which the coast was static, dike improvement layers may be added over a prolonged time. Examples of static coasts are large parts of the coasts of Frisia and Lower Saxony.

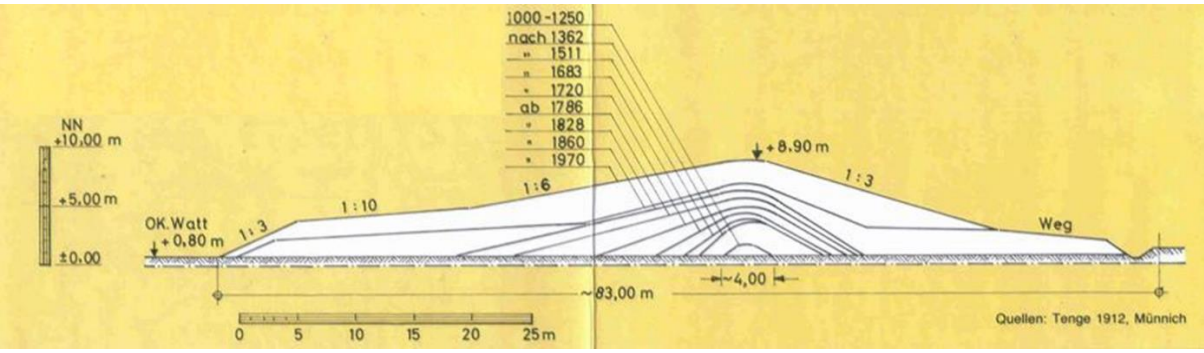


From a Stackdeich to a clay dike (after https://upload.wikimedia.org/wikipedia/commons/5/5b/Küsteningenieurwesen_Deichverstärkung_1.jpg)

1c) *A retreating coast* where the sea-level rise and storm surges outpaces the deliverance of sediment. It should be realized that storm surges and dike failure may lead to flooding and subsequent (peat-)erosion (e.g. Dollard) of low-lying areas behind the dikes further increases the disbalance. In such coasts new dikes had to be built from time to time more inland. This continued until technical capabilities had improved enough to stop further erosion. Examples of retreating coasts can be found in Schleswig Holstein and the Land Wursten and along the former Zuiderzee area. Especially in retreating situations sediment availability was low as forelands from which clay could taken were scarce. For that reason, so-called Stackdeiche (or Holzungen) were built where the dike profile was small, and the outside was protected with woodwork and after 1731/34 with stone works. This type of dike proofed to be unsuccessful and it was decided in Denmark and Germany to go back to broader dike profiles, which was mainly done with clays taken from the tidal marshes and sometimes inland clay. In sluices and harbors stone work protection was used.

2) <u>*Relative sea-level rise*</u>

Relative sea-level rise is the relative rise of the sea with reference to the land surface. So far, as sea-level rise and MHW rise do not differ too strong along the Danish, German and Dutch Wadden coasts. Thus, the most important factor is the subsidence of the land surface. Especially in peat-rich areas subsidence may be severe up to 1m/century. This makes such diked areas vulnerable to dike failure and storm surges (e.g. the land loss in the Dollard region in the 16th Century) and forces to heighten the dikes.



Development of the dike profile at the west coast of Butjadingens (http://cuxpedia.de/images/1/19/Deichprofile.jpg)

3) <u>History of storm surges</u>

At the beginning of the large-scale dike era people lived on dwelling hills and higher patches of land, surrounded by relatively high-lying lands. Raising crops was concentrated between spring and autumn. During winter time there was no need to fully protect the agricultural areas and wave overtopping of dikes or even flooding of the land was allowed. Hence, originally dikes were mainly used to protect from summer storm surges and had small dimensions. As relative sea-level rise became more important and several severe storm surges (e.g. 1570, 1634, 1717, 1825, 1953 and 1962) showed that dike heights were too low dikes were gradually heightened and broadened in several steps.

High value industrial area behind the dike of Delfzijl https://beeldbank.rws.nl, Rijkswaterstaat / Harry van Reeken

4) <u>The value of the protected area</u>

As described in point 3, originally the agricultural areas were of low value. When population began to grow they migrated into the polders and higher dikes were needed to protect the area. During the industrial revolution investments in the area grew and better dikes were needed to protect goods and people.

Sources of clay

Originally, dikes were built from clay taken from the tidal marshes and clay layers landward of the dikes. As dike dimensions increased the volume of clay needed also grew. Where dikes were static the volume needed was relatively small. However, where new dikes had to be built the huge amounts of clay needed provided a major challenge. Newly built dikes nowadays mostly consist of a sand core which is covered by a 1 to 2 m thick layer of clay.

As the requirements for dikes became increasingly technical also the quality of the clay became more important. Also, the clay top gradually weathers and should be kept up. Marine clays from the tidal marshes or polders do not always have the right characteristics to use for dike building (too much salt, too much sand). In the Netherlands this made it sometimes necessary to use riverine clays for dike building and improvement. Experiments (for instance, double dike, broad green dike, meegroeidijk) are currently underway to test if different approaches allow the use of local clays and dredging sludge. In Bremen and Hamburg experiments were carried out to use dredged muddy sediments to build dikes. Germany and Denmark continued to use local clays. In Schleswig Holstein it was decided relatively

recently to not use clay from the tidal marshes as the mud is needed to grow with (accelerated) sea-level rise.

Research Questions

1 If sea-level rise accelerates dikes have to be strengthened even more, not only due to the higher water levels but also due to the water pressure under and against the dike. At what point do the volumes of clay needed become impractical?

2 Dikes are 80 to 100 m broad. The total sea dike system is several 1000 km long (estuaries included). Thus, for every m higher dike some 80-100*10^6 m^3 is needed. This is comparable in magnitude with sedimentation within larger areas of the Wadden Sea over a century. When does clay retrieval from the Wadden Sea system becomes a threat to the ability of the area to grow with sea-level rise?

3 Much clay can still easily be mined landward of the dikes, resulting in lower areas which are often turned into (brackish) wetlands. What is the social support for, and the added value, of such nature resorts?

Stakeholders

From the above it becomes clear that both sedimentation in the Wadden Sea and estuaries and diking with use of local clay both occur over centuries. For both huge amounts of mud (clay) are needed. Taking local clay from the Wadden Sea influences the ecosystem and might improve the quality if done right but decreases the amount of mud for natural functioning of the system. Taking local clay from the area behind the dike may improve the ecology of the area (bird breeding islands, brackish nature etc.), but will decrease the agricultural value of a highly profitable area. Thus, diking which is mainly in the hands of waterboards, municipalities and the state is also of importance for nature conservationists, tourism developers, provinces and farmers.

Literature

Top photo: https://beeldbank.rws.nl, Rijkswaterstaat / Hans Venema