CHAPTER 75

SOME ASPECTS OF LAND RECLAMATION IN THE NETHERLANDS.

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ABSTRACT

A description is given of the land-reclamation works along the northern coast of the Netherlands. The works are placed in their historical background, and possibilities for their future are discussed. This opens an opportunity to regard them against a general frame of land-reclamation works and future plans in the Netherlands.

1. INTRODUCTION

The first and foremost object of this paper is to give a description of the very remarkable and in many of its aspects unique coastal engineering work, that has been carried out for centuries and is still being carried out along the northern coast of the Netherlands: the land-reclamation. There can be no doubt that this work is interesting from a technical point of view. However, the usefulness of the undertaking and the sense of its continuation can only be understood by placing it in a historical perspective on the one hand, and on the other hand in the frame of other Netherlands' projects to gain land or to improve security from the sea.

It appears useful to give a brief geographical outline of the Netherlands, in order to illustrate the situation of the various projects. In fig. 1 a schematic map of the Netherlands is given, with a division into areas that will facilitate a discussion of hydraulic engineering works. The Netherlands are roughly rectangular, with a westerly and a northerly side bordering the North Sea. The westcoast is smooth; in front of an almost closed belt of dunes very fine sandy beaches can be found. In the southwest this coast disintegrates into a system of islands and estuaries (area D). This is the Delta-area, where the stormsurge of 1953 struck, and where the Delta Plan is now being executed. From east to west the country is crossed by large rivers (area E): two Rhine branches and the lower course of the Meuse, all debouching into the delta of area D. One branch of the Rhine bends off to the north and debouches into the former Zuiderzee (area C), which is called IJsselmeer since it was dammed off from the sea in 1932, and which is being partly reclaimed by the construction of polders. Between the western belt of dunes and the IJsselmeer is the area of the reclaimed lakes and marshes (area B). The often very large lakes in marshy territory were reclaimed mainly in the 17th and 19th century. This area is low, in many places several meters below

mean sea level. In a general way one may say that the west and north of the country are below or about sea level; only the central, southern and eastern parts are hilly and the level is higher.

The northern coastal area (area A) has not yet been mentioned; it will play a dominating part in what follows. In the south the area is bordered by the dykes protecting the northern part of the Netherlands, and by the enclosing dam of the Zuiderzee. The northern limitation is a belt of "wadden-islands", on which dunes are found. The area between is the Wadden-Sea, the eastern part of which is shown in fig. 2. It is a territory of extensive sand-plates, lying roughly at mean sea level. Between the islands there are deep indentations by the sea, branching out into a complicated system of channels and gullies in the Wadden Sea, through which the seawater comes in at each tide. At high tide the area is completely covered with water and cannot be distinguished from a normal sea-area, at low tide the sand plates are left dry and water stays behind only in the gullies. The land reclamation works that will be discussed, take place in the narrow strip, showing on fig. 1 as a fat black line, on fig. 2 as a hatching.

In this paper the term "land reclamation" will be used in several meanings. To forego confusion, a closer definition will be given. In a narrower sense land reclamation means the system of technical measures, taken to stimulate the settlement of silt in a suitable environment, with the aim to obtain arable land. It should be mentioned that apart from the coastal strip indicated above, this work is also done in the more easterly German and Danish wadden-shallows, and, to a lesser degree, also in the Delta (area D).

In a wider sense land reclamation means each technical measure, taken to change a water surface into land, and to make this land suitable for some purpose. An instance is the reclamation work in the IJsselmeer (area C). Essentially, the Deltaplan is not covered by this definition, as the chief purpose is not gain of land but of security. It has, however, aspects of water management and of opening up isolated areas, and the project has a logical place in the general review that is to be given at the end of this paper.

2. THE DEVELOPMENT OF THE COASTAL AREA OF FRIESLAND AND GRONINGEN.

In fig. 3 a few maps are shown that have been taken from various publications and been slightly schematized. They give a picture of the development of the Netherlands' coast as it is known or supposed to have been. It must be assumed, that about 4000 years ago in the north of the country, too, a more or less closed ridge of dunes existed. Possibly because of sea level rising and land subsidence this wall, in the long run, could not withstand storm surges. The sea gaps that still exist were formed by breakthroughs, the remnants of the sea bar are the present wadden islands. In the west the sea penetrated to the "Flevo-lake", which afterwards slowly grew out to form the "Zuiderzee"; to the north and north-east of this the Wadden Shallows developed: of these only the eastern part is of importance for this paper.

If the Wadden Sea can be regarded as a transition zone between land and sea (sea at high tide, land at low tide), the area that around 1000 A.D. was situated to the south of it must be taken to have been land. Its level was above that of normal high tide, but it was not secure against higher sea levels.

What motives have driven people to habitation in this inhospitable area, is not quite clear, although it seems, that about 2000 years ago this country was less unfriendly than later on. There can be no doubt, anyway, that humans lived here around 1000 A.D. Their means of support could only be cattle breeding though much earlier agriculture may have been possible. Safe places for themselves and their cattle people created by building artificial mounds, called "terps". On these, people lived and to these they withdrew during floods.

Presumably one of the reasons for the construction of the first dams has been the wish to safeguard the connection between the various habitations. Closed rings of such communication dams must be regarded as the first reclaimed areas (polders), and, by linkage of these, in the long run larger territories with increased security against the sea developed. By the beginning of the 14th century a coastline with a coherent line of dykes exists, the security of which, compared with modern standards, was of course negligible. It does not surprise therefore, that there have been several intrusions by the sea, with a preference for places where smaller or larger water courses debouch into the sea. In those days the "Middelzee", formed in the early Middle Ages, had already been forced a long way back; by subsequent reclamations it has entirely disappeared. The "Lauwerszee" however, having reached its largest extension around 1100, was never entirely reclaimed (the enclosing operation that is being carried out in the present will be discussed later). Around the mouth of the German river Ems the Emsestuary developed; from this, between 1300 and 1500 A.D. a large bay branched off, called Dollard. The extension of this, too, was gradually reduced by reclamations.

Fig. 4 gives a picture of the dykes built for security and reclamation purposes since the 15th century. It is notable, that each time relatively narrow and longish strips of land are dammed in, and that each next dyke lies roughly parallel to the preceding one. What happened is, that after each damming in the shallow foreland was subjected to a slow process of heightening, caused by the settling of sand and silt particles: in this way the soil became very fertile. After these grounds had reached a certain level, vegetation of salt-resisting grasses began, and the land, at that stage called "salting", could be utilized for cattle grazing. After such a strip had grown to a sufficient width, and if the means could be found, the work of damming in was taken up, as in this way rich agricultural soil could be obtained.

It is interesting, but outside the scope of this paper, to study the complicated an often hard systems of customary law, that resulted from the struggle between man and water. One rule, however, has a bearing on the subject of this paper, the so-called right of accretion. If anyone was owner of a plot of ground along the coast, this meant that of rights he became also the owner of

all the land that grew on the sea-side of his territory. It stands to reason, therefore, that the farmers took trouble to stimulate natural accretion if humanly possible. The necessary work for this was carried out in periods during which the farming trade offered an opportunity, which was generally during autumn and winter. In this way in the northern coastal area the land reclamation works developed. For centuries they were carried out on a strictly private basis, and their principle differed but little from the methods still practised nowadays, albeit, since a few decades, by the government.

For a good understanding of the modern land reclamation works, it is necessary to go into a closer examination of the circumstances prevailing in the Wadden Sea, of the causes for the accretion, and of the methods applied in the past for its stimulation.

3. CAUSES FOR ACCRETION AND NATURAL SILTING UP.

Evidently, it is beyond the scope of this paper to go into an exhaustive description of the scientific and technical background of the land reclamation. For this, reference is made to the various publications, of which that by KAMPS (lit. 11) is certainly the most important one. The sole aim of this paper is to spread knowledge about this remarkable coastal engineering work, and to consider its usefulness.

Large though very variable quantities of silt in suspension are found in the water of the North Sea, to the north of the wadden islands. It is almost certain (lit. 10) that this silt originates from the large rivers Rhine and Meuse (area E). By way of the delta (area D) it arrives in the sea and is carried northward by the sea currents. With each flood tide this silt-laden North Sea water enters the Wadden Sea through the gaps between the islands. Of the silt, through causes to be discussed presently, a fraction remains in the Wadden Sea, and the silt content of the outgoing ebb water is slightly lower than that of the flood water. It is impossible to give a correct siltbalance, but measurements have been carried out, the results of which show that the amount of silt concerned is so large, that the explanation of the processes occurring in land reclamation does not present any difficulties from a point of view of quantities. This is true notwithstanding the following facts:

- only a small fraction of the incoming silt settles out;
- a large part of the settled - out silt is lost again;
- only part of the finally remaining silt is profitable for land reclamation.

The silt in suspension consists of very fine particles (< 20 micron), partly held together in very lightweight flakes. The settling velocity of this material is so small, that even at the watersheds between the sea gaps (where currents and wave effect are at a minimum) the time between two low tides is not sufficient for the silt to settle out. Evidently, the settling takes place in a different way.

On the sandy shoals of the Eastern Wadden Shallows extensive banks of mussels (Mytilus edulis L) are found, while cockles

(Cardium edule L) and other lamellibranchiae play a similar part. These animals feed by a process resembling filtration, the Sea water entering the body, and leaving it again after the food has been removed. Also during this process, the silt particles remain in the body, accumulate to coherent balls, and are expelled as faeces-lumps. In these little balls the silt is concentrated to such a degree, and the diameter of the balls is so much bigger than that of the particles, that settling is possible. A conservative estimate shows, that in the described way a quantity of 1.3 million tons of pure clay is converted annually on the shallows north of Groningen alone.

For a short time the faeces lumps remain in the vicinity of the lamellibranchiae. When the waterlevel falls, current and waves make their influence felt, the lumps are picked up and transported to the edges of the sandy shoals. By the tide, these units, now suitable for sedimentation, are

- partly transported to the sea by way of gullies and channels;
- partly brought back to the sandy shoals;
- partly beaten to pieces, back to their original state, where they a not fit for sedimentation;
- partly transported in the direction of the coast.

Generally speaking, immediately under the north coast of Friesland and Groningen the most favourable conditions are found for final sedimentation: this strip lies under the lee of the prevailing winds (SW to NW), so that here calm water occurs more often than further out. Most favourable are those parts, lying in the vicinity of the watersheds (fig. 4) behind the islands. Here, the currents are mostly feeble and the islands give shelter from turbulence caused by waves and winds from directions between NW and N.

Though it is impossible to go deeply into this matter, it cannot be left unmentioned that, in the initial fixation of the settled particles, unicellular plants play a part, the so called diatoms, that cover the mud with a more or less coherent, slimy layer. When turbulence occurs, this layer is easily destroyed, but it does materially increase the critical measure of turbulence, that just leaves the sediment where it is.

The mechanism of natural sedimentation, that will be described now, is no longer found along the coasts of Groningen and Friesland. For an understanding of the land reclamation, however, the description is necessary, but it should be realized that it relates to territory outside the northern dykes as it was some centuries ago, before man started active stimulation of sedimentation.

In the preceding an explanation was given of the way, in which sedimentation of silt happens, and of the fact, that the probability of its final sedimentation is greatest in places close to the coast. It is evident, that the sand, of which the bottom of the shallows consists, is able to settle down by its own weight, that it is also liable to uprooting by turbulence, and that it can settle under the coast. The coastal strip outside the dyke of the untouched shallows will therefore show an inclination for heightening, but the sediment will mainly consist of sand. As soon as

this heightening reaches a level of M.H.T. (mean high tide) ÷ 0,3 to 0,4 m (which is 0,6 to 0,7 m above the national datum), spontaneous vegetation of saltresisting plants occurs (fig. 5, 1st stage). The plants stimulate tranquility in the water, and with it, sedimentation of silt(mud). Moreover, the vegetation, which is evidently a little irregular, causes the outgoing ebbwater to seek preference paths. In this way, small gullies develop, that unite into larger ones (2nd stage). In the long run, an intricate system of smaller and larger gullies and of channels develops, of which finally the main channels break through the ungrown shallow, and reach the channels of the Wadden Sea (3rd stage).

Now this sequence of events has created a drainage system, which, at low tide, causes the deposited clay to dry out quickly and obtain a more firm position. Also, the evaporation caused by the vegetation itself, contributes to the drying out. The conditions have been created for a further heightening of the bottom by sediment of increasing silt-content. The vegetation gradually extends in seaward direction, and under favourable circumstances saltings are formed. Saltings are green areas of very fertile sediment, with a level of several decimeters above M.H.T.

There are also disadvantages to the vegetation. When the sea is rough, the outer vegetation will mainly catch sand, while closer to the land clay is deposited. In an unfavourable case it may happen, that in the sandy area erosion by the sea takes place, which may result in a sharp edge of the clay sediment. This never disappears again, but often grows higher, and inevitably leads to erosion of the salting. These receding rims of saltings sometimes reach a height of one meter (fig. 6).

The vegetation itself can only be dealt with briefly. The first plant growth consists of glasswort (Salicornia Herbacea L.), but nowadays also of cordgrass (Spartina Townsendii H. and J. Groves). The latter, of which it was known that it had a favourable influence on the process of silting up elsewhere, has been imported, and its adaptation to the new environment did not proceed without difficulties. It does grow spontaneously now, but appears to have more drawbacks than advantages. One of the disadvantages is, that it impedes the establishment of the grass species that is actually wanted, the sea poa (Puccinellia Maritima Parl.). This begins to grow at a level of M.H.T. ÷ 0,1 to 0,2 m, and is found on all ripe saltings as the dominating vegetation. It is saltresistant and is well liked by the cattle.

4. METHODS OF LAND RECLAMATION.

a. THE FARMERS' METHOD.

According to a centuries old customary right, a land owner, whose territory was bordered by the sea, automatically received the ownership of any land that grew in the sea as a direct extension of his posession. This made it attractive to stimulate, if possible, this growth. This could be done (fig. 7) by constructing earth dams perpendicular to the dyke, with varying distances between them, often about 200 m. These dams furthered the tranquility

in the water, and so the sedimentation of mud. Perpendicular to these dams grips were dug at mutual distances of 5 to 6 m. The grips emptied into a drainage channel, midway between and parallel to the earth dams. Together, this functioned as a drainage system. There was also a slightly more complicated variant, with grips perpendicular to the dyke.

Because the grips always filled up again by siltation it was necessary to re-dig them regularly. The mud from the grips was thrown upon the fields between them.

The gripping was done on the parts already grown over, up to about 100 m into the ungrown area. It was not considered justified to start working on a subsequent area, before the outermost field was entirely or at least largely grown over.

With this method, human intervention into the natural processes was still very limited, and the object was the formation of high saltings. If these were of sufficient width, they were dammed in if feasible, but care was taken, that outside the dyke a strip of salting remained, because this made it possible to build a dyke without special provisions at its foot and with grass talus: the high foreland gave a good protection against wave attack.

b. THE SLESWICK-HOLSTEIN METHOD.

The farmers' method was employed until round 1930. Social and economic circumstances, and conflicts about ownership made the method less attractive after that. There is a possibility, moreover, that the centuries old gain of land in northerly direction had made the conditions for sedimentation unfavourable to such a degree, that the method had become too primitive to yield sufficient results.

In the same period the State was in search of objects, suitable for provision of additional work to fight unemployment. After the ownership relations had been settled by contracts the State took over the land reclamation. The farmers' method was given up, and a modification of the Sleswick-Holstein method, custumary in Germany, was applied. A description of the original German method follows now, illustrated by fig. 8.

Sedimentation fields measuring 400 x 400 m are constructed. The boundaries of these fields are no longer formed by earth dams, but by so-called brushwood-dams. These are made by driving two rows of stakes into the ground, and filling the space in between with bundles of brushwood, that are stamped to a firm packing and fastened with galvanised iron wire (fig. 9 and 10). The top of the dams is 0,3 m above M.H.T., the foot is strengthened by depositing mud against it. These dams are semi-pervious constructions, which is advantageous for the tranquility in the water, and for a rapid and inagressive filling and emptying of the fields, and which is also essential for the resistance of the dams against wave attack.

Each sedimentation field comprises two main drainage channels perpendicular to the dyke, and is further divided by earth dams according to the scheme of fig. 11 into fields of 100 x 100 m. The grips are also perpendicular to the dyke and give into drainage ditches parallel to the dyke; these, in turn, give into the main channel. The profiles of the grips are small: the function of the grips is drainage, but they have to be re-dug at regular intervals,

because they fill up by siltation.

Sedimentation fields are constructed and maintained in those places, that have already reached a level of sufficient height to allow vegetation to grow. Outside this area one more sedimentation field is constructed, but no further work is done in it: the tranquility it brings into the water stimulates heightening with sandy material; as soon as the height is sufficient for vegetation, work is started on the field, which results in the sedimentation of material with a higher clay content; at the same time, further outward, a new sedimentation field is built.

c. THE MODIFIED SLESWICK-HOLSTEIN METHOD.

All methods or processes discussed so far aimed at or lead to the formation of saltings. The thickness of the fertile layer that results is mostly much above the needs of agriculture according to modern views, and the clay content, too, is generally higher than experts find desirable nowadays.

By modifying the Sleswick-Holstein method in the way to be described now (fig. 12), it was aimed at the creation of an agriculturally justified bottom profile, and gain of height stopped playing a predominant part. With this method, a seaward depth of two or more sedimentation fields was constructed simultaneously, and maintenance work is begun immediately on all of them, independent of initial level. Especially in the fields of low level wide and deep grips are dug; the grips now have a double function: drainage as well as catching of warp. The increase of level is brought about by depositing the larger quantities of material caught in the grips, on the fields between the grips. The better the conditions for sedimentation, the more frequently this can and must be done, as the grips have to maintain their drainage function: this is especially important in low areas. Dependent on the heightening of the fields and on the vegetation, the measures of the grip profiles can be reduced.

It is apparent, that soil improvement involves gain of height, but level is no longer a criterion for the quality of the soil. The argumentation further on makes it important to note, that those who introduced the method described above, must have had in mind a flood-free damming in of the land reclamation works, as the level that is gained is insufficient for any other utilization.

It is generally stated that the increase of level to be obtained amounts to 0.02 to 0.07 m per annum, dependent on circumstances. In case the damming in should not be carried out, but the works nevertheless continued, the increase of level will continue anyway. If this goes on, the frequency with which the area is flooded will eventually decrease, which means that the heightening will be slowed down considerably. Thus it will doubtlessly take decades before a stage of ripe saltings is reached. In past centuries this may have been all right, or even necessary, in these days it is absolutely unacceptable.

d. MECHANIZATION.

In the days of unemployment the land reclamation was carried out with the aid of hundreds of labourers, and this number sometimes grew to considerably more than a thousand. After 1955 unemployment decreased rapidly, but in view of the fact that the State had entered into obligations in settling the ownership rights, the works had to be continued. These circumstances initiated a development, that ended with the complete mechanisation of the excavation work. It is true that some digging is still done by hand, but even now this is the result of labour surplusses. Attempts are being made to end this, as it is very inefficient compared to mechanical digging. The construction and maintenance of the brushwood groynes continues to be carried out by hand. Possibly the introduction of plastic materials will eventually lead to more rational methods in this field as well.

The mechanical excavation work (figures 13, 14 and 15) is carried out by hydraulically driven digging machines, equipped with either a gripper or a shovel, and mounted on a pontoon. This pontoon "floats" on the warp, and is anchored by a very long cable to a place beyond but in line with the grip. On the pontoon the cable is fitted to a hydraulically driven winch: when the cable is wound up the pontoon moves backward along the grip. In turn a part of the grip is dug, the material is placed on the field, and the machine is moved over a small distance. Experience has shown, that a pontoon is the best means to move the machine over the soft muddy ground. A very important advantage, moreover, is that, when the flood tide comes in, it is not necessary to bring the machine to the dyke: it is anchored on the spot where it happens to be, and remains afloat during high tide.

Mechanical digging is not only considerably quicker and cheaper, it also leads to better results, as the excavated ground is deposited on the fields in large lumps, that are not easily eroded away by the water. This is especially satisfying with the large grip profiles of the modern method. The total annual amount of clay moved in this way is nowadays a little less than 1,5 million m^3.

As was demonstrated previously, higher and well grown grounds demand a smaller grip profile, while the large lumps of clay are a disadvantage to vegetation. In these areas a large fraise, specially constructed for grip digging, is utilized. The ground is more firm, so the machine can move on caterpillar tracks, and the fraise spreads the material evenly over the field (fig. 15).

It should be mentioned, that the land reclamation is, to a large extend, seasonal work. The weather conditions are often far from agreeable in summer; in winter they become so bad, that the work with machines becomes too risky. Digging by hand and repair work at the dams is sometimes continued in the winter season, during spells of reasonable weather.

The working conditions, for that matter, deserve a short description (figures 16 and 17). The land is absolutely flat, and the view is almost unhampered by unevennesses. The wind from sea is mostly cold, also when there is no rain or storm, and when the

weather is not misty or foggy. Those at work on this "land" know, that it will be flooded by the sea a few hours later: a suddenly rising wind may cause this to happen even sooner than expected. To get to the place of the work special clothing is needed, of which high boots are indispensable. Starting from the dyke the walk begins by crossing grass land, on which cows or sheep are grazing. After that, a main dam is often chosen: at first, this is firm, and the heads of the original brushwood dam do not or only just protrude from the centre of the dam. Walking further in seaward direction, the ground becomes more slippery, and more can be seen of the bruswood construction. More and more the foot sinks into the mud. Further out (in the 3rd or 4th sedimentation field) the ground is, in places, very soft to a depth of one meter or more. Experienced mud-walkers have a special technique to move in this area; for an unpractised visitor there is no danger as long as he is accompanied by experienced guides. Without them, entering this territory is not to be recommended.

5. COMPLETION OF THE LAND RECLAMATION WORKS.

The question is legitimate, and keeps engaging the attention of many concerned, in which way a profitable and economically justified completion of the land reclamation works can be realized. From a point of view of engineering the question as such is not very interesting. As, however an important part of the Netherlands originates from land reclamation, the question will gain meaning from a consideration of the motives, that determined the decisions formerly taken in the cases of some other land reclamation - or similar projects.

The degree to which the Netherlands are a land reclamation country is shown in fig. 1. For closer consideration a limited choice is made from the reclaimed areas and the following projects will be discussed:

- the reclaimed lakes in the marshy west of the country (area B);
- the "Zuiderzee" works (area C);
- the Delta-Works (area D), in combination with the canalisation of the river Rhine (area E).

The history of area A has been discussed previously; at the end, the information collected will be used to consider, whether a vision for the future of the north of the Netherlands can be derived from it.

a. RECLAMATION OF THE LAKES IN THE MARSHY WEST.

In the very low marshy area in the western part of the country a large number of lakes could be found in the 16th century (fig. 1, area B). Between 1600 and 1900 nearly all these lakes have been impoldered, pumped dry and cultivated. When it became apparent, that the hydraulic engineers were able to carry out these tasks, it was an interesting way for the rich Amsterdam merchants to acquire fertile ground, thus investing their money, earned by their trade in the "East Indies".

There was yet another advantage to these reclamations: the wind waves on the large water surfaces caused the marshy banks to

recede to a sometimes frightening extent. This was especially the case with the "Haarlemmermeer", that was a serious threat even to Amsterdam in the 19th century. The reclamation of these 18000 hectares [1]) of water surface, a gigantic work in those days, was begun from sheer necessity and completed in 1852.

In this case already, it becomes apparent, that for the execution of a really large hydraulic engineering work the security aspect is decisive. The economic profits often considerably surpass the expenses, but this is only noticed so many years after, that it never has any influence on crucial decisions.

b. THE "ZUIDERZEE" WORKS.

In the 19th century it was repeatedly stressed that the Zuiderzee formed a threat to the surrounding country. This meant heightening of dykes or damming off of the Zuiderzee, the latter possibly followed by complete or partial reclamation. This seemed to be a profitable affair, as the bottom could be made suitable for agricultural purposes, and there was a definite need for agricultural land.

Several plans were made, but none of them were carried out. In 1916 a storm surge caused a catastrophe, that cost lives along the coast of the Zuiderzee and did economic damage to a large extent. After this the decision to construct an enclosing dam was rapidly taken: it was completed in 1932. At the same time it was decided to reclaim a total area of 226000 hectares, of which today about half is completed (fig. 1, area C). The remaining lake was called IJsselmeer. Its water by now is completely fresh, and the lake mainly serves as a fresh water reservoir for the surrounding land.

At the time that the decision to execute the Zuiderzee Works was taken, there was a considerable need for arable land, and the efficiency of the works, from a point of view of gain of land was never doubted. Nevertheless a catastrophe was necessary to force the community to sacrifice the expenses needed. It is true that a substantial heightening of the dykes around the Zuiderzee would have brought the desired security as well but this would not have resulted in any reduction of expenses, certainly not if compared to the cost of the enclosing dam alone. The challenge of the more spectacular plan, moreover, was gladly accepted.

It is difficult to obtain a reliable insight into the total cost of the project, for which there are several reasons: the long period of execution, the continuous inflatory tendencies, and modifications in the objectives, that are changing from agriculture to town-planning and recreation. It has become apparent, however, that the cost per hectare of reclaimed land, arable and brought into cultivation, lies, for the new polders, between fl.15.000.-- and fl.20.000.-- [2]). This is no longer regarded as an economically acceptable price, the more so, as the national economy is no longer in need of agricultural territory. Voices are even heard

[1]) 1 hectare = 2,47 acres

[2]) fl.10.-- = £ 1.-- = $ 2.8

nowadays arguing the necessity to discontinue the works. Presumably, however, the works will go on anyway, if it were only from considerations of national sentiment, and there can be no doubt whatsoever, that future generations will be grateful for it.

c. DELTA WORKS AND RHINE CANALISATION.

In the Delta area in the south-west of the country (fig. 1, area D), the struggle against the water has, of old, been the most violent. This cannot be described in detail, but it should be apparent, that the present situation of islands and water surfaces has developed during many centuries from the fight between man and water.

It had been known for a long time, that the dykes in the Delta-area offered insufficient security to the low and economically very valuable country behind them. The correctness of this statement, however, had to be proved by the flood catastrophe of 1953, before it became possible to start executing the necessary measures, that had since long been contemplated.

To a much higher degree than is the case with the Zuiderzee Works, the principle of the Delta Works is shortening of the coast. In stead of heightening and strengthening of 900 km length of sea defence dykes, sea branches are closed by dams with a total length of 25 km, not counting a few kilometers of secondary dams (fig. 18). The Western Schelt and the New Waterway, entrance routes to the harbours of Antwerp and Rotterdam, remain open. For this, there is no technical reason: considerations of harbourinterest, that presumably could not bear a critical analysis, have imposed this decision.

In actual fact, the Delta Plan is not a land reclamation project; winning of fertile soil will only be possible to a very limited degree, though harbour- and industrial areas may be reclaimed here and there. The predominant justification of the plan is the very necessary increase of security. According to an estimate from 1960 the cost of the project will amount to 2 milliards of Dutch guilders. This is more than the bare strengthening of the existing sea defences would have cost, but in the decision a.o. the following advantages have been taken into account:

1. Formation of fresh water reservoirs, and fighting the salt infiltration of the low country;
2. Opening up of the so far relatively isolated island area of the Delta by construction of roads on the dams;
3. Improvement of inland navigation and water management, because the possibility to canalize the Lower Rhine (area E) is opened. The possibilities for navigation on the Lower Rhine are improved by the canalisation as such, that on the IJssel because after canalisation of the Rhine the IJssel receives a larger portion of the water; this, again, causes the IJsselmeer to receive a larger portion of the available fresh water supply.

Again it is seen that a plan, that represents a great vision, is chosen above the conservative one. It must be said, for that matter, that the financial sacrifices the plan demands are

often rather exaggerated: the expenses, devided over the 25 years the execution will take, annually amount to no more than about 10% of what is needed for maintenance and improvement of the system of roads in the Netherlands.

d. POSSIBILITIES FOR THE NORTHERN COASTAL AREA.

When the preparations for the Delta Plan were in full swing, one of the experts involved has stated as his opinion, that the Netherlands, forced by land subsidence and sea level rising, would have to curl up like a hedgehog behind high dykes. Fig. 19 shows what he meant. The concluding work would be a damming in of the entire Wadden Sea. In the following a connection will be made between this and the problem of the future of the land reclamation works.

The land reclamation along the coasts of Friesland and Groningen is an activity that devours millions and has to be concluded. Of the various possibilities suggested the simplest is, to reduce the utility of the works to the task they fulfilled in the fight against unemployment, and to discontinue them now. This, however, would mean the loss of everything gained so far, which is a frustrating thought. Also, as was mentioned before, the State has taken upon itself such obligations, that this way of putting an end to the works cannot be effectuated.

The other extreme, which of course is advocated by the people of the coastal districts, is damming in of the works by dykes giving security against storm surges. Notwithstanding the fact, that in this way the expenses for the necessary and very drastic strengthening of the existing sea defences can be saved, this solution is not a financially attractive object for anybody, least of all for the State. There has also been a suggestion not to construct the dyke tightly around the landreclamation, but e.g. 1 km further seaward. A chain of woods on the strip of sandy soil to be so reclaimed, would have recreation value, and would mean an improvement to the northern climate, that indeed is pretty grim.

Where, among the various possibilities lies the one with the best chances of being chosen? The author believes, that the authorities will try to adapt the objective to that of the neighbouring German coast: maintenance of a high foreland, utilizing a moderate degree of land reclamation, thus reducing the expenses for the dykes; in the Netherlands' case this would also mean that the State could fulfil its contractual obligations. Contrary to this, local interests will try to exert pressure in favour of more drastic measures, and this, dependent on local circumstances, with varying chances of success. To make this clear, a division of the coastal strip into three parts is made (fig. 2): the easterly part (Groningen), the westerly part (Friesland) and the central part (Lauwerszee).

1. The Lauwerszee. The damming in of the Lauwerszee is in execution and will be completed in 1969. As the tidal volume in the final closing gap is 120 million m^3, this is a Deltawork of average magnitude (fig. 20), with shortening of the coast as chief objective, and with solution of drainage problems, creation of areas for land- and water-recreation and military training as

secondary advantages. It is apparent, that for this area the future of the land reclamation works (1300 hectares) is no longer a problem, at least if money for cultivation becomes available. Of this, however, there can be hardly any doubt.

2. The western (Frisian) part. As figures 2 and 4 show, opposite the Frisian land reclamation the large Waddenisland of Ameland is situated. From the intensive tourist traffic to and from this island follows, that the future construction of a traffic dam on the Ameland watershed is not entirely hypothetical. In Friesland live many supporters of the construction of a second dam, from the western end of Ameland to the coast. This, however, would be a large scale and expensive damming-in operation, possibly to be regarded as a first phase of a partial or total damming of the Wadden Sea: for that reason, the plan also meets violent opposition.

Important advantages would be: the heightening of a large part of the Frisian sea defences would become redundant; cultivation of the grounds improved by land reclamation (about 3000 hectares) would become possible; there would be a chance to create a large and beautiful recreation area.

From a point of view of economics this plan is not unattractive. The authorities do not yet take a positive stand, which is understandable. It is not sufficient to show, that the expenditure of a sum is justified: the sum must also be available.

3. The eastern part (Groningen). In this area the situation is so complicated, that it is impossible to give a clear picture of it in a short review. The land reclamation works (3900 hectares in these parts) will probably not be given up, but neither will they be dammed in. Thus, the only chance that they will ever be changed into agricultural land is, that the Wadden Sea will in future be closed, or at least the eastern part of it. Considerations on this matter will be given in the next and final part of the paper.

6. DAMMING IN AND RECLAMATION OF THE WADDEN SEA.

In the previous chapter it was pointed out, that a damming in of the wadden area south of Ameland might be regarded as the beginning of a more drastic closing in of the Wadden Sea. It is of course possible, that the Ameland plan and other similar plans will be carried out in the future, each time that there is a reason for it. This might lead to a fragmentary reclamation of the Wadden Sea, that again might or might not finally result in one large concluding closing operation.

A different possibility, that is better suited for a discussion is, that an integral plan for closing the Wadden Sea shall be adapted and carried out. With regard to the technical possibilities VAN DER BURGT in lit(1) has given an exposition. It would go too far to repeat this here, but the main data are summarized in figures 21 and 22. From the many possibilities one rational design was chosen and schematically mapped. Regarding the execution a network planning was made, based on an annual expenditure in the same order of magnitude as the annual amount now needed for the Delta Plan. A simple comparison of the geographical extension and the tidal volumes to be closed off in

the Delta Plan and the Wadden Plan is sufficient to show, that the latter surpasses the former several times. The estimated cost of 6 milliard guilders is 2 to 3 times as high as that of the Delta Plan, the duration of the execution (minimum 18 years) amounts to 46 years with the chosen assumptions. The earliest date for the beginning of execution is after the conclusion of the Delta Works and the Zuiderzee Works, that is roughly in 1980. This would result in a completion around 2025, supposing the execution meets with no interruptions.

To obtain a picture of the chance, that this gigantic project will actually be carried out, a number of related aspects will be briefly discussed.

1. Security. The plan leads to a certain shortening of the total length of primary sea defences, but in this respect is much less spectacular that the Zuiderzee Works or the Delta Plan. The immediate demands of security, moreover, make it necessary that the northern dykes be strengthened to fulfill the norms of the Delta Committee within a short time: this will result in a security equal to that offered by the Delta Plan, and for a fraction of the cost of the Wadden Plan.

2. Land reclamation. It will be possible to convert the strip of almost 7000 hectares of land reclamation works into agriculturally useful land. For the rest, the bottom will be sandy, and sea branches will become lakes. Great problems regarding desalting and prevention of sand drift have to be solved before a balanced vegetation will be established. As to utilization it is possible to think of recreation, establishment of industries or harbours, and settlement of people.

a. Recreation. In the Netherlands there is a need of recreation space, but as in this respect thoughts on a European scale grow more and more common, it is doubtful, whether this need will prove to be permanent.

b. Industry and harbours. These are mainly found in the western part of the country, and spreading would be desirable. The feasibility of this is questionable, however.

c. Settlement. If the predictions regarding increase of population are correct, there will possibly be a need for settlement areas, although there still remain thinly populated parts even in the Netherlands. The chances for slowing down the increase of population, moreover, are becoming better.

3. Water management and drinkwater supply. For water management there is no special need of fresh water lakes in this area. Drinkwater people do think of larger reservoirs, but preferably not in these parts.

4. Nature protection. The Wadden Sea is unique from a biological point of view, and if the experts are right, interests on a larger than national scale are involved with respect to migration of birds. For these reasons nature lovers are, in this rather premature stage, in open opposition against every interference with the Wadden Sea. In view of the preceding it is far from certain whether the reasons for damming in will eventually stand up against this very positive pressure in favour of maintaining the status quo.

To summarize, there is every reason to suppose, that a future as coastal protection works awaits a large part of the land reclamation works in Friesland and Groningen. Under favourable circumstances they may reach the stage of saltings fit for cattle grazing.

Although many experts have taken and are taking the eventual closing of the Wadden Sea for granted, and although every hydraulic engineer would gladly participate in the very interesting work of executing such a plan, the author, for the time being, is sceptical with regard to the chances of realization of the project.

ACKNOWLEDGEMENT

The author wishes to express his gratitute to Mr. R.J. de Glopper for his help and advice, and to various members of staff and personnel of the departments of Land Reclamation and of Coastal Research for their expert cooperation and unfailing patience.

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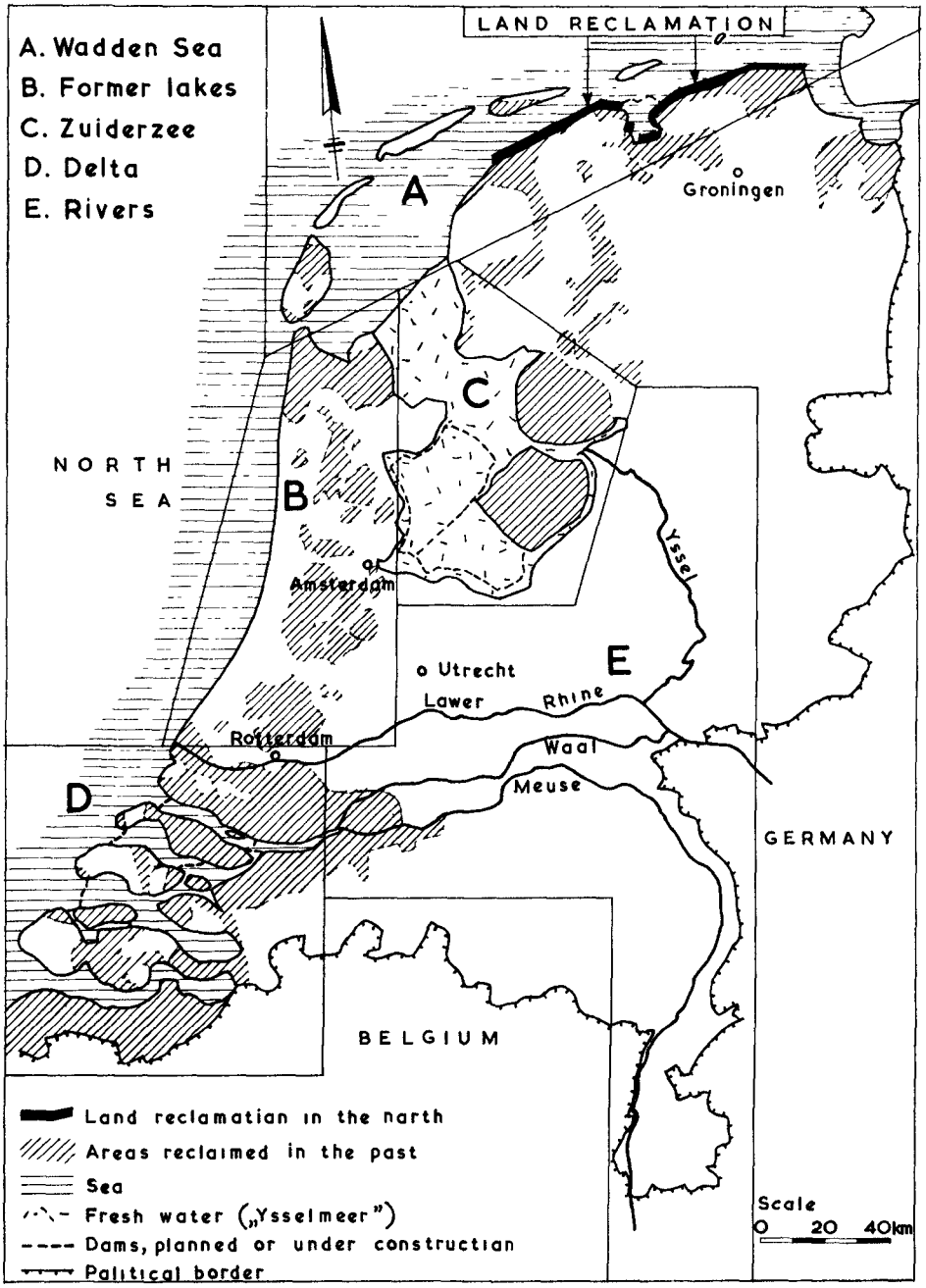

Fig. 1. The Netherlands with land reclamation, past and present.

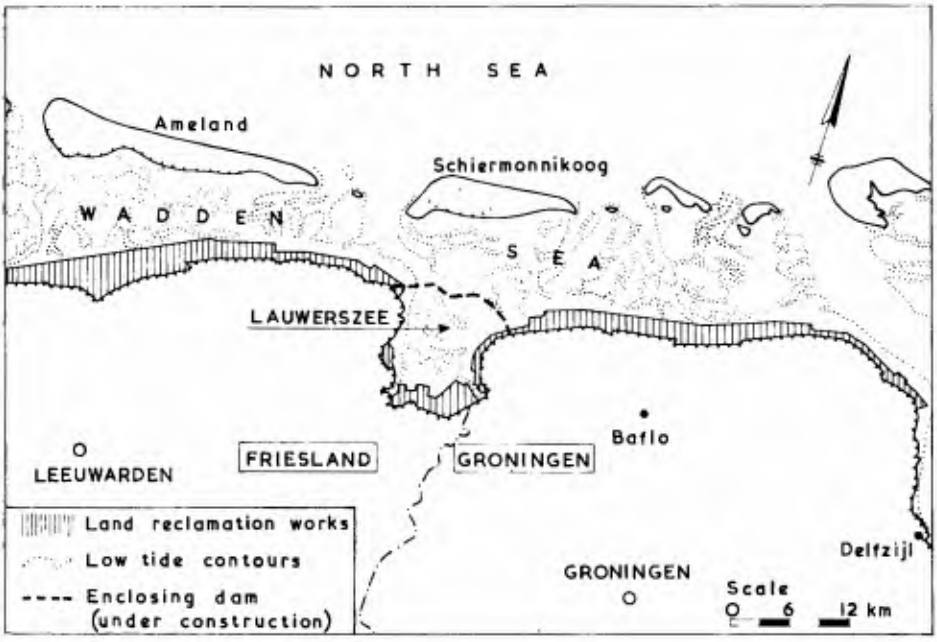

Fig. 2. Eastern Wadden Shallows, with land reclamation area.

Fig. 6. Receding rim of salting.

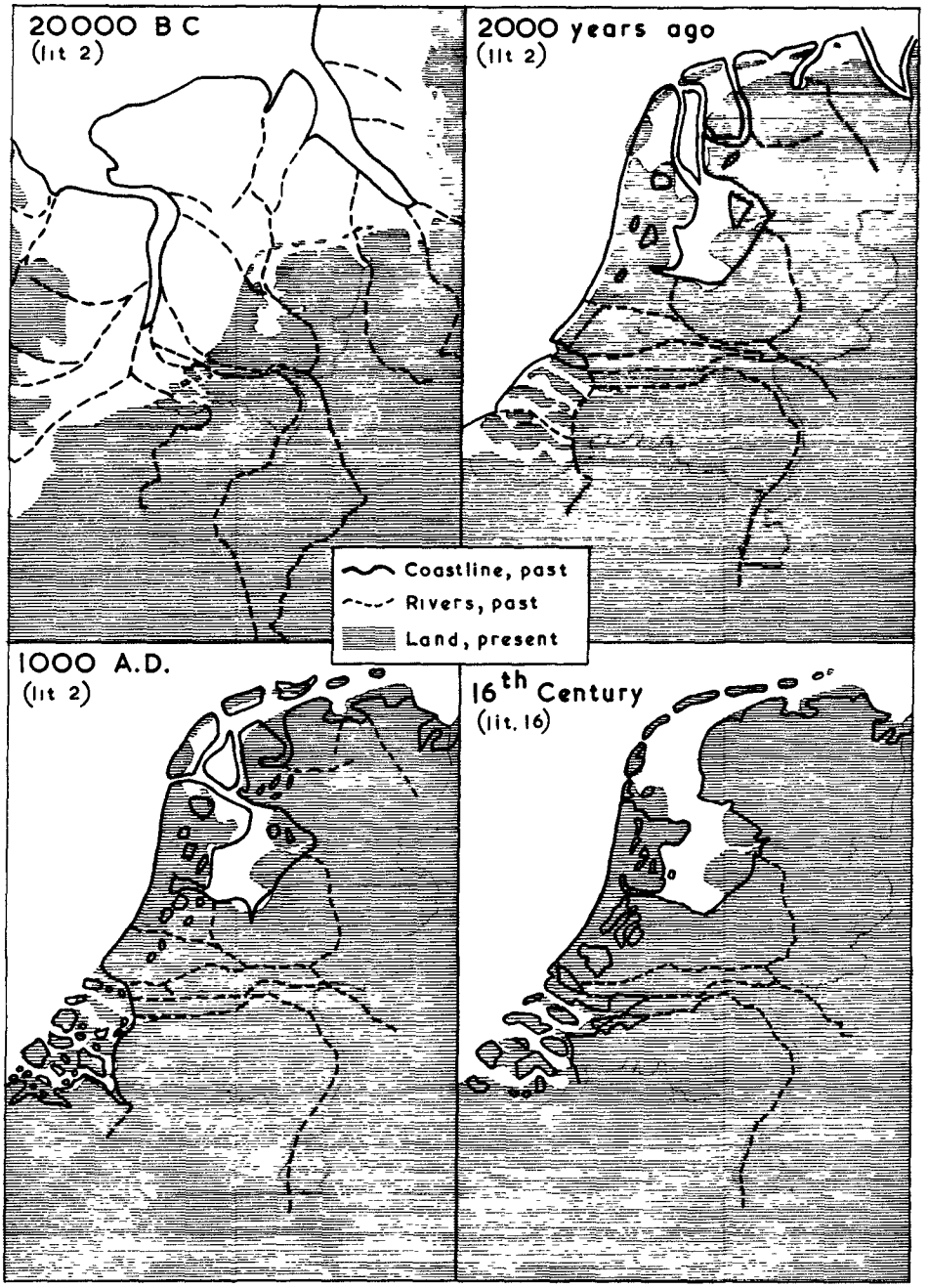

Fig. 3. Probable development of Netherlands' coastline.

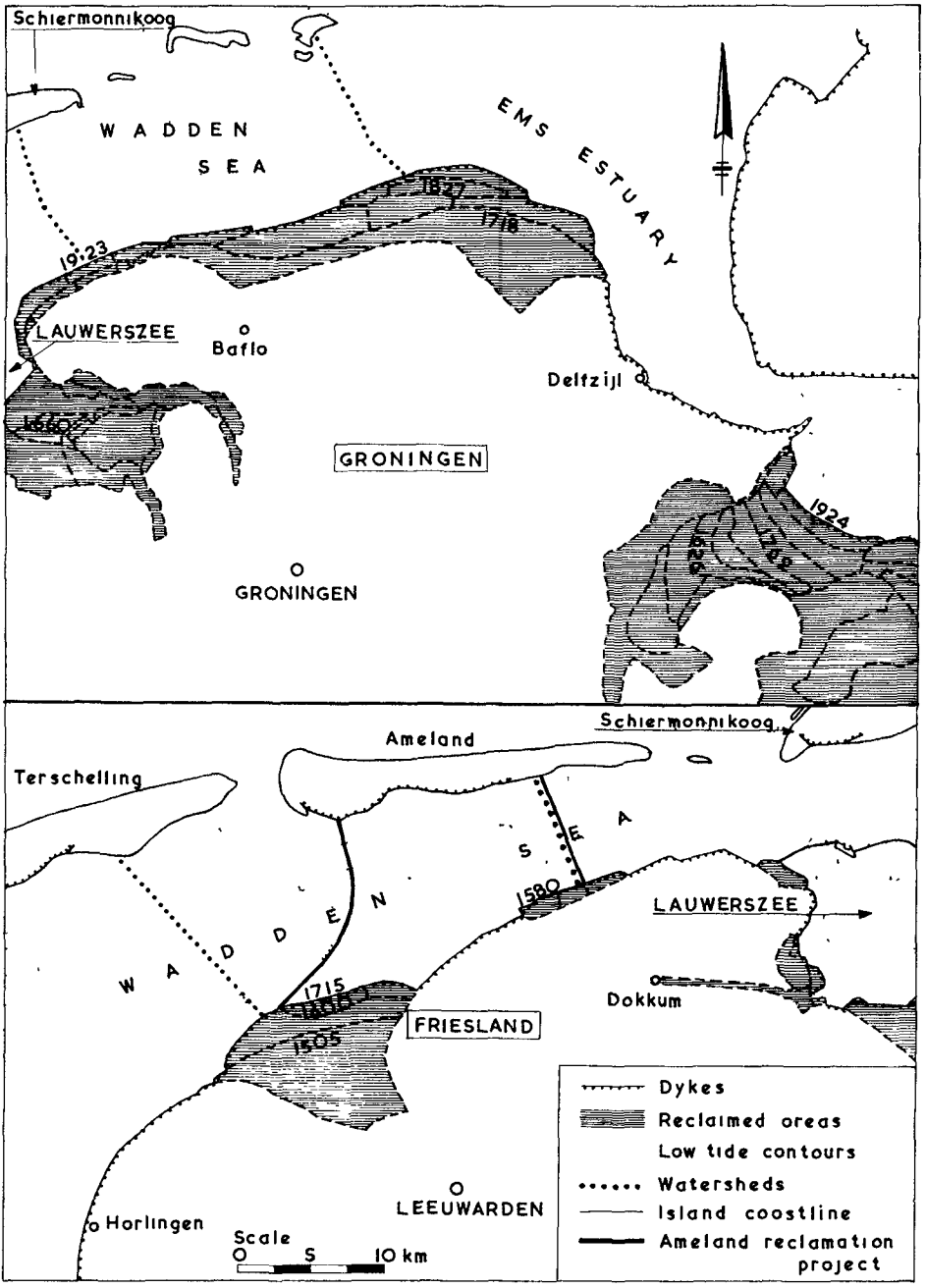

Fig. 4. Land reclamation in the north later than 1400 A.D.

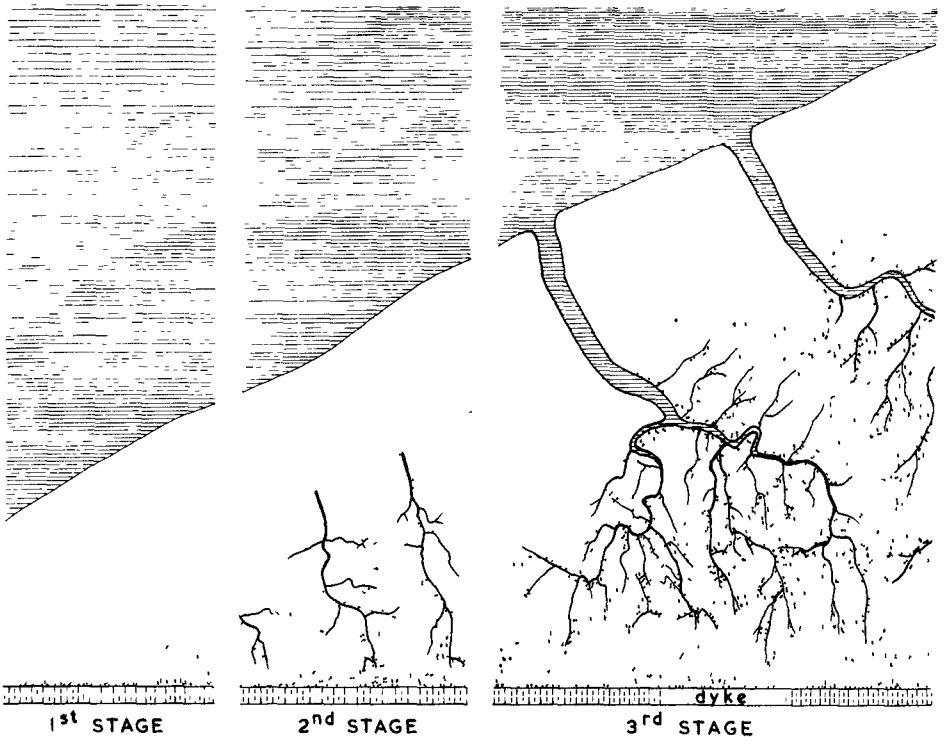

Fig. 5. Schematic picture of natural accretion (from lit. 11).

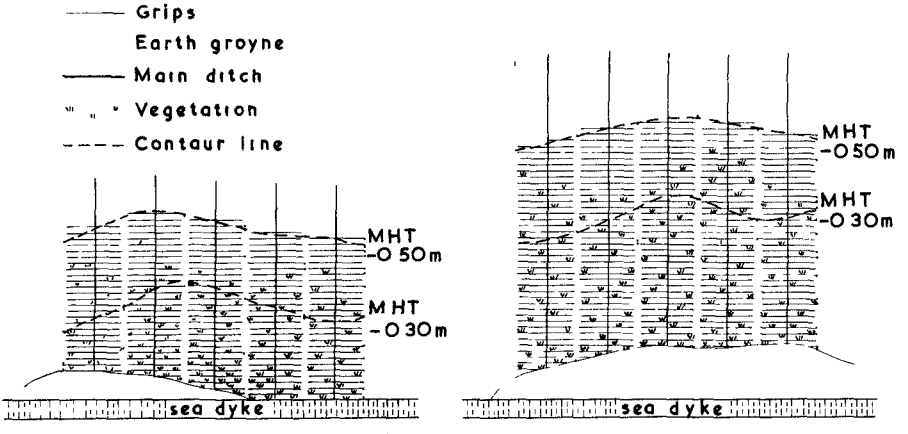

Fig. 7. Farmers' method, schematic (from lit. 11).

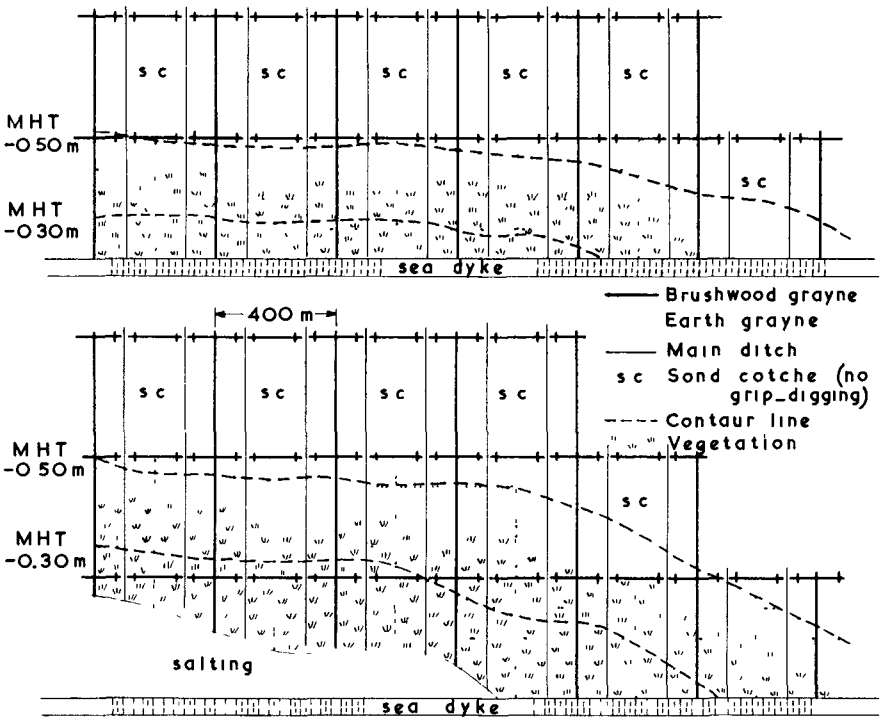

Fig. 8. Sleswick Holstein method, schematic (from lit. 11).

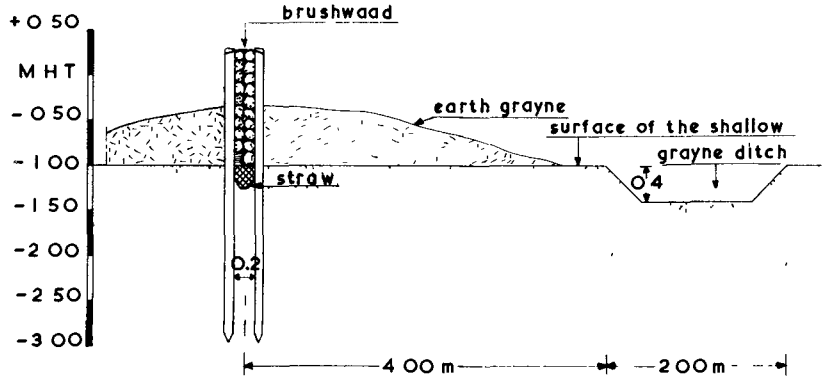

Fig. 9. Initial construction of main dam, with brushwood construction and groyne-ditch.

Fig. 10. Main dam with brushwood groyne (early stage).

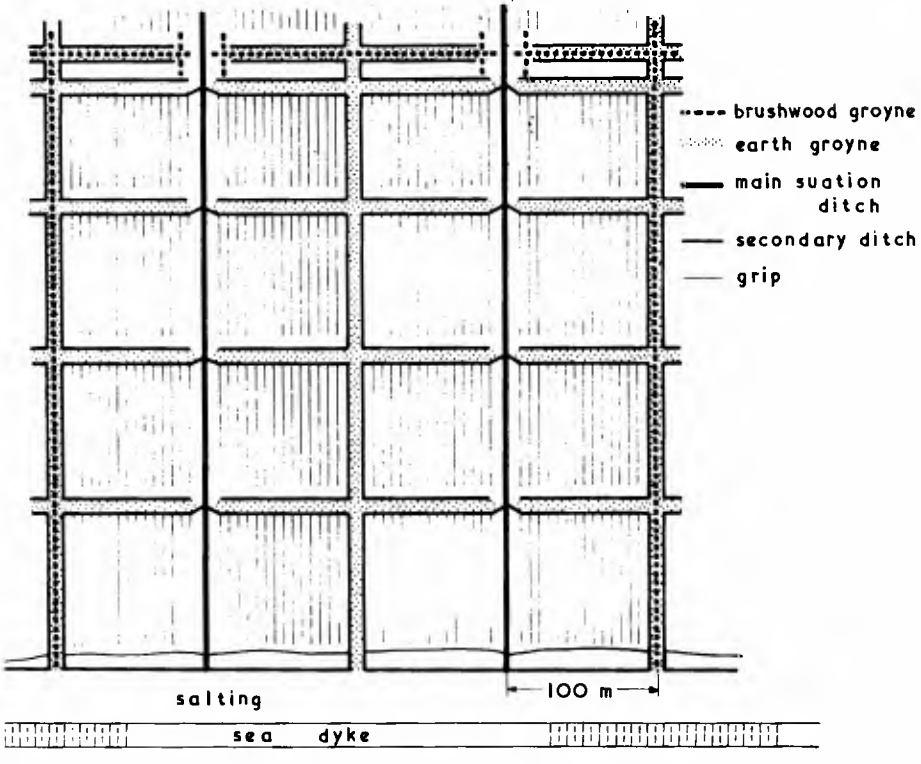

Fig. 11. Sedimentation field (schematic).

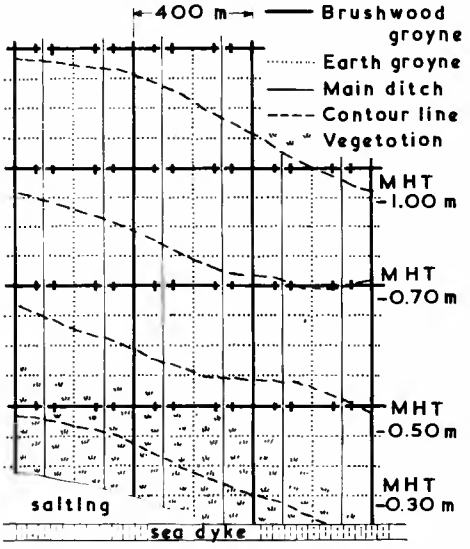

Fig. 12. Modified Sleswick Holstein method, schematic (from lit. 11).

Fig. 13. Mechanization "Floating" excavator in low sedimentation field.

Fig. 14. Mechanization. Dots on horizon are similar machines.

Fig. 15. Mechanization. Gripping "fraise" on high sedimentation field.

Fig. 16. View of saltings and sedimentation fields.

Fig. 17. Walking in sedimentation fields requires practice.

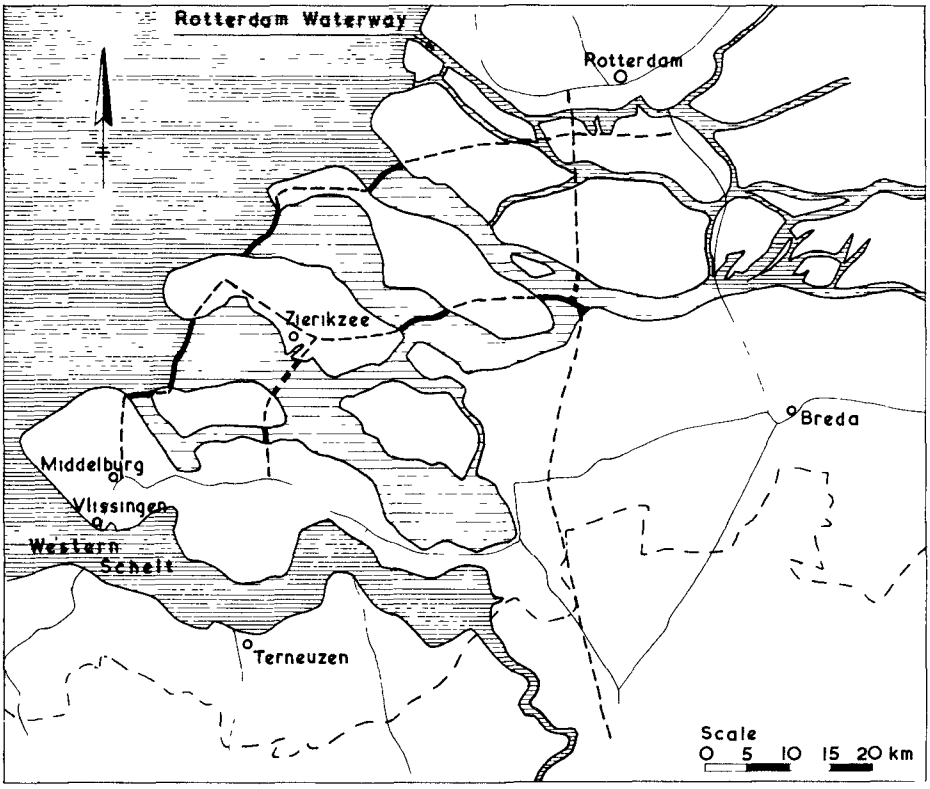

Fig. 18. Delta Plan. Simplified general picture.

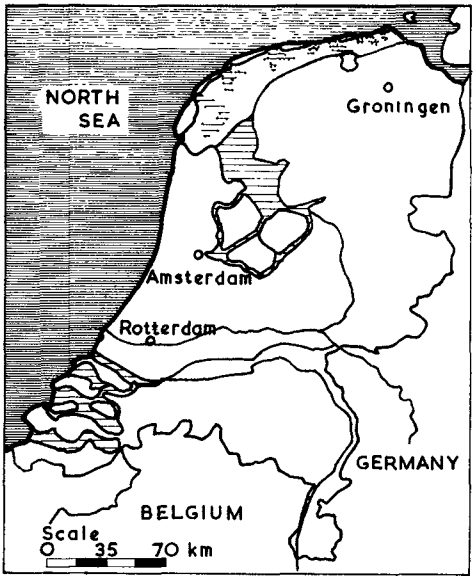

Fig. 19. Netherlands, fiction or future?

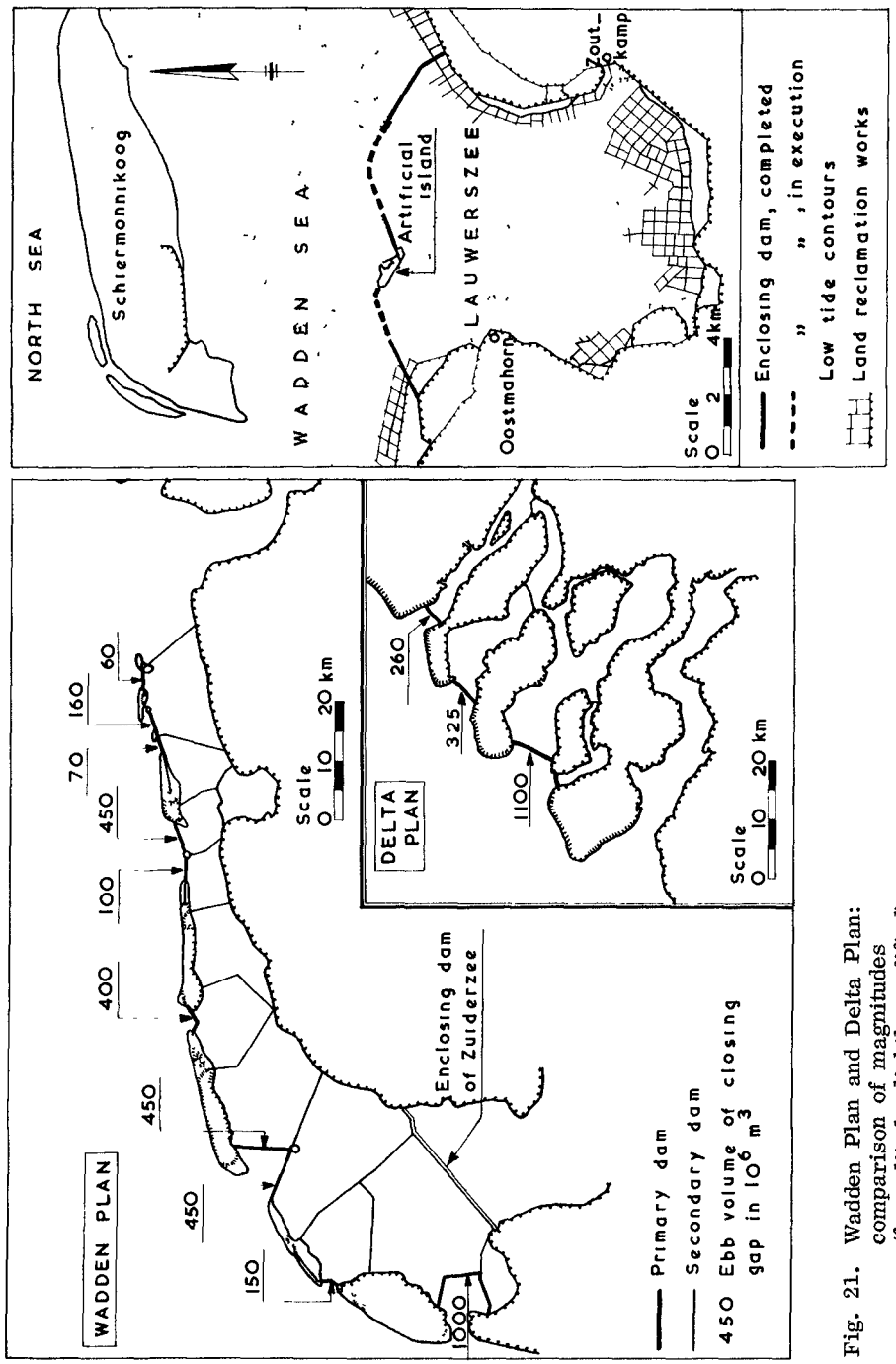

Fig. 21. Wadden Plan and Delta Plan: comparison of magnitudes (from lit. 1, slightly modified).

Fig. 20. Enclosing of Lauwerszee. Situation spring 1966.

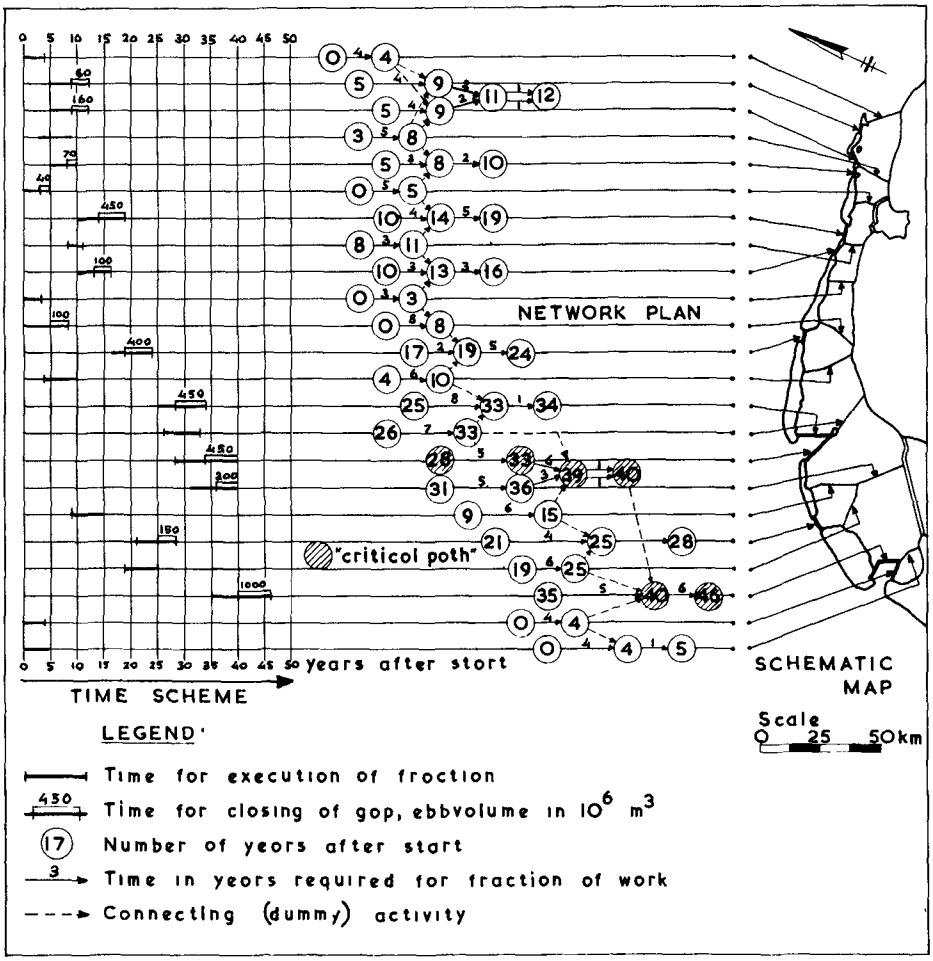

Fig. 22. Network Plan of Wadden Project (from lit. 1, slightly modified).