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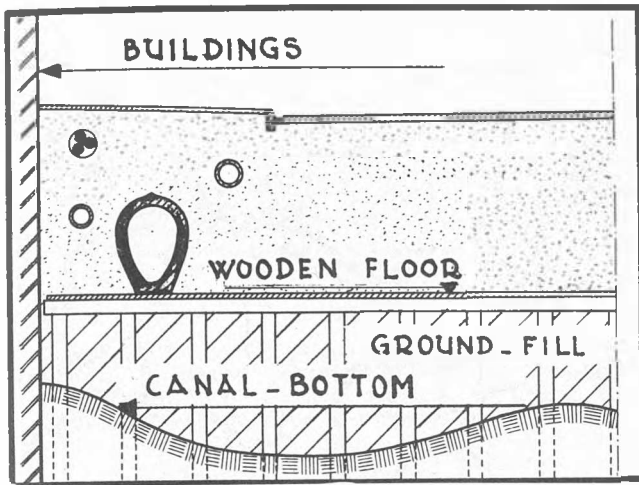


FIG. 9

also used for the construction of Rotterdams Broadway, the "Coolingsingel". A former canal was filled with soil and the upper sand fill had to be supported by a wooden floor and piles (fig 9).

A reinforced concrete construction on wooden piles supporting a sand fill was used for a road near Hazerswoude. The wooden piles were driven upside down, in order to have a higher point resistance (fig. 10).

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- 3) Roads and Road Construction, 1-12-1938 pg 390.

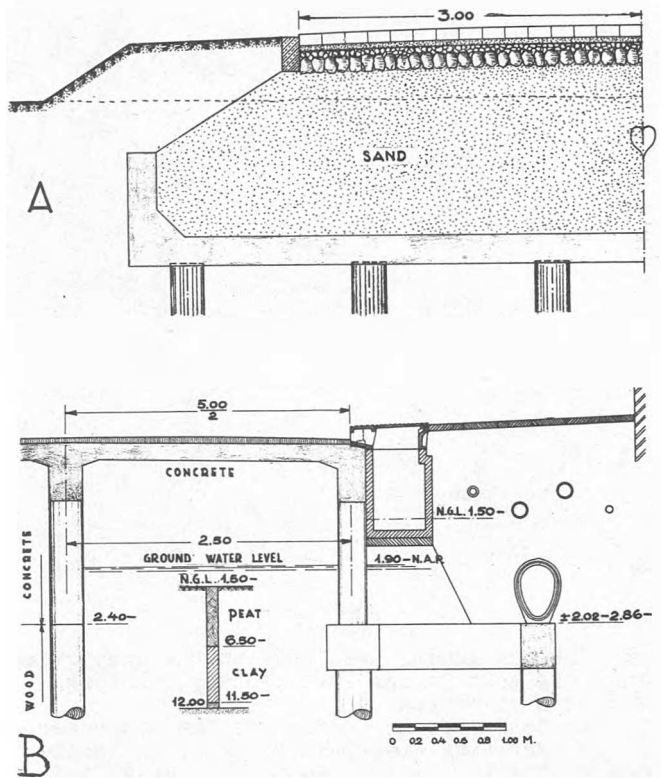


FIG. 10

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THE GEOLOGY OF THE NETHERLANDS IN CONNECTION WITH SOIL MECHANICS

Ir. T.K. HUIZINGA

It is with great pleasure that I deliver this short lecture to you this afternoon. I intend to tell you something of a general nature about our country, and more in particular about its western part, which is unique in its kind and which nowadays lies down to several meters below sea level and as such has given its name to the Netherlands (the Low Countries). Not less than 38% of the total area of our country would be flooded at high tide, if there were no dunes and dikes along the sea and along the rivers, as is illustrated in the first picture. Only the dotted part would remain dry.

That this flooding does not happen we owe to our organization in the past and in the present on the point of water-defence and water-management. It implies a continuous care and struggle and it is not to be wondered, that is has left its mark upon the character of the inhabitants of this country.

"The dutch character has sometimes been summed up as a queer mixture of obstinacy tempered by common sense. And there were good reasons for it. A man who has to watch out all the time, to prevent the sea from flooding and drowning him, has to be an obstinate person or he has to pack up and look for a less troublesome place elsewhere. A man who has to live behind dikes and on a rather small piece of soil with little or no useful minerals in it has to use a lot of common sense to make both ends meet.

The water was also his friend in exchanging merchandise and ideas. He carried the goods of the world in his ships, he carried the thoughts of the world in his brain. He is a serious minded person in whose mentality the struggles of the past, against nature as well as against human enemies have left their traces. But with a keen eye for the good things life and the world have to offer and quite ready

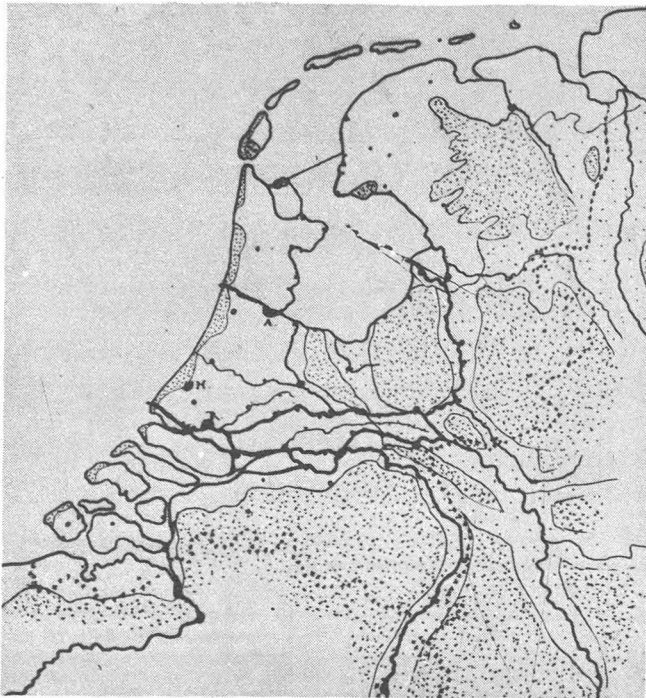


FIG. 1

for a hearty laugh, even beneath the grey skies, which his most famous 17th century painters laid down on canvas.

In no European country has the character of the territory exercised so great an influence on the inhabitants as in the Netherlands. And on the other hand no people has so extensively modified the condition of its territory as the Dutch. They turned sea into land, land into canals, unruly streams into normalized rivers, inland lakes and impenetrable marshes into fertile meadows." x)

This requires an extensive organisation of services by government and provincial agencies. Next to this there are a great number of so-called water or polder districts, public bodies, which, under the supervision of the first mentioned, are responsible for the maintenance of dikes and hydraulic structures and for the regulation of the waterlevels. Three quarters of the area of our country is divided-up in water districts, each with its own water or polder board, each with its own waterlevel. All in all there are more than 2600 of these boards. As a comparison I may mention that the total number of municipalities in the country amounts to 1100.

Apart from the effort, all this involves substantial expenses.

Now I first propose to give you a sketch of the way our home is built and how it is fitted out and, remembering we are soil specialists we shall first conduct an investigation into the foundation soil.

To begin with, you should know that since thousands of centuries the bottom of the North Sea is in process of subsiding. This subsidence is pivoting round an axis situated just over the border in Germany and Belgium, so that the layers of loose sediments deposited by sea and rivers increase in thickness from South-East to North-West, where they reach a thickness of several hundreds of feet.

x) After: Peter Bricklayer: Holland's House.



FIG. 2

For a clear understanding of the subsequent building-up of the foundation soil I must ask you to go back in thought about a thousand centuries when Holland was partly covered by glaciers during the Riss glacial period.

Ice covered our country up to a line roughly running from Amsterdam to Arnhem. The glaciers brought large masses of sand and stone from the Scandinavian countries and also the renowned boulder clay which has been so useful in constructing the dikes in the Zuidersea.

During the next glacial period (the Würm period) our country remained free from glaciers.

At the end of this period, about 20,000 years ago, the level of the sea was 60 meter lower than it is now and the coast-line was situated much further to the North, in the neighbourhood of Doggersbank (fig. 2). The country was lying on a flat slope and had the character of a tundra-country consisting of sand brought down by the rivers and by the ice, intersected by erosion and with some hills, among which were the present island of Texel, Wieringen, Urk, the Muiderberg etc., relics of the Riss-glacial period and consisting partly of glacial loam. Owing to the cold climate, the ground was permanently frozen. When the temperature rose gradually and the frost left the soil, sand-drifts occurred and a growth of birches and fir-trees developed. This firm-layer serves now at many places in our western provinces as support for foundation piles underneath heavy structures. From a great number of borings, soundings and deep excavations the position of this sloping so-called "low terrace" is well determined. It is situated at a depth of usually not more than 20 meters.

After this period the climate becomes warmer and dryer, while the sea level rises continuously as a result of the melting of the icecaps. At the beginning of the Holocene pe-

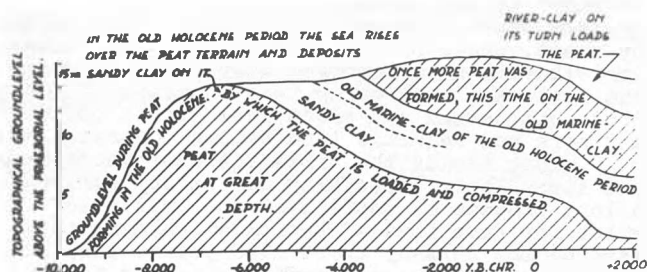


FIG. 3

riod, about 8000 years B.C. the sea level is still 20 meter lower than now. As a result of the higher ground water table in the lower part of the country reedmarshes come into existence which develop into a thick peat layer with the gradual dampening of the climate. With the rising of the watertable the thickness of this peat layer increases and nowadays it may be found almost everywhere in Western Holland as a thin strongly compressed layer, the so-called "peat-at-great-depth". This compression is caused by the weight of the layers deposited on top in later times (fig. 3). For as a result of the sustained rise of the water the West of our country is flooded completely by 5000 B.C. stopping the growth of the peat and causing sand to be deposited on top in shallow water. These sandy layers may also be used sometimes as a support for foundation piles. Frequently however the sand in these layers has a very loose packing, so that they offer a low resistance to penetration and in that case one has to go down to the underlying preglacial layer all the same.

After this warm and dry period, the so-called Boreal-period, the climate changes again and the Atlantic-period begins with a sea climate. On the coast sandbanks are formed on which dunes develop (the so-called old dunes), whereas behind, in the shallow inland sea the old blue sea-clay is deposited. In many places this inland sea is gradually transformed into a swampy fresh water region, where once more an extensive growth of peat takes place.

On the strips of dunes the first inhabitants settled and later on a great many settlements developed. The settlers found here a firm foundation soil and the neighbouring low lands gave opportunity for cattle farming.

During the subsequent dryer period, the Subboreal-period, beginning about 2000 B.C. no new dunes were formed, perhaps owing to a temporary lowering of the sea level. Nor was any more peat formed because of the dryness of the climate.

Then, some hundreds of years after the beginning of our calendar the climate changes into the present one, moist and cool. The rise of the sea level continues, the coast line is attacked and the young dunes are formed. On the peat behind these dunes, where it is not carried away, the so-called young sea clay is deposited. But the attacks of the sea proceed: About the year 1300 A.D. the Zuidersea is formed by erosion of the peat and the overlying thin layer of young sea-clay, the wide estuaries in the South are created by storms and high floods.

During the heavy storm of November 1421 a vast stretch of land along the rivers in South-Holland was flooded through the breaking of the dikes. Large areas of peat were taken away and some deep channels were formed. For a long time this region has been left as a



FIG. 4

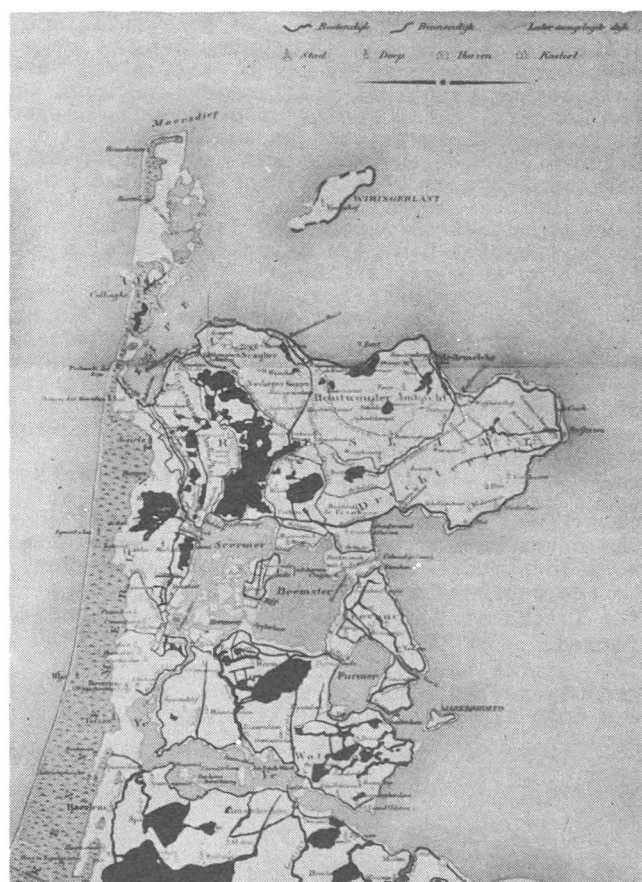


FIG. 5

vast sheet of water and marshes, the Biesbosch, but little by little dikes were constructed again. Some of the old channels still exist as is apparent from picture no. 4. However, plans have been drawn up now to reclaim the whole area.

Loss of land may also occur by act of man, for instance by digging peat as fuel, which caused the formation of extensive lakes.

To what extent land has been lost by the inroads of the sea is clearly shown by the map of the province of North-Holland round about 1300 (fig. 5). Another form of landloss

occurs in the province of Zeeland. There the loose packed sandlayer which I mentioned gives rise to the notorious coastal flow-slides, on which a report has been published in the Proceedings by Mr. Weinberg and Mr. Koppejan.

With the rise of the sea level man begins his struggle against the water. First in a primitive way: the inhabitants who at the period of constant sea level had taken possession of the beach plateaus enclosed by the dunes for cattle raising and agriculture, start throwing up mounds in order to protect themselves against the rising water.

Pliny describes this as follows: "In this constant struggle one may doubt whether the soil belongs to the land or to the sea. There a miserable people inhabits high hills or mounds thrown up with their own hands to the level of the highest flood known to them by experience and on these they have built their huts. They resemble seafarers when the water covers the surroundings and castaways, when the waters have receded".

I may add to this, that the volume of some of these mounds was as great or even greater than the Egyptian Pyramids.

In the West only the high dune-lands are inhabited, the remaining country has become a vast marsh overgrown by birch, willow and hazel, obstructing practically all communications. On the long run the throwing up of mounds, appears to be insufficient, so that another method of defense against the water was necessary namely the construction of dikes. This happened already before the 8th century. Naturally the best stretches of land, that is where the young sea-clay had been deposited, came in first for this reclaiming.

So we have seen that in the beginning this struggle, which has continued up to the present day, was essentially of a protective and defensive nature and was conducted piecemeal, on several isolated places, but gradually also the offensive was started, the reclaiming of new land, which proceeded as a matter of fact with many set-backs.

In the beginning, the first embankments and dikes are of small dimensions, since at that time, the land was at a higher level above the water than at present. More and more dikes were constructed and the enclosed lands grow to one coherent area. Picture No 6 shows how the Island of Goeree and Overflakkee has been formed.

Inside the dikes the location of the groundwatertable can be regulated at will, this was done in these polders at first with primitive

means, later (as from the beginning of the 15th century) by the picturesque wind-mills, at present often by means of pumping plants driven by steam, crude oil or electricity. The remaining wind-mills have proved very useful during the last war, when owing to a shortage of fuel, crude oil, steam and electrical plants could not work and valuable land became inundated.

Since inside the dikes the watertable dropped appreciably especially during dry summers, a long process of settlement was initiated, which for some time of the older polders is lasting now already about 1000 years. Also the requirements of modern agriculture led to a more and more intensified draining, which in its turn resulted in an increasing settlement.

In this way the surface of the peat country has in course of time subsided 1 to 2 meters and, since sea level and river levels have not altered much, the west of Holland shows itself now to a visitor as a low lying country, intersected by many high canals with a water level at about 2 meters above the surrounding land.

Apart from these lands of which the formation and the situation below the sea-level may be said to have come about in a natural way, there are the reclaimed polders, where the ground surface lies 4 to 5, even 6 meters below sea level. These were lakes which have been drained by means of wind-mills as is shown on picture No. 7, or by means of pumps driven by steam. These lakes were either formed by nature, for instance by the sea washing the land away (as in the case of the Zuidersea and some lakes in North-Holland) or by man when digging for peat. The soil therefore often consists of old sea clay. Sometimes the old streambeds, that were still existing during the period of sedimentation of this soil in the lakes behind the shorewall, may still be seen.

After the reclaiming of such new land it is still necessary to go on removing the redundant water by means of wind-mills or nowadays mostly by mechanical pumping plants. For the water levels outside are even at low tide mostly so high, that draining by gravity through sluices is in many cases never or hardly ever possible. The polder the Alblasserwaard is such a polder with wind-mills for dewatering. We shall visit this scene on the boat trip on the final excursion.

All this is not yet a complete account of our fight with the enemy. He also turns up when we would least expect him via the pleistocene

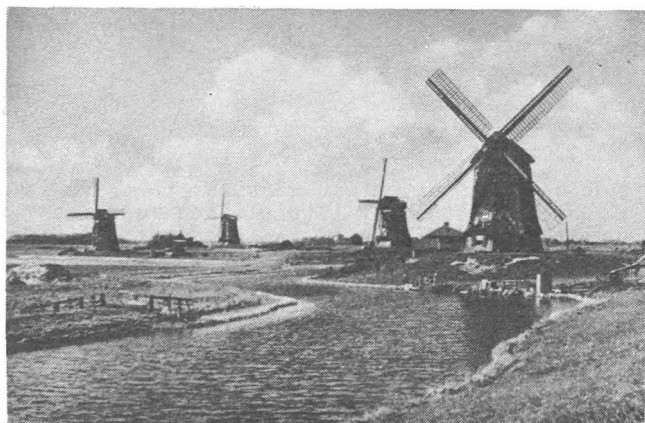


FIG. 6

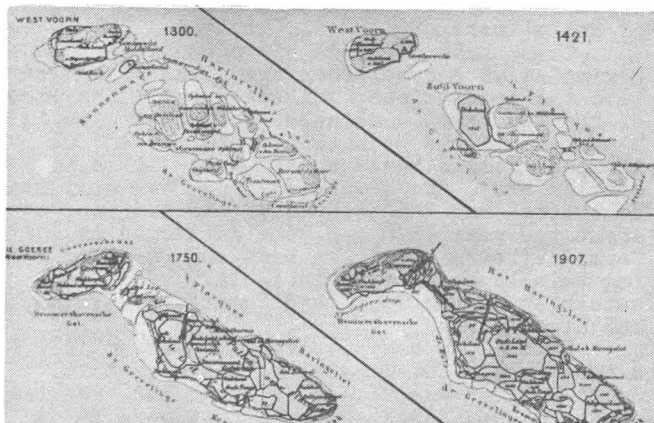


FIG. 7

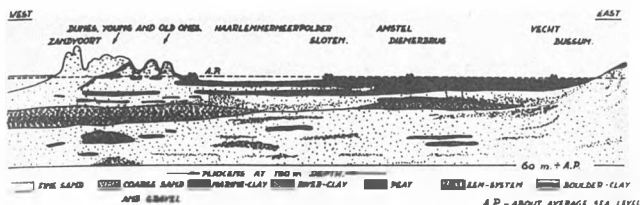


FIG. 8



FIG. 10



FIG. 9



FIG. 11

subsoil, this time in the shape of salty water percolating upwards. Again, through all the outlets and openings in the lower reaches of the rivers and through the sluices and locks the salty water penetrates into our home. Our final aim must be to build a continuous rampart all along the coast-line.

The closing of the Zuidersea is the beginning.

Most of what I told you before is summarized on picture No. 8, showing a section through the Western part of the Netherlands.

From left to right (West to East) dunes, a reclaimed polder, a peat area, and a river-landscape can be seen until the higher grounds are reached.

Next picture No. 9 shows you the peat country of IJpendam, which you will pass by on the excursion to the Wieringermeer next Sunday. Here the lakes and water reaches, originating from the digging of peat have led to purely water born traffic and houses are built on the only road through this bog. The construction of roads and railways under such conditions is not a simple problem, as you have heard already from Mr. Dibbitts and Mr. Cuperus.

Further to the North we may also find these watery regions. Photo No. 10 shows the peat lands covered with a thin layer of clay at Broek op Langendijk where again the ditches and canals have been continually dredged to get material for raising and manuring the fields and in the course of time have thus become very wide. As a contrast you see in the background the Heer Hugowaard, a reclaimed polder, with soil-surface about 3 meter below sea level.

I want to show you yet another method of raising the surface of low lying peat lands. The natural formation of peat continues after the digging away of peat for fuel: the natural vegetation of marshland, rushes, reeds etc. may form at the surface of the water floating pieces of "land" which are connected to the

bottom with roots only. In Giethoorn these floats are cut loose (fig. 11) and are towed to their destination. It is intended however to reclaim these marsh lands.

However the people of this country have not only been fighting against the water. At times this water was their ally in the fight against other nations. On the higher places the access had then to be prevented by other means. So the towns were defended and fortified by constructing ramparts and moats, which later on, when the towns grew, were demolished and filled, but there are still some of those towns existing as they were some hundred years ago.

Up till now I have hardly gone into the use of the soil by man in this in every respect remarkable landscape of water, fields and wind-mills. For, as I remarked in the beginning of my story, in this low lying Western part, the density of population is higher than anywhere else: 44% of the total Dutch population lives in the West on only about 18% of the total area. The population density there is 740 inhabitants per square kilometer (about 1900 per square mile), this as against 300 inhabitants per square kilometer over the whole of the Netherlands. The three largest cities, Amsterdam, Rotterdam and the Hague are situated here.

But it should be clear that, notwithstan-

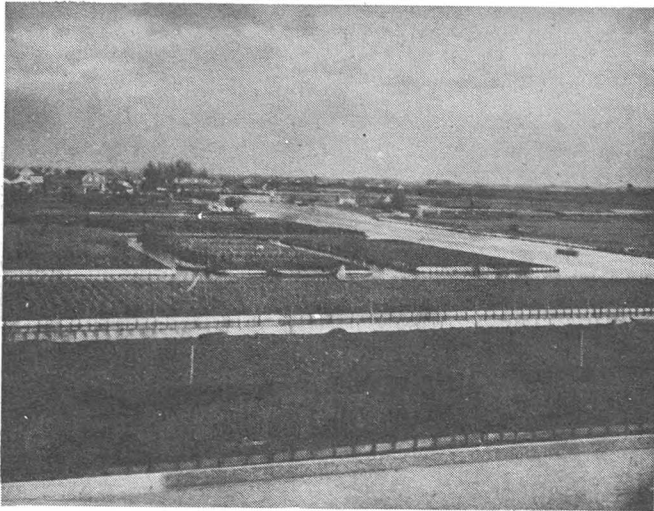


FIG. 12

ding the dense population which requires a large space for itself, there must remain room for agriculture and cattle farming, and that they more especially the first of the two must be done intensively. That is why this Western part is one large garden, tended with loving care. So it is that this soil yields a very high output, which is in the first place due to the construction of works for regulation and management of the water. That the peat areas need not only be used for grazing fields, shows the photo of the surroundings of Aalsmeer (fig. 12), where on land only 30 cm above the water nurseries are established for trees, shrubs and flowers. The plants are sold with a certain amount of soil and exported. So it is necessary to raise the fields again and again with soil dredged from the surrounding lakes.

Also at Boskoop (fig. 13) each scrap of ground is utilized for the growing of shrubs and flowers. In this region lies the road, Mr. Dibbits mentioned, where peat-blocks have been used.

The intensive use of the soil is also apparent in bulb fields near Hillegom. Every square yard is cultivated there, mainly for export. For this cultivation the land is dug down to 40 cm above the groundwater table. The sand thus obtained is also utilized, it is mixed with lime and pressed into building stones. The water table has to be maintained on a very constant level.

As a final example I may show you a picture of the vegetable and fruit nurseries of the Westland (fig. 14), which the ladies will visit. You see that the glass-houses and gardens stretch right to the foot of the narrow strip of dunes. At the same time you may note

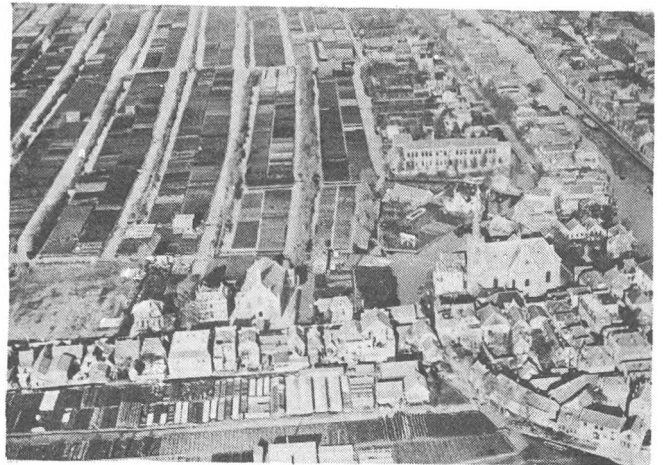


FIG. 13

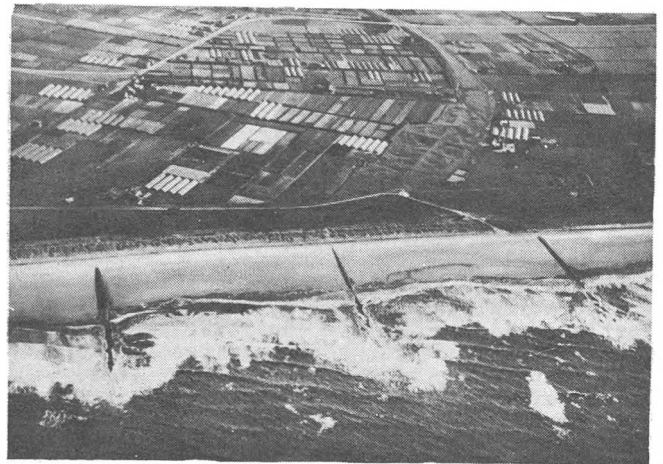


FIG. 14

a type of shore defense consisting of groynes built up in heavy stones to reduce the effect of the waves and currents.

I hope to have given you in this brief sketch and the accompanying illustrations a certain idea of the origin of this "low country on the sea" and of the continuing daily fight for its preservation. I have dealt very summarily with the problems in the field of soil mechanics, but I suppose you must have a notion of what they are and how this low land is one vast consolidating test. On the excursions during the coming days you will have ample opportunity to acquaint yourself better with this low country.