

THE CONSTRUCTION OF A DRIFT-SAND DYKE ON THE ISLAND  
ROTTUMERPLAAT

K.P.Blumenthal.

Chief engineer Rijkswaterstaat (Public Works),  
department for Land Reclamation at  
Baflo, Holland.

SUMMARY

In the paper a description is given of the construction of a dyke using drift-sand on a sandy shoal off the Netherlands' Northcoast called "Rottumerplaat", and of the experiences gained hereby. Only where necessary for general understanding reference is made to conditions and experiences in other places in Holland, where dunes or dykes are built using drift-sand.

The object of the dyke under consideration is to obtain a flood-free strip of land in an area, where this may be useful for future hydraulic engineering works. A special circumstance on Rottumerplaat is the low level in relation to the tidal curve: it has always been assumed that construction of a drift-sand dyke, starting on such a low level, would have no chance of success.

The most important points to which attention is drawn are the following:

- a) The choice of the design-plan (layout) and the position of this plan in relation to the winning area and to wind directions;
- b) The method of catching sand by windscreens, and the materials used for the construction of these screens;
- c) The method of fixing by vegetation the sand once it is caught.

The most frequently used species of plants will be discussed in this context.

Compared to all other techniques of constructing seadefence drift-sand dykes and dunes are very cheap. They cannot be used, however, for important sea defence design, because a driftsand dyke cannot be realized in a short time, and also because the influence

of chance is not to be neglected.

With the exception of the special case of Rottumerplaat drift-sand dykes or dunes are therefore only used to improve or strengthen existing sea-defences.

## 1. INTRODUCTION.

The knowledge of techniques to construct drift-dykes and drift-dunes is very old in the Netherlands. For this reason, and also because the principles of these techniques are relatively simple, little has been published on this subject. There is evidence, that in other countries there are many, who do not even suspect the existence of these methods. It appeared to be useful, therefore, to give some information on recently gained experiences in this field.

Drift-dykes or dunes have been and are being built or maintained in the Netherlands in several parts of the islands in the south-west, on the westcoast and on the islands bordering the "Waddenzee" in the north. In many parts, by the existence of a belt of dunes the construction of an expensive sea-dyke becomes redundant. In places where the width of the chain of dunes is too small for sufficient security, it is possible when circumstances are favourable, to increase the security by stimulating the growth of dunes by drifting sand on the seaward side of the existing dunes. Also, especially on the "Wadden"-islands, low areas are being protected against the sea by a drift-sand dyke, the construction of which is far less expensive than building a real sea-dyke.

In the following a description will be given of the construction of a drift-sand dyke on the island "Rottumerplaat", the geographic position of which is shown in <sup>fig. 1</sup>fig. 1. With respect to its function this dyke occupies a special place. The Rottumerplaat is a somewhat unstable sandy shoal on the northern edge of the area of shallows called the "Waddenzee". Before the building of the drift dyke began, the height of the shoal (with the exception of a small circular dune near the south-eastern end) was such, that it was entirely flooded during storms several times each year. The reason for the construct-

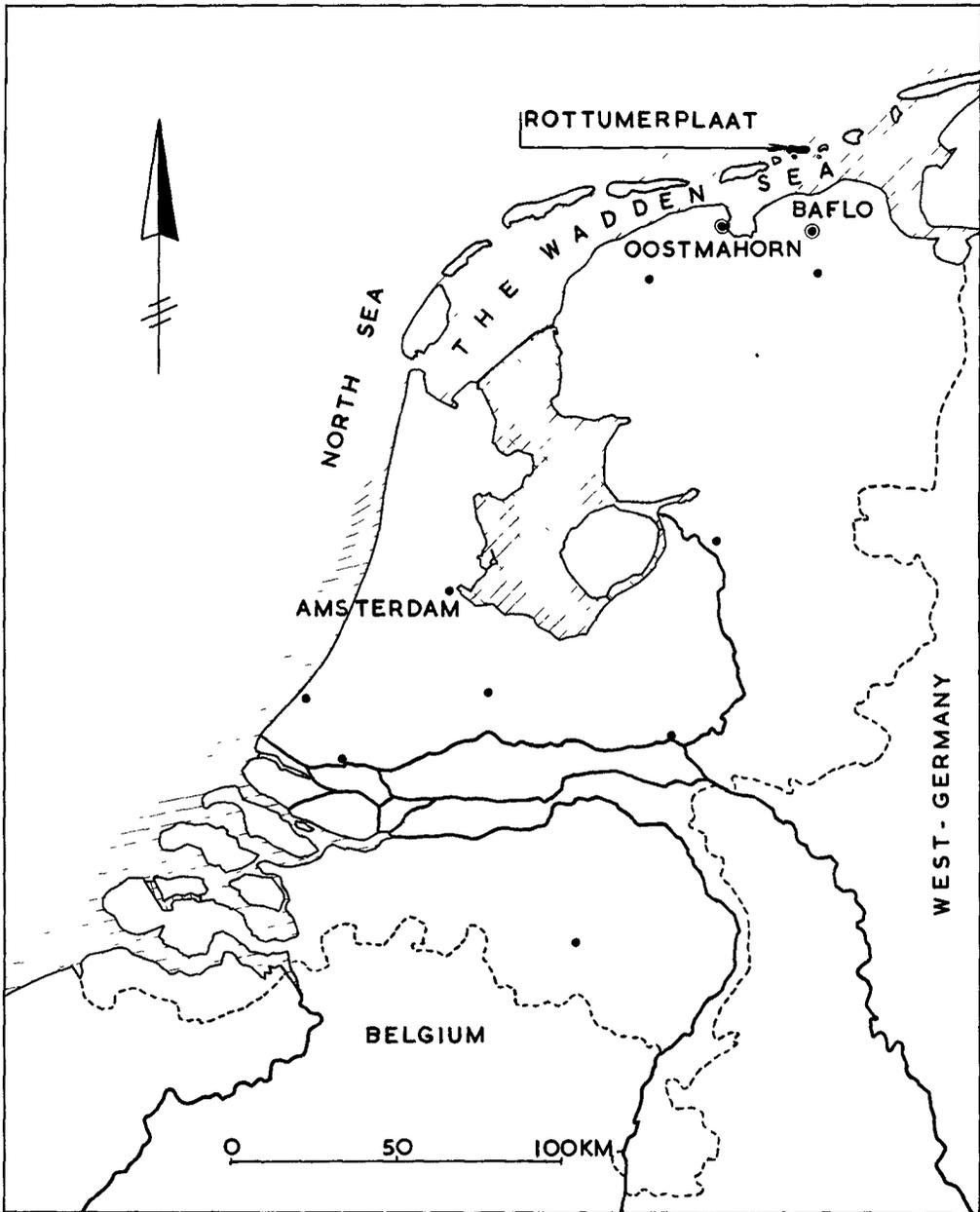


FIG. 1 THE NETHERLANDS, WITH GEOGRAPHIC POSITION OF THE ROTTUMERPLAAT

ion of the dyke was to obtain without great expense a base for possible future damming and reclamation works in the "Waddenzee". Beside other considerations, that will be discussed later, the choice of the layout (fig. 2) was determined by the necessity to keep the sand dyke, if possible, clear of the influence of the instability of the shoal, caused by the tidal currents.

It should be pointed out, that no generally accepted technique exists for the construction of drift-sand dykes or dunes. Beside personal preference or experience, the method is largely determined by local circumstances and by the result that is expected. Although in the following from time to time other possibilities will be pointed out, the argumentation is determined by the experiences on the "Rottumerplaat", and does not claim general validity. The object of the paper is only to show to those who are interested but have not previously heard of it, how, by utilizing drifting sand, it is possible to obtain a sand dyke of considerable size with relatively small expenses.

## 2. GENERAL OUTLINE OF THE CIRCUMSTANCES AND OF THE RESULTS.

As an illustration of the changes the Rottumerplaat has undergone, fig. 3 gives the positions of the contour-line of mean high tide (MHT) for a number of years between 1900 and the present. Though not very distinct, there is apparently a periodicity of decrease and increase, especially of the northern shoreline. This phenomenon can be explained if it is assumed, that the transportation of sand from west to east along the islands, takes place, at least in part, by the movement of sand-banks. Such a sand-bank unites with the Rottumerplaat causing the shoal to expand. The tidal currents then gradually clear the expansion away, which is a different way of saying that the sand-bank moves on in easterly direction.

In this way the size of the accumulation area, that is the beach situated to windward of the projected drift-dyke, from which beach the material for the dyke is obtained, is constantly changing. To ensure the safety of the drift dyke, the ground-plan has to be designed at sufficient distance from the extreme landward extension

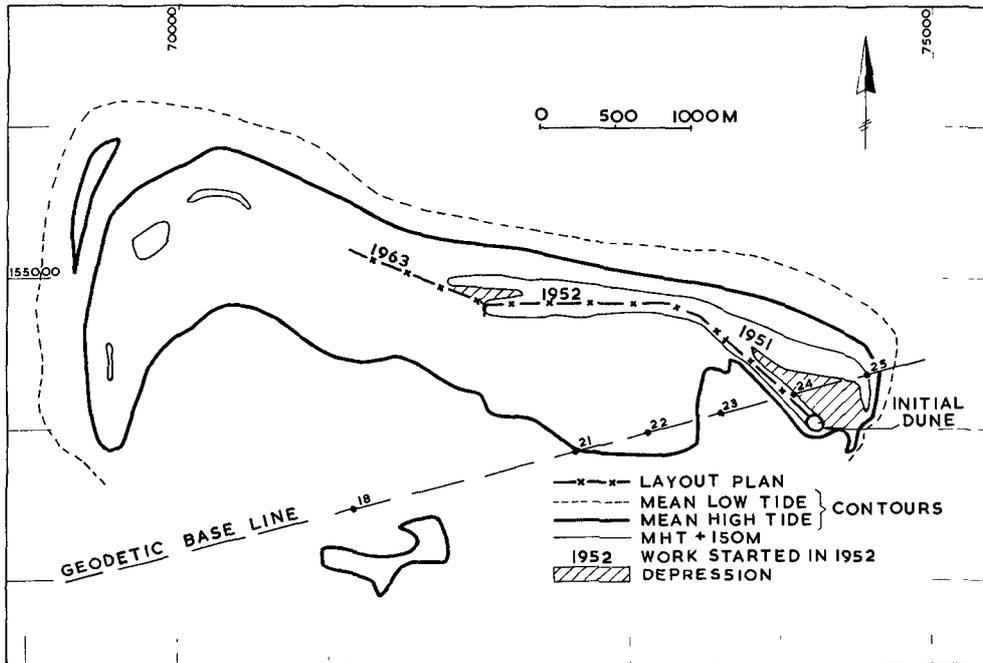


FIG 2 SITUATION OF ROTTUMERPLAAT WITH LAYOUT PLAN OF THE DRIFT-SAND DYKE AND CONTOURS

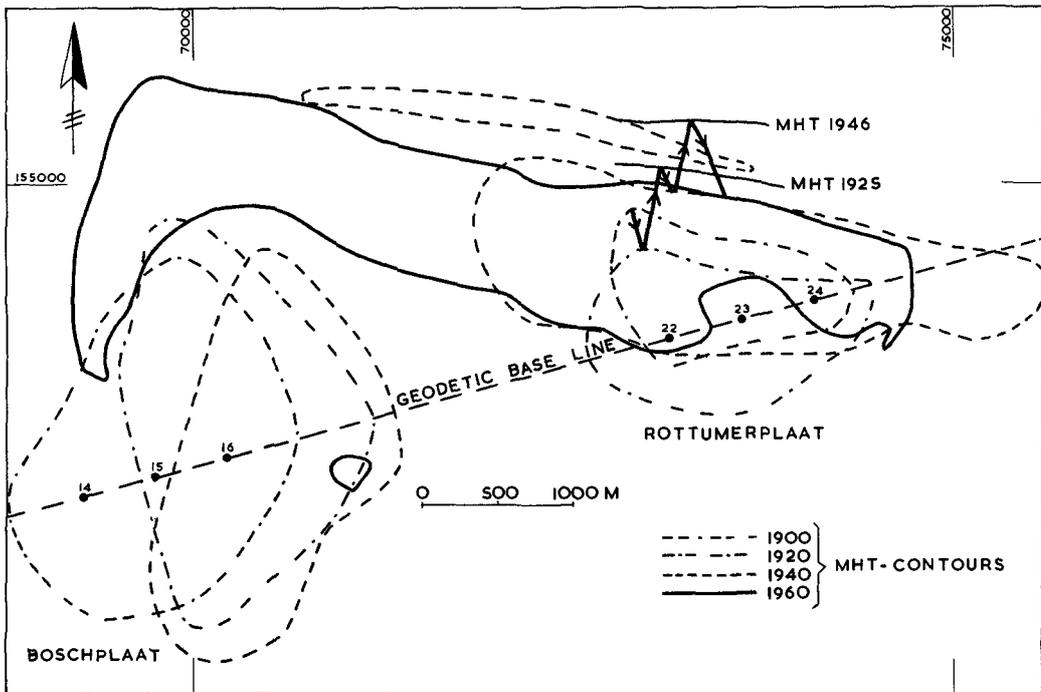


FIG 3 ROTTUMERPLAAT COURSE OF MEAN HIGH TIDE CONTOURS FROM 1900 TO 1960

of the MHT line.

Fig. 4 shows a cross section of the Rottumerplaat that is to be regarded as more or less characteristic. The same cross section is shown for different years, i.e. 1952 (the year in which the work began) and some of the subsequent years to 1962 incl. Naturally the initial situation as shown in the figure is only valid for this one profile, but to put it in a more general sense, before the beginning of the work the height of the shoal in the places covered by the design plan, was between N.A.P. (national zero level) + 1,25 m and N.A.P. + 1,65 m, or roughly between MHT + 0,25 m and MHT + 0,65 m. This is at variance with the general opinion, that the initial height should not be lower than MHT + 1,00 m. In the beginning indeed it looked as if the work yielded little result, especially on rough visual observation.

Fig. 5 shows a graph giving the sums of the acquired quantities of sand (in  $\text{m}^3/\text{m}^1$  drift-dyke) plotted against the years 1950 to 1963. The quantities have been determined by cubature of annual levelings. From this, as opposed to the superficial impression, it is apparent that the annual gain during the first years has not been less than later on (the depression in the graph relates to a year in which the dyke suffered considerable damage from a storm surge). The course of events during the first years is, that the sand, acquired during the drift season, is flattened to a "pancake" by the water during the winter season. In this way a wide base is formed, that does have a height of 1 m or more above MHT. Only after this stage has been reached, rapid heightening can be pursued. This means that, if the work has to be started at a low level, it is sensible to place the windscreens (to be discussed later) initially in such a way that width is gained rather than height. This makes it possible to adapt the width of the base consciously to the planned height of the drift-dyke. For instance, in the case under consideration, where a height of N.A.R. (national datum) + 7,0 m is pursued, the basic width should be 50 m at a level of N.A.P. + 2,5 m. Evidently these figures are strictly related to the characteristics of the prevailing tidal circumstances.

The graph of fig. 5 shows, that the total profit in a period

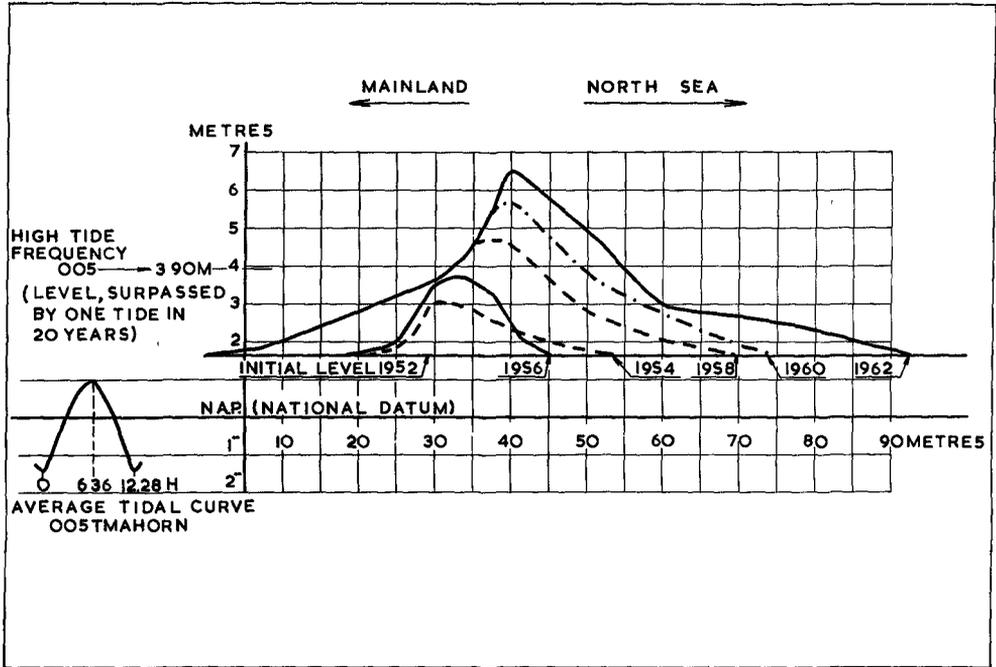


FIG 4 DEVELOPMENT OF THE DRIFT-DYKE LEVELING RESULTS IN A CROSS SECTION FROM 1952 TO 1962

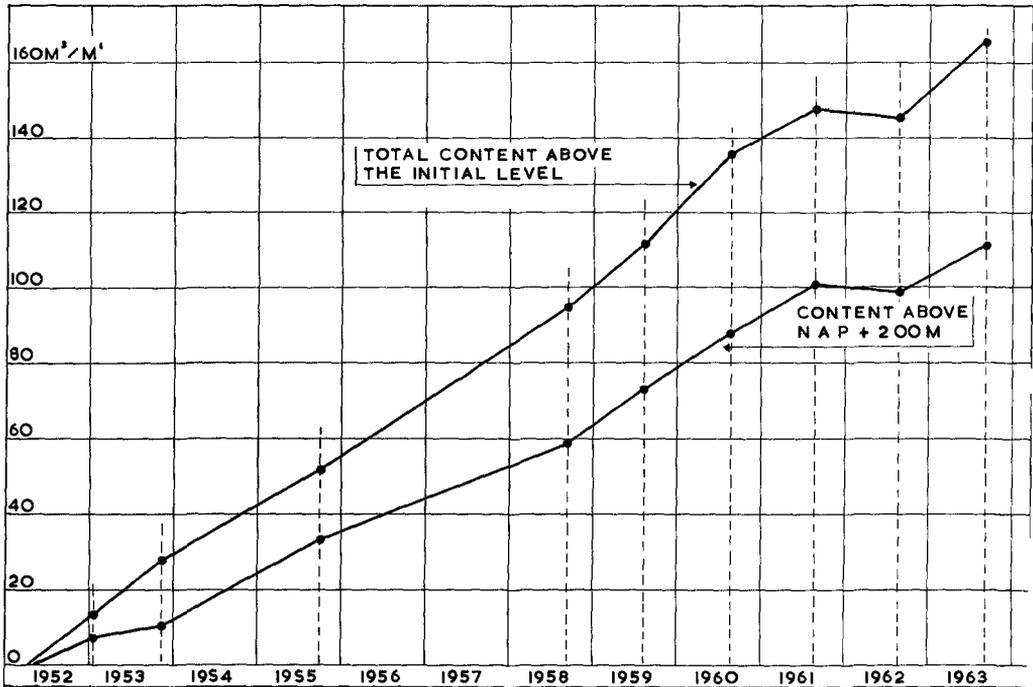


FIG 5 ANNUAL INCREASE OF SAND-CONTENT IN  $M^3/M^1$  OF THE DRIFT-DYKE ON THE ROTTUMERPLAAT

of 11 years amounted to about 160 m<sup>3</sup> per running metre.

### 3. TECHNICAL DATA.

For the technique of the construction of a drift-sand dyke two factors are of paramount importance: the determination of the most favourable layout-plan, and the method of catching the sand. Both are largely determined by local circumstances and by the result that is to be obtained.

a). The layout. On the Rottumerplaat two facts were established from the beginning: the ground-plan had to be joined to the existing dune at the south-easterly end of the shoal, and from there it had to run roughly in the longitudinal direction of the shoal, that is west-north-westerly.

To obtain more detailed information on the most favourable design a number of crosses was set up as shown in fig. 6. The crosses were made from brushwood-screens, and their object was to show where and from which quadrant the best catch of sand was to be expected. In the judgement on this, visual observation played an important part. The figures given in the sketch are based on the leveling of a single profile over the cross and are only meant to give rough figures for the ratios. More direct methods to measure the transport of sand across the shoal were unknown in those days, at least in the department in charge of the execution of the work.

The foregoing was regarded to be sufficient to determine the layout as given in fig. 2. Even now it is not to be seen that a different plan would have yielded better results, although experience has shown that favourable and less favourable conditions have played their parts.

Highly favourable is the exposition on the dyke with respect to the accumulation area and to the wind direction. Although winds from the north-east quadrant are not very frequent (they often occur during the spring), they have a strong drying effect and are accompanied with low sea levels. Indeed, an important part of the annual profit is often made during a few days with a strong wind

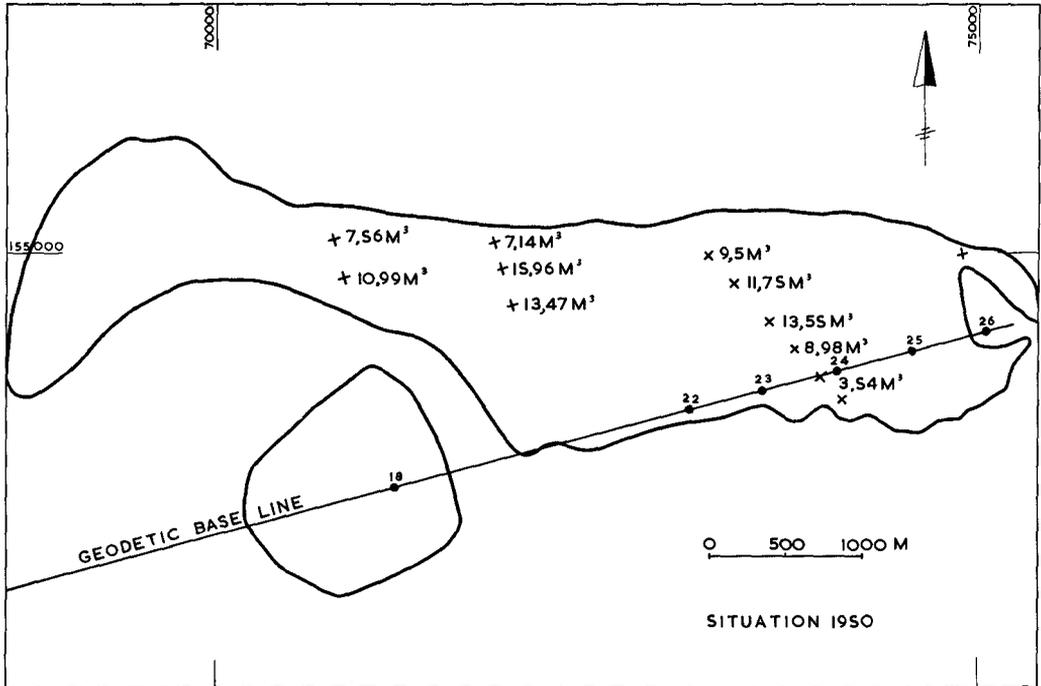


FIG 6 RESULTS OF DRIFT TESTS FOR CHOICE OF LAYOUT

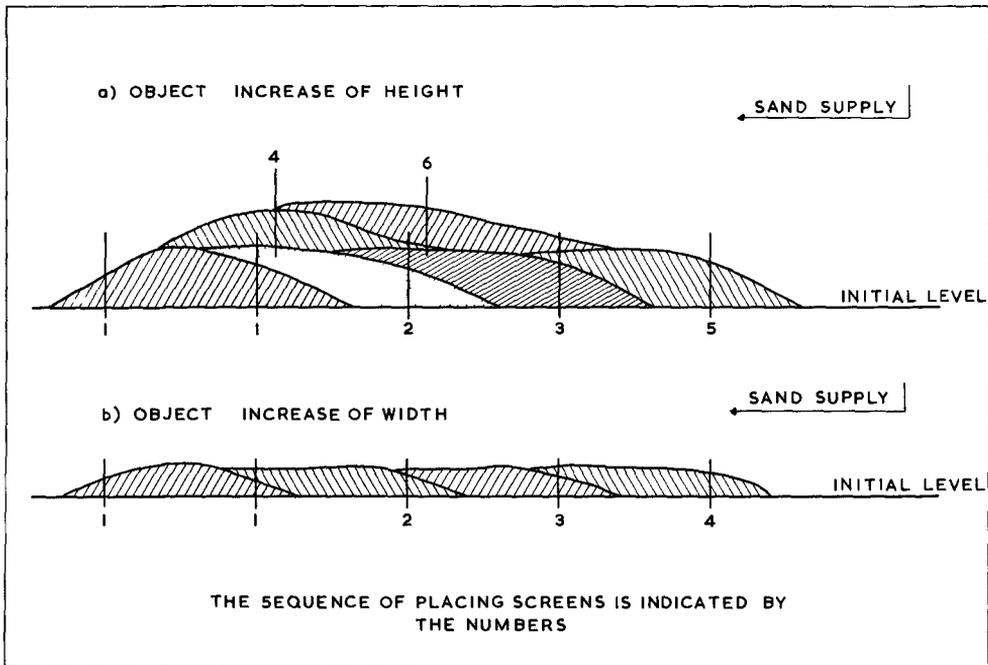


FIG 7 THE PRINCIPLE OF PLACING WIND SCREENS

between north and east.

This is not to say that a different exposition would prevent the possibilities of constructing a drift dyke: although winds from westerly directions are more humid and may, when sufficiently strong to cause drifting, be attended with high sea levels, they occur with much higher frequency in the Netherlands. The only requirement for a drift-sand dyke with orientation towards the west would be, that the level of the foreshore (accumulation area) must be considerably higher with respect to the local MHT than is the case on the Rottumerplaat.

The position of the ground-plan with regard to the accumulation-(production-)area is not equally favourable in all places. The relatively high foreshore, occurring along the entire northern shore, is regarded as accumulation area. The contours given in fig. 2 show, that the foreshore borders the drift dyke in some parts, but in others is divided from it by a depression. With time, the foreshore varies in width, in keeping with the formerly mentioned sand banks that either unite with the coast or are scoured away. During winter on the foreshore small parabolic dunes are formed, that supply material for the drift dyke during drift-winds in spring. In this way, the small dunes disappear relatively soon, but in favourable circumstances sands from the flat foreshore also drift towards the dyke.

Where the dyke borders the high foreshore, circumstances are generally favourable. Where, in front of the dyke, a depression is found, it appears that part of the drifting sand does not reach the dyke. Apparently this is caused, on the one side, by the fact that the sand is caught away by the depression itself, that is often still wet, on the other side, and especially, by the fact that in the low areas spontaneous growth of sand couch (*agropyron junceum*) occurs. In this way local dunes are formed, absorbing sand that otherwise might have served to build up the dyke. In these places the height of the dyke is appreciably inferior to that in places where there is no depression.

A general conclusion following from the foregoing is that, in

places where the first signs of growth appear in front of a drift dyke, this growth should be destroyed relentlessly. Once the growth has a firm hold, it is almost impossible to destroy. On the Rottumerplaat, where timely defrayal has been neglected, destruction of the unfavourable growth by mechanical means is now being considered

Even if all this would have been appreciated right from the start, it is doubtful whether this would have resulted in a different choice of the layout: the width of the foreshore does not only vary with time, but also from place to place. For the following reasons the dyke should not approach the MHT-line too closely: 1. A landward shifting of the MHT-line (shrinkage of the foreshore) must never result in a threatening, not only of the dyke itself, but also of the accumulation area; 2. As will appear later the method of catching sand involves, that the gaining of height, which is coupled with the gaining of width, goes in seaward direction; 3. Should it become desirable to build a second dyke or belt of dunes, this has to be done on the seaward side, as the existing dyke would prevent the winning of sand on the landward side (in all probability, this point will have no bearing on the Rottumerplaat).

b). The catching of sand. The catching of sand is realized using screens made from brushwood (osier) or reed (photographs nr. 1 and 2). In principle two systems are practicable.

1. Utilization of low screens: in case (e.g. in the first stages) width is pursued, or if, later on, the foot of the dyke has to be built forward before a further heightening is realized.

2. Utilization of high screens, which makes it possible to gain height rapidly.

The two systems are schematically shown in fig. 7. It must be stressed, that these sketches are indeed schematical, as for practical purposes it is necessary to judge in the field, in what place a new screen can be expected to yield the best results. The rather simple general principle is to set up for instance two rows of screens in longitudinal direction of the dyke, and, as soon as these screens have been almost buried by sand, to set up more rows on top and in

front of the elevation, and so on.

In the Netherlands, brushwood and reed are used, because these materials are easily available, and have the desired properties. On the one side, the screens must be sufficiently close to paralyse the air stream in such a way, that it drops the sand it carries, on the other side they must be sufficiently open to prevent collapse under the load of the sand deposited in front of the screen: an entirely closed screen would result in deposition of sand only in front, and hardly at all behind the screen. Here, the flexibility of the material is also an important factor. The desirable degree of openness might be described by the term "half transmitting wall", The result is, that in front of, as well as behind the screen sand is deposited, thus gradually improving the support to the screen. This will only become completely buried after the placing of new screens on top of the obtained elevation.

As to the materials used: part of the screens are made from so-called "Hollands rijshout", (a name, indicating quality and species of the brushwood branches and twigs, as well as measures of these branches and of the bundles). This material is supplied in lengths between 1,5 and 2,5 m, bound together at the upper and lower ends to form bundles 0,4 m or 1,0 m round. The smaller bundles, after removing the upper band, are put into the ground as they are, the larger ones are taken apart and spread out. Also, on the Rottumerplaat, the so-called "Biesbos" - reed is used, that is supplied in bundles, long about 2,5 m, and 1,25 - 1,5 m round. After having been sawed to lengths of about 1 m, these bundles are taken apart. A groove is dug out, into which the material is placed in a vertical position. For brushwood, the depth of the gully is 0,35 - 0,45 m, for reed 0,25 - 0,30 m. It is important to take care, that the upper edge of the screen is straight and horizontal. Depressions in the screen are reproduced in the dyke, which, at a later stage, may result in wind-erosion.

The mutual distance of the screens and the number of screens to be placed per season, are factors that have to be learned from experience, and that will also depend on circumstances. It is

possible to catch about  $5 \text{ m}^3$  of sand per running metre between two brushwood screens at a distance of 5 m. To catch  $15 \text{ m}^3/\text{m}^1$  it is therefore necessary to place at least 4 screens. When utilizing low (reed-) screens, a larger number has to be placed.

In this context, too, it might be useful to be able to carry out quantitative measurements of the transport of sand. It is doubtful, however, whether their usefulness would be very great, as the result at best would be some knowledge on transport-capacity. This knowledge would not enable to predict anything about the quantities that will actually be transported in any given season. No method of measuring is known at present, sufficiently accurate to determine the ratio between material transported and material caught.

On the Rottumerplaat the quantities of sand caught are being verified by annual levelings.

c). Special features. Because of the function assigned to the drift dyke (base for future damming projects), already mentioned in the introduction, and because the Rottumerplaat is an uninhabited island this work occupies a special place in the Netherlands. Contrary to the situation in most of the other cases, the sea, at high flood levels, has access to this drift dyke from all sides. Moreover the dyke, by its very seaward position, is exposed to frequent and dangerous attacks of the sea. This became apparent during the storm surge of 16<sup>th</sup> and 17<sup>th</sup> february 1962: a breach was formed at the bend of the dyke to the north-west of the initial dune (fig.2). The storm blew predominantly from westerly directions, resulting in a very exposed position of the bend with respect to the currents caused by the wind. The breach was about 150 m long and was subsequently closed by mechanical means.

The island is not only uninhabited, but it is also, during the winter months, practically inaccessible. Only during the working season (march to october incl.), workmen are on the island on behalf of the drift dyke. Inspection or repairs are impossible during winter. For this reason, screens are placed at the end of the season, that run a great risk of being swept away. Their main object is to catch sand during favourable winds in early spring, when work on the

island is still impossible.

In this context it may be useful to state, as a general remark, that it is not practicable to build drift-sand dykes without consciously accepting risks. Beside understanding and experience the factor chance plays a more important part than in other hydraulic engineering works. As however, even if set-backs occur, a drift dyke is considerably cheaper than any other construction, this element can be accepted, on condition, that no narrow time limit is set to the completion of the work.

#### 4. THE STABILIZATION OF SAND ON THE DRIFT DYKE.

One of the subjects discussed in the foregoing was the method used to catch the sand. The sand caught in this way is, however, an incoherent mass and may, in dry weather, be lost owing to an unfavourable wind. It is important, therefore, to take measures as soon as possible to stabilize the sand.

It is conceivable to realize this by artificial means, such as bituminous products or cement. Such a method would, however, raise the expenses to an unnecessarily high level, and would be opposed to the real aim: the creation of a dune, as far as possible by natural means. A temporary fixation can be rapidly obtained by using dead plants or their remnants; seaweed is sometimes used (it is often found in large quantities on the spot), and also straw.

Normal practice, however, on the Rottumerplaat and elsewhere, is to stabilize the sand by means of plantation. Generally speaking, it will be correct to use plant-species, belonging to the surroundings and the climate of the area, where the drift dyke is built. On the Rottumerplaat and elsewhere in the Netherlands the most frequently used species are marram-grass (*am m o p h i l a a r e n a r i a*), lyme grass (*e l y m u s a r e n a r i u s*) and sand couch (*a g r o p y r o n j u n c e u m*). The suitability of these species mainly depends on the level at which they are planted. Sand couch and lyme grass can endure several floodings by salt water per growing-season, and can be planted at minimum heights of MHT + 0,50m and MHT + 0,75 m, respectively. For their growth they are dependant



**FIG. 8**                      **Photograph nr.1**  
**Brushwood screen.**



**FIG. 9**                      **Photograph nr.2**  
**Reed screen.**

on the supply of fresh sand, from which they mainly draw nitrogen. For this reason it is not possible to give a generally applicable highest level at which these plants can still grow. Both species are eagerly sought after by rabbits for their food. Fortunately, these animals do not occur on the Rottumerplaat. As far as possible, rabbits should be kept down in places, where drift dunes or - dykes are being constructed, as they hamper the growth of the dyke. This has, for instance, become apparent on the island of Rottumeroog (to the east of the Rottumerplaat), where rabbits do occur.

For marram grass, requirements with respect to its growing place and to circumstances are less specific. It frequently occurs, therefore, in older dune formations. It is planted in those places, where the previously discussed species do not grow so well, generally on the higher levels. The photographs nr. 3, 4 and 5 may serve to illustrate the various types of growth.

The growth is able to spread by natural means, but, as long as heightening or lengthening of the dyke is actively pursued, this is not sufficient. The expansion of the vegetation is promoted by the vegetative or by the generative method. The latter is the cheapest, but the results vary. When using the vegetative method, parts of the plants are cut off and planted again; this is generally successful. Of course the method and time of planting, the density with which the vegetation is planted etc., are factors that influence the result. Local circumstances, experience and biological know-how have to show the way in this respect.

In circumstances as outlined above, and provided the planning is good, the cost of planting is low. In the case of the construction of a new drift dyke in an area without vegetation, however, it is necessary to supply all the plants to the site, which may result in high initial cost of plantation.

It should be mentioned, that plant-diseases and insect-plagues have, as yet, hardly at all influenced the work on the Rottumerplaat. In the first stages, here and there artificial fertilizers were applied, but later this was stopped in order to stimulate the development of a natural plant-association.



FIG. 10

Photograph nr.3  
Marram grass  
(*ammophila arenaria*)

FIG. 11  
Photograph nr.4  
Lyne grass

(*elymus arenarius*)



FIG. 12  
Photograph nr.5  
Sand couch  
(*agropyron junceum*)



FIG. 13                      Photograph nr.6  
Shrubbery on the Rottumerplaat  
Creeping willow  
(s a l i x   r e p e n s)



FIG. 14                      Photograph nr.7  
The oldest part of the drift dyke,  
seen in north-westerly direction

The most important aspect regards the question concerning the part of the dyke that should be protected by plantation. One possibility is to plant on the outer talus. A large part of the sand then drifts over the dyke and causes the inner talus to grow, which means, that the growth of width of the dyke takes place on the landward side. Elsewhere, this method is applied successfully. On the Rottumerplaat, however, the aim is to catch the largest part of the sand on the outer talus, as fig. 7 shows. The growth of width now takes place in seaward direction, and it is indicated to cover the inner talud with plants, up to the top of the dyke or a little further. In this case, planting of the outer talus would have little effect, because the quantities of sand caught are so large, that the vegetation would be smothered.

The reason why this method is applied is the open position of the drift dyke. The "landward" side is exposed to attacks from water and wind, whilst no accumulation area is found on this side.

A third possibility is to cover the entire dyke with plants. If this is done right from the start, wind screens can, at least theoretically, be omitted: this is the principle of organogenic formation of dunes. The quantity of sand caught by the vegetation is such, that the growth of the plants can keep pace with the increase of height. Advantages of this method are, that it is, at least as far as maintenance is concerned, less labour consuming; that the chance of succes is better, and that, to a certain degree, the profile is stronger because of the intricate system of roots. A disadvantage is the considerably slower rate of growth. Moreover, a condition is, that the initial width must be larger than with the other methods. Also, it is necessary that the height at which the work is begun be such, that floodings of the site are rare.

Experiments with organogenic dune formation on the Rottumerplaat have met with little succes. This has been traced to the circumstance, that the experimental sectors were bordered by sectors with wind screens. The idea is, however, to cover the entire surface with vegetation as soon as the dyke will have reached a desired minimum profile. Further growth will then be slower, but it is hoped

that the resistance of the dyke will increase.

With regard to planting the following additional remarks can be made:

a). Implements. A specially designed plant-spade is used, a.o. for the planting of marram. A normal spade, however, is very suitable, for planting as well as for lifting.

b). In addition to the plants that have already been discussed, in recent years also various types of shrubbery have been planted. With this object, a nursery was set up on the mainland. Among the shrubs used are creeping willow (*s a l i x r e p e n s*) and other types of willow, sea buck-thorn (*h i p p ó p h a ã r h a m n o ï d e s*), box-thorn (*l y c i u m h a l i m i f o l i u m*) and abele (*p o p u l u s a l b a*). The aim is to strengthen the dyke by a close shrubbery and the deep and intricately branched system of roots that goes with it. This type of vegetation, however is as yet nowhere sufficiently close to justify an opinion on the results (see photograph nr. 6).

c). Under the lee of the dyke a spontaneous vegetation develops. The type of vegetation depends on the height of the territory, on the groundwater level, on whether or not the area is cut off from the sea, etc. It would carry too far to discuss this in more detail. Behind the dyke on the Rottumerplaat a reasonably varied flora has developed.

Photograph nr. 7 was added to give a general impression of the oldest part of the dyke on the Rottumerplaat.

##### 5. LABOUR PERFORMANCE AND COST.

Detailed data on achievement per man and cost of the dyke are not available. There are, however, some rough figures that may be worth mentioning.

With regard to the placing of screens, there are many circumstances influencing the pace of the work. It is, for instance, unfavourable, if on or below the surface wreckage-wood is found, or if the screens have to be placed in freshly accumulated sand, where

the grooves cave in as soon as they are dug. If such circumstances do not occur, and if the material is supplied and distributed in such a way, that unnecessary moving of persons is avoided, it is possible to obtain a mean performance per man per 9-hour work-day of 145 m length of screen put up.

The performance with planting depends on the distances between plants. For sand couch these vary from 0,5 x 0,5 m to 0,75 x 0,75 m, for marram grass and lyme grass from 0,3 x 0,3 m to 0,5 x 0,5 m.

As a guide it may be mentioned, that the mean performance per man per day is about 75 m<sup>2</sup> when the plant pattern is 0,3 x 0,3 m, and about 175 m<sup>2</sup> at 0,5 x 0,5 m.

As regards the cost a rough calculation shows, that during the first years fl.1.-- (Dutch guilders) was paid for each m<sup>3</sup> of sand; at present this is about fl. 0.50. Taking the average of these figures, and taking into account that the total gain amounts to 160 m<sup>3</sup> sand per m<sup>1</sup> dyke, the result is that up to the present the dyke has cost about fl.120.-- per m<sup>1</sup>. This includes only the cost of wages and material. Owing to the special circumstances on the Rottumerplaat, cost of housing and cost of transport of men and material to and from the shoal have to be added. According to a rough estimate this doubles the total expenses, which would mean that a price of fl. 250.-- per m<sup>1</sup> dyke in the present situation may not be far off the truth.

#### ACKNOWLEDGEMENT.

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