Chapter 18

THE DISASTER IN THE NETHERLANDS CAUSED BY THE STORM FLOOD OF FEBRUARY 1, 1953

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SITUATION OF THE NETHERLANDS WITH REGARD TO THE NORTH SEA.

It will be useful to show first a sketch of the situation of our low lying area with regard to the North Sea (Fig. 1). We might idealize the North Sea in the shape of a rectangular pocket, nearly 400 miles wide and 500 miles long, open to the Atlantic in the line Duncansby (Scotland) - Bergen (Norway). For its size the North Sea is relatively shallow. The depth is of the order of magnitude of 60 m. The funnel-like Southern part, between England and the Netherlands, is not more than 40 m deep. The average width of this part is 250 miles.

Figure 2 shows the peculiar topographic nature of the Netherlands. The more elevated Southeastern part may be regarded as the real delta of the rivers Rhine and Meuse. This area is entirely above the highest floods of the North Sea. The lower part initially was a lagoon, sheltered from the sea by a barrier beach built up by the sea. Originally this barrier was a riff of elongated sand banks, gradually they were heightened by waves and wind. Behind this protecting barrier the sea and the rivers deposited sand and silt, on which a marshy vegetation flourished. All the time the vegetation was submerged by the sea and successfully struggling to keep above the water. In this way the lagoon has been built up by formations of peat and marine clay and sand to about the level of normal astronomical high water. This is today the low part of our country, defended against the sea by 2000 miles of dikes. An important part of this area consists of reclaimed lakes, with the height of the land from 2 to 5 m below mean sea level. This situation has not been permanently established and it cannot be considered as stabilized. There are two factors which not only keep the menace of the sea alive but even strengthen it gradually. These are:

a. The gradual settling of the layers of soil which have filled the lagoon; as a result the level of the land, including the bases of the dikes and the dikes themselves, is lowered slowly. In some cases the crest of the dike has subsided 2 m in 400 years. That indicates an average sinking of 50 cm per century by a process of soil mechanics.

b. The territory of the Netherlands is subject to a gradual sinking relative to the sea level of about 15 cm per century. Therefore the height of the stormsurges slowly raises.

It is clear that on account of these two causes the situation of the Dutch polderland has steadily grown more difficult during the centuries. This has become apparent with fearful clarity in the recent years. A great handicap for a thorough investigation of this vital problem is the lack of accurate records from the past.

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Fig. 1. Low lying area of the Netherlands with regard to the North Sea.

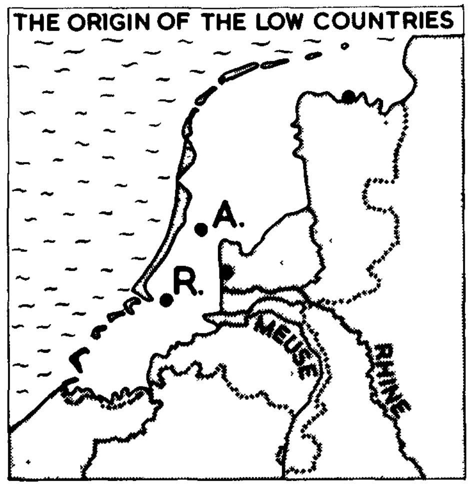

Fig. 2. Peculiar topographic nature of the Netherlands.

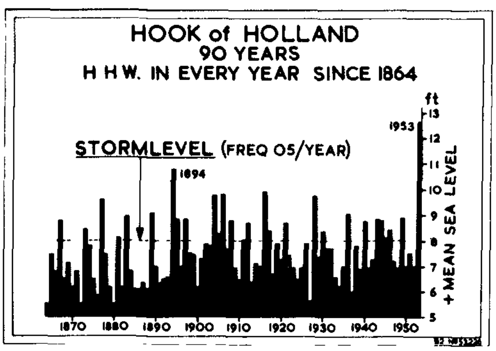

Fig. 3. Diagram of the yearly maxima of storm surges from 1864 to 1953.

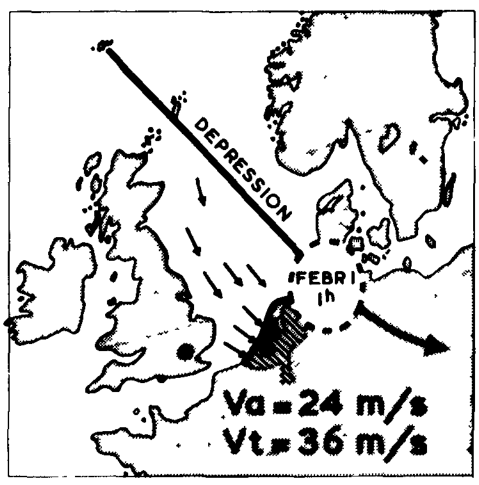

Fig. 4. Track of the depression and position of the storm center at the moment of the beginning of the disaster.

Moreover, extreme floods are not well defined fixed phenomena. They range within a wide scale of possibilities. A systematic change in the pattern of this scale can only be detected by means of an extensive statistical study. Without such a study it might escape the attention altogether.

The insight necessary for a methodical treatment of this problem has been developed only during the last 10 or 15 years. This has led to a new search for data from the past. Included is an investigation of the atomic structure of Carbon in organic deposits from old settlements, N_{13}, C_{14}, C_{12}, by which the age of layers can be detected within an accuracy of two or three hundred years.

The tidal motion of clearly semi-diurnal type is naturally accompanied by powerful tidal currents in the estuaries. Near the mouth of some of the estuaries the discharge at the moment of maximum flood or ebb current is 100,000 m^3/sec. Twice a day these huge tidal currents run in and out the estuaries. They have a maximum velocity of $1\frac{1}{2}$ to 2 m per sec. They scour channels in the sand to a depth of 30 to 40 m and in some places even more. Until recently technical possibilities were entirely inadequate for closing off inlets of this size. Moreover the discharge of the rivers Rhine and Meuse has to find its way seaward through these estuaries. It is clear there was no choice but to accept the situation handed down to us by history.

The normal tidal motion is subject to continuous disturbance by wind. As a rule this amounts to but a few inches and is seldom greater than two feet.

Regular daily observations were not started before the middle of the nineteenth century. If we prepare a diagram (Fig. 3) of the yearly maxima for the 90 year period, 1864 to 1953, we obtain an insight into the varying characteristics of tho storm surges. Sometimes long periods pass without any serious storm surge. For tens of years the serious gale of 1894 has been considered as an extremely high one. In any case it has been made painfully clear to us in February 1953 that nature does not recognize any limit that has been prematurely impressed on the human mind.

From statistical considerations developed in recent years* we know that theoretically we will have to reckon with much higher floods than have been known in the past, and which will surpass even the 1953 flood.

On the strength of this consideration, the work of re-establishing the decreased safety had already been started. Newly constructed dikes and the large enclosure dam of the Zuiderzee, for example, already had been given considerably higher crests. But the disastrous storm surge in the beginning of this year overtook us before we were ready to meet it.

THE GALE OF FEBRUARY FIRST

From a meteorological point of view the gale of 1953 was different

*P.J.Wemelsfelder - Wetmatigheden in het optreden van Stormvloeden. (A statistical investigation on the probability of storm surges) De Ingenieur 1939 No. 9

from other heavy gales in two respects:

a. It had an extremely long duration.
b. The track of the storm was very unfavorable for our country

If we investigate the tracks of storms which caused earlier high storm surges we find tracks traveling over Great-Britain, particularly over Scotland, in an eastward direction and disappearing over Norway or Denmark. The gale of February 1 is markedly different from this well known type (Fig. 4). This time the center of the depression of the storm has crossed the North Sea diagonally from Scotland to Hamburg. During all this time the wind to the right hand of the center was Northwest and consequently it was directed straight toward our coast. The sketch gives the position of the center of the depression at the moment of the beginning of the disaster. Evidently the track of this storm was extremely bad for piling up water against the Dutch coast. As long as meteorological data has been gathered, never has such an undesirable storm been observed. However, this gives information over only half a century.

On February 1 the wind velocity in the vicinity of the coast was about 24 m/sec. with gusts up to 36 m/sec. If we draw a diagram of the wind effect at the time of high water at different stations we obtain a fair picture of the geographic features of the storm surge (Fig. 5). On the East Coast of Great Britain, the wind effect is little more than 2 ft. at Leith in Scotland. Going South, the effect increases, reaching 8 ft. in the Washbay and 7 ft. in the Thames Estuary at Chatham, both enlarged in comparison with the raise in the line of the coast due to the normal funnel effect in bays. Toward Southampton the curve shows a sharp decline, as has been represented by the dotted line. But if we cross the Channel from Dover to Calais and proceed in a northeast direction along the other shore, we see a sharp rise past Ostend and Flushing to the Dutch Coast. Here the increase in level over the astronomical height of the tide extends to 10 ft. The summit of this curve extends all along the West Coast of Holland. At Den Helder the coastline curves to the east and from here we find a considerable decrease of the wind effect. In the German Bight it is but 4 to 6 ft., and in Denmark it is less than 3 ft.

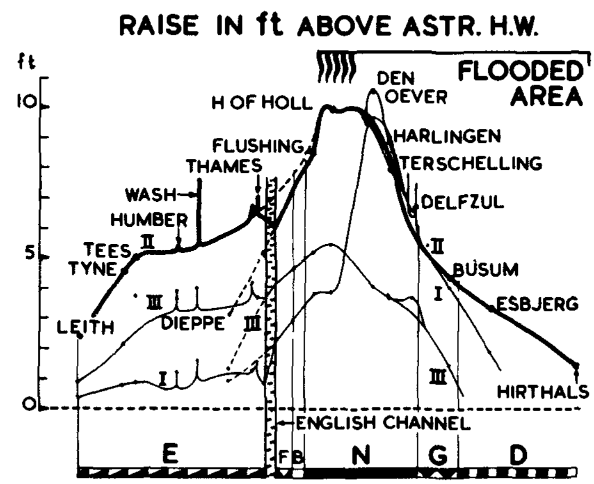

Fig. 5. Diagram of the wind effect at the time of high water at different stations.

At the bottom of the diagram in Fig. 5 there is given an indication of which parts of the coast belong to England, France, Belgium, the Netherlands, Germany and Denmark. As one can see the highest

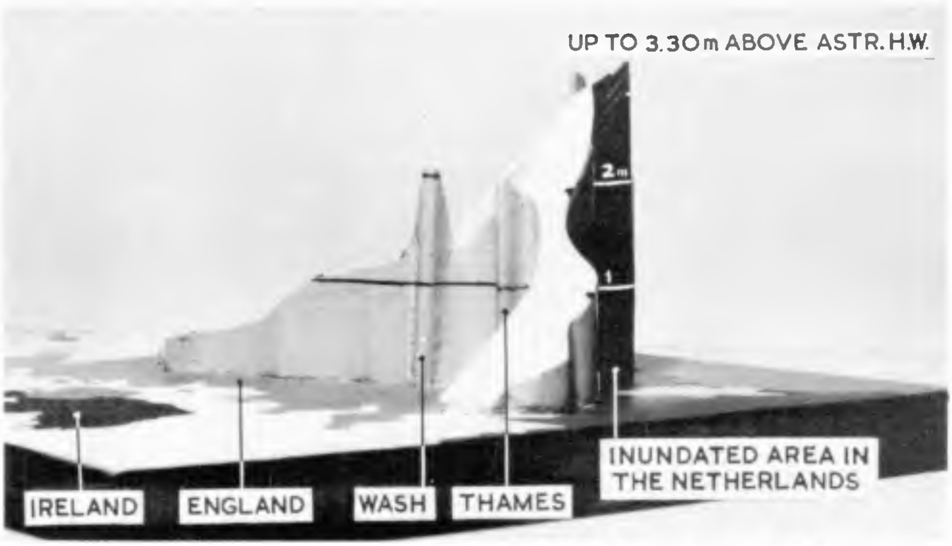

Fig. 6. Photograph of a model showing, to an exaggerated vertical scale, the elevation of the water level at the time of highest high water above the astronomical high water. Note the extreme height along the Dutch Coast, the Wash, the Thames and the English Channel.

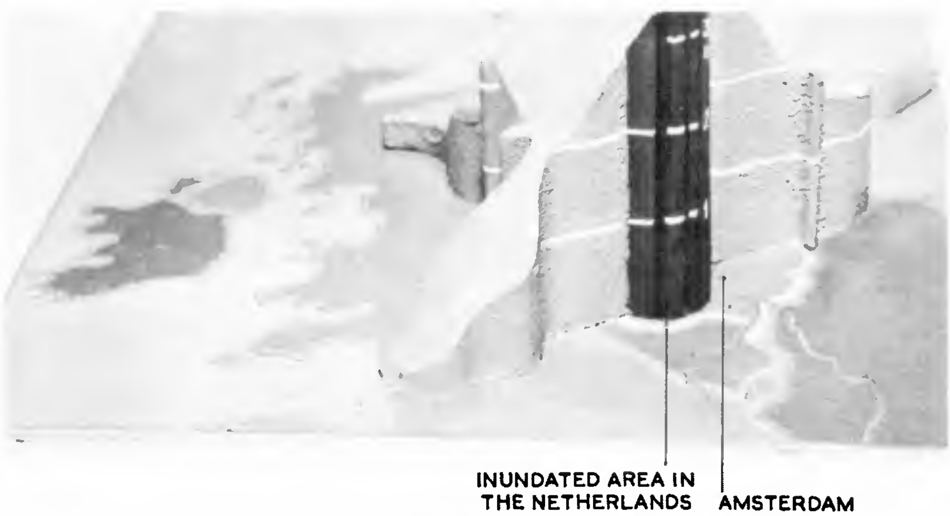

Fig. 7. The same model as in Fig. 6, seen in the northern direction. The dark part represents the estuaries in Zeeland and Suidholland, the center of the catastrophe.

elevation above the normal tide took place just along the coast of the Netherlands.

As an aid to our discussion of the problem a small model of the North Sea was constructed. The same figures of the rise above astronomical high water of Fig. 5 are in this model, placed vertically (Figs. 6 and 7). What is seen here is not the true level of the sea at the moment of the disastrous flood, but the excess elevation due to the wind.

It should be noted that this model does not represent the inclination of the sea at one single moment during the storm surge, since the moments of the astronomical high water do not occur simultaneously at all points. Every high tide enters the North Sea north of Scotland. It then moves along the East Coast of England in a southward direction. It crosses the Seven Straights, at the same moment joining with the tidal wave coming from the Channel, the latter being only a small part of the whole tidal motion. Then the tidal wave turns along the coast of the Netherlands to the northeast and up to the German Bight and Denmark.

The surge appeared at 4 PM on January 31 in Leith. It then passed to the Straits and arrived there at midnight. It reached the greatest elevation about Hook of Holland at 2 o'clock in the early morning Sunday, February 1, 1953. At 8 o'clock the surge was at Den Helder and then disappeared toward the east.

You will remember that the British East Coast and the Belgium Coast along the Scheldt also were stricken by the flood. It was the Netherlands, however, that had to bear the brunt of its violence. It is clear from Figs. 1, 6 and 7 that the attack of the storm surge was concentrated particularly on the Dutch coast. Taken roughly the wind effect here was twice that on the East Coast of Britain. As you know, the catastrophe occurred in the dead of night from Saturday to Sunday. Eyewitness reports are few. A photograph (Fig. 8) made at daybreak at Flushing near the mouth of the Wester Scheldt, conveys a feeble impression of the violence of a turbulent sea assaulting the shore defenses.

Fig. 8. An illustration of the violence of the turbulent sea, made at daybreak near the mouth of the Wester Scheldt at Flushing.

The effect of the gale on the water level as a function of time can be seen from the gage records at Rotterdam (Fig. 9). The diagram shows the recorded curve together with the predicted tidal curve. It is seen that:

a. The wind effect increases and decreases roughly linearly. The irregularities are of little importance. There are no sharp peaks discernable.

b. The maximum storm effect fortunately did not coincide with astronomic high water, but it occurred near low water. This maximum amounts to 3.70 m. At high water it was but 3.0 m.

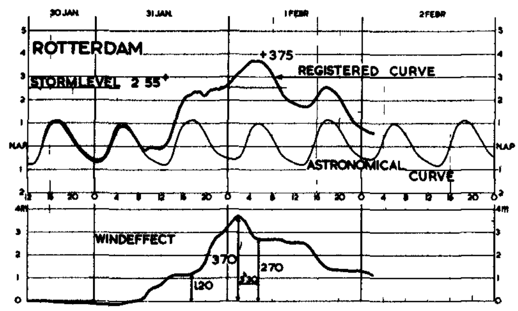

Fig. 9. Diagram of recorded and predicted tidal curve at Rotterdam.

The corresponding diagram of Hook of Holland shows a similar shape. At the moment of high water, the wind effect amounts to 3.0 m The largest wind effect occurred 3½ hours before high water. It amounted to 3.3 m (11 ft.). There was an additional set-up between Hook and Rotterdam of 0.4 m, partly due to the piling up of the Rotterdam Waterweg by wind and partly due to funnel effect.

The exceptional character of the storm surge appears from its location on a frequency curve. The diagram (Fig. 10) shows frequency curves for three stations along the Scheldt. The highest levels for a period of 90 years are all represented in the diagram. The height, H, is entered on a linear scale in a vertical direction, the number, N, on a logarithmic scale in a horizontal direction. The frequency curves in this diagram show a fairly smooth curve. They are not entirely straight, nor should they be straight on a Gaussian scale, a Gumbel scale or any other scale. No theoretical discussion will be presented; however, the single example we have here is sufficient to show the inadequacy of any simplified method to represent the rather complicated true condition. For practical reasons we often prefer the semi-logarithmic paper as being the most simple to use.

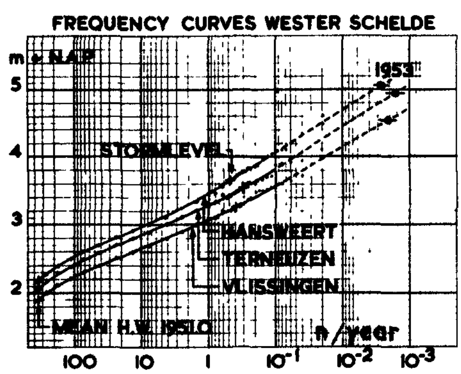

Fig. 10. Diagram of frequency curves for three stations along the Scheldt, showing the extent to which the 1953 level exceeded the levels recorded before.

A plausible extrapolation on this paper would lead us to assume for this super-gale a frequency of 0.0025, or once in 400 years. The diagram shows the extent to which the 1953-level exceeded the levels recorded before. In this light it is admitted that practically nobody expected the occurrence of such a storm. The disastrous consequences will no longer be surprising. In the entire territory of the Southwest Netherlands the levels were 50 to 70 cm above thè highest levels that have ever been recorded.

THE ATTACK ON THE DIKES AND THE INUNDATION

During the gale of February 1 the water levels in themselves exceeded by 50 to 70 cm the design levels of the dikes. Hence the water level came near to the crest of the dikes and overflowed it at many places, especially in harbors and other sheltered spots where strong waves never penetrated and the safety margin of the crest level was small. As a result of this the dikes were damaged over many miles, and in many places they were washed away completely.

The damage practically never started at the outer side of the dike as one would usually think, but always at the inner side. Fig. 11 shows a dike that has been damaged but not pierced. The sea is to the right, the land was to the left. As you can see, the inner face has been eroded away by the water flowing over the crest. This occurred not at only a single point, but over tens of miles one could find the same condition.

From this and similar evidence it appears that the catastrophe was not the result of insufficient maintenance. The dike faces opposed to the enemy are still intact. The extreme high water level has led to an attack from the rear for which the earth-dikes were not adequate.

The first stage of the attack can be seen in Fig. 12. The sea is to the left, the land to the right. On the crest of the dike a low concrete wall has been constructed, in order to prevent the waves from overtopping the structure. It was not sufficient for this super-flood At the landward side of the crest a lengthwise fissure can be seen. It can be interpreted as the start of a slide in the water-saturated earth of the dike, caused by the strong pressure difference in the ground water. The water dashing over the crest penetrates into these fissures and this has frequently resulted in a rapid collapse of the dike (Fig. 13). In many places the dike has been washed away to the base, sometimes over several miles at a stretch.

Still much more serious were those cases where the jetlike flow bursting through the dikes cut out a gully straight to the interior. Where that occurred the sea had not access merely to the polder for one tide, but a fatal connection had been established between the estuary and the polder (Fig. 14).

The strong tidal motions in the estuaries made millions of cubic meters of water flow twice daily in and out of the polders. The differences in level at the breaches were 2, 3 or even 4 ft. giving rise to flow velocities of 4 to 5 m/sec. It is not surprising that in one case in a short time a channel was scoured 30 to 35 m in depth and 500 m in width, through which four times a day powerful currents occur to fill up and to empty again the polder.

Fig. 11. A damaged dike. The sea is on the right and the land was to the left. Damage occurred at the inner side.

Fig. 12. The first stage of the attack. The fissure on the crest is caused by the strong pressure difference in the ground water.

Fig. 13. The jetlike flow cut out a gully straight to the interior.

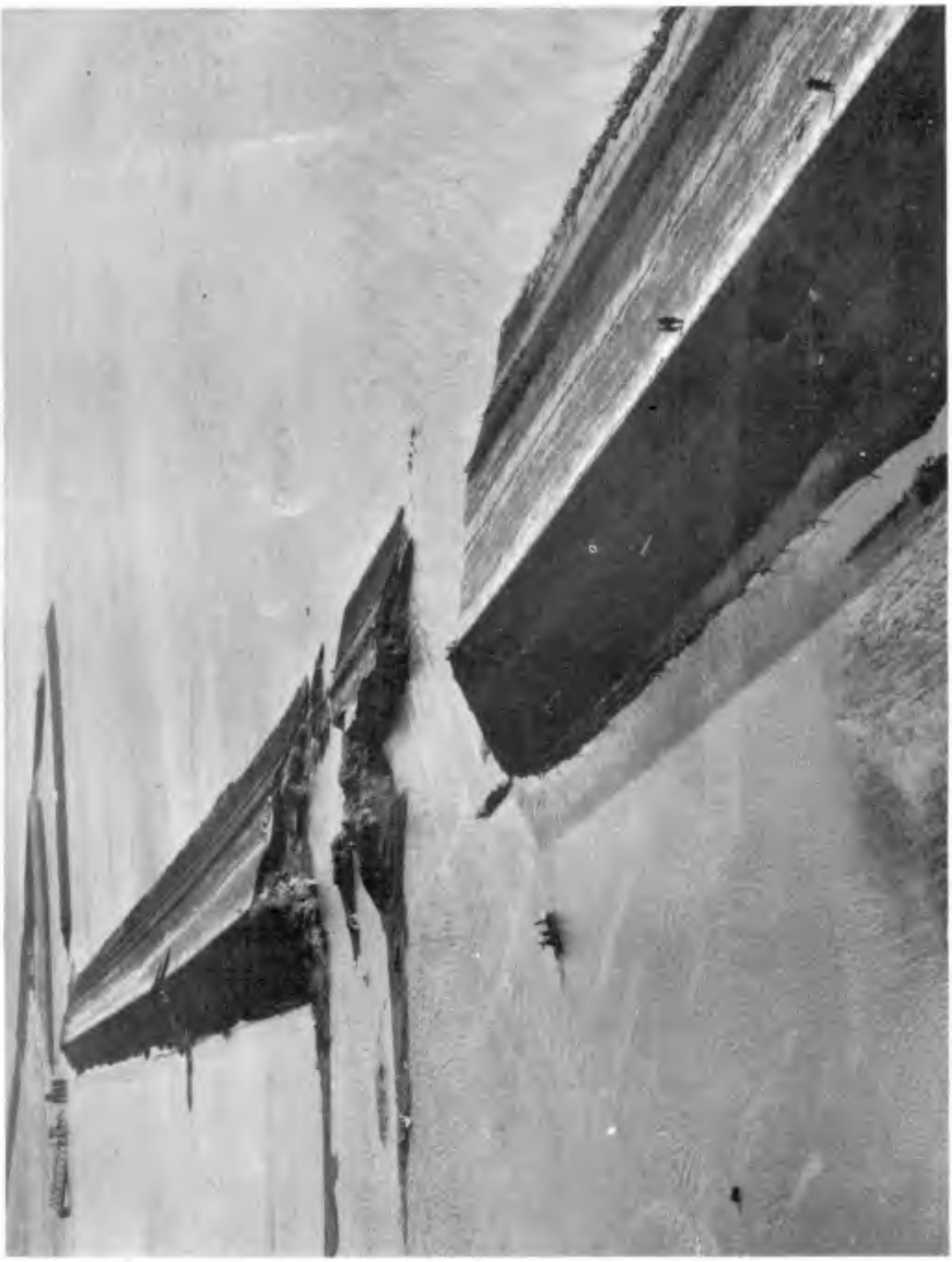

Fig. 14. Collapse of a dike.

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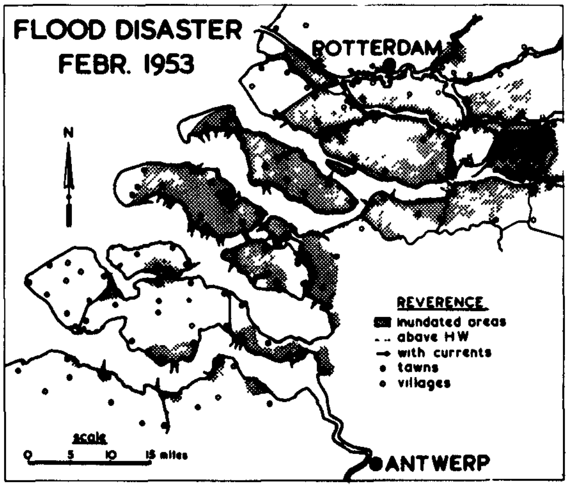

Fig. 15. Flooded Areas

The map (Fig. 15) shows the flooded areas. The stretches showing serious damage are indicated by small black squares. The arrows indicate the 67 breaches with fierce tidal currents. Where the sea defences gave way over a great length, the impact of an advancing steep waterfront struck down several houses and farms (Fig. 16). Other buildings were damaged later because of wave action in the inundated polders. Interior dikes, dividing the polders to a certain extent into smaller sections, did not protect the polders situated farther from the shore. The sections immediately behind the dikes were filled rapidly to sea level (Fig. 17) and from these the water overflowed the secondary dikes into the adjoining polders. This explains the enormous extent of the inundations.

A summary of the damage gives the following figures:

200,000 ha (800,000 acres) were flooded;
1783 men, women and children drowned;
100,000 people were evacuated;
47,300 houses were damaged, from which
9215 were badly or irrepairably damaged.

The damage to dikes, buildings, agriculture, livestock, etc. is estimated at 250 million dollars. The tidal currents, continually flowing in and out destroyed in little time, often on the first day of the disaster, the roads in the polders (Fig. 18) rendering it impossible to transport heavy equipment for rescue purposes. Hence it was extremely difficult to reach the villages and give immediate aid so urgently needed.

I feel compelled to mention here the extensive help which was offered in those days from all over the world. Especially I may bring here into remembrance the rescue effected by a large number of helicopters of the United States and other countries by which the lives of more than 2000 people were saved who could not have been helped in any other way. These signs of a growing brotherhood among men have met in the Netherlands deep feelings of rejoicing and gratitude.

Fig. 16. Damaged houses and farms.

Fig. 17. Water overflowing the secondary dikes.

Fig. 18. The tidal currents destroyed the roads in the polders in a short time.

THE DISASTER IN THE NETHERLANDS CAUSED BY THE STORM FLOOD OF FEBRUARY 1, 1953

PROJECTS

After the sea had displayed its power of aggression, with not a little more fury than we had thought possible, the general opinion favors radical measures for an adequate protection of the Low Countries in the future. For this purpose extensive studies are in progress, under the direction of a board of prominent experts called the Delta-Commissie. The answer of the Low Countries to the challenge of nature in the beginning of this year will be:

1. The reclamation of the flooded areas, the rebuilding of the damaged farms, buildings and houses and the restoration of the agricultural possibilities of these fertile soils.

2. An investigation into the possibility of the enclosure of three of the five large estuaries in the southwestern part of Holland.

3. An investigation of the strongest possible gale and highest possible storm surge with modern oceanographic and hydrodynamic scientific means and the fixation of the design storm to some 2 or 3 ft. higher than the level of 1953.

4. The enlargement and heightening of the dikes as far as they remain exposed to gale effects.

5. Improvement of the dike-army of the local residents who come into action when there is any danger to limit destruction in the very beginning.

6. Improvement of the storm-flood-warning system and the forecasting from meteorological data.

These points give us a program for tens of years. Concerning the first point, the reclaiming of the inundated areas, we have already made great progress. From the 67 breaches with fierce tidal currents, 66 are already closed and we hope that the last one will be closed in the near future.*

As to the other five points of this large program, the reports of the Delta-Board will give further information from time to time.

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* The last gap "Ouwerkerk" (200 m wide, 20 m deep) was closed on 6 November 1953.