The Dutch way to cope with storm surge disasters

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1. introduction

The Dutch sea-defence system is 1368 km long; 320 km sandy coast, 793 km sea dike and 255 km along tidal rivers. Sea-level rise has its impact on the full 1368 km. The 320 km long sandy coast along the North Sea is a dynamic coast. At some locations it is accreting, at other places there is erosion. The location of the erosion varies during the years. Behind the dunes are low lying polders (very often with a ground level even below the low water line), in which millions of people live. The coastal erosion endangers the strength of the dunes as a sea-defence. Erosion of narrow dunes (at some places the dunes are less then 200 m wide) can therefore not be tolerated in the Netherlands. Over a length of 40 km of coastline the dunes have no more than 10 m extra width available to cope with the erosion problem (this means that at, for example, a yearly erosion of only 1 m/year after 10 years the dune is not able any more to work as a sea-defence structure).

But the dune coast is not the only sea-defence line in the Netherlands. The Netherlands are in fact a delta of the rivers Rhine, Meuse and Scheldt. Many estuaries exist. In the Middle-Ages there were 13 estuaries and tidal inlets in the above mentioned 320 km long coast. Through these inlets and estuaries the storm surges could enter deep into the country. Dikes were built along the waters to protect the land from the daily movement of ebb and flood. The polders behind the dunes were artificially drained (by windmills). Extracting water from the soil caused subsidence. This made more pumping required, causing more subsidence. And all the subsidence made it necessary to increase the height of the dikes.

Increasing the dike height was often not done in time. So the Netherlands suffered from many floods, caused by the sea as well as by high river run-off.

In order to solve the problems of flooding in the Netherlands, in the Middle Ages special autonomous and independent authorities were formed with a special task to construct the dikes, to maintain all sea-defences and to build and manage all the pumping works. These agencies, the Polder Boards, still function. They collect their own taxes and have their own elected council and administration, chosen by the inhabitants of the polder. At this moment the Polder Boards are responsible for maintaining the dikes and the dunes as a primary sea-defence. However, they are not responsible for combating the coastal erosion. Erosion prevention is a task of the national government.

2. the Dutch coast

The Dutch coast is built by the waves -bringing sand from the bottom of the sea to the coast- and the wind -blowing the sand together in dunes. This way an almost closed coast was generated which was only interrupted by some river-mouths. Marshes grew behind the coast with big forests on its surfaces. "Holland" means "woodland". A peat layer of 10 to 25 meters thickness resulted. Only some hunters and fisherman could live in the marshes. About 2000 years ago the marshes were 3 m above sea-level and were almost insusceptible for floods.

In the Roman age the original inhabitants learned to drain the marshes and to cultivate them. With drainage subsidence of the bottom began. The surface of the land was lowered meters and was more often flooded by the sea. As a result the river-mouths scoured to wide estuaries and the Middle-sea -a forerunner of the Wadden-sea- in the north was born. About 400 years later the first "environmental" disaster in the Netherlands was completed: the area behind the

dunes was changed in enormous mud-flats and became uninhabitable. The people had to retreat in the dunes and in the higher parts in the east. It took another 400 years to let the marshes grow to such a level that they were inhabitable again. When men came back, drainage and subsidence started again. They knew then 1000 years ago- to build dikes along the creeks and the estuaries. This way the polders were made. Later they dammed the creeks. Amsterdam, Rotterdam and other towns with "dam" in their name were founded at that time. These towns were situated near water on strategic places where the inhabitants later could earn a lot of money with navigation and trade all over the world. They dug peat for fuel to heat their houses and created in this manner lakes. The water of these lakes threatened some towns later. The food for the population of these towns came out of the fertile polders. When the polders could no longer supply the food for the grown population of the towns, the process of reclamation of the lakes and estuaries started, continuing until some years ago.
Today the surface of the land in the polders is no longer 3 meters above sea level, but 3 meters below sea level. The surface in the reclaimed polders lays up to 7 meters below sea level. Together this is more than 50 % of the Netherlands including the heart of Dutch economy: central Holland. Subsidence is still going on and the sea is still rising. Subsidence and sea level rise together work out like a pair of scissors. This is the main problem of the Netherlands and the sea.
The Dutch have coped this problem of their sinking country and the rising sea over 1000 years successfully and some times less successfully. During these centuries some lessons could be learned:

a. Dikes can be built and polders can be drained only when landowners cooperate. This collective interest has already 1000 years been the base for waterboards
b. People who are interested in protection against water and in drainage, have to pay for the execution of these tasks and have the right to decide on these tasks. They elect the members of the waterboards, the oldest democracies in our country.
c. When collective interest of flood-protection and private interest conflict, the collective interest is considered as being the most important.
d. Dikes were built and broke through. The generation living at the moment of such a disaster decided that such a disaster might never happen again and repaired the damage and strengthened the dikes. The next generation often finished this job. The third generation knew the disaster only from the stories of their grandparents and had no longer a strong awareness of the danger of the water. Neglecting of dike-maintenance started and continued during the 4th generation. Then the dikes would break again. This way a cycle of disasters grew, sometimes completed by war-hostilities.

3. the dikes

Determination of dike height until 1953

In history determination of the height of dikes was always a problem. Usually dikes were designed at a crest level of 0.5 m above the highest known water level, with a surcharge for wave run-up. After a serious flood, most dikes in the coastal zone were improved. The height was increased up to a level related to the highest storm. However, because of bottom subsidence the crest height of the dikes became also lower in respect to level of the sea. After the second world war engineers and mathematicians warned that this approach is not correct, and that an extreme value statistic should be applied. The consequence of this approach would have considerable financial consequences, and no political decision was made.

The 1953 storm surge disaster

On february 1st, 1953 it stormed. The water-level rose to a level of 0.6 m higher than the highest observed storm surge (of 1894), with as consequence that 1365 km^2 was inundated and 1835 people were killed. 47300 houses were damaged, the total damage was 1500 million guilders (in 1953 1 U.S. $ was approx. 3.60 Dutch guilders). In comparison, in 1916 687 km^2 and in 1894 306 km^2 was inundated. Because most of this area was also below mean sea-level, after passage of the storm, the polders were still covered with water. Repairing 160 km of dike took more than a year at a cost of 380 million guilders. The total direct costs of the disaster were 2000 million guilders, which was 14% of the gross national product in 1952.

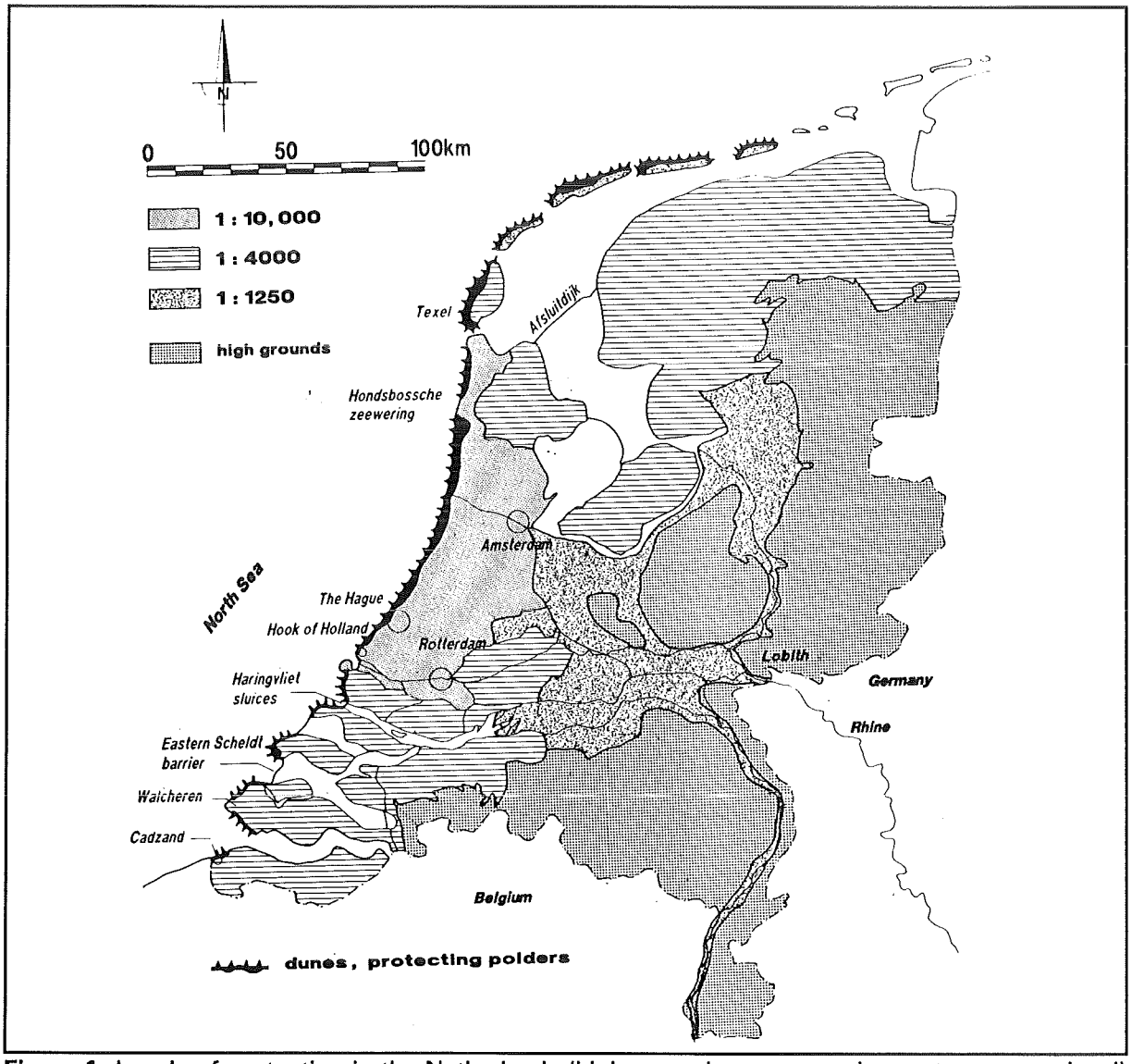

Figure 1: Levels of protection in the Netherlands (high grounds are areas above storm surge level)

The main conclusion was: this should never happen again. A committee of specialists, the delta-committee concluded that dikes should be designed on a design storm-surge level with a given probability of occurrence. From economic considerations followed that storm-surge levels with a probability of less than 1/10,000 a year are the optimum for the densely populated central part of Holland. For the other provinces this value is 1/4000 a year. See

figure 1. The shaded areas in this figure are protected from flooding by dikes or dunes; this part of the Netherlands mainly is lower than the daily high water level.
The 1/10,000 storm surge level was determined from extrapolation of all known water-levels at Hook of Holland, and resulted in a design water-level of 5 m above mean sea-level. This figure has to be corrected for the various locations along the coast.
The improvement of all dikes to this level of safety was called the *Deltaplan*. It consisted of closing some estuaries (and thus reducing the length of the estuarine dikes from 1500 km to 800 km), improving the strength of the dunes and heightening the remaining dikes.

The Deltaplan was undertaken energetically. Dikes and dunes have been strengthened with money of the central government to the new national defined standards. Estuaries have been closed off from the sea with the stormsurge-barrier in the Eastern-Scheldt being the largest project. This structural improvement of the safety is finished now except the stormsurge-barrier in the Rotterdam Waterway. The latter will be finished in 1996. In the same period a program to strengthen the dikes along the main rivers was undertaken which will be finished in the year 2008. In that moment the situation before the Roman era will be restored: the Netherlands are humanly speaking almost insusceptible for floods and the coast is closed again except the Wadden-sea.

For the future there are two important challenges:

1st. The safety for the polders attained with the Deltaplan has to be maintained. The cycle of disasters has to be broken. For this purpose the Water Defence Bill is developed and is in discussion in parliament now.

2nd. The erosion of the North Sea coast has to be brought under control. This problem was not tackled in 1953. Then the dikes broke through. So the dikes had to be strengthened. Like an old colleague once said: "One is always preparing for the war that was." The new coastal defence policy is developed to tackle the problem of the erosion.

In the following paragraphs will be described how these two challenges will be faced.

4. legislative background

One of the lessons from of our history is that landowners could only get good protection against the water when they cooperated. They joined forces and founded waterboards. Soon there was a need to supervise the waterboards in the tasks they execute for instance because a lot of the waterboards were small bodies. In the first centuries the landlord was the supervisor. Later the provinces -then the almost independent federal states of the Republic of the United Netherlands- took over the supervision. Around 1800 the centralistic French occupiers gave the central government also a task in supervision. This history lead to the following system:

* Waterboards manage dikes and dunes. To manage means:
  ** to maintain in the technical sense and to strengthen the dikes if necessary.
  ** to protect the dikes from damage by acts of men. Nobody is allowed to do anything in, on or near a dike or dune without a licence from the waterboard.

  The costs -except some grants of the central government- are met by the landowners inside the territory of the waterboard. They pay the waterboards taxes proportional to the area they own. Nowadays buildings are taxed too and there are so much buildings, that the owners of buildings pay together more than the landowners in some waterboards, but all proportional to the value of their properties.

The law provides in the power for the waterboards to execute their tasks. This way the waterboards are governing bodies operating on the same level as the municipalities but with a specialised task.
The waterboards manage the drainage of the land and the quality of the water in local waters in the same way.

* The provincial governments supervise the waterboards in the execution of their technical duties, but also in their administrative and financial powers. The provincial governments have the power to give the waterboards instructions. The provincial government lays down also the regulations of the waterboard describing their task: which task, which dike for instance. This way the provincial government are nowadays the founders of new waterboards.
* The central government -in particular the Minister of Transport, Public Works and Watermanagement- supervises the provincial governments in the way they supervise the waterboards. In particular this is important when the territory of a waterboard is in the territories of two provinces. The minister has the power to give the provincial government instructions. If the province and the waterboard do not execute these instructions, the minister can execute measures at the expenses of the waterboard.

This system -as laid down in a law of 1900- will be revised in supplementary laws giving the waterboards more contemporary powers. The supervision will be less detailed and in principle in retrospect. Only new dikes or essential modifications of dikes need an approval before the execution. These revisions are possible because since World War II the waterboards did strongly concentrate into larger bodies. This way they became a wider financial base and they could improve their administrative and technical qualities. Before long the tenants of real estate have also to pay taxes to the waterboards to strengthen the financial base of the waterboards furthermore.
The above described system was temporary modified by acceptance of the Deltaact. This act provides the closure of the estuaries in the south-west by the central government and provides a 100% grant from the State for waterboards in the costs of strengthening the dikes and dunes for the first time to the new standards. The State is allowed to take over the management of a dike temporarily for the time the State herself would strengthen that dike.

5. the Water Defence Bill

The Water Defence Bill is in discussion in the parliament now. The goal of this bill is to preserve the safety which is reached by the execution of the Deltaplan for the future by some lasting modifications of the system described in the foregoing paragraph. The essential part of the bill is a qualityassurance system. The nation has the right to expect that the waterboards preserve the safety of the polders paid by all the Dutch citizens together and may ask a quality assurance for it. In the same time this system guarantees the right on safety of the inhabitants of the polders. The above described supervision-system of provinces and central government on waterboards will be given a more concrete form:

* The system of national standards will be fixed in the law. The standard is defined as the maximum chance there will be a storm-surge or -on the main rivers- a discharge heavier than the design-base of the dikes and dunes. In Holland this chance may not exceed 1/10000 a year, in the north and south-west 1/4000, on the Wadden-islands 1/2000 and along the main rivers in the east 1/1250. These standards are used for the strengthening of the dikes and the dunes and already earlier accepted in parliament. These standards are defined for every dike-ring. A dike-ring is an area protected by one closed ring of dikes and dunes.

* The Minister of Transport, Public Works and Watermanagement has to monitor the developments of the water: sea level rise, river-discharges, stormfrequencies, waves. The minister has to publish every 5 years an actualised survey of these hydraulic load-factors.
* The minister has to make the scientific development translated into practical technical guides for the dike-managing authorities. For this purpose the minister has installed a technical advisory board with representatives of Rijkswaterstaat, provinces, water boards and the scientific institutes: Delft Hydraulics, Delft Soil Mechanics Laboratory and the Technical University Delft.
* The water boards have to test the strength of dikes and dunes every five years on the standards using the last hydraulic load-factors and technical guides. They have to report to the provincial government on the results and -if necessary- on the planned improvements.
* The provincial government has to report about the safety of the dikerings in their territory to the minister referring to the reports of the waterboards.
* The minister will evaluate the reports of the provinces and report to the parliament.

This way the safety will be tested every five years on an actual base. This period has two reasons. First: the developments of the water and of the wear and tear of the dikes are not yet great and can be coped within the normal maintenance. Second: the staff of the authorities are not yet completely renewed, there will be continuity.
Above only waterboards are mentioned as dike-managing authorities. By exception Rijkswaterstaat can also have these tasks. That is when a clear territory for the taxes of a waterboard does not exist. This is for instance the case for the dams in the south-western estuaries serving more dike-rings. A second reason is when a strong financial base for a good waterboard does not exist. It is the case on the Wadden-islands. In these cases Rijkswaterstaat has the same duties as a waterboard.

Furthermore the bill provides some grants from the central government to the waterboards -the 80% grant for the first strengthening of dikes along the main rivers and a 20 % grant for costs of maintenance and management- and regulations for the alarm-system.
Finally the bill orders the minister to control the erosion of the North-Sea coast. That means monitoring, execution of measures, planning and financing. The reasons to leave this task no longer on the water boards are:
* Erosion is of a national scale and needs a national approach to cope with.
* The interests of erosion control are of a national scale and the costs can not be born by the water board where it "accidentally" occurs.

The water boards keep their responsibility for the safety and strength of the dikes and dunes along the North-Sea coast.
The erosion control of the central government is exclusively aimed at structural erosion of the coast. Short-term losses of sand during storms are incidents compared to the structural erosion. To cope with these losses if necessary is the task of the water board.
The new coastal defence policy points out how the minister will execute this task, anticipating on the moment the Water Defence Bill comes into force. The problems were too serious to wait until the Water Defence Bill will be accepted.

6. Sea dikes and sea-level rise

As mentioned, in the Water Defence Bill it is also stated that the boundary values (such as water-levels) have to be recalculated every five years, and that dike managing authorities have

to certify every five years that their dike still fulfils the requirements. So, they have to check the height of the dike, the quality of the slope protection, etc. In this way it is attempted to prevent that the effect of climatic changes causes surprises. Dikes will be adapted to the new situations regularly. This is the main reason that design water-levels, etc., are not given in regulation, but only their probabilities.
Adapting the dike height to a higher water level is technically no problem. We have quite a lot of experience in the construction of high dikes. There is not much difference if one lives 5 meters below sea-level or 6 meters. In fact in the Netherlands the infrastructure is available to cope with a sea-level rise. The only thing we have to do is to adapt the used value of 20 cm/century to a higher value. In the Netherlands the main problem is public acceptance. Especially in built-up areas increasing the dike height has a big influence on the cultural and social environment (houses have to be removed, etc.).
The system with dikes, elected Polder Boards, special laws and taxes, pumping works, etc., has been developed during the last 1000 years. In countries where such an infrastructure is not present, the problems to overcome sea-level rise will be much bigger then they are in the Netherlands.