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SEMINAR

CONVENTION ON THE PROTECTION AND USE OF TRANSBOUNDARY WATERCOURSES AND INTERNATIONAL LAKES

INTERNATIONAL DECADE FOR NATURAL DISASTER REDUCTION

WORLD HEALTH ORGANIZATION
REGIONAL OFFICE FOR EUROPE

WORLD METEOROLOGICAL ORGANIZATION

Distr.
GENERAL

MP.WAT/SEM.2/1999/12

6 July 1999

Original: ENGLISH ONLY

SEMINAR ON FLOOD PREVENTION AND PROTECTION
(Berlin, Germany, 7-8 October 1999)

RISK-BASED FLOOD PROTECTION POLICY

Discussion paper transmitted by the Government of the Netherlands */

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GE.99-32061

ABSTRACT: The low-lying situation of the Netherlands makes it essential to ensure that there is an excellent protection against flooding. This protection is provided by means of an extensive system of dikes and dams. These are subject to certain safety requirements. In the current safety approach, these requirements are expressed as a prescribed water level which the dikes must be able to withstand. In the near future, a safety approach will be used which is based on the risk of flooding. Safety requirements for dikes and dams are derived from this. This article describes both safety approaches, the reason for changing over to a new safety approach and the instruments to be developed.

1 INTRODUCTION

About a quarter of the Netherlands is below mean sea level. Without dikes and dunes, about two-thirds of the country would be flooded during storm tides at sea or high water in the rivers (see figure 1). That is why in a country such as the Netherlands, protection against flooding is such an important task. This protection is provided by an extensive system of so-called primary dikes.

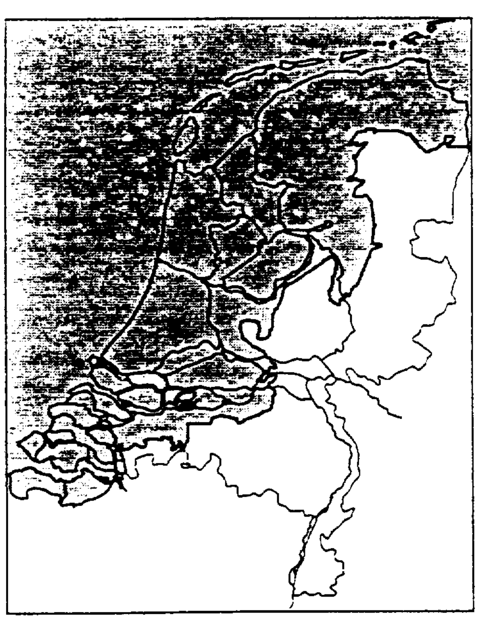

Figure 1. The Netherlands without dikes

The area which is protected by a linked system of primary dikes is called a dike ring area (dijkringgebied). The primary dikes around a dike ring area can be divided into dike sections, in which load and strength characteristics are comparable. Together these sections ensure the safety of the area.

Safety requirements are set for the primary dikes. In the current safety approach, these requirements are expressed as a prescribed water level which the dike must be able to withstand (see paragraph 2). The aim is to adopt a safety approach which is based on the risk of flooding for each dike ring area. Design criteria for dikes are derived from this. The reason for changing over from the current safety approach to the new one is described in paragraph 3. Paragraph 4 follows on with a description of the development of knowledge which is required. In paragraph 5, the current situation is explained, after which paragraph 6 sketches the subsequent developments.

2 CURRENT SAFETY REQUIREMENTS

In determining the desired height of dikes, the traditional method used until well into this century was to take the highest known water level, plus a margin of 0.5 to 1 metre. The Delta Commission, which was set up shortly after the disastrous floods of 1953, laid down the basis in 1958 for the current safety standards with regard to protection against high water. The Delta Commission argued for a much more scientific approach in designing dikes.

The starting point for the scientific approach as proposed by the Delta Commission was to establish a desired level of safety for each dike ring area. This safety level would need to be based, on the one hand, on the costs of construction of dikes, and on the other hand, on the possible damage which would be caused by flooding. The commission did realise, however, that back in 1960 this presented a somewhat 'ideal picture'. A large number of recommendations were not yet feasible for technical reasons. The main problem was that the probability of a dike breach occurring, and thus the probability of flooding, could not be estimated with an adequate degree of accuracy. This was one of the reasons why it was decided at that time on a simplified safety approach, based on prescribed load. The starting point in this is the prescribed water level as the most dominant load factor. In designing the dike, a certain margin is subsequently applied with regard to this water level, which is dependent on wind and wave conditions. The object of this is to ensure that each individual dike section is high enough to withstand a certain extreme water level with its accompanying wave pressure.

In this way, a safety standard has been established for each dike ring area. This standard is expressed as the mean yearly frequency that the prescribed high water level is being exceeded. By this is meant the average probability per annum that a water level higher or the same as a certain value will occur. The standards vary from 1/10000 to 1/1250 per annum, depending on the economic activities and size of population in the protected area, and the nature of the threat (river or sea). In 1996 the standards were laid down in legislation when the Flood protection Act (Ministry of Transport, Public works and Water Management 1996) came into effect. The present policy on safety is aimed at realising the statutory safety standards laid down in this legislation, before the year 2001. This is primarily realised by raising the dikes.

3 POLICY DEVELOPMENTS

As described in the previous paragraph, the prevailing safety standards are expressed as a frequency that hydraulic loads, which each uniform section of the dike must be able to safely withstand, are exceeded. The height of the dike is the single measure of protection provided against flooding. This measure is simple, easy to explain and protection against flooding can be realised in a relatively short time by strengthening and raising the dikes. Nevertheless, merely

measuring dike height provides insufficient information where it concerns protection from flooding. Two technical arguments can be cited for this: the geotechnical stability of dikes and the correlation between the failure of different dike sections.

If, during periods of high water, the dikes lose their resistance to for example sliding, a dike breach can occur without the water flowing over the crest of the dikes. This contributes to the probability of a dike breach or flooding. The required resistance to these largely geotechnical failure mechanisms cannot be expressed in terms of a hydraulic load standard or crest height. In the present situation, additional requirements are laid down for the probability of a dike breach occurring at water levels below the prescribed water level.

The larger the polder, the more dikes sections are needed to protect the area. If these sections together with the hydraulic load on these sections are fully correlated, the safety of the area can be expressed as the safety of a single dike section. In practice, this is not the case. Both the strength of and the load on the dike sections around the area are not fully correlated. Other types of constructions, such as discharge sluices, are to a large extent responsible for this. The probability of a dike breach in an arbitrary dike section, followed by flooding, is thus always greater than the probability of a breach in a single dike section. The probability of a dike breach is not adequately established under the current safety standards, while the probability of a dike breach followed by flooding is the most tangible measure of danger. After all, flooding results in economic damage and, depending on the situation, victims from drowning.

In addition to the technical limitations of the current safety standards, other limitations can be mentioned. The general safety policy of the Government is based on a chain approach, meaning that all aspects of a risk-bearing activity undertaken are taken into consideration. Policy with regard to protection against flooding is also developing on the basis of the chain approach. On the one hand, this development is prompted by the general safety policy, on the other hand there are limits to the degree of protection which the dikes can provide. Simply raising the level of the dikes time and time again along the rivers is not a long-term answer to the question of how the low-lying Netherlands should be protected. For protection against high water, the risk chain (see figure 2) is built up from: extreme river discharge, extreme water levels, the probability of a dike breach and the consequences of flooding. Measures aimed at offering adequate protection against flooding can be taken with regard to all elements of the risk chain. With the current water level standards, the effects of such measures cannot be compared with each other, which prevents measures being assessed properly and an optimal choice being made.

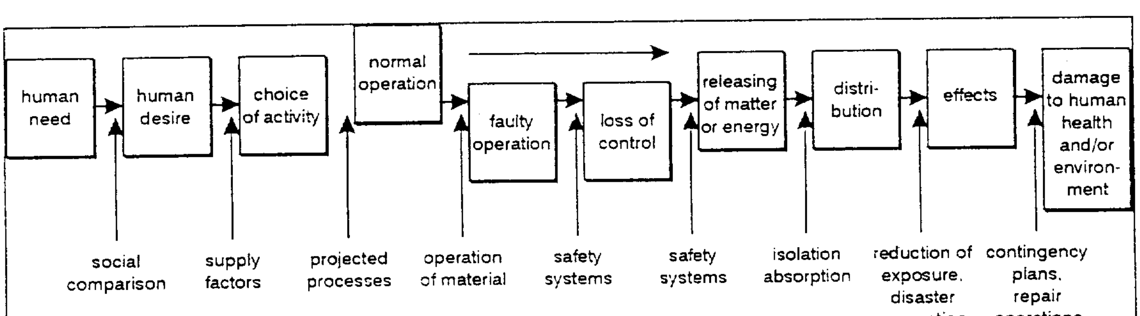

Figure 2. Risk chain

Since the current safety philosophy (based on an admissible probability of overloading a dike section) has its limitations, the aim is to devise a new safety philosophy based on a flooding approach. With this, safety is related to the risk of flooding in terms of multiplying the probability of flooding with its consequences, expressed in damage and victims. This safety approach offers the possibility to consider and assess measures in the entire risk chain and to

make an optimal choice. Through measures which reduce the probability of high water or which limit the damage caused by a dike breach, just as great a contribution can be made to protection as with raising the height of the dike itself. A summary of possible measures (Berger, Ras & Wondergem 1997) is set out in table 1. In choosing the measures, social wishes from other activities and interests must be taken into consideration. These activities will be affected: space for them will be withdrawn, but at the same time there will be new opportunities created, for example for landscape and recreation.

Table 1. Summary of possible measures

measures to prevent flooding			measures to reduce effects of flooding
dike	outside the dikes	elsewhere	
dike strengthening	limiting use of winter bed lowering summer bed winter bed compensation lowering groynes lowering winter bed removing hydraulic bottlenecks auxiliary channels removing summer quays reducing roughness removing high water-free areas widening winter bed limiting wave strength altering discharge distribution	water conservation retention high water dike green rivers altering discharge distribution storm flood barrier lowering target level increasing sluice capacity greater level fluctuations flooding openings compartmentalisation	improving disaster contingency plans insurance escape routes public information to raise awareness of risk warning and information systems compartmentalisation preventive measures in building and infrastructure

Figure 3 shows how the risk-concept and the regular safety assessment of dikes may interact (Jorissen & Stallen 1998). The present flood protection policy and the risk-concept are shown as two circles besides each other. The circle at the right side is the present policy of safety assessment aimed at maintaining the prescribed safety standard. The circle at the left side represents the future risk-assessment.

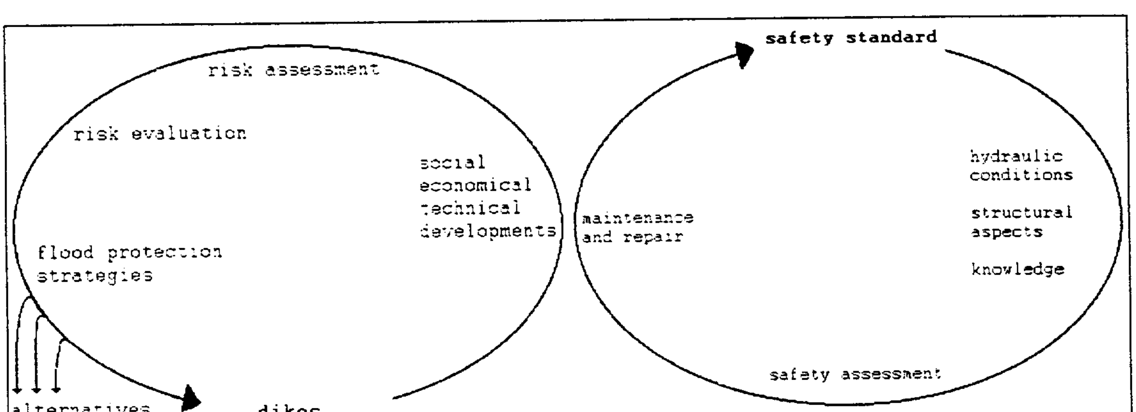

Figure 3. Present flood protection policy and the risk-concept

The risk-assessment circle includes the socio-economic effects and the evaluation. This evaluation will not remain confined to flooding risks, other sources of risk will be taken into account as well. The risk-assessment will give information on expected damages in case of a flood. This figure may be accepted or rejected, given other sources of risk and the effort required to reduce the flooding risk. To reduce the flooding risk several strategies and measures can be considered. One of the alternatives is to heighten or strengthen the river dikes, which can be expressed as a higher safety standard. This safety standard can be maintained again using the right-hand circle, which is the core of the present flood protection policy. Given the time-scale of the processes involved the interaction between the both circles should not be frequent.

4 TECHNICAL DEVELOPMENTS

Research is necessary to make the changeover from the current safety philosophy to the safety philosophy based on a flooding approach. The research programme Marsroute of the Technical Advisory Committee for Water Retaining Structures (TAW) (TAW 1997) aims to make this changeover possible.

In order to achieve an accurate safety philosophy based on the risk of flooding, it is essential that the probability of flooding and its consequences can be calculated sufficiently accurately. It is also important to establish what is felt to be an acceptable level of risk.

4.1 Probability of flooding

Because of the variation in types of water-retaining structures, there is also a variation in the nature of the threats. After all, the threats to dunes are different to those to dikes. This means that the systems of dikes and water barriers can fail or collapse in different ways (mechanisms) and in different places (sections) (see figure 4). The failure or collapse of a single element can cause the entire water-retaining system to fail, causing the area to become flooded anyway.

To calculate the probability of flooding, the Marsroute research concentrates on probability descriptions of load, the strength of the dikes and collapse mechanisms and the development of system failure models.

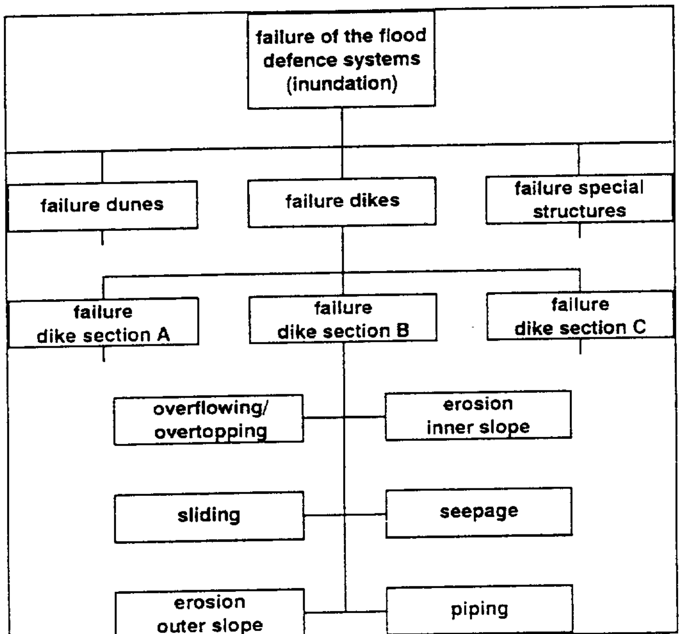

Figure 4. Tree diagram of events

4.2 Consequences of flooding

Flooding usually results in extensive material damage. The extent of the damage depends on the nature of the threat (sea water or fresh water, short or long period of flooding, expected or unexpected) and the characteristics of the flooded area (depth, built-up areas, industry, exact location of the dike breach). In particular, deep floods or fast-flowing water can have serious consequences in the form of victims, extensive damage, and disruption to normal life and infrastructure.

In calculating the consequences of flooding, the Marsroute research is concentrating on developing an instrument by which damage and victims for each dike ring area can be calculated in a uniform and practical manner. Warning and information systems contribute in taking the right measures at the right moment, by both government and the individual citizen. Applying these types of instruments influences the consequences of flooding in a positive way. A High Water Information System (HIS) is currently being developed for sections of the river lands. This can be used before and during high water for predicting the way in which any flooding will take place, monitoring water levels, waves, the condition of the dikes and the availability of the road network, determining the effects of any measures taken, announcements, communication and decision-making.

4.3 Acceptable level of risk

The standards laid down in the Flood Protection Act are translated into standards based on the probability of flooding for each dike ring area. The current differentiation in standards for each dike ring area will mean other forms of safety in terms of flooding probabilities than in terms of overload frequency. The term "probability of flooding" is closer to the actual safety of an inhabitant of a dike ring area than the term "probability of overloading per dike section". A consequence of calculating the flooding probabilities will also be that a discussion will be initiated with regard to the greatest permitted level of the probability of flooding and its associated risk. Instruments for conducting this social discussion need to be developed.

5 CASE STUDIES

It is difficult to assess whether knowledge of the step towards a flooding risk approach is sufficiently developed to allow the changeover to be made from the current safety philosophy to the new approach. To try and ascertain this, case studies are being carried out, whereby the envisaged path towards a flooding risk approach in a number of concrete cases is followed.

Between 1994 and 1997, case studies were carried out for eight dike ring areas. In the first part of the case studies design methods were compared. The second aspect of the case studies was the calculation of flooding probabilities. With a system approach (Agthoven, den Heijer & Kraak 1997) a rough estimation of the flooding probability for the entire polder was made. The system of dikes enclosing a dike ring area was divided up into a number of dike sections, and reliability was determined for each dike section by considering the most important failure mechanisms. Subsequently the probability of failure for the different dike sections was combined to produce a probability of failure for each dike ring area. The estimated probability of flooding was larger than the prescribed water level frequency.

The case studies will be regularly repeated, making use of the techniques which have become available in the meantime. This allows for a regular comparison with the original method. For example, the flooding risk will be determined for the first time in case studies to be carried out in mid 2001. The damage which would arise as a consequence of flooding will also be determined, after which the risk can be determined.

6 SUBSEQUENT DEVELOPMENTS

6.1 Technical developments

The methods currently available will need to be further developed before the new safety philosophy can be used. The instruments for calculating the consequences of flooding still need to be developed for a large part. The instruments for calculating the probability of flooding have already been further developed, and it is already reasonably possible to determine the probability of flooding of a dike ring area. There has been less development in the probabilistic formulation of geotechnical failure mechanisms. Knowledge of a relevant phenomenon such as the breach growth in material such as clay is practically non-existent.

6.2 Communicative developments

Investment in transparent and clear communication to all those involved is of great importance (Janssen & Jorissen 1996). People that live alongside the large rivers in the Netherlands, would like full protection against water damage, something that, by definition, cannot be guaranteed. High water levels are a natural part of rivers, and absolute safety simply does not exist. Significant efforts will have to be put into information services, to make people aware of the fact that high water levels are and will always be a real possibility. This information is especially important in periods with no high water levels in the rivers. The communication on flooding risks also needs a significant effort. The protection offered by dikes and other measures is limited and every year a flood may occur. This has to be accepted as a fact and cannot be banned from the lives of those who live along rivers and seas.

Public awareness of the flooding phenomenon and the measures taken must lead to a public acceptance of the protection offered against flooding.

6.3 Developments for the purpose of developments in policy

The safety philosophy based on the flooding risk approach needs to be placed in a larger

context. Table 1 shows that dike height and the behaviour of the water system in front of the dike are only two of the possible measures which can be taken to reduce the flooding risk. This means that in the future more attention must be given to models which can weigh up the effects of various measures which would limit the effects of any flooding which might occur. For example, it should be possible to decide whether it would be more useful to invest in a disaster plan, or in strengthening the old inner dikes with which the progress of flooding is influenced.

In addition, when establishing an acceptable safety level, a link must be sought with other social risks and risk standards developed elsewhere. In order to make it possible to compare the risks of flooding with other social risks, the starting points and methods of standardisation must be comparable as far as possible. This means that we must have insight into the probability of a calamity and the possible effects (wounded, material damage etc.). A safety approach based on flooding risks offers this possibility.

7 CONCLUSIONS

The Netherlands is protected against flooding by a system of dikes, dams and water-retaining structures. Safety requirements are laid down for all these structures. In the current safety approach these safety requirements are expressed as a frequency of exceedance of the design water level. Each individual dike section must be sufficiently high to be able to withstand a certain extreme water level which forms part of this frequency with which the standard is exceeded, together with its associated wave load.

A number of comments can be made concerning the current safety approach. On the one hand, the probability of actual flooding is unknown in view of the fact that the probability of a dike ring area flooding is not the same as the probability of exceeding the prescribed water level at a particular dike section. On the other hand, in establishing an acceptable level of safety, a link must be sought with other social risks and risk standards developed elsewhere. In order to make it possible to compare the risks of flooding with other social risks, the starting points and methods of standardisation must be comparable as far as possible. This means that we must have insight into the probability of a calamity and the possible effects. The current safety approach does not provide this possibility.

Because of the above-mentioned reasons, a new safety approach based on the flooding risks is being developed. In this system, safety is related to the flooding risk in terms of multiplying the probability of flooding with the effects of it, expressed in damage and victims.

The new safety approach makes a review possible with regard to the safety level, and in addition a new category of measures will be made available for improving protection against flooding. In the current approach, safety can only be increased by strengthening the primary dikes or by lowering extreme water levels. By explicitly choosing risks as the basis for a safety policy, the height and strength of the primary dikes with regard to the prescribed water level is no longer the only variable. The potential effects of flooding can also be affected. After all, the risk of flooding can also be reduced by improving escape routes, optimising the instruments for contingency plans or by building compartmentalising dikes, for example.

Research is necessary in order to make the changeover from the current safety philosophy to a safety philosophy based on a risk of flooding. The research programme Marsroute of the Technical Advisory Committee for Water Retaining Structures aims to make this step possible. The case studies occupy a central place in the research programme. The object is to indicate in existing dike ring areas how great the probability is of flooding in the area concerned, according to current insights. The case studies must on the one hand increase our knowledge in this area, and on the other hand provide the opportunity for implementing new ideas.

In spite of all the technical and administrative measures at our disposal, a watertight guarantee that flooding will not occur is not possible. After all, there is always a chance, however small, that a calamity will nevertheless occur. Investment in transparent and clear

communication to all involved is therefore of great importance.

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