Fundamentals on Water Defences

(English translation of the Dutch Guidelines
'Grondslagen voor Waterkeren')

January 1998

Technical Advisory Committee on Water Defences

The Netherlands

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PREFACE

‘For even though the Dutch water wizards are clothed in jackets, they do retain something of the magician, strangely enough, who practices his rites in secret. When they work, they prefer no spectators. They are unable to explain what they do in any case, for their speech is crammed with mystical utterances.’
A. den Doolaard, *Het verjaagde water* (The water driven away), Querido, 1947

Our sea dikes are at the correct height and we hope that we can say that about the river dikes within the next few years. For the time being the Netherlands seems to be achieving its goal of offering its population reasonable protection from flooding. That does not mean that we need give it no more thought. There are a number of reasons to discourage any complacency.

- The climatologic studies and discussions are still ongoing, but it would appear that we will have to take higher water level into account.
- As the Netherlands sinks, our country is becoming home to more and more people and objects. As early as 1970 Minister Bakker wrote in his policy document TP 2000: “It will therefore be necessary to subject the safety of the new flood defences at that time to new considerations'.
- The risks we run as a consequence of high water levels are not easy to compare to other risks our society is exposed to.

The Technical Advisory Committee on Water Defences feels it necessary to collate *Fundamentals on Water Defences* at precisely this moment in time, when an important step is being taken in the completion of the protection infrastructure on the one hand, and many new developments are ongoing on the other. These *Fundamentals* must be seen as the best manner for the Technical Advice Committee on Water Defences to apply the *Flood Defences Act* in practice. They can also serve as a basis for the next stage of expanding our insights and the discussion on water defence.

For a long time, flood defence was something for insiders. Experts decide how high the dikes must be and how best to realise them. The visibility of flood defence has led many to wonder whether they should not have a point of view too. The resulting discussions and misunderstandings were manifold. At the moment the majority appears to be a thing of the past and communication, mutual understanding and cooperation on current dike reinforcement programmes appear to be good. One of the achievements this has brought about is the integration of the aspects of landscape, nature and cultural history in dike reinforcement programmes.

We still need these ‘insiders’ to realise a proper flood defence policy and the *Fundamentals* are meant for them. Those people who work with guides and technical reports issued by the Technical Advice Committee on Water Defences are provided here with the background and the context. Those people who draw up new guides are provided with a foundation on which the approach must be built. Making this publication an essential read for everyone who is professionally involved in flood defence.

Developments are always ongoing. The tragedy of a story such as this is that it is the newest of the outdated stories, by definition, even though it covers something as rudimentary as fundamentals. All comments are therefore more than welcome.

The Hague, January 1998

W. van der Kleij
Chairman, Technical Advice Committee on Water Defences

CHAPTER 1 INTRODUCTION

1.1 AIM OF FUNDAMENTALS ON WATER DEFENCES

Water defence is primarily about safety. But there are many more aspects that play a role in decision making with respect to flood defences. Economic, environmental and other social interests are given weight when making any decision. These are processes that involve many parties, each based on a specific vision, objective, interest or believe.

Fundamentals on Water Defences aims to offer an overview of this field. This Technical Advisory Committee on Water Defences (TAW) document describes (1) the systems that lead to the need for water defence, (2) the systems whose function it is to retain water or which are related to it and why this function is allocated, and (3) the decision-making systems.

Thanks to the broad interface, *Fundamentals on Water Defences* is a report that is interesting, and even essential for everyone who is professionally involved or interested in water defence. The target group consists of three categories.

- Everyone interested in water defence;
- Users of TAW guides;
- Authors of TAW guides.

Those with an interest will be especially interested in the background and the why and wherefore of water defence (chapters 1 through 6). Those who want to find out how the design process is structured and what the management of flood defences demands will find the information they crave in chapters 8 through 10, with a description of the dike improvement procedure in annex V. The experts, including the users of TAW guides, can find information on the similarities between the various systems, while chapter 7 describes the fundamentals for dimensioning water defences. Authors of these guides will find targeted information in annex IV.

The choice of the broadest possible target group is a conscious one, despite the disadvantages of writing for such different categories of readers. One of the most predominant points of departure for *Fundamentals on Water Defences* was the creation of a collective basis for all those involved. For that reason all relevant information has been included in one document. To promote the clearness and clarity of the information mathematic formulations have been avoided wherever possible in the main text. Neither have calculation models been included in the *Fundamentals* for the design and safety monitoring of flood defences. Detailed information on these subjects can be found in the specific guides and technical reports, drawn up by the TAW. *Fundamentals on Water Defences* provides insight into the knowledge and information needed to make well-considered choices with respect to the desired safety of the low Netherlands and the other functions allocated to the flood defence.

Flood defences are a classic example of the interweaving of social functions. The benefits and the necessity of a bridge or a building can be the fuel of a raging discussion, but the function is unambiguous. At flood defences the opposite is true. The necessity is usually unchallenged, but the interweaving with other functions is so strong that adaptation is often a laborious process.

Ground is scarce in the Netherlands and as a result it has been sought to build under the ground in a number of cases. This sort of ‘Plan B’ is not applicable for flood defences. The functional interweaving is a matter of fact here. That means that a traditional technical, sectoral approach is actually impossible. In other fields too, in water management care agreement and cohesion between sectoral approaches is increasingly often sought at an early stage. Figure 1.1 illustrates the place of the flood defence manager in the social field.

Three important questions must be answered when building or adapting a flood defence.
- What necessitates the intervention or management measure?
- What needs to happen?
- How will that happen?

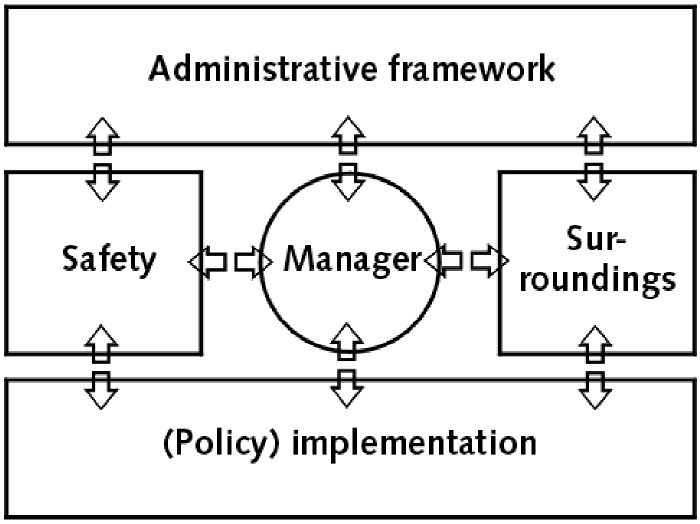


Figure 1.1 Social field for flood defence management

Using *Fundamentals on Water Defences* managers, designers, decision makers and other interested parties are able to check their success in achieving the aims set. Besides the most important points for attention, Fundamentals explains the background and the context. As such *Fundamentals on Water Defences* is a package of essential knowledge and vision needed for water defence.

1.2 BENEFITS AND NECESSITIES OF *FUNDAMENTALS ON WATER DEFENCES*

Fundamentals on Water Defences appears to come a little late in a very long day. After all, the majority of Dutch flood defences have been improved in the past few decades. And the ongoing river and lake dike improvement programmes will be completed in 2000.

This document is however far from surplus to requirements. On the contrary, there are a number of clear reasons to publish *Fundamentals on Water Defences* right now. The completion of the current improvement programmes will take some time, and new knowledge and insight can contribute to even better results. It is also wrong to think that this was the last challenge. The *Flood Defence Act*, for example, prescribes that all flood defences must be monitored for safety every five years. This lead the TAW to publish *Leidraad Toetsen op Veiligheid* (Guide on Safety Monitoring of Water Defences) with practical guidelines for conducting such monitoring, which will demand a great deal of effort and will undoubtedly provide new knowledge and ideas about the strength of our flood defences. There are still more reasons to issue the *Fundamentals on Water Defences*.

Dike bursting and flooding have claimed many victims through the centuries and been the source of great damage to the economy

The number of people to be protected and the scale of investment in the Netherlands continue to grown after all. A periodic revision of the insured value is therefore not illogical. Furthermore, the water levels to be retained on sea and along the rivers are more likely to rise than fall as a consequence of expected climate development.

In addition, both social and technical developments make new approaches desirable and possible. The attention for the other functions of a flood defence, most notably the values of landscape, nature and cultural heritage, have led to another approach to design. These values have been taken into account from the first stages of improvement works. Besides the continued expansion of knowledge of the structural aspects there is also more knowledge available in the field of approaching risks to flood defences. That substantially increased the possibilities of comparing protection from flooding with risks in connection with industrial installations of management. The TAW has set out a 'Marsroute' ('Line of March') aimed at expressing the risk of flooding in the same terms as other social risks. That is currently not possible.

All the points mentioned above have been under development for the past ten years and will continue to be developed in the next few years. The process is a continuous one. There is accordingly no 'best moment' to draw up definitive fundamentals for water defence. As a consequence of the developments realised in the past few years, together with the path now being taken, the TAW feels it is necessary to collate in book form the foundations of the work to be undertaken in coming years and its points of departure. It is in the first instance an overview of the state of the art, bearing in mind that the guides published until now are all oriented to a specific type of flood defence or an aspect of water defence. An attempt has been made to develop a thread and provide as few details as possible. Fine-tuning will obviously be needed once important steps have been taken in the development of knowledge and in the discussion of social choices.

1.3 PLACE OF FUNDAMENTALS ON WATER DEFENCES

1.3.1 Determining the place of water defence

In the nineteenth century the poet Willem Bilderdijk wrote: 'Happy Holland, had we not dug and even diked, We were now living above the rivers, That must cut the land, but now run over it in manmade channels, Whose bottom is ever higher raised by falling silt, And so rise ever more above the land and in force and violence their dikes can overwhelm.'

In the future climate change will be the source of higher peak discharge along the rivers than are currently taken for granted. It may be asked whether it is justifiable for us to continue reinforcing dikes or whether there are other options. The process that Bilderdijk describes is most notably the consequence of a constant intensification of land use and the discharge it entails (see also chapter 2). It is however clear that a flood defence is not the sole means of influencing the risk of flooding in low-lying areas (the probability of flooding and the consequences thereof). A lower water level or wave attack is rendered as a reduced load and so usually a lower flood defence.

The consequences of higher peak discharge values for the water levels along the rivers are dependent on the space that the river is given to drain precipitation water. The possibilities of preventing the continued rise in the normative water levels along the rivers in the scope of 1997's *Fourth Policy Document on Water Management* among others (see *Beschermen tegen hoogwater*). Any measures for the branches of the Rhine are listed in a broad study (see *Integrale verkenning inrichting Rijntakken*) (see figure 1.2). This does not only address measures aimed at lowering the water level, but also those based upon other social wishes (for shipping and nature for example).

The study shows that it is possible to reduce the water level, most notably be lowering and broadening the river forelands. This last solution demands that the river (winter) dike is set back, which obviously has a number of planning consequences. The development of nature in the river forelands, by developing floodplain forests for example, will lead to greater resistance and so a rise in the water level upstream. Little can be said at the moment about choices and their consequences.

These measures have no effect in the lower reaches of the rivers. The water levels are primarily determined by the sea level. Dams and tidal flood defences may reduce water levels along river mouths and estuaries, as is the case in the *Delta Plan*. This is not so on the coast however, and a rise in sea level must be taken into account. Other means of limiting the risk of flooding is to construct terps, to introduce facilities to buildings and to avoid low-lying areas when developing expansion plans for housing and industry. These means are easy to apply in the Meuse valley in Limburg for instance, but less suited to polder areas. In the former situation the land rises as the distance from the river increases. This contrasts with the low-lying polders along other branches of the river. Along the southern Meuse high water causes a great deal of damage, but no directly life-threatening situations.

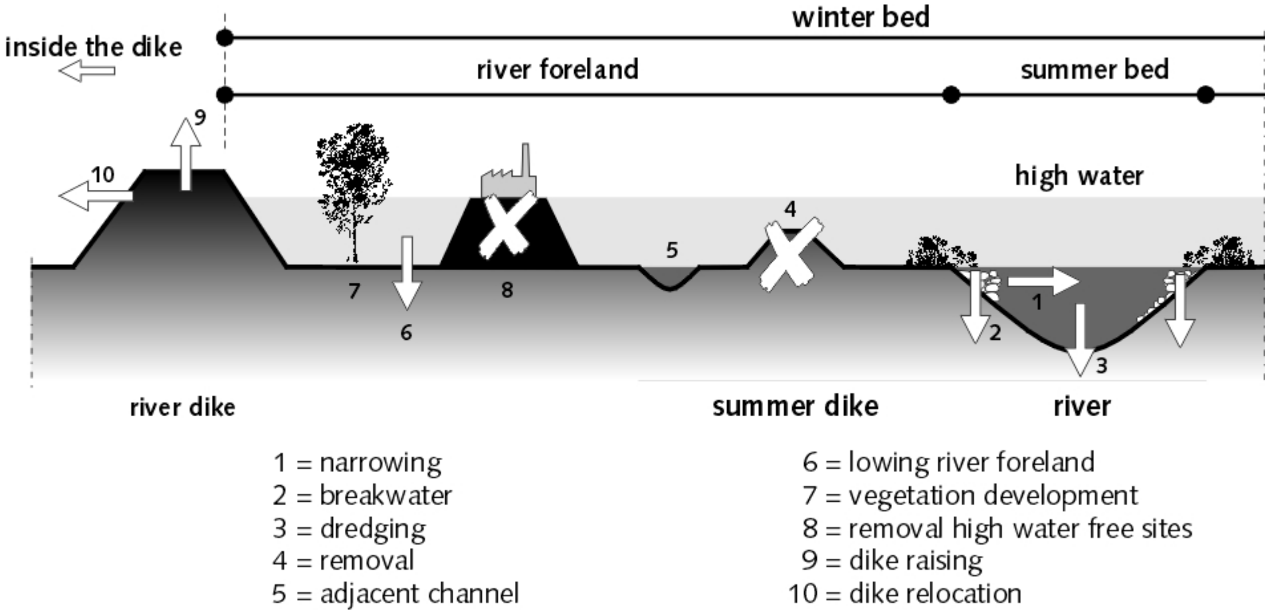


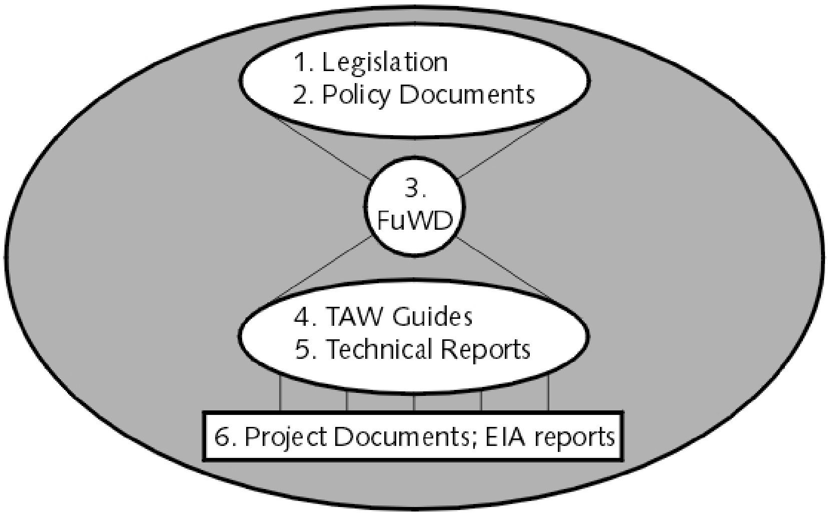
Figure 1.2 Possible interventions in river beds (*Integral Verkenning inrichting Rijntakken*)

Nevertheless, after the floods of 1993 and 1995 embankments were introduced to protect buildings in the high water bed of the river. These embankments are beyond the scope of the *Flood Defences Act*.

As the name implies, *Fundamentals on Water Defences* is almost exclusively directed to water defence and especially the so-called primary flood defences. Secondary flood defences, discharge/drainage canal embankments and the embankments in Limburg are not addressed in any detail.

1.3.2 The place of Fundamentals

Figure 1.3 indicates what place *Fundamentals* occupies in the total package of documents relevant to water defence. *Fundamentals* is the hinge between legislation and policy documents at strategic level and the specific guides and project documents at implementation level. The most important piece of legislation is the *Flood Defence Act* (FDA). The text of this act is accordingly annexed to this publication (annex I). *Fundamentals for Water Defence* provides a foundation for the practical application of this act as it is understood by the Technical Advice Committee for Water Defences.



1. Legislation. Including *Flood Defence Act*, *Delta Act*, *Rivers Act*, *Spatial Planning Act*, *Environmental Management Act*, Provincial regulations, water boards. See also section 2.4.2.
2. Policy Documents. Including *Policy Document on Water Policy*, *Policy Document on Spatial Planning*, *Nature Policy Plan*, *Ruimte voor de rivier* (Space for the river). See also chapter 6.
3. Hinge. *Fundamentals for Water Defence*.
4. TAW Guides. Including *Leidraad Toetsen op veiligheid* (Guide on Safety Monitoring of Water Defences, 1996), *Leidraad zandige kust* (Guide on Sandy Coasts, 1995), *Leidraad voor het ontwerpen van rivierdijken* (Guide for the design of river dikes) *(deel I: Bovenrivierengebied* (Part I, Upper river area, 1987) and *deel 2: Benedenrivierengebied* (Part II, Tidal river area, 1989), *Leidraad zee- en meerdijken* (Guide on Sea and Lake Dikes, 1999), *Handreikingen rivierdijken* (Guides on river dikes. various volumes, 1994).
   N.B. The above are existing guides. The TAW is currently examining the desirability of new guides.
5. TAW technical reports. Including *Golfoploop en golfoverslag* (Wave run-up and wave overtopping,1994), *Klei voor dijken* (Clay for Dikes, 1996), *Basisrapport zandige kust* (Sandy Coasts Design Basis Memorandum, 1995), *Marsroute veiligheidsbenadering* (Line of march, approaching safety, 1994).
   See also *Overzicht TAW-publicaties*.
6. Project documents etc. A project document and an EIA report is ultimately drawn up for each dike route. See chapter 8. The flood defence manager makes a report in the context of safety monitoring. See chapter 10.

Figure 1.3 The Place of *Fundamentals*

1.3.3 The layout of Fundamentals

To clarify the hinge function, chapter 1 begins by sketching the social framework, based on the elements in figure 1.1. Chapter 3 provides an overview of categories and types of flood defence, whereas chapters 4 and 5 handle the most important aspects of water defence: safety and values and functions.

Chapter 6 summarises the care of water defence. 'Care' is used in this publication as a term to describe the combined responsibilities and instruments in the field of water defence. Policy is the integrated whole of administrative choices, whereas management is the implementation thereof (see also the top and bottom of figure 1.1). Care covers both, including the interaction between policy and management. That interaction is an essential part of our democratic system. As policy implementation, management is the realisation of decisions that have been taken, whereas management experience plays an important role in policy preparation.

Chapter 7 handles the fundamentals of dimensioning flood defences. Finally, chapters 8, 9 and 10 provide points for attention and procedural aspects in the design, construction and (day-to-day) management and maintenance of flood defences.

In this way the fundamentals of the society's field of influence in which water defence must be given form converge into the realisation and maintenance of flood defences. The specific guides and reports published by the TAW provide the information needed for more detailed elaboration.

CHAPTER 2 SOCIAL FRAMEWORK

Chapter 2 illustrates the social field of influence in which water defence occurs. Aspects of content and procedure are addressed.

2.1 INTRODUCTION

Without habitation by people flooding of low-lying areas is no longer a more or less autonomous natural phenomenon. In populated areas protection against flooding is a social issue. A sketch of the social framework in which the management of flood defences occurs is accordingly necessary at the beginning of the *Fundamentals*.

The social framework is important in two ways at flood defences, being (1) the determination of the desired degree of protection and (2) the adaptation of the flood defence to the surroundings. Protection and adaptation can be separated. The fulfilment of requirements that follow on from the adaptation to the surroundings can also influence the degree of protection chosen. If all economic factors were taken into consideration, the rivers area would be subject to stricter safety norms for example. The prevailing, less strict norm limits the loss of landscape and cultural heritage values. This choice is based on social considerations and can only be made by administrative organs. Engineers have the task of quantifying and clarifying the necessary elements in the selection making process as well as possible.

In this chapter the elements found in figure 1.1, that is safety/protection as the main function of the flood defence in relation to the surroundings, coordinated by the administrative framework and resulting in the implementation of policy. These elements are explained individually in the following sections.

2.2 SAFETY (SECURITY)

In the history of the Netherlands floods are much more common than battles. The schoolbooks tell another story however. It appears that floods are considered to be less calamitous, or at least more natural. Many people may also experience that relative distinction. But that does not change the fact that floods are not acceptable in today's society. That was not only proven in 1953, but also in 1993 when the Meuse caused a great many problems in Limburg, without threatening the integrity of the dikes or putting human life in danger. In 1995 it was proven to an even greater extent, when several hundred thousand people were forced to flee their homes because the river dikes could no longer be relied on.

Our increased prosperity means natural violence can cause a great deal of damage. And bearing in mind there is less willingness to accept it, citizens are changing the demands they set on government. People want to live their lives without feeling threatened by the water. But more importantly, the manner in which the land is used means that the consequences would be far greater now than they were a few centuries ago (see box).

HISTORICAL DEVELOPMENT

Until the middle ages man adapted to nature. In the coastal areas there were settlements in the higher dune areas or on terps and in the rivers area on the natural bank walls of the rivers. As a result, the regular floods had little effect and even deposited slit on the land, which enabled the land to approximately keep pace with the naturally rising sea level.

The rise in population meant that increasing numbers of lower-lying areas were taken into use. Provisions were put into place in relation to agriculture to drain the land and peat was dug up in many places for fuel and salt. The consequence was a fall in the level of the ground surface, as a result of which flooding became a greater problem. In response the first dikes were constructed. Initially they only supplemented the natural heights; in the rivers area for instance, perpendicular to the bank walls to redirect river water flowing outside the banks along populated areas to lower-lying back lands. In the coastal area the influence of the sea increased steadily. In the southwest the great estuaries formed and in the north the Zuider Sea, which meant that more and more lowland had to be diked in.

Further use of low ground led to more diking. The result was the increase in the extreme water levels along the rivers and in the delta area, because of the loss of the lowering effect of a flood on high positions. Improved drainage, first by windmills, and later by mechanical pumping systems, was the cause of a further fall in the level of the ground surface. The ultimate result, for example the peat areas of Holland, is that the land currently lies approximately three metres under sea level, as opposed to on average approximately three metres above sea level one thousand years ago. Only a small proportion of this change is due to a natural rise in the sea level. It is mostly due to human influence (see figure 2.1).

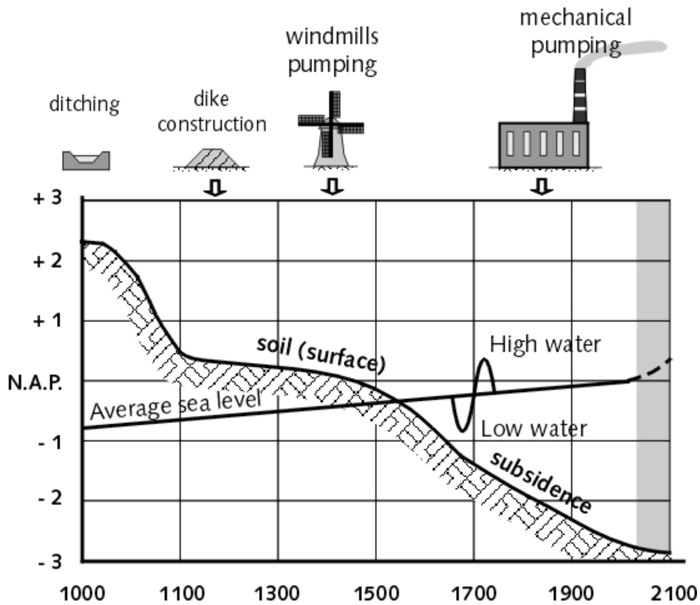


Figure 2.1. The fall in the peat surface (subsidence)

The situation is a little more favourable in low-lying areas beyond Holland, where peat does not play any great role. The increasing problem of protection from the sea led to a reduction in the coastline by means of the Zuider Sea Works and the Delta Works in the twentieth century.

In contemporary the Netherlands almost all low-lying land is densely populated. Most large-scale urban expansions are concentrated in low-lying polders. There is no more natural silting and the land has sunk a few metres in relation to the water. The consequences of a flood will therefore be much more serious than ever. The result of a thousand years of efforts by our forefathers is a densely-populated, highly developed, but low-lying area, where flooding could lead to the loss of human life, tens of billions of guilders' damage and the breakdown of society. There is no way back and the only thing we can do is ensure that we secure our residential areas prudently. That will be more difficult because the interventions necessitated in the other functions of the flood defence are increasingly found to be unacceptable.

2.3 SURROUNDINGS

2.3.1 Multi-functionality

At the IJsselmeer polders, which lie metres lower than the surrounding water, the dikes visibly retain the water twenty-four hours a day. At many river dikes and some sea dikes the main function, protection from flooding, is only called upon for a small percentage of the time. Many flood defences traditionally have other functions, such as housing, work, traffic and recreation. Plants and animals have also found their place there. Since the arousal of social evaluation, they have become Nature values. A comparable awakening led to the evaluation of Landscape and Cultural Heritage. In the jargon of water defence there are called LNC values (or Nature Values). A flood defence is often very visible and accordingly determines the experience of the surroundings to a great extent, sometimes for hundreds of years. The secondary functions are the only visible functions the majority of the time at many flood defences. Which makes it understandable that society attaches great importance to giving these aspects sufficient attention. Multi-functionality and cohesive flood defence management have been points of departure in policy during the past few years. This shows that a mono-functional approach – both to the design at reinforcements and to management – does insufficient justice to the above-mentioned social interest. This leads to another approach to the management of flood defences, that does not need to be controlled by

May 1953: closure of a dike hole near Kruiningen using caissons

Closure of the closure gap. It can be clearly seen that the cause of the dike collapse was overtopping water. The outside slope is mostly undamaged.

one institution. It is very common that a road on a dike is managed by a municipality, while responsibility for the water retaining function is lodged with the water board.

Cohesive management is about the harmonisation and integration of the various interests. The 1993 Boertien Committee report and the political decision-making connected to it confirm this tendency.

Furthermore, at the moment no fully formed picture of management can be sketched. The possibilities of private use (via land leasing for instance) will greatly depend on availability of space for the flood defence, because a limited space sets higher demands on the quality of the revetment on dike slopes and so their use. It is therefore clear that the degree of multi-functionality is not the same for every type of flood defence and can even vary location by location for a specific flood defence. An embankment used as a flood defence will be experienced as mono-functional by most people, while dunes are often considered to be natural areas. In these examples there is a great difference in the water-retaining grade per m^2. At dunes this definition is even the origin of two extremes in the approach of management: define a narrow strip that is almost only intended to retain water or take a much broader strip where other functions can also be realised (ref. *Guide on Sandy Coasts*).

2.3.2 Landscape, Nature and Cultural Heritage values (LNC-values)

Based on the selected safety norm government policy is especially oriented to the preservation of the components of landscape, nature and cultural heritage, to which values are allocated. That policy also consists of a further development of those values and the development of desirable new values. The dunes are usually too young to be labelled cultural heritage, but landscape and nature in the dunes have been allocated a very high value almost everywhere. River dikes are increasingly seen as architectonic elements, which determine the landscape to a great degree, and can be used positively. An obvious key concept in the design of these elongated structures is continuity. Specific solutions are demanded to keep that continuity intact for local facilities for the functions of traffic, industry or recreation. Variation in buildings on the other hand is seldom experienced as an infringement of the continuity of the dike. That shows that the scale of the elements on and around the dike is important. In terms of spatial experience, it is preferred that sophisticated structures be designed for the preservation of nature values.

2.3.3 Other functions

Besides nature values other functions traditionally play a role at and on flood defences, such as housing, traffic, agriculture, water-related industry and recreation. They are called user aspects. To a degree these user aspects can be easily combined with the water retaining function and the nature values; sometimes they are inconsistent with them or with each other.

For example, buildings can be problematic in relation to an efficient management of the flood defence or even the water retaining capacity. Cattle breeding can be the source of problems in the management of grass stretches due to trampling or manuring (fertilizing). Traffic on the flood defence may demand a much broader crest than strictly needed (including any inspection road). The same may apply to such recreational facilities as picnic spots and panoramic views. All these facilities can influence the natural experience.

The many and various functions and values that play a role in the improvement of the flood defence make the selection and decision making process more complicated. To make that complexity easier to understand, a vision is developed for a dike improvement zone. It includes a list of functions and values, bottlenecks, priorities and the solution orientation. This is addressed in more detail in chapter 5.

The monument to a dike worker on the IJsselmeer closure dam

2.4 ADMINISTRATIVE FRAMEWORK

2.4.1 Organisation

The care of the flood defences in the Netherlands is spread over three administrative layers: the state, the provinces and the water boards. The municipalities are involved in spatial planning (as representative of other interests at flood defences like housing and traffic) and in the case of a threatened calamity.

A central role is reserved for the water boards. A water board is a functional administrative form, oriented to water management and flood defence management. The province has a regulatory task, both for the municipality and the water boards and can therefore take binding decisions in the event of a difference of opinion (see box).

DIVISION OF TASKS BETWEEN ADMINISTRATIVE ORGANS

Water board

Water boards are responsible for the construction, management and maintenance of primary flood defences that surround a dike ring area. Water boards are controlled by an elected representation of landholders: the parties with interests in the protected area. The water boards have the power to issue the by-law needed to secure the water retaining function. The management and maintenance is chiefly financed through taxation of landholders. The construction costs connected to the current round of dike reinforcement are too high for the majority of water boards however, and are therefore (largely) subsidised by the state. The construction subsidy for the river dike reinforcements were transferred to the provincial fund in 1993. The financing of integral flood defence management is a source of discussion, bearing in mind the limited terms of reference of water boards in the functional administration. It is expected however, that an integral vision on management will increasingly become common property and that financing will adapt to that. The aim is to form large and decisive water boards. This is connected to the ever increasing demands placed on the administrative and technical capacities of a water board, certainly in comparison to the situation just after the second world war. In less than fifty years the number of water boards has been reduced from around 2500 in 1950 to less than seventy now.

Province
The provinces oversee the water boards. The Flood Defence Act distinguishes two specific tasks: (1) monitoring the technical quality of management, and (2) supervising proper harmony between municipal and water board policy. This last aspect is a guarantee within our polity for the adaptation of functional water board management in the general administration. The terms of reference of the water board is laid down by the province in the water board regulations. The plans for dike reinforcement and the flood defence manager's five-year report prescribed by the FDA on the hydraulic state of the primary flood defences must also be submitted to the Provincial Executive. The regulating function also includes the national flood defences in the province. Furthermore, the province plays an important role in the organisation of the system of water boards, in the concentration of water boards mentioned for example. The setting of norms for drainage/discharge canal embankments and secondary flood defences are also provincial tasks.

State
The state has a number of responsibilities, including (1) legislation, (2) supreme control of the system of water boards, (3) the management of primary water defences that protect various dike ring areas (especially sea arm barriers) and the dune coast of the Wadden islands and (4) the management of the large waters and rivers. With respect to the sandy coast the state plays a specific role, of great importance to the flood defence managers along the coast. The state is responsible for maintaining the location of the coastline, one of the preconditions of the security of dunes and sea dikes. The river manager must ensure, among other things, that undesirable resistance is not created in the riverbed and that the water coming from upstream can be easily drained. The supreme control is expressed in the five-year report by the Provincial Executive to the minister of Transport, Public Works and Water Management on each dike ring area in its province, as prescribed in the tasks of the province.

Municipality
In the field of spatial planning the municipality draws up zoning plans in which flood defences must find a place. Whereas water boards are oriented to protection against flooding, bearing in mind their functional administration tasks, the municipalities are oriented to the other functions of water defence. In addition, the municipality has responsibilities in the case of a flood, including drawing up a contingency plan, maintaining public order and security and ensuring public health.

2.4.2 Legal basis

Article 21 of the Constitution calls the care of the habitability of the Netherlands a fundamental task of government. A number of legislative fields are especially important for flood defence management and improvement:

- Water management legislation (particularly the Flood Defences Act (1995), Water Control Act (1900), Delta Act (1958), Delta (Major Rivers) Act (1995), Rivers Act (1908), Water Management Act (1989), Water Boards Act (1992), provincial regulations and water board by-laws;
- Planning legislation, particularly Spatial Planning Act (1962), Expropriation Act (1857);
- Environmental legislation, including Environmental Management Act (1993), Soil Protection Act (1986), Pollution of Surface Waters Act (1971).

These acts are explained individually before.

The main role of the Flood Defences Act (FDA, annex I) is to legally anchor protection from flooding by the outside water. The FDA is the legal foundation for construction, improvement and maintenance of flood defences and provides all dike ring areas with a safety norm (see annex I). The management of the flood defences is also regulated in the provincial regulations and the water board by-laws.

The principal aim of the FDA is to guarantee security. It is a fact that social understanding of the risks of flooding decreases as the years elapse since the latest flood. Article 9 of the Act obliges the manager of the flood defence to report on the state of the defence in relation to the norm every five years. This is an attempt by the legislator to prevent the consequences of the process of a decreasing understanding of risks. The Delta Act regulates the damming of the sea arms in the South-West Netherlands and the improvement of the other flood defences along the whole Dutch coast (including the financing thereof). The Delta (Major Rivers) Act is an emergency act aimed at improving the weakest dikes along the great rivers in a short space of time after the high water of 1995.

The Rivers Act is oriented to ensuring that the water discharge function of the rivers continues to be guaranteed. This is also connected to the normative water levels for protection against flooding. A permit is therefore required for all works in (the winterbed of) the river.

The Water Management Act regulates in itself nothing with respect to flood defences, but the Fourth Policy Document on Water Management based on this act addresses in detail the relationship between water levels and the arrangement of the riverbed.

The Spatial Planning Act (SPA) is the basis of other zoning plans. A municipal building permit is needed for building of or on a flood defence, granted on the basis of the zoning plan. In the zoning plan the main purpose of the area of the flood defence is hydraulic. In turn, the water board draws up a by-law in which the permissible uses from a water retaining function are stated. The SPA set of instruments is also important at any building activities outside the dike.

The Expropriation Act regulates the legal procedures for ground acquisition, needed for improvement works, in the cases in which it is not possible to reach an amicable agreement.

The Environmental Management Act (EMA) regulates matters that are relevant to dike improvements. The EIA (environmental impact assessment report) procedure, which is mandatory at improvement projects, is based on the EMA. The EMA is also applicable in the final execution of improvement works.

Materials used in flood defences must fulfil the Building Materials Decree based on the EMA. If this is not the case then a permit must be requested on the basis of the EMA.

The Soil Protection Act (SPA) covers both preventative protection and curative decontamination of the ground. The latter comes into play when a flood defence must be reinforced on soil that is very contaminated.

The Pollution of Surface Waters Act (PSW) is applicable when there may be pollution in the adjacent surface water, such as at bank facilities and use of clay screens in dikes.

2.5 POLICY IMPLEMENTATION

Numerous policy documents and regulations are important for the implementation of policy in the field of water defence. They will be addressed in the relevant chapters.
The point of departure in the implementation of policy is a multi-functional approach by which the water retaining function does not suffer, which means that the defence must fulfil the safety requirements set. The social framework is sketched above within which dike improvements and flood defence management occur. Clearly, there is no 'best solution' for a specific case. There are always various possibilities that fulfil the many functions and aspects to a greater or lesser degree, and they are often (precisely) contradictory. The task of the manager and designer is to indicate that possibility and its consequences, including the financial ones. The challenge in the design is attempting to find a solution that fulfils its primary function and is well adapted socially and affordable.
The issue of sharing the financial burden is relevant not only to the design, but also to dike improvement. Dike improvement literally intervenes in an existing situation. It is often a good moment to introduce other desired improvements in secondary functions, for instance with respect to traffic or recreational facilities. Not everything is on the account of dike improvement. An integral approach means that as many things as possible are taken into account, but not that the manager or the giver of a subsidy is left with the whole bill. Facilities that are not a consequence of, or necessitated by the improvement of the flood defence, are usually paid for by the institutions or market parties responsible for the facilities.
An other aspect of the sharing of the financial burden is the origin of the financial resources. Improvements usually come from a different financing source (subsidy from state or province) than maintenance (apportionment from residents). The prevention of improper choices at improvement works due to this difference in financing is the responsibility of all parties.
The multi-functional character of flood defences also plays a great role in management. The choice of broad dune flood defences, precisely to offer other functions more space, is one example. Another form of management of grass dikes, with less pasturing and manuring (fertilizing), creating a much more variegated and erosion stable vegetation also points to this. Good agreements on the other functions of the flood defence are needed to prevent conflicts. This is addressed in more detail in chapter 10, 'Management and Maintenance'.

CHAPTER 3 THE SYSTEM OF FLOOD DEFENCES

Chapter 3 provides an overview of flood defences and related systems. A distinction is made between categories (the place in the security of dike ring areas) and types (forms).

3.1 INTRODUCTION

Three systems play a role in water defence, as set down in the Flood Defence Act (FDA):
1. The system of the protected dike ring areas;
2. The water management systems (outside the dike) bordered by the flood defences;
3. The system of the flood defences itself.

The system of the protected dike ring areas
In the protection against high water distinct areas can be distinguished, each surrounded by a unbroken system of flood defences, possibly in combination with high grounds. High grounds are grounds that are high and broad to a very satisfactory degree to allow them to retain outside water without management being necessary to maintain the situation. Encircled by flood defences and any high grounds, such an area is called a 'dike ring area'.

The water management system (outside the dike) bordered by the flood defences
The water management system outside the dike sets the preconditions for the loads that work on the flood defences. The relevant water retaining aspects for these systems are handled in the following chapters.

The system of the flood defences themselves
The system of flood defences around a dike ring area, including any dunes and locks, is called an encircling dike. The safety of people and goods in the dike ring area is dependent on the adequate performance of the whole encircling dike, perhaps in combination with the flood defences that are situated in front of the dike ring area. The encircling dikes of dike ring areas and any defences situated in front of it, are called primary flood defences.

Secondary defences, such as the majority of compartment dikes, are beyond the operation of the FDA and are therefore not handled here. The same applies to drainage/discharge canal embankments, which fulfil an important function in keeping large parts of the Netherlands dry (*Technisch Rapport voor het toetsen van boezemkaden/Technical Report on safety assessment of drainage/discharge embankments*).

3.2 CLASSIFICATION BY CATEGORY

In line with the Flood Defences Act, the primary flood defences can be subdivided on the basis of the following two characteristics:
1. A defence retains outside water or does not retain outside water. The concept 'outside water' is limited within the Act to the surface water, the water level of which is directly influenced by high tidal floods, high surface water of one of the major rivers, high water of IJsselmeer or by a combination of these factors. Grevelingen lake for example, is therefore not outside water in the sense of the Act. Outside water accordingly indicates the most important threat. Inside water is all surface water except outside water.

2. A defence belongs to the system of flood defences that encircles a dike ring area or is located in front of a dike ring area.

The combination of these characteristics leads to the following four categories of primary flood defences:
1. The flood defence belongs to the system that directly encircles the dike ring area and retains outside water;
2. As category 1, but not intended for direct retention of outside water;
3. The flood defence is situated in front of a dike ring area and retains outside water;
4. As category 3, but not intended for direct retention of outside water.

No land is located behind the flood defences of category 3 and 4, but water. Examples of category 3 are the IJsselmeer closure dam and the Tidal Flood Barrier in the Oosterschelde, both of which retain high water levels on sea. In this context it makes no difference that the IJsselmeer closure dam always retains water and the Oosterschelde barrier only closes when the sea level is high. An example of category 4 is the northern part of Grevelingen dam, which has inside water on both sides. The function of flood defences of categories 3 and 4 is to prevent the occurrence of (too) high levels of water behind it, at least to greatly reduce the probability thereof. In doing so they limit the loads on the flood defences that separate the water behind them from the land in front of them.

The following distinction can be made within category 2:
a). The flood defence retains outside water;
b). The flood defence only retains water if another defence has collapsed.

Examples of category 2a are the dikes of Goeree-Overflakkee and Schouwen-Duiveland on Grevelingen lake, an inside water separated from the sea by the Brouwers dam. In the case of category 2b the flood defence separates the toe dike ring areas. An example is the Dief dike, which runs over land, on the provincial boundary between Zuid-Holland and Gelderland, from Everdingen on the Lek to Gorinchem on the Merwede. The Dief-dike separates two dike ring areas with a different protection level (see annex I) and has the status of primary flood defence. Finally, there is a fifth category, primary flood defences beyond the Netherlands. This situation is found where dike ring areas extend beyond the borders of the Netherlands. These are the dikes along the Rhine, Schelde and Eems. A collapse here can result in flooding in the Netherlands. It will be clear that international consultation is needed to realise the desired security level.

3.3 CLASSIFICATION BY TYPE

3.3.1 General

A large part of the Dutch coast is protected against tidal floods by natural dunes. The high grounds also form a natural protection against flooding. All other flood defences are manmade and are traditionally made of a combination of clay and sand, so-called soil bodies. The reason is obvious. The material is available in great quantities, is easy to process, flexible, easy to maintain and adapt and very durable. In combination with grass, clay is reasonably erosion stable. Such structures as locks and cuts were designed in situations where the flood defence is crossed by (water) ways. In that way water retaining hydraulic structures, in the past most often made of wood and brickwork, were later also concrete and steel.

The number of these structures is mostly limited in connection with the risk of not being able to close them (on time) and the problems of the watertight connection of these stiff structures to a soil body. There may be other reasons not to use a soil structure, usually following on from the other functions the flood defence has been given. For instance, the wish of vessels to moor on the flood defence demand a vertical wall, which leads to a retaining wall structure. In the reinforcement of a flood defence it can be decided to execute it completely or partially as a wall or screen structure, in order to gain space to save any buildings that may be considered to be of value for example.

This does not change the fact that initial thoughts are concentrated on the design of a soil structure when designing a new flood defence, and also when reinforcing existing flood defences, for the above reasons.

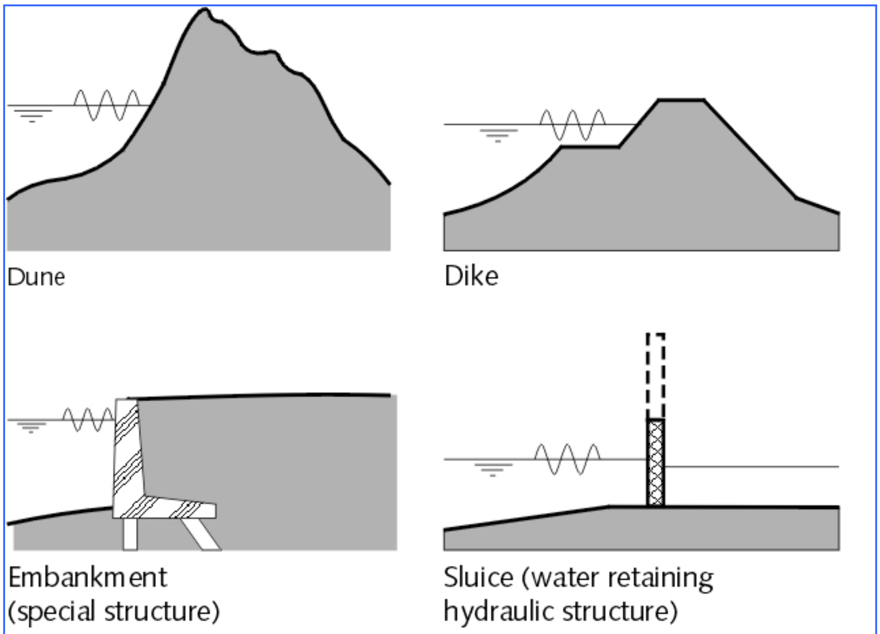


Figure 3.1 Main types of flood defence

On the basis of the above, there are four (main) types of structure for the protection of a dike ring area against high water. These are (see also figure 3.1):
- Dunes;
- Soil structures (dikes, dams);
- Special water retaining structures (including cofferdam, retaining wall, sheet piling);
- Water retaining hydraulic structures (including locks, cuts, tidal flood barriers, pumping stations).

In addition, there may be objects in, on and alongside flood defences, such as pipelines, buildings and trees. These objects typically have no-water retaining functions, but could influence the water retaining capacity. For all flood defences, it must be said that the water retaining capacity must be assessed using the height and firmness of the whole structure, including objects.

3.3.2 Dunes

Dunes are natural landscape forms. They are formed by the wind from washed up sand in combined action with the vegetation that catches and holds the sand. The stabilisation can be accelerated or reinforced by marram. That vegetation is not meant and not able to stop erosion of the sand grains by waves at high water levels however. The effect of dunes as high water defence is solely based on the total mass of the sand. This mass must be so great that sufficient sand will stay put to retain the water level difference between sea and hinterland after sloughing by storm. After the storm the building up process by the wind can begin again. This dynamic character means that dunes demand special attention in terms of management and maintenance.

The tidal flood defence in the Oosterschelde guarantees the safety of the area behind it, while retaining the unique tidal eco-system

3.3.3 Soil structures

Dikes and dams are manmade soil bodies. In contrast to dunes, which are not very able to withstand erosion by wave impact, dikes often must be, due to their smaller dimensions. A dike derives that erosion stability from the materials used, clay with grass vegetation for example, or a revetment of stony materials or asphalt. A characteristic of these structures is the form of the soil body, which is trapezium shaped in sectional plane. The water retaining capacity of the structure is supplied by the height and the form of the cross section. It must be ensured that there is sufficient resistance to shearing (firmness) and water tightness. The dike derives its firmness from the shear strength of the dike body and the subsoil.

3.3.4 Special water retaining hydraulic structures

Special water retaining hydraulic structures have the same water retaining function as a soil structure, but the form and the materials can be very different. Examples are dike wall, cofferdam, and sheet pile. The special thing about these structures is that they make possible a greater freedom in form and functionality than a traditional dike design. Conversely, they do usually demand a great deal of attention in terms of management and maintenance.

These structures derive their strength from the materials used such as a steel, concrete and wood, which are able to withstand great pressures than clay for instance. The general stability is due to friction (retaining wall with soil), by piles (retaining walls on piles, see figure 3.1) or by wedging in the bottom (cofferdam). Special attention in the design is demanded by the transition of the special water retaining hydraulic structure to the connecting soil structure.

3.3.5 Water retaining hydraulic structures

Water retaining hydraulic structures are made for another ('utilitarian') function that crosses the flood defence. Such a function may be:

- Shipping through a navigation lock (IJmuiden) or tidal flood barrier (Nieuwe Waterweg, Hollandse IJssel);
- Water through a pumping station (Katwijk), an outlet sluice (Haringvliet locks) or tidal flood barrier (Oosterschelde);
- Road or rail traffic through a cut (Lobith, Harlingen).

Owing to these utilitarian functions these hydraulic structures are usually provided with one or more moveable means of closure. In a closed state these means carry the forces that work upon them over to the inflexible part of the structure.

The tidal flood defence in the Nieuwe Waterweg (New Waterway) makes dike reinforcement in cities like Rotterdam and Dordrecht superfluous

3.3.6 Combinations

The above clearly shows that the bounds between the various types of flood defence and the objects they comprise is not very acute. Special structure can reinforce, supplement or completely replace soil structures. Special structures may be fixed or moveable, whereas water retaining structures are actually always movable. Buildings can be saved by special structures or become part of a special structure. In some cases the building components with a specific water retaining function are easy to recognise. Figure 3.2 illustrates this.

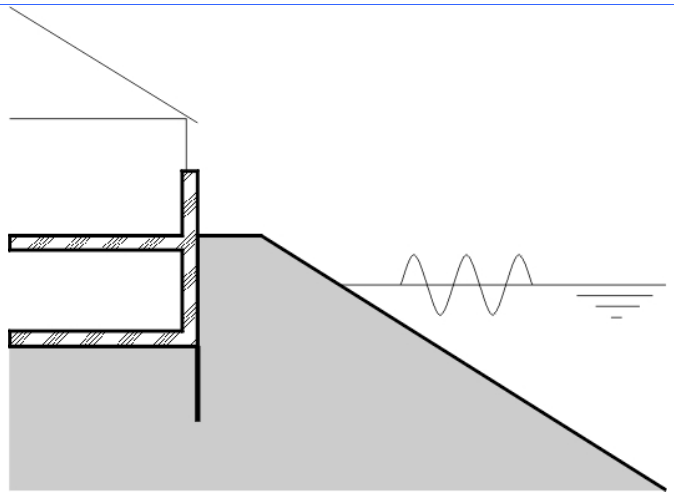


Figure 3.2. Example of a house that is also a flood defence

3.3.7 Objects

'Objects' covers a large number of matters that are not introduced for the primary function of the flood defence, but are still part of it. These are buildings, roads, pipelines, trees et cetera.

Objects in the flood defence demand extra attention in the design and extra care in the management. Pipelines can form potential leaks in the soil body for example. Buildings can lead to a weakened flood structure due to seepage capability, but may also be made in such a way that they form a special structure.

CHAPTER 4 SAFETY

Chapter 4 gives an overview of the development of ideas in the Netherlands on protection against flooding. How is that arranged theoretically? And what practical and psychological problems are encountered in practice? The TAW line of march, a contemporary approach to the principles of the Delta Committee, is also addressed.

4.1 INTRODUCTION

High water levels that threaten the lower areas of the Netherlands are caused by (1) storms that drive up water levels at sea and on lakes, and (2) precipitation that increases the discharge of the rivers. Figure 4.1 shows a comparison of the possible course of an extreme rise in water level at Hook of Holland and Lobith. It shows that the character varies greatly. On the river the rise in the water level is greater and most notably longer than at sea. Besides high water levels, waves form the most visible threat to flood defences. Waves increase the pressure or are the source of extra impact on defence structures, both on the outside and the inside in the case of wave overtopping. The difference in character observed of water levels along the coast and along the rivers is reinforced by the wave loads. High water levels along the coast are caused by storms and are therefore always accompanied by high waves, while high river discharge values are independent (see figure 4.2).

On the coast the threat is usually short and violent; the violence of the waves plays a dominant role. Along the rivers the threat is much less violent, but lasts much longer, which may lead to dike weakening or collapse due to the flushing out of soil. This is addressed in more detail in chapter 7.

The protection against flooding by flood defences is never absolute. Upper limits of natural phenomena like wind and rain are not known. Instead it must be assumed a certain exceedance-probability of these phenomena. Figure 4.3 shows an example of the water levels at Hoek van Holland and Lobith. These preconditions for flood defences are worked out in the report on Hydraulic Boundary Conditions (*Hydraulische randvoorwaarden)*.

Under extreme conditions flood defences can collapse and the land behind it will flood. Under less extreme conditions the behaviour of the flood defence cannot always be predicted, so there is always a (small) probability of collapse.

The consequences of a flood can be far-reaching: loss of human life, goods and means of production and damage to landscape, nature and cultural heritage. The approach is addressed below, along with the choices that have to be made and the developments involved. First the considerations that should play a role in the construction and maintenance of flood defences are indicated. Knowledge is always limited so not all aspects mentioned can be assessed in full.

4.2 BASIS

4.2.1 Dike ring areas as a whole

The starting point for all safety approaches is the risk that accompanies the problem in question. In the case of water defence the risk is the probability of flooding combined with the corresponding consequences. This can be expressed as the probability (so many times a year) multiplied by a certain consequence (a measure of the loss of money and/or human life). The measure for the risk is the average loss of money or human life per year. The definition of a certain accepted risk indicates that the greater the consequences the smaller the probability must be. It is not possible to totally preclude risk, because the probability 0 is impossible, given the lack of an upper limit to natural phenomena. The choice, and so also acceptance of a risk level is accordingly all about pros and cons. In practice emotions also play a role in the ultimate choice.

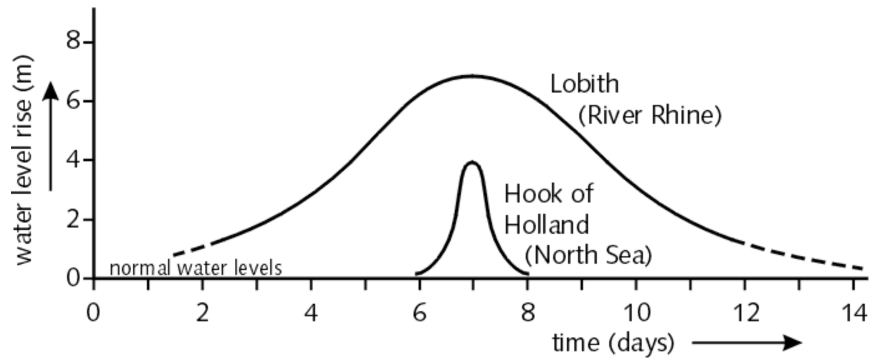


Fig 4.1 Raising in relation to average water level (=0)

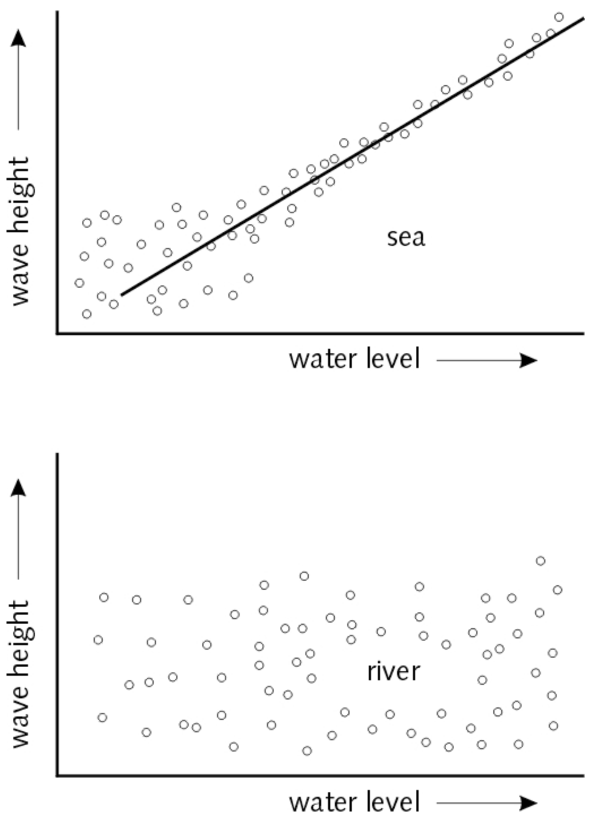


Fig 4.2 Link between waves and water level at sea and river

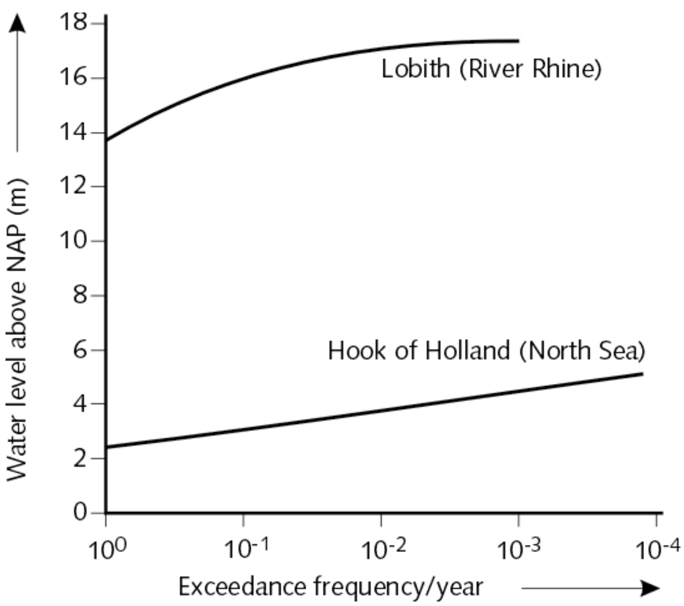


Fig. 4.3. Average frequency of a water level higher than the level indicated

For a dike ring area with a flood defence, society must reserve finances, a sort of insurance premium, for the evacuation of people and the repair of damage. The higher, stronger and more reliable the flood defence, the smaller the probability of collapse and damage. And so the smaller the risk and the insurance premium.

On the other hand, the improvement of flood defences also demands sometimes great social sacrifices. This is all about the expense for the construction and maintenance of flood defences, and the loss of landscape, nature and cultural heritage that can be the consequence of the construction or improvement of flood defences.

The requirements set for the degree of safety of the areas behind it must therefore be based on a consideration between the social sacrifices and the benefits of flood defences. The risk approach is an aid here, by which both certain occurrences (investments) and uncertain occurrences (probability of dike collapse and the consequences) can be assessed. If the investments and the sacrifices are both expressed in financial terms then an econometric calculation can be made, to determine the optimal safety level. Any loss of human life makes this approach a discussible one to say the least. So in the consideration both objective and subjective elements play a role.

The consequences of a flood are not the same for every dike ring area. They especially depend on the nature of the threat and the characteristics of the dike ring area. The consequences of a flood by river water is for example, different to those by sea water: fresh versus saltwater, warning for evacuation in the long term versus warning for evacuation in the short term, et cetera. A small polder will fill more rapidly than a large one, and people will have less time to evacuate. In a deeper polder there will be more damage than in a shallow one. In a dike ring area where many people live and work and where there is a great deal of industry, the damage will be greater than in a sparsely populated area. And finally, the consequences depend on the degree to which the population in a dike ring area is prepared for evacuation and the effectiveness of that preparation. As the consequences of a flood increase the probability of a flood must decrease. This basic principle determines the requirements set for the flood defences.

The costs and other social sacrifices needed to achieve a specific safety level in relation to the construction or improvement of flood defences can also differ from dike ring area to dike ring area. As the sacrifices increase the consideration of sacrifices and benefits will result in lower requirements for the degree of safety.

So because the sacrifices and the benefits are not the same for every dike ring area, the outcome of the consideration, and so the desired degree of safety, from dike ring area to dike ring area vary. Indeed, the Flood Defences Act also acknowledges differences in the safety norm for dike ring areas (see annex I). From the point of view of equality before the law for citizens, a certain uniformity in safety norms has to chosen. As a result, the differences are always smaller than would be expected on the basis of the reasoning with respect to sacrifices and benefits.

Closure of Veerse Gat in 1960

The protection of the Netherlands against flooding will always demand our attention. There are various reasons for this. First, the natural phenomena involved have a dynamic character (rise in the water level, sedimentation in the rivers, subsidence of the land) and flood defences are worn by time.

Secondly, the components in the sacrifices-benefits consideration change, like the sacrifices of construction and maintenance of the flood defence and the consequences of any dike collapse. For example, in many polder areas the invested capital and the number of residents and workers has risen sharply in the past few decades.

Thirdly, the evaluation of sacrifices can change under the influence of changed social insights, not least due to the occurrence of flooding. Section 4.5 details the work of the TAW in including these developments in the safety considerations. Adaptations to flood defences do not occur continuously, but periodically. Due to the time dependent factors mentioned the safety level typically decreases as long as man fails to intervene as time goes by. This should be taken into account when setting requirements for flood defences.

4.2.2 Distinction within a dike ring area

The sacrifices and benefits of improving flood defences differ not only between two dike ring areas, and within the system of flood defences round one dike ring area. The sacrifices will differ in an urban area and a rural area. The benefits of improving flood defences are formed by the reduction in (the probability of) the harmful consequences of flooding. The consequences of collapse of parts of the encircling dike can vary due to variation in the height of the site, but also the spread of population, buildings and industry over the dike ring area. Differences in the consequences may also be caused by the nature of the threats (sea or river for example) and the type of flood defence (flooding/inundation due to a dike collapse is quicker and more violent than at a culvert with a limited opening that has not been closed).

The differences mentioned mean that it is possible that different requirements can be set on the various flood defences around one dike ring area. That does not negate the fact that these different requirements are based on the same principles and that the safety of all parts of the dike ring area must be considered together.

The differences may also lead to the wish to divide large areas into compartments, by means of secondary flood defences. This limits flooding to a smaller area. Compartmenting also has disadvantages however. Small compartments fill rapidly, adversely affecting the safety inside. If a compartment dike has been granted the status of primary flood defence in the Flood Defences Act (see chapter 3) it may be assumed that both aspects are considered and that a conscious well-considered choice has been made. For the other compartment dikes the choice is usually not so well-considered. But even if a soil body, over which a road or rail line runs, does not have the status of flood defence, it does have the effect of compartmenting. The consideration of pros and cons is needed in that case too. Either the situation will remain unchanged or measures will be introduced to create openings in the (unintended) compartmenting dike.

During the con of onstructithe Delta Works newer and newer methods were developed and used. Cableways were set up for the closure of flow channels in het Haringvliet and Grevelingen. Cable cars were used to dump stones or concrete blocks in the channel

4.3 DELTA COMMITTEE'S SAFETY PRINCIPLES

Before 1953 the risk estimates (safety definitions) were either formulated on the basis of intuition or experience. The 'highest known water level' on site played a crucial role. The flood defence was designed at that level plus a certain margin. If a flood defence proved too low for a new and higher water level, then this automatically became the highest known water level and the dike was raised.

After the 1953 disaster the need for a more unambiguous approach, along the lines of the section above was adopted. The safety requirements in the prevailing guides placed on the flood defences have their origins in the Delta Committee's body of ideas, collated in its 1960 report. An econometric view was set up for Central Holland. The econometric optimum safety level was fixed at approximately 1/125,000 per year, assuming a complete loss of capital goods. The loss of human life and the breakdown of society was not collating in this view.

Assuming a flood probability of 1/125,000 per year this would mean about the same collapse probability for the flood defence. However, it was impossible to determine the probability of collapse of a dike with any precision due to insufficient numeric insight into the collapse mechanisms. As a result, partly in light of the other uncertainties, another approach was chosen. The requirement was that it must be possible to 'completely retain' a water level with an exceedance frequency of 1/10,000 per year (the design level, the Normative High Water, MHW). That was considered to be true when only 2% of the accompanying waves running up the dike were exceeding the crest of the dike.

For Hoek van Holland it was determined that a level of NAP +5m has an exceedance frequency of approximately 1/10,000 per year, the so-called base level of the Delta Committee. For Central Holland the design level (MHW) is the same as the base level. For other locations along the coast the base levels have been determined by assuming conditions with the same exceedance frequency. For the MHW along other parts of the coast an economic reduction was applied however, varying from 0.2 to 0.6m. The accompanying exceedance frequency of the MHW along the coast varies from approximately 1/4000 to approximately 1/1500 per year. The economic reduction was motivated by the fact that the consequences in the case of dike collapse are not always as serious as in Central Holland.

For the upper rivers area the River Dikes Committee (the Becht Committee) recommended an exceedance frequency of the design discharge (to which the MHW is linked) in 1977 equal to 1/1250 per year. The 'extenuating circumstances' in the rivers area in relation to the coast included: fresh versus saltwater and announcements in the long term versus announcements in the short term. The loss of Nature values also played a role in the choice of this number. The Boertien Committee made a similar choice in 1993, the result of which was the same exceedance frequency of 1/1250 per year. This number was chosen in spite of the fact that a material risk consideration would lead to a lower frequency (Boertien I Final Report, *Toetsing uitgangspunten rivierdijkversterkingen*).

The considerations of the Delta Committee and its elaborations have since formed the core of the safety requirements. The exceedance frequencies of the MHWs form at this time the most tangible expression of the degree of protection against high water, offered to various areas. This is the norm given in article 3.1 of the Flood Defences Act.

The concept 'completely safe' is worked out in the design rules. It should include a margin due to uncertainties in such matters as water levels, wave attack, soil & material characteristics and behaviour of the water retaining structures. The Delta Committee chose the freeboard for this margin, the difference between the crest height of a dike and the design level. This difference is decided in the design by such factors as the wave run-up, any fluctuations in the water level due to wind, estimated settlement of the flood defence and such like. The Delta Committee recommended that the freeboard, even when there is no wave attack to speak of, should be at least a couple of decimetres.

Annex III explains how this principle – safe water retention at MHW – is worked out in existing TAW guides. The classification of the guides is according to type of flood defence on the one hand (dikes, dunes, hydraulic structures, see chapter 3) and according to area on the other (coast, tidal rivers, upper rivers).

For primary flood defences that do not directly retain outside water the Flood Defences Act (article 3.3) demands that they offer the same safety (expressed in strength) as the day the Act came into effect. That is because the probability of the collapse of primary flood defences is difficult to determine and serves to prevent the quality of these structures from declining, as long as there are no better calculation methods. This is also true of flood defences in categories 2 and 4, see section 3.2.

For non-primary flood defences and drainage/discharge canal embankments there is a lack of a legal basis and the setting of norms is left to the provinces.

STATISTICS AND MISUNDERSTANDINGS
A water level with an average exceedance frequency of 1/1000 per year corresponds to the probability of 0.1% that a higher water level will occur in one year. That is also expressed as once per thousand years.

That is where many misunderstandings originate. Once per thousand years does not mean that a flood can only occur once every thousand years or that it will be a thousand years before a storm occurs again. It means that a flood *on average* occurs once every thousand years. Roll a die six thousand times and you get a four (approximately) one thousand times; that is a four *on average* every six throws. If you roll a four it does not always take four throws before you get the next one. But the probability is 1 in 6 or 16.6% every time you throw. You can also throw a four three times in succession, although the probability is much smaller. The chance that a 'once in a thousand years' water level occurs next year is 0.1%. In a human life lasting 75 years that probability is (approximately) 7.5%.

The transition from 1/1000 per year to once per thousand years can be the source of another misunderstanding. Because the physical-geographical situation along the coast and on the rivers is changing constantly, as is the climate, the same situation never occurs for a thousand years. Designs on a situation of (on average) once per thousand years is therefore not possible. We are unable to look a thousand years into the future, but we do allow for an occurrence that, in the present situation, has a probability of occurrence of 1/1000 per year.

4.4 DEVELOPMENT IN WORKING OUT THE SAFETY APPROACH

In this section four design methods are given for flood defences:
1. Overload approach per dike section;
2. Overload approach per dike ring area;
3. Flood (inundation) probability approach;
4. Flood (inundation) risk approach.

The overload approach per dike section became the usual approach at the time of the Delta Committee and is at the root of the norm setting in the Flood Defences Act. The other methods are an extension of it and provides an increasingly accurate approach to the actual risks, but also demand more knowledge and data. Section 4.5 details the Marsroute initiated by the TAW into the use of those better methods and how they should be handled in the meantime.

4.4.1 Overload approach per dike section

The basis of the rough design methods indicated by the Delta Committee is known nowadays as the 'overload approach per dike section'. The original formulation of 2% wave run-up was subsequently rendered as the quantity of overtopping water. Overloading is felt to occur when the discharge q over the defence is greater than a permissible discharge q_t. The idea behind this working method is that it is not easy to find out what exactly happens when overtopping is greater than q_t.

Consequently – depending on a few rough structural characteristics – a small, only just permissible overtopping discharge q_t is defined in a deterministic manner. If it is exceeded the flood defence is 'overloaded' (which does not have to mean that the defence will collapse).

Safety requirements

1. The probability of exceedance of the discharge q_t may for every dike section not exceed the norm mentioned in the Flood Defence Act for the relevant dike ring area. Here a design water level (MHW) is typically assumed, with associated wave climate from which a wave run up/or wave overtopping follows on.
2. For water levels equal to or lower than MHW the probability of failure due to other factors than wave run up/overtopping may not exceed 10% of the norm mentioned in point 1.

These safety requirements form the interpretation of the concept 'maintain complete safety given the design water level', as used by the Delta Committee.

The overload approach by dike section is the target for future developments, which is worked out in more detail in section 4.5.

The term 'overload approach' indicates that the degree of safety is linked to the probability of exceedance of the hydraulic load considered permissible for the wave run up and overtopping mechanism. In the decades following the publication of the Delta Report other failure mechanisms (see chapter 7) than wave run up and overtopping forced their way onto the agenda. The term 'by dike section' indicates that the design is based at the level of a section, that is a section of the flood defence with uniform characteristics and conditions. At a later stage design methods were developed by which explicit account was taken of the variations of conditions along the route of the dike ring and their influence on the safety of the dike ring area as a whole.

4.4.2 Overload approach per dike ring area

The overload approach per dike ring area is about the probability that more water overtops somewhere along the encircling dike than the overtopping discharge considered permissible. This is not necessarily the same probability as that for the overload approach per dike section. Uniform conditions are prevalent along a dike section (see section 4.4.1); along a encircling dike the conditions can vary as a result of differences in location with respect to a wind direction or when the encircling dike is loaded by both high river discharges and high sea levels. As a result the probability that overload will occur somewhere along the dike ring is greater than when every dike section is considered individually.

Safety requirement

1. The probability that an overtopping discharge occurs somewhere along the dike ring area, that is greater than the permissible discharge, may not exceed a permissible probability;
2. In the case of overtopping discharges equal to or lower than the permissible value, the probability of failure somewhere along the dike ring area due to other causes than wave run up/overtopping, may not exceed more than 10% of the value mentioned in point 1.

The first requirement is intended to verify the crown height in combination with other geometric characteristics and the quality of the inside slope; the second is to verify all failure mechanisms at which overload does not occur. The rendering of these requirements in design rules at the level of a plane remains free.

4.4.3 Flood (inundation) probability approach

The flood (inundation) probability approach is about the probability that failure (that is, a scale of flooding considered impermissible) will occur somewhere in the dike ring area. Failure means here 'sum' of all possible mechanisms that lead to this impermissible flooding.

Some characteristics of the flood probability approach are:
- Strength and load are handled in a (semi-) probabilistic manner for all mechanisms (see also chapter 7);
- The spread of the permissible failure probability over the mechanisms and over the components are not compulsorily prescribed.

Safety requirement
The chance of failure somewhere along the dike ring area may not be greater than a value to be fixed.

4.4.4 Flood (inundation) risk approach

The flood (inundation) risk approach is about the risk, expressed in the probability of the number of victims and the scale of the material damage that occur at the dike ring to be designed. An flood risk approach is a safety consideration, in which account is taken of the fact that the consequences of flooding (victims, damage) of the collapse point can vary and that this can be expressed in the dimensioning of the various components. Dike sections at which the consequences of flooding are small are therefore more lightly dimensioned and vice versa.

Safety requirement
The flood risk must be smaller than a value to be fixed. The flood risk can be expressed in
- individual probability of death, *and/or*
- frequency spread of the number of victims *and/or*
- expected value of the material and economic damage

4.5 FROM DESIGN WATER LEVEL TO FLOOD (INUNDATION) RISK APPROACH

4.5.1 Current situation

The repercussions of the developments sketched earlier in this chapter in thinking on safety with respect to water defence are found in the current design methods, laid down in the TAW's guides. Summaries of these guides are found in annex III.

This clearly shows that the current set of guides are not built up completely consistently from one and the same fundament. This is the result of the fact that the various guides came into being at various times; in a country two-thirds of which is vulnerable to flooding thinking is being developed constantly.

The high waters of 1993 and 1995 lead to the implementation of the Delta (Major Rivers) Plan

But in drawing up the guides, the nature of the mechanism and personal preferences of the authors also played a role. This was possible because there was no one clear and common fixed principle. The principal formulated by the Delta Committee was always used as a reference point in the practice of developing the guides, but it was often also considered to be inadequate and outdated. In that way the overload approach and the flood (inundation) probability approach can be found in the guides (at dunes for example, where the overload approach cannot directly be used because wave run-up and wave overtopping are not normative mechanisms). And also a dike section - as a dike ring area approach. At a few locations risk-analytical considerations are also included.

The purpose of this *fundamentals* document is not to change this situation directly. There are no or insufficient reasons to immediately withdraw and replace the current guides. It is proposed here that a more uniform approach must be pursued in the future. The precise formulation for the common basis and the accompanying timetable and phased plan is being studied. The combined timetable and phased plan are called the Marsroute, and is carried out by the TAW.

4.5.2 Marsroute

The aim of the Marsroute is to achieve a uniform assessment method for all flood defences in the Netherlands. These uniform assessment methods must in the first instance be based on the flood probability approach, mentioned in article 3.2 of the FDA (see 4.4.3). It is also checked to what degree it is possible to include elements of the flood risk approach (see 4.4.4) in the assessment methods as quickly as possible.

The first step in the Marsroute is the formulation of a target that can serve as a basis for comparison for changes in methods that will be proposed in the future. This target is the overload approach per dike section. Depending on the outcomes, the following steps in the Marsroute will be formulated.

High water on the Waal in 1993 at 'Poort van Neerijnen'

The study in the scope of the Marsroute is oriented to six areas.

1. Preconditions and loads;
2. Strength of flood defences and failure mechanisms;
3. Breach development and flooding risk;
4. Damage and victims;
5. Case studies;
6. Factor weighing and norm setting.

The case studies are an important part of the study. They are initially oriented to obtaining information to increase insight into the flood risk. Subsequently, attention in the case studies will switch to factor weighing and norm issues.

The Marsroute initiated by the TAW is actually a logical continuation of the step taken by the Delta Committee with the econometric analysis and the probability approach of the loads. At the time however, there were no means (and to some degree they are still lacking) to go further down this route.

In spite of this, the flood risk approach is ultimately the best form with which to communicate with society on protection against flooding. It is in line with ideas about other risks caused by industry and transport for example. There it is usual to define the risk in terms of location-bound risk of death (somewhat confusingly also called 'individual risk'), the number of deaths and the material damage. This formulation largely corresponds to what is called flood risk approach above. The TAW is attempting to quantify these risks for flooding by means of studies.

Section 7.7 describes the way in which the target point of the overload approach per dike section is rendered as the failure probability of a flood defence. Together with the flood development and its consequences this ultimately provides the flood risk. When it is possible to calculate reliable values for the risks for the dike ring areas in the Netherlands, they will be determined. In the Flood Defences Act such a development has already been provided for to a great degree: article 3.2 provides the possibility of expressing the norm for the flood safety in flood probabilities.

It is expected that the dike improvements initialised since 1953 will provide a varied picture of the safety, expressed in the flood risk. It is then down to the politicians to decide whether further action is desired on the basis of the various numbers. The same consideration of sacrifices and benefits applies as mentioned in paragraph 4.2.1. As with the introduction of frequencies and probabilities by the Delta Committee a similar changeover, with consequences, will ring in a new phase in social thinking on the protection of the Netherlands. Government and parliament must take such a step consciously. The TAW has an advising role. Depending on the estimated consequences of flood a permissible flood probability can be chosen for every dike ring area or it can be decided to maintain the existing safety level.

For the secondary flood defences too, a flood risk approach will provide the necessary clarity. The consideration of various flood scenarios and their probability of occurrence and consequences is the only manner to determine whether the current compartmenting is the best conceivable solution within a dike ring area. But it may also be determined whether a new soil body is acceptable. In cases where interventions at secondary defences are planned or where changes to the compartmenting are scheduled, it will have to be checked on a case by case basis what the best approach is, bearing the above in mind.

4.5.3 Special cases

The new design methods described in section 4.4 will be included in new guides when they are published. At the time of publication of the *Fundamentals* study results are available for the flood risk approach to some degree. It is therefore possible to use the calculated risks for comparison in special cases where the application of the prevailing approach is not satisfactory. The definition of such a situation is at the discretion of the institutions responsible for the construction and management of flood defences. It is recommended that advice be sought from the TAW with respect to the choice, application and results of the design method.

In section 4.3 the origin of the safety requirements used for flood defences is indicated, namely the Delta Committee, and the degree to which safety is expressed by this exceedance, namely the exceedance frequency of the design level, by which the water defences offer the dike ring area complete protection. This manner of formulation and the numbers chosen in relation to it, are political choices that were worked out partly on the basis of the knowledge available at the time.

To avoid bucking a trend in the safety level, an advanced technical elaboration will also provisionally be based on the result of the choices made at the time. The numeric values corresponding to the safety norms of the more advanced methods are therefore no more than mathematically determined variables that serve as a basis of comparison in the application of various methods. The procedure is that the number for a designed alternative, optimised dike ring is equal to the number that corresponds to a dike ring designed in accordance with the overload approach. A condition of this is that the crest height along the different sections along the dike ring is ultimately at least equal to MHW plus a few decimetres.

CHAPTER 5 VALUES AND FUNCTIONS

Chapter 5 provides an overview of how to handle the other functions of a flood defence than the retention of water. The Nature values have a central place here. Although they have played a role in dike improvement works for quite some time, these values were first given a clear place in the decision making process by the Boertien committee.

5.1 INTRODUCTION

The main function of flood defences was at the core of the previous chapter. This chapter addresses the other functions and values. These other functions formally follow on from planning decisions taken by state, provinces and municipality. Values is used in the sense of the meaning allocated to landscape, nature and cultural heritage (LNC or Nature values). Some of these values are laid down in policy documents, but in this chapter it is also explained how to handle the Nature values for which no policy judgement has been made. The allocation of Nature values is often only expedient when activities are planned that may affect these values.

This aspect is given a relatively great deal of attention. New insights have been rapidly developed since the Boertien I Committee (1993, *Toetsing uitgangspunten rivierdijkversterkingen*), and new policy and new procedures formulated. Much experience has been gained for handling such planning functions as housing, traffic, agriculture, industry and recreation on and around the flood defence and various procedures exist. The significance of the dunes for nature and landscape was recognised a long time ago and fitted into policy and management. In terms of cultural heritage, the dunes are usually too young and too dynamic. As a result this chapter is chiefly oriented to Nature values of dikes in drawing up a design and maintenance plan. The planning functions are described in spatial plans and plotted on plan maps accompanying municipal zoning plans, provincial regional plans and national policy plans (policy documents and plans for spatial planning, water management, nature and environment management, nature space, drinking and industrial water, traffic and transport). The functions housing, industry, traffic, agriculture and recreation are based on their contribution to employment and income. Their value can be expressed in market value. The functions landscape, nature and cultural heritage are based on a subjective allocation of value, for which no gauge exists in the form of a market price. The allocation of such subjective values must use the principle of the democratic selection process. The selection of value is based on a majority of votes or even better a consensus of opinion. Here, it is assumed that the person who votes has taken cognisance of the results of objective research into the aspects landscape, nature and cultural heritage. The allocation of values by an advisory group must be ratified by the competent authorities. This procedure is especially relevant in the design process and the Environmental Impact Assessment (EIA-report/or EIR) to be drawn up as part of it. Chapter 8 handles the steps in that process; this chapter addresses aspects of content.

5.2 NATURE VALUES

5.2.1 General

The Nature aspects (also known as LNC values) are developed or preserved as a matter of national policy, in so far as that is reconcilable with the fulfilment of the desired safety. This policy judgements offer insufficient information as yet to work out a plan for a section of the flood defence to be improved along a river, the coast or a lake bank. On the scale of a few to a few dozen kilometres in length, choices must be made on the continued existence of a certain building, a specific landscape structure, a location with special flora or fauna, a campsite, et cetera.

Values may be allocated to characteristics that are considered important on a national, regional or local scale. Such valuations can be found in national and provincial policy documents and plans, such as the Environmental Policy Plan, the Gelderland River Dike Plan (*GRIP*) or the Brabant LNC-guideline for dikes (*LNC-richtlijn dijken*).

Sometimes the flood defence runs right through the town, like here in Voorstraat, Dordrecht

Many Dutch towns developed at strategic locations along a river

A value on national or regional scale allocated to the dike, is that of ecological line of connection. This is found in the Environmental Policy Plan in the Ecological Main Structure. Because nature in the river forelands is increasingly being put under pressure, the insight has come into being that the dike slopes have an essential role in the protection of the typical floodplain flora and form an ecological connection zone between the nature areas in the river forelands. The function of ecological connection, thanks to the ribbon shape, has been allocated an authorised value in the policy.

Also separate from the Ecological Main Structure, some objects or characteristics have also been valued. They are protected villages, the protected and endangered red list species, and the cultural-historic monuments. They have been allocated a value by political decision making. On a regional and local scale there are typically many other LNC-objects with no authorised value. They must be catalogued separately for each improvement project. That is an overview of what is found where. That catalogue offers the possibility to select what is considered to be of value. Objective and subjective aspects play a role in the careful allocation of value. The objective aspect consists of care in cataloguing the Nature aspects. The catalogue also demands that the degree of rarity, distinctiveness, and extent to which replacement is feasible, completeness, authenticity, cohesion and suchlike are checked. The knowledge of these characteristics is objective because it is gained with well-defined methods and is therefore independent of the personal preferences of the researcher.

The subjective aspect is the evaluation. Objects of special value must be chosen from the large selection of objects in the catalogue. The allocation of value rests on a personal preference. It is also influenced by knowledge, but is primarily subjective. The allocation of values is needed because it enables the bottlenecks to be pointed out. A bottleneck is a situation in which the Nature value is threatened by an improvement project. Advisory groups are established for the allocation of Nature values. They are populated by representatives of the competent authorities and the interest groups. The advisory group usually has access to all disciplines needed for the project. If more information is needed experts are called in.

5.2.2 The vision of the dike improvement

The adaptation of a design plan or a management plan in a higher scale level than that of a dike section is very important for the continuity and cohesion. To be in a position to name the spatial characteristics that must be taken into account, it is recommended that a vision be developed for a stretch of a few dozen kilometres. The values and functions will be processed in it that is allocated to the branch of the river, the region or the dune area by the national and provincial policy. They are rendered into the form of a vision at the level of the dike or coast route in question. The higher scale level provides direction in the reinforcement of a flood defence in a town or village centre. As a result the values and function in the improvement plan can be included in the policy decision for spatial planning and nature development.

To be in a position to develop a vision the catalogue must first be drawn up. The catalogue consists of an overview of the functions laid down by planning, of the allocated (that is authorised) Nature values and of the area-oriented descriptions of landscape, nature and cultural heritage. That description of the area supplies knowledge of the nature aspects not (yet) valued.

The vision is then formulated on the basis of the following steps: valuation, indication of bottlenecks and of potentials, priorities and mapping of solution orientations. The great importance of the vision on the flood defence improvement is that it explicitly shows what the aims are and where the hurdles are. The aim that always has priority is the fulfilment of the safety requirements set. It is also the aim of policy to preserve the Nature values to a maximum level and develop them further.

The policy objectives set for the other spatial functions are also included in the vision. As a result it gives direction to the search for the optimal realisation of these objectives. The optimum for safety plus Nature values will often be different from that for safety plus housing, work, and traffic. The development of two or more options can then determine to what degree these interests can be reconciled and where the essential choices must be made.

The vision development is therefore a selection process that converges with every step on the basis of interests and bottlenecks. That occurs on the basis of existing knowledge and existing policy. The knowledge gaps are also exposed. If there is a lack of knowledge needed to dissolve a bottleneck then an additional study will be needed. That knowledge is then used in the last phase of the vision development, that is the phase in which the alternative solutions are described. The vision development is connected with the start of the environmental impact report (see chapter 8).

5.2.3 Catalogue of Nature aspects

The first step in preserving and reinforcing Nature values is gaining knowledge. That consists of three components.

- The first is the collection of data from publications and archives on landscape, nature and cultural heritage.
- The second is the supplementation of missing data by field cataloguing.
- The third is the collection of judgements in policy documents in which value is allocated to LNC characteristics or elements in the study area.

Cataloguing also covers the reporting of the degree of rarity on a local, regional, national or international scale of each object or characteristic found. That also applies to the extent to which replacement is feasible (a year, a century or not at all), the degree to which it can still be determined how an object came into being and how it was used in the past. The relevant parameters for this component of the catalogue are found in the TAW guide Cataloguing and Valuation of Nature Aspects (*Handreiking Inventarisatie en waardering LNC-aspecten*). Some parameters are applicable to all three Nature aspects, such as cohesion. Others are specific, such as readability (L), diversity (N), authenticity (C). The cataloguing of this parameter data is a task for experts. This knowledge is important to the people who must allocate the value. The parameterisation must however, not be confused with valuation. Therefore, a weight must be allocated in a subjective manner.

The provincial environmental catalogues are great sources of landscape and nature oriented material. For cultural heritage a fine source is the National Service for Archaeological Heritage and the department for the Preservation of Historic Buildings and Sites.

A great deal of information is found at nature and environmental organisations like *Natuurmonumenten* (Society for the Preservation of Nature in the Netherlands), the provincial landscape organisations, *Vogelbescherming* (Bird Protection Society), *Vlinderstichting* (Butterflies), *Vleermuiswerkgroep* (Bats), *Das en Boom* (Fox and Tree), *Behoud het Rivierenlandschap* (River Landscape Preservation Society) and others. Such organisations as *Heemschut* can also be the source of a great deal of knowledge.

To make the range of information easily accessible it is important that good maps are produced. For much information separate maps for Nature aspects are a good solution. Besides maps per aspect, maps are also worthwhile on three scale levels.

The characteristics are described on a regional scale, distinguishing the area in which the route to be improved is found from the rest of the rivers area, the IJsselmeer area or coast area.

On the local scale level of the route to be improved the characteristics of the spatial relationships with the surroundings are described. They include visual landscape structures, ecological migration paths, groundwater flows and historical growth patterns.

The third scale level is that of the flood defence itself as a ribbon shaped element. At that level there is a description of what is found on and in the immediate vicinity of the dike or dune. Examples are a characteristic bend, biotope or a historic lock.

During the collection of the information that already exists the gaps are also exposed. At the same time a pattern emerges of which elements are characteristic or special. The emergence of a gap is a direct reason to conduct additional cataloguing activities.

5.2.4 Valuation of the Nature aspects

The great bank of catalogued data must then be allocated a value. Owing to the subjective nature of the values, policy judgements must be sought and a procedure mapped out to achieve new judgements. Policy judgements are found in legislation, policy documents and plans. They include lists of protected species, maps of protected nature areas, protected cultural buildings and sites, protected landscapes, ecological main structure to be laid out and such like. That shows which objects in the Nature catalogue for the area of study already enjoy protection and so already have a value (the authorised Nature values). The mapping of the procedure to allocate the Nature values from the catalogued data to supplement the already authorised values, demands an approach fundamentally different to previous activities. Cataloguing can be conducted by specialised researchers from a government service, an engineering consultant or another institute.

The values must be allocated in accordance with the political decision making model. That occurs in the form of an advisory group, named per project. The initiator (water board, Directorate-General for Public Works and Water Management) is responsible for its establishment, names the chair and supplies such facilities as secretariat, agenda and documentation. The competent authorities (province, ministry) ensure that the various interests are represented. That occurs via participation in nature and environmental organisations, historical associations, research institutions, residential associations, local or regional political and economic interest groups. The advisory group can accordingly be large in size, resulting in a great deal of consultation. The consultation is directed at achieving consensus, so that a large basis is created for decisions. The investment in time in this part of the vision development is in this way 'rewarded' with a greater commitment of the region, which benefits the execution of the plan and reduces the probability of delay due to appeal procedures. If no consensus is achieved, the bottlenecks and the choices to be made are addressed in a clear way and the competent authorities are responsible for cutting the Gordian knot.

The subjective aspect of selecting what is considered valuable is given a solid and consistent form via the consultation in the advisory groups. The objective aspect, that is the methodically collected knowledge of the Nature aspects, demands a great level of care. To achieve quality in this selection process the participants are requested to go through the subject thoroughly and be prepared to listen to the explanations and arguments from all sides. They must also be prepared to make a final decision, realise compromises and make painful choices. The consensus orientation that characterises Dutch society must be utilised to the full. It is important that the chair adopts an independent attitude, and in doing so enjoys the confidence of the consultation partners. That independence means among other things that the chair ensures that the choices are always based on the safety norm and take account of the authorised values. The chair will also have to create space in particular for strong arguments in the allocation of new values and the solution orientations in order to prevent them being pushed aside by the process in which the wishes based on local interests become dominant. Its legitimacy need not be challenged.

By creating clarity on the kind of arguments introduced, the chair can make important contributions to creating a consistent reasoning leading to the choices.

5.3 VALUATION OF OTHER SOCIAL FUNCTIONS

The advisory group can also express its views on the desired degree to which the plan must take account of housing, work, traffic and recreation via a broad based representation of interests. The division into authorised planning functions and desired functions also plays a role here. The planning functions are the embodiment of policy laid down in national, regional and zoning plans. The desired functions are championed by the interest groups, but have yet to go through the decision making procedure. The advisory group can take cognisance of the fixed and desired functions. As these are functions and wishes that are close to the residents and for which there are usually interest groups that have relevant experience, this point is not addressed in detail in this publication.

The discussion in the advisory group is accordingly about the degree to which all requirements and wishes are reconcilable. The fulfilment of safety requirements is a dominant factor in this discussion. Bearing in mind the other policy judgements, the advisory group will have to make judgements on priorities and compromises. The competent authorities may also be requested to set priorities and allocate preconditions.

5.4 BOTTLENECKS AND SOLUTIONS

Bottlenecks are situations in which a Nature value or other function is threatened by an improvement project. As the policy is oriented to the preservation of those values and functions an improvement variant is sought bottleneck by bottleneck to spare it. The bottleneck is then removed.

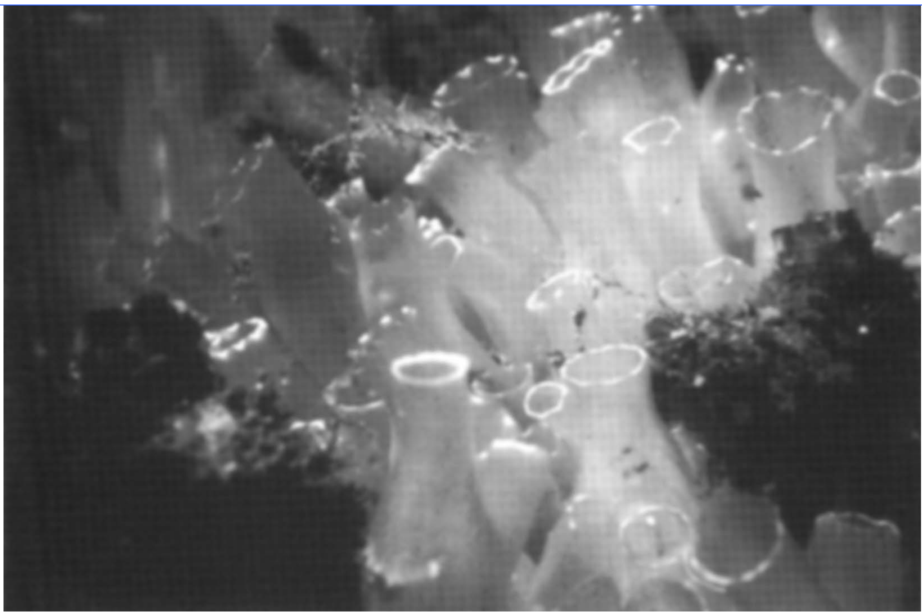
With respect to dike improvement situations occur as a result of which it is not possible to combine the solution to a traffic problem with the preservation of an important landscape dike route. Conflicts between the individual Nature values cannot be ruled out either. There may be a scour hole on one side of the dike route with value for landscape and nature and on the other side a building with culture-historical value. Sparing one value may lead to the destruction of the other. If it is not possible to spare both values via a sophisticated design one must be chosen above the other. This necessitates a judgement from the advisory group.

5.5 CHOICE OF OPTIONS

Once the values have been allocated and the bottlenecks indicated the improvement options most likely to preserve the Nature aspects and the functions can be sought. The vision of the introductory memorandum of the EIA procedure has a great effect on the orientation of the content of the ultimate EIA. Only these alternatives need be worked out further. That prevents a situation in which unnecessary work is carried out and in which new options have to be studied at a late stage on the basis of participation or appeal.

As the preservation of Nature values is the policy objective, the preferred improvement option is typically the most environmentally friendly alternative (MEA). The law says that the MEA must also be a realistic option. The desired safety must be achieved within this option, while the solution must be technically and administratively executable. First, the choice of Nature values that are eligible for preservation and new development is made, resulting in the MEA, but if this is considered to be too expensive a preferred alternative may be described that is viable. The description of the MEA is then worthwhile because funds will probably be found elsewhere for achieving that objective. The same can be said of the consensus achieved in the advisory group (which has an advisory voice as the name implies) with respect to other functions. Especially when there is a desire to expand the other functions, another source of financing may have to be found than the dike improvement budget.


In the nature experiment test dike on Neeltje Jans, the influence of the dike revetment on the vegetation is being studied. Photo RIKZ


Translucent sea squirts are animals that live on stones under water and digest food from the water by means of contractions. Photo RIKZ

VISION

Summary of the process from cataloguing to formulating options in four steps:

1. Cataloguing:
- authorised Nature values;
- functions and wishes laid down in the planning;
- literature study;
- field catalogue per Nature aspect (also potentials);
- parameter description on three scale levels.

2. Valuing:
- authorised values and functions: done;
- for the values to be allocated use political decision making model. Parameterised knowledge is available in the catalogue. Potentials for new development can also be allocated as value.

3. Analysing bottlenecks:
- tracing bottlenecks by confronting the improvement plan with values and functions;
- setting priorities if more than two values compete at a bottleneck and sophisticated design does not offer a solution.

4. Formulating options:
- indicate the search orientation for options that are likely solutions to bottlenecks, for developing the potentials and for finding compensation.

The gaining of objective knowledge is realised in step 1 (cataloguing) by professional experts and experts volunteers. The subjective choices in steps 2, 3 and 4 (vision development) are of a political nature and are directed by the advisory group and authorised by the competent authorities.

CHAPTER 6 CARE OF WATER DEFENCE

Chapter 6 provides an outline of the care for the realisation of the responsibilities involved in water defence. Where chapter 2 looks at the social framework, this chapter details and works out the aspects that directly affect the systems mentioned in chapter 3.

6.1 INTRODUCTION

Existing defences must be maintained by management and maintenance. Improvement of the flood defence is needed if it shows weaknesses. The Flood Defences Act ensures that the manager can and must fulfil its responsibilities to maintain a quantified safety level. *Leidraad Toetsen op Veiligheid* indicates how the safety level is to be monitored (every five years). Inspections, maintenance and any improvement work are the means the manager has to exercise this care. For cases in which the norms laid down by law are not (yet) fulfilled, due to insufficient height and/or strength, new development or reinforcement is needed, not always on the same site.

Care must go further in the long run. The developments in the surroundings that influence the performance of the flood defence will also have to be actively followed. New policy must be developed when and where it is needed. Policy consists of administrative choices, whereas management is policy implementation and monitoring of the continued relevance of policy. The concept of 'management' accordingly also covers the design of improvements to flood defences.
The title of chapter 10 is 'Management and Maintenance', also described as day-to-day management.

The concept of 'flood defence care' is an umbrella term for all these matters. It therefore comprises the whole system of responsibilities and instruments that play a role in policy, management, design, construction and maintenance of flood defences. Flood defence care is about realising the responsibilities that the managers of flood defences and the regulating authorities have, now and in the (distant) future. The first responsibility for this care rests with the flood defence manager, typically a water board, that keeps its finger on the pulse of all developments that may be of importance for water defence. The province has the task of regulating this and of integrating the safety interest with the other interests. The role of the national government is oriented to creating legal and policy frameworks and supreme control. In this chapter the interpretation of the concept of flood defence care is outlined in a broad sense. The outline of the social framework, together with the developments in thinking on safety and functions outlined in chapters 4 and 5, direct that interpretation. 'In a broad sense' means that the security provided by flood defences in the total system of land and water is examined. In that totality spatial planning and water management also play an important role.

6.2 CARE PROCESS

6.2.1 General

This section maintains the same system classification as chapter 3:
1. The system of the protected dike ring areas;
2. The water management systems (outside the dike) bounded by flood defences;
3. The system of flood defences itself.

This chapter comprises an overview of the interrelationship between the processes in these three systems, in so far as they are relevant for protecting from flooding. The role and the activities of the various managers of the systems are also briefly handled. Wherever formulated policy exists in the form of policy documents it will be mentioned.

The manager of a flood defence certainly does not have primary responsibility for all three systems. In fact, only the third system is its direct responsibility. It must take the other systems into account to a greater or lesser degree. Relevant developments in one of the systems are best kept up with in existing reports per management unit, the water board's annual report for example. If need be, the flood defence manager and the competent authorities will keep each other formally up to date, possibly with the request for action.

6.2.2 Dike ring areas

The safety norm is laid down for each dike ring area in the Flood Defence Act, provisionally in the form of an average exceedance probability of a water level on which the flood defence must be calculated (article 3.1). A substantial increase in the population in a dike ring area, especially in the lowest parts, or of the invested capital by industrialisation or other economic activities, should lead to an adjustment of the safety level, perhaps not immediately but eventually. At this moment this is hardly possible, if at all, but once the flood risk approach described in chapter 4 has been worked out, it will be.

In that case the flood defence manager has prime responsibility to make its reservations known from the point of view of safety. It is also conceivable that the flood defence manager not only makes its reservations known but also objects to the new development plans in the lowest parts of the dike ring area (in the zoning plan procedure) on the basis of the safety level of the existing flood defences and the problems that raising would create.

Another point that plays a role in the area inside the dike in protection from flooding is all intentional and unintentional compartmenting of the dike ring area. All compartmenting has an influence on the spread of the flood risk in the dike ring area. That includes existing and any new secondary flood defences, and new roads and rail tracks, which could operate as (pseudo) defences. A small compartment will fill up rapidly as a result of inundation, and that carries a relatively large risk when the population density is high. On the other hand, limiting flooding by compartmenting reduces the total risk for the dike ring area. Here too, the flood defence manager has prime responsibility for monitoring this.

6.2.3 Water management systems outside the dike

Along the coast and the rivers there is a relationship between protection from flooding and the area outside the dike. Along the rivers it is chiefly about the influence of flood defences by measures upstream and in the river bed. Along the coast it is about the influence of tidal flood barriers on water levels, but also the location of the coastline as a precondition for the dunes as flood defence.

All outside water, as defined in the Flood Defences Act, is managed by the state. The policy it is based upon is described in the Third Policy Document on Water Management (D*erde Nota waterhuishouding*, the fourth policy document is due for publication in 1998) and the accompanying

Management Plan for National Waters (*Beheersplan Rijkswateren*). That means that the state has prime responsibility for determining and influencing the preconditions for primary flood defences. Changes in design water levels are periodically included in the relevant publications. The prevailing design water levels are used in the five-year monitoring of the flood defences laid down by law.

The Delta (Major Rivers) Plan is on schedule

Rivers

The current normative high water levels along the rivers apply to the rivers area in its current form. Climatologic developments indicate that extreme river water levels are more likely to rise than fall. Changes to the upstream discharge system (land use, surface hardening, damming, urbanisation et cetera) can reinforce that process. That demands that the decision making process upstream is followed closely and perhaps influenced in international consultation (see *Grundlagen und Strategie zum Aktionsplan Hochwasser*).

Changes in the riverbed in the Netherlands (changes in breadth and width for shipping, the creation of secondary channels in the river forelands, floodplains and suchlike) have a direct influence on the water levels for the flood defences. Construction outside the dike also deserves special attention in this context. There is a fairly constant social pressure to build in the (usually) dry parts of the riverbed. On the one hand this can raise the water levels, on the other 'outside the dike' literally means that the buildings are no longer protected by a flood defence.

Bearing in mind their direct relationship to the flood defences, it is also conceivable that the preconditions are consciously influenced by interventions in the water management system. The *Fourth Policy Document on Water Management* says: 'The aim is to avoid a new round of dike reinforcements wherever possible – in spite of a higher normative discharge – by measures in the river bed, such as the removal of unnatural obstacles that hamper water discharge and by deepening, and where possible broadening, the winter bed' (se also the box in section 1.3).

In anticipation of this the government has published a policy document (*Beleidslijn Ruimte voor de rivier*) to combat the further restriction of the space as much as possible. That is especially important in relation to the decision as to whether (construction) activities should be allowed in the winter bed of rivers. For work on the river that is unavoidable (such as waterway facilities) the answer is 'yes, provided…'. In addition, any rise in the water level must be compensated in a sustainable manner. For all other activities not directly bound to the river (such as house building) the answer is 'no, unless…'. The initiator must show that there are weighty social interests and that the activity cannot be realised outside the winter bed.

This line of policy is regulated from the spatial planning side (via regional and zoning plans) and the river management side (via permit granting in the scope of the Rivers Act). When granting permits for new activities that may lead to damage at high water a safety level of 1/1250 per year is demanded outside the dike too. The policy line only applies to the upper rivers area; in the tidal rivers area the normative high water levels are hardly ever determined by the river discharge and almost always be the sea level.

Coast and IJsselmeer
On the coast and in the tidal rivers area in a number of locations hydraulic structures have been built that are essential to protecting from flooding. Tidal flood barriers in the Oosterschelde, the Nieuwe Waterweg and the Hollandse IJssel and the Haringvliet locks ensure that the water levels along the dikes located behind them are less high then they would be without these hydraulic structures. The Haringvliet locks can also be opened at other times in anticipation of a high water wave on the river. As a result it is possible to lower the high water level around Gorinchem to a limited degree.

The defence at Ramspol also serves to limit rises in water level, in this case as a result of wind in the IJsselmeer. For the IJsselmeer as a whole the water levels can be influenced to a limited degree by choosing a lake level.

Wherever movable hydraulic structures are able to influence the water levels, their management is laid down in management documents. In the management of tidal flood barriers there is a field of tension between water levels that are too high for the flood defences behind them on the one hand, and a situation in which they are closed too often on the other. If they are closed too often there may be consequences for the ecosystem (Oosterschelde) or for shipping (Nieuwe Waterweg). In addition, the closure regime plays an important role for any buildings outside the dike behind a flood barrier, although the flood barrier is not meant to play a role here.

Sandy coasts
For the dunes there is an entirely different way in which influence is exercised by the area outside the dike: the location of the dunes. This directly influences the point of departure of the dunes as flood defence. The coastline is continuously changing and the main function of the dune flood defence can be compromised, especially when there is structural erosion. Beach nourishment can be used to influence the location of the coastline..

The state has taken on responsibility for maintaining the coastline as laid down in 1990 (see *Kustverdediging na 1990*, *Kustbalans 1995* and *Leidraad Zandige Kust* among others). In the

Provincial Consultation Organ for the Coast (POK, established on the basis of the Flood Defence Act, FDA) the provinces consult with the state, the water boards, the coastal municipalities and any interest groups. The POK advises the minister of Transport, Public Works and Water Management with respect to beach nourishment within the scope of the preservation of the coastline. The minister lays down the national priorities for beach nourishment after all POKs have been heard.

6.2.4 Flood defences

Besides ensuring that a flood defence can fulfil its main function, the interweaving with other functions is the most important point for attention for the flood defence manager. On the one hand the water retaining function is a decisive factor in relation to the possibilities for the other functions in an area. This can have a limiting effect (for building for example) and a stimulating effect (for traffic and nature for example). On the other side, the allocated functions (in regional and zoning plans for example) in an area determine the possibilities and the location of the flood defence to a great degree. This interweaving becomes clearer as the pressure on the lack of space increases. A more rigid separation of water retaining function and the other functions is usually an attractive option for the flood defence manager. Integration may precisely lead to a very attractive solution for society.

In the rural areas flood defences are often part of the ecological main structure. Flood defences function as a through route for the distribution of flora and fauna. Most important is vegetation and soil use. Dune flood defences are often seen as nature areas themselves; the choice of management limits is accordingly an important point. On the seaside that is fairly clear, but less so on the landside because dunes are often much broader than strictly necessary for the water retaining function.

One of the big questions in the management of flood defences is the permissibility of buildings. The question of whether buildings are desirable must be answered for the perspective of spatial planning, in relation to any future improvements among other things. The vast majority of the population now lives in the lower parts of the country and that is where protection by flood defences is chiefly oriented. It no longer appears to be so natural to live on or alongside a flood defence as in the time that the high grounds where the places of refuge for man and beast. In cases in which the decision to live on the dike is a conscious one, that is the new development of housing, the costs (including any future raising) must be weighed against the advantages.

Construction in the dunes, outside the erosion zone, is particularly a problem of spatial planning. Inside the erosion zone construction is inadvisable and is not usually permitted by the manager. Semi-permanent buildings on the beach are not always harmful for the flood defence and cannot be refused for that reason. Damage to these buildings is always at the risk of the owner.

In an urban environment flood defence and town form such a cohesive unit that the situation is fixed for a very long time (often for centuries). When housing is an integral part of the flood defence, the design must ensure that the defence is able to continue to fulfil its main function, by calculating the foundation on the basis of future raising for example, well after the plan period. This approach is analogous with that of hydraulic structures like locks. Furthermore, primary flood defence care must be guaranteed (inspection, maintenance and reinforcement, also in the long run).

In general, the care of the possibilities of reinforcement in the future is important. Normally, a period of fifty years (the plan period) is taken into consideration for the construction or improvement of a flood defence. All foreseeable changes in that period are taken into account, such a rise in the sea level and settlement of the structure. The possibilities of guaranteeing the protection of the dike ring area are also examined for the period after that plan period. The possibility that natural conditions will change must also be borne in mind (rise in sea level and/or river high waters) and that the flood defence will have to be raised further in the future. The Fourth Policy Document on Spatial Planning therefore argues for space to be reserved for future dike raising. When the possibilities for future reinforcement in the current route are exhausted, protection may be relocated to another site. The zoning plan procedure must then ensure that there is a reinforcement possibility elsewhere.

6.3 MANAGEMENT OF FLOOD DEFENCES

As explained above, management comprises all the activities that guarantee the fulfilment of the functions of the flood defence. The interpretation must rest on a vision on the various functions and on the question of how to handle them. A management plan is a good means of laying down this vision and the manner in which it is worked out.

6.3.1 Management vision

The aims of the various functions are formulated in the management vision and the choice of management method for every route is based on it. The management of the flood defence is not an isolated matter. It is closely linked to the (future) use of the adjacent area. These uses are outlined in the various plans drawn up by municipality, province and national government. The impulse for the management vision is a catalogue of known and potential functions on the basis of the plans of the various governments among other things. This is a good basis for the so-called planning functions in particular. A separate catalogue will often be needed for the Nature aspects on and around the flood defence. The approved prevailing and potential nature values of the dike slopes are important here. The catalogue of landscape, nature and cultural heritage is only important if these values are influenced by the management of the flood defence. Chapter 5 provides a detailed description of the catalogue. The choice of preservation of landscape and nature values and cultural heritage is usually made in the plan formation stage. But any management choices that must be made may be addressed in the management plan.

Function allocation cannot always occur automatically. If the river foreland has been allocated a nature function for example, the same function may also be allocated to the outside slope, as a secondary function, in order to create an ecological connection. In certain areas however, this may be illogical; when the prevailing and potential nature values are present not on the outside slope but on the inside slope for example. Floodplain vegetations supporting many species are most prevalent in warm, dry habitats and that may be the inside slope exposed to the south. In that case the inside slope will also be included in the ecological connection.

6.3.2 Management plan

The need for an integrated management plan is dictated by a number of arguments, of which the necessity of five-year monitoring is only one. The entirety of functions, responsibilities and financing can best be described in such a management plan that, together with the water board regulations and by-law, form a clear basis for management, also for interested parties. The plan accordingly plays an important role in communication with the outside world. It obliges the flood defence manager to invest efforts; for third parties the obligation to do and not to do something is applicable if it is laid down in the by-law.

For the water boards a plan for management, containing the management vision, is desirable to avoid repeated discussions on future management, during the plan formation stage of a dike improvement programme for example. A total plan for management also prevents inconsistency. The finishing of the slopes can be harmonised with the designated management form during the technical plan formation for example. Consider the composition of the covering layer for example, the choice of sand mixture, the inclusion of maintenance strips, fencing et cetera. Such a plan also provides insight into the costs of future management (see chapter 10 '*Management and Maintenance*').

6.3.3 Management limits

The limits of flood defences indicate the area in which the flood defence manager has legal powers to carry out its responsibilities. For dikes and hydraulic structures those limits are typically fairly clear. For dunes things are more complicated, especially on the landside (on the sea side the depth line of NAP –20m is recommended). To a large extent, the breadth of the flood defence zone in the dunes area determines the possibilities of other functions. If a narrower flood defence zone is fixed the result will be the stringent implementation of the provisions of the by-law. That restricts the possibilities in that zone for the development of other functions of the dune area than the water defence function. A narrower flood defence zone is usually fixed in narrow dune areas or dune areas with buildings (see numbers 2 and 3 in figure 6.1).

In broad dune areas a broad flood defence zone is recommended with a freer exemption policy in the by-law. That means there are more possibilities for the other functions of the dune area. The fixing of the breadth of the flood defence zone is part of the management vision and the breadth will therefore also be found in the management plan (see *Leidraad Zandige Kust*).

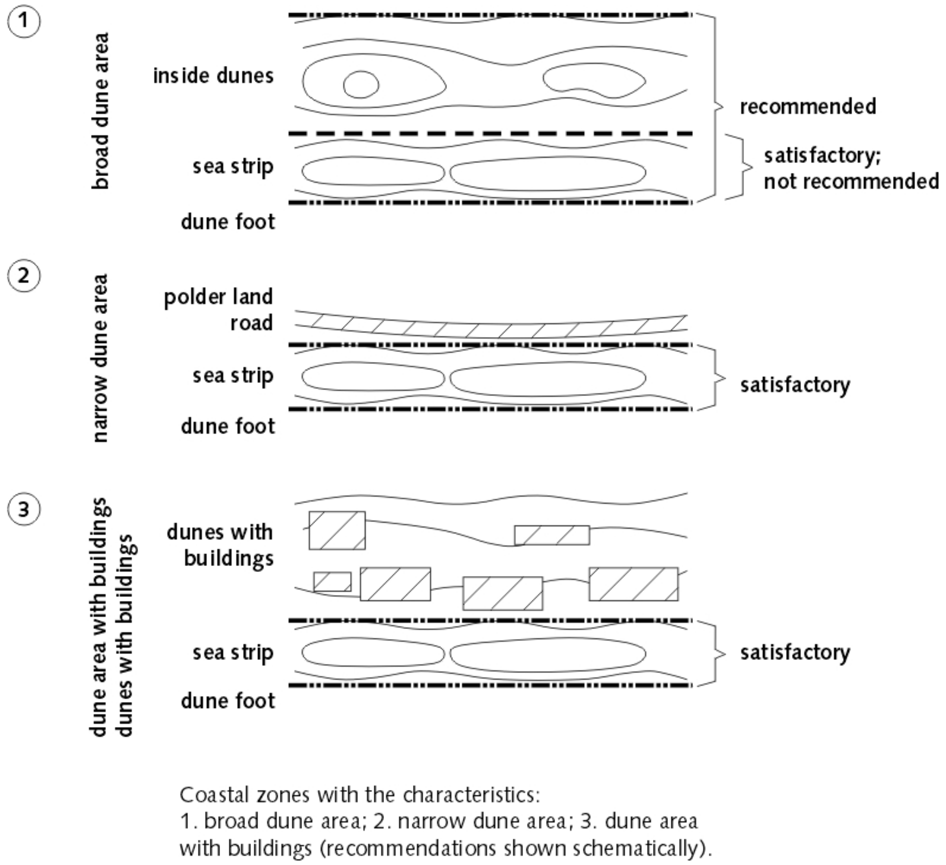


Figure 6.1. Possible management limits in dune areas

CHAPTER 7 DIMENSIONING OF FLOOD DEFENCES

Chapter 7 provides a technical elaboration of the principles for the safety in chapter 4. The transition from a deterministic design approach to an probabilistic one is an essential part of the Marsroute begun by the TAW. It demands study by the users of TAW guides and some knowledge of statistics.

7.1 INTRODUCTION

Chapter 4 (Safety) explained the reason for switching from a overload approach to a flood risk approach. It is a logical continuation of the work of the Delta Committee, by which an attempt was made to achieve a more acceptable safety level from an insurance oriented approach. Furthermore, it is the only manner in which to gain an impression of the actual risks that are involved in the flooding threat. That makes it the best manner to communicate with society in terms that are the same as for other risks, such as the number of victims and the scale of damage.

This does mean however that it must also be possible to determine the probability of failure or collapse of the flood defence. And that demands a whole other calculation technique for dimensioning than was usual up to about ten years ago (see box). The construction of the Oosterschelde tidal flood contributed to the development of this calculation technique to an important degree.

The essential characteristic of the new dimensioning technique is a probabilistic approach in contrast to a deterministic one. Deterministic means that only a single normative combination of loads is considered, making assumptions about the strength and safety realised via non-explicitly substantiated safety coefficients, but based in part on experience and in part on intuition.

In a probabilistic approach however, the structure's failure probability is central. The uncertainties that are always present in load and strength parameters are taken into account. An important element here is the recognition of various failure mechanisms of a flood defence, such as the washing away of an inside slope by waves or the shearing of a soil body by the water pressure on it. There may also be a link between two failure mechanisms.

The approach of the Delta Committee may be described as a probabilistic approach to the loading, which is limited to the one failure mechanism, overtopping of water. And in the working out, to one load case, a high water level with an accompanying wave. The strength is approached in an entirely deterministic way. Probabilistic calculation techniques are more laborious and complicated than deterministic ones, but correspond better with the aim to produce sophisticated structures and have insight into the actual risks. The 'safety coefficient' used in deterministic practice actually says little about safety: the same value means something completely different depending on the mechanism.

To avoid making the design work too complicated in practice, a method is used that may be considered as a mix of the two. The safety coefficients are always worked into the mix (per failure mechanism), but they are now derived from the acceptable failure probability using probabilistic calculations.

As a result, the similarity between old method and new is only pretence. The degree of underpinning that can be given varies from mechanism to mechanism. More is known of one mechanism than of the other. In that respect too, there is a mix. Subjectivity accordingly retains its place in dimensioning, but instead of determinism with a drop of probabilism, the opposite now applies.

The probabilistic approach is described in general terms in this chapter. Annex IV goes into more detail about the probabilistic method, using the example of a single failure mechanism.

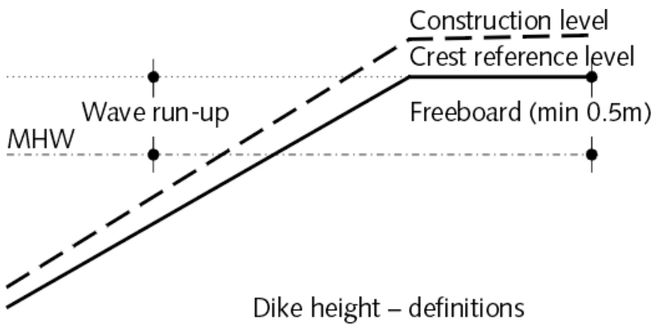
DIKE HEIGHT

The difference between a deterministic approach and a probabilistic one is expressed in the determination of the necessary dike height.

The predominantly deterministic determination, as worked out by the Delta Committee (see section 4.4.1.), assumes the normative high water level (MHW) that the dike must be able to retain. This MHW includes a rise in sea level in the plan period (up to now 0.1m for 50 years) and wind effects on the local water level. In addition, the wave run-up is the most important parameter in the determination of the crest height. The wave run-up is calculated on the basis of a certain wind at MHW and the corresponding waves (bearing in mind the geometry of the foreland and the outside slope). This is expressed in the level that is exceeded by 2% of the waves or a certain overtopping discharge. The so-called crest reference height is therefore equal to this level.

Settlement of the soil body over a certain maintenance period is also taken into account to avoid a situation in which the height of the dike is lower than the crest reference level needed. That results in the so-called construction level. The difference between crest reference level and MHW is called the freeboard. At least 0.5m is usually maintained for that, also when the calculated wave run-up is lower. This is in connection with uncertainties in the determination of the MHW's among other things, and to ensure that the crest is easily passable in the case of extremely high water levels.

In a probabilistic approach, as in the inundation probability calculation (see section 4.4.3.), the result of the above-mentioned approach can still be used as an initial estimate. The probability that the defence will fail must subsequently be calculated. That may be due to a defence that is too low or too weak. The inundation probability is studied after integration with all failure mechanisms. The whole range of combinations of water levels and waves are included. A lower defence may then be possible than would follow from a deterministic approach, because other dike sections or mechanisms contribute less to the failure probability. The determination of the ultimate dike height is therefore much less direct than in the deterministic method. MHW plus a few decimetres is however retained for the time being for the dike height.



Dike height – definitions

7.2 FAILURE AND COLLAPSE

In the assessment of flood defences it is worthwhile making a distinction between failure and collapse of a structure. A flood defence fails if one or more functions are not fulfilled. Collapse means the loss of cohesion or large scale changes in geometry. A flood defence can fail by collapsing and vice versa. The water may flow over the defence for instance and inundate the hinterland, without the defence collapsing. Conversely, a defence can collapse at low water levels, as a consequence of a vessel breaking a lock gate for instance, without inundation occurring. Repairs will obviously have to be carried out quickly because the safety function will have been damaged. General collapse is therefore usually covered by the term failure.

The failure or collapse of the flood defence is determined by the geometry and material characteristics of the defence on the one hand, and the threats and load on the other. The primary threat to the functioning of the flood defence is formed by high water levels and waves. More aspects must however be taken into account in the design and management of the defence. Numerous physical, biological and human factors can affect the water retaining capacity and therefore form a threat.

The manner in which the water retaining capacity is lacking is called a failure mechanism. The first step in the assessment of the safety of a flood defence is the catalogue of all threats and corresponding failure and collapse mechanisms. As soon as a mechanism is known, it is attempted to make a model of it. That model can be of an experimental or mathematical nature. The model must assist the designer or manager in obtaining insight into the conditions in which the defence performs well and those in which it does not. The regularity of the conditions in which performance is unsatisfactory is then estimated. This can then be the basis of a decision on the safety level of the (existing or designed) structure.

7.3 OVERVIEW OF THE FAILURE MECHANISMS

This section provides an overview of the failure mechanisms by type of primary flood defence.

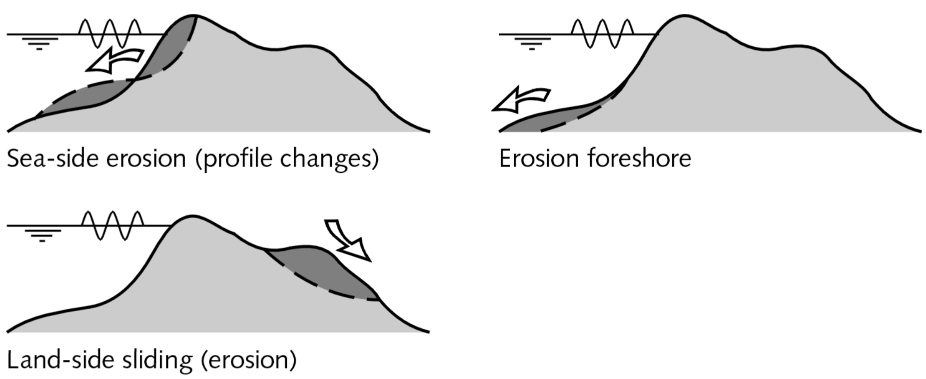


Figure 7.1 Failure mechanisms at dunes

7.3.1 Dunes

Figure 7.1 provides an overview of the possible failure mechanisms at a dune. Of all of these mechanisms dune erosion is by far the most important. Waves erode the outside slope and whole pieces of dune disappear into the sea. The sand is deposited seawards of the original dune, creating a gentler incline on which the waves are able to break. The resulting tendency is one of equilibrium during a storm, depending on the water level, the grain diameter of the dune sand and the intensity of the waves.

The other mechanisms, which are less important to the dunes, are discussed in section 7.3.2.

7.3.2 Soil structures

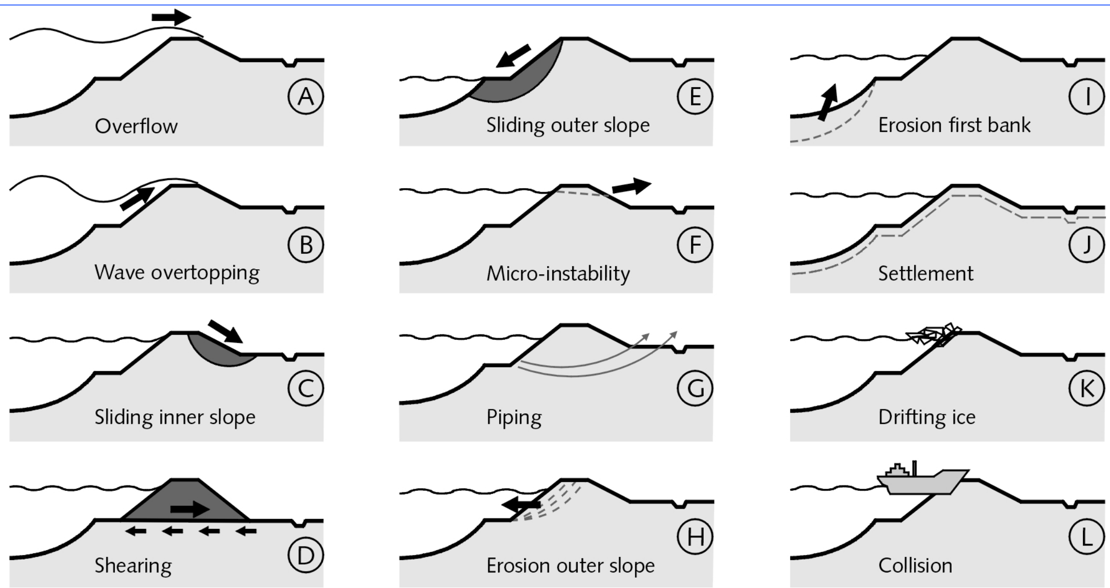


Figure 7.2. Failure mechanisms soil structures

In the assessment of the safety of dikes and dams the following failure mechanisms are important (see figure 7.2):

- Inundation of the dike ring area through a combination of high water level and wave overtopping without the collapse of the defence structure (A);
- Erosion of the inner slope by the force of the flowing water and by a combination of high water level and wave overtopping (B);
- Instability (sliding) of the inner slope, due to either infiltration of the overflowing water in a combination of high water level and wave overtopping, or water pressure against the defence and increased water pressure in the subsoil (C);
- Shearing of a soil body, also by water pressure against the defence and increased water pressure in the subsoil (D);
- Sliding of the outer slope in the case of a rapid fall in the outside water level after high water (E);
- Instability of the inner (or outer) slope by exiting seepage water through the soil body (micro-instability) analogous to failure mechanism C, but at lower water levels (F);
- Piping as a consequence of seepage flow through the subsoil so that erosion starts behind the dike and soil is borne along (sand boils) (G);
- Erosion of the outer slope or the toe and foreshore by current or wave movement (H, I);

- Large-scale distortions of the soil body (I);
- Mechanical threats like ice and shipping (K, L).

Beach nourishment is a good method to guarantee the safety of sandy coast

7.3.3 Special structures and hydraulic structures

Besides the above-mentioned mechanisms like wave run up and wave overtopping at hydraulic structures and special structures the following failure mechanisms may be important:
- Strength and stability upper structure including retaining means;
- Strength and stability foundation and subsoil;
- Strength and stability transitional structures (especially piping and erosion);
- Failure to close gates for locks and sluices (on time).

The last failure mechanism is very different from all other mechanisms mentioned, because it is not only about the behaviour of materials, but also people and machines. Clearly, entirely different factors play a role here than at other types of flood defence.

7.3.4 Objects

If there are objects in or near a flood defence, or they are designed in it, each case must be checked for possible failure mechanisms. In part they are the same mechanisms as can occur when a hydraulic structure fails. Other failure mechanisms are possible however, such as:

- Trees and shrubs blown over and uprooted by the wind, creating a scour that can initiate erosion mechanisms;
- Buildings on a dike or in the slopes leading to high current velocities locally in the case of flood;
- Roads with traffic, which can cause instability and distortions due to their loads;
- Structures that do not show the same settlement behaviour as the surrounding soil and so affect the integrity of the flood defence.
- Pipelines where leaks can occur with erosion and explosion.

The consequences for the long-term management of the flood defence must also be considered. After some time the need may arise to modify the flood defence. Objects may then form an extra difficulty factor.

7.3.5 Fault-tree

Table 7.1 provides an overview of the mechanisms as discussed above and the structure types at which they must be checked for.

For the assessment of a flood defence the interrelationship between the various failure mechanisms is important. This can be shown in a fault-tree, in which an undesirable top event is defined, for instance the complete collapse of the defence or a certain quantity of water that flows or tops over the defence. The branches of the tree show how different causes can lead to the top event. The probability of occurrence of the individual failure mechanisms and the interconnection between them determines the probability of occurrence of the top event.

	Dune	Soil body	Special	Hydraulic structure
Wave run up/overtopping		x		
Erosion of outside slope/erosion	x	x		
Macro-instability slopes		x		
Micro-instability slopes		x		
Piping		x	x	x
Large-scale distortion		x	x	x
Strength and stability upper structure			x	x
Strength and stability foundation			x	x
Strength and stability transitional structures			x	x
Failure to close on time				
Leak pipelines		x		

Table 7.1. Overview of mechanisms

The value of a fault-tree is self-evident: by illustrating the connection between the parts of the flood defence and their failure, the weal spots in the structure are also more easily identified.

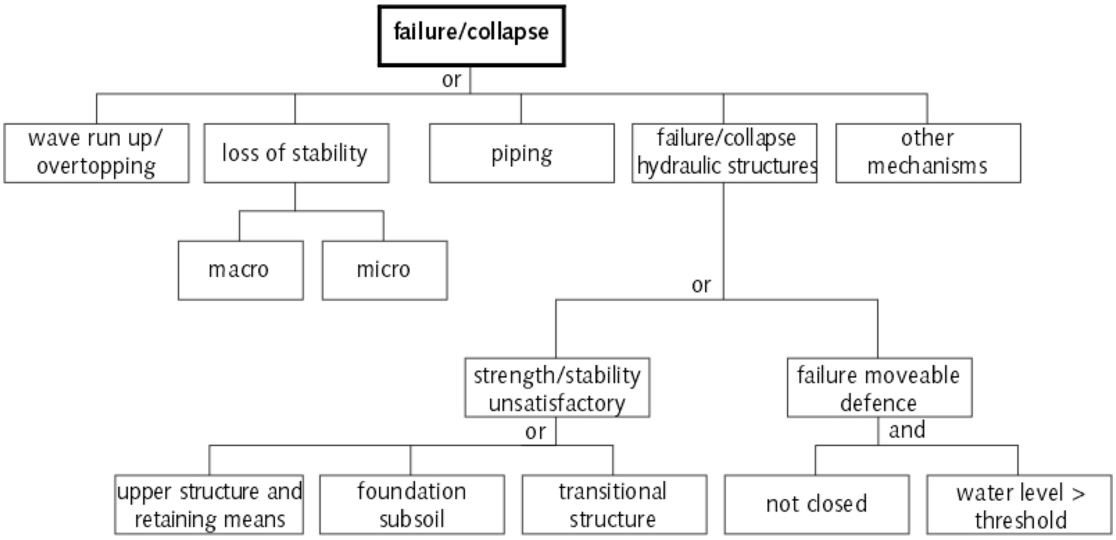


Figure 7.3 Fault-tree for a dike section

The choice of the top event depends on the safety approach used. For the failure probability approach and the overload approach that is the occurrence (event) of a certain mechanism per dike section. For the flood (inundation) risk approach that is a flood with a certain number of victims for example. Figure 7.3 shows a simplified fault-tree for the failure of a dike section. A hydraulic structure, including the connections to the adjacent dike sections, is considered as one dike section.

7.4 THREATS AND LOADS

7.4.1 Introduction

The catalogue of threats is an essential part of the safety analysis and the accompanying loads. The table below provides an (incomplete) overview of the most important loads/threats that must be borne in mind in the design of a flood defence. The loads are categorised according to how they occur.

Permanent loads	Own weight Soil pressure (at hydraulic structures)
Changeable load	Water level and currents Waves Precipitation Wind Temperature (at hydraulic structures) Traffic Fauna/cattle
Special loads	Collision Ice loading Explosions/earthquakes

The performance of the flood defence is especially threatened by the water that must be retained. The pressure of the water on the defence, the current along, through and under the defence and the waves against and over the defence are by far the most important loads. In addition, the defence can be damaged by, for example, precipitation, floating ice or shipping. Traffic over the defence can also form a load. This is discussed in more detail in the various guides. This chapter is limited to the hydraulic loads.

7.4.2 Hydraulic boundary conditions

Central to the design of the flood defence are the so-called hydraulic boundary conditions. The hydraulic boundary conditions consist of a collection of statistical descriptions of the hydraulic loads, such as river discharge, water levels at sea, water levels on the IJsselmeer, wind waves, swell, wind oscillations and wind gusts et cetera. The hydraulic conditions are normally defined in such a ways that a defence to be designed does not influence them. They are defined at some distance from the defence. This is in contrast to what load on a defence is understood to mean, determined among other things by the location and the form of the structure and its immediate vicinity. An example is the reduced effect of a shallow foreland (such as a salt marsh) on the load by wave attack.

The boundary conditions needed for the design of a flood defence are partly dependent on the design method. For a deterministic approach the normative high water level and the accompanying representative wave data will suffice. For a more advanced approach, such as the flood probability or risk approach, all kinds of combinations of water level and wave data are needed to work out the various load cases. In the tidal river area the combination of river discharge and sea level also plays a role in determining the water level.

Work is ongoing on an overview of simultaneous distribution of preconditions of water levels and waves, oriented to an flood risk approach. The development of the boundary conditions along the time line is also important here. Some failure mechanisms, like piping, are time dependent. The development of hydraulic conditions is needed in that case to calculate the development of the inundation.

7.4.3 Loads and load effects

The load can vary per mechanism. The discharge of the overtopping waves is the ultimate load for the assessment of the collapse of the grass cover on the inside. The form of the wave spectrum and the direction of the waves also play a role. For piping on the other hand only the water level really matters. For revetment stability and dune erosion yet other combinations are applicable. Duration and development along the timeline are also important for most mechanisms.

Loads on the outside also initiate numerous physical processes within the flood defence. Water pressures build up, degradation occurs et cetera. These changes are indicated by the collective term load effect. If the load or the load effect is greater than the corresponding resistance of the defence to it (the strength) local or complete collapse will occur.

An example of a load effect is the influence of the high water on the water pressure in a soil structure. A dike derives its stability on the shear strength, which in turn depends on the friction between the soil grains, the effective stress. This effective stress is reduced as the water pressures increase, creating a greater threat of loss of stability. A comparable phenomenon occurs at hydraulic structures that derive their resistance to shearing from friction which is reduced by the rising force of the high water.

The difference between load (only influences by the external geometry) and load effect (influenced by external and internal geometry and the material characteristics) is not always equally sharp. A load effect may even be seen as a reduction in strength by the load and so shows that the distinction between load and strength cannot always be distinguished sharply.

7.5 STRENGTH AND CALCULATION MODELS

The strength of a structure is its capacity to offer resistance to the loads exercised upon it to such a degree that collapse or failure does not occur. Knowledge of the strength characteristics of a structure, be it existing or in the design phase, is essential if the safety with respect to inundation is to be assessed. The strength of a structure is a variable with many components. It is not possible to just talk of 'strength'. The strength can vary by failure mechanism and by load situation.

The strength of a structure is determined in a design or during monitoring using calculation models. This can be more or less schematised.

On one side of the scale are the models with which the behaviour of the structure during a succession of loads is simulated in detail (for example, a computer program which can determine the distortion of a soil body at every spot in the sectional plane). On the other side of the scale are the empirical models and rules of thumb (for example, a piping rule much used in the past with which the stability was simply determined with a ratio of water level difference and seepage length). In those case designs were generated without a clear insight into the underlying physical processes.

Finally there is a third way: the simple physical models (for the shearing of a slope, for example). Here an attempt is made to show the essence of the physical process in the model, and a number of less important matters are left out.

It is difficult to say which models are preferred. Accurate models appear better initially, but often have the disadvantage that they offer the user little insight into the operation of the model and the values of many parameters are often also difficult to estimate. There is also often little experience with the models in practical situations and they are expensive and time-consuming. At the other end of the spectrum, models that are too simple often fail to reflect the complexities of reality.

In many cases there is much to be said for examining a structure with methods of various depth. For example, a complex model, which demands a great deal of calculation capacity, to solve a difficult detailed problem and a simpler model to make many calculations for a statistical analysis.

7.6 LIMIT STATES

A number of definitions are handled in section 7.6 and 7.7 that are important in the probabilistic approach to dimensioning of flood defences. This is fairly complex material, and some knowledge of statistical concepts is necessary. It has however, been decided to include them in the main text of the Fundamentals, *because it is an essential element in the flood probability and flood (inundation)* *risk approach for flood defences in chapter 4. Annex IV provides more detailed information for the authors of specific guides.*

The concept of limit state has been introduced for the dimensioning and assessment of the strength of a structure. A limit state is the transition from the desired state, in which the structure performs as desired, to the state in which failure or collapse occurs.

The consequences of failure may differ from case to case. The most serious form of failure is that in which the flood defence no longer fulfils its primary function and inundation of the hinterland occurs. This is the 'Ultimate Limit State'. An example is the breach dune or the collapse of a lock gate due to high outside water levels.

It is however possible that failure or collapse occurs with respect to parts, sub-mechanisms or non-primary functions. Inundation need not automatically occur, but intervention in the short term (maintenance) is advised. In that case there is a 'Serviceability Limit State'. An example is the washing away of the revetment at the site where the uncovered dike body possesses some strength (the so-called residual strength) or the breaking of a lock gate due to a collision at low water levels. The collapse of large parts of a flood defence usually goes hand in hand with direct damage to the primary function and must therefore be counted as the ultimate limit state. The collapse of parts will often have the character of a serviceability limit state, but a sharp distinction cannot always be made.

A so-called limit state function can be established for all failure mechanisms and sub-mechanisms for which a calculation model is available, commonly represented by Z. All dimensions, variables and parameters occur in that function that describes the structure and the load. These are so-called stochastic functions, which means that their precise value is uncertain. The limit state function Z is defined in such a way, that values smaller than 0 correspond to failure and values greater than 0 correspond to non-failure.

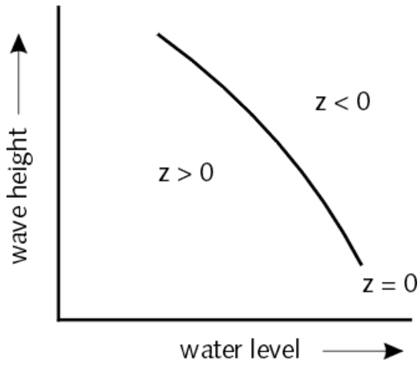


Figure 7.4. Failure, non-failure and limit state for the wave run up/overtopping mechanism (only 2 stochastic functions shown)

Figure 7.4 illustrates this for the wave run up/overtopping mechanism. This figure shows that a combination of a high water level and a low wave or of a low water level and a high wave can lead to failure. Every combination of water level and wave leads to a probability of occurrence.

Furthermore, the resistance to erosion or shearing will have a certain probability spread. All these factors together ultimately determine the probability of failure as a result of wave run up or overtopping. The probabilistic dimensioning is all about this probability.

In many cases the limit state function can be written explicitly for a specific failure mechanism as the difference between a strength and a load:

$$Z = \text{Strength} - \text{Load} \tag{7.1}$$

For each failure mechanism a limit state function Z can be established. Here both the strength and the load consists of various parameters. The precise formulation of the function, and especially what is understood as strength and load, is arbitrary to a certain degree. The formulation (7.1) is also used to compare a load effect and the (internal) strength. In that case the load is also a function of a number of construction parameters.

The models for the majority of limit states important for the flood defence can be found in the material and flood defence type oriented guides. The overtopping mechanism for example (see figure 7.4). The load is the discharge that overtops the defence and the strength is indicated as being the critical overtopping discharge. The limit state function can accordingly be written as

$$Z = q_c - q \tag{7.2}$$

q_c = critical overtopping discharge (strength);
q = overtopping discharge (load).

The critical overtopping discharge depends on the quality of the revetment (a grass covering for example), the slope incline and the duration of the load. The overtopping discharge depends particularly on the water level and the wave height, which depend in turn on the wind speed and wind direction (see also annex IV).

In both strength and load functions there is also a model factor representing the reliability of the model. All calculation models are liable to simplifications, imperfections or even errors in the representation of the actual physical processes. The model errors may be made voluntarily (otherwise it is too complicated) or necessarily (we know no better). The model factor or model uncertainty is the repository of all imperfections in the model and is handled as a stochastic variable. There is sometimes good insight into the average and the spread of the model factor due to tests or observations, but sometimes it must be determined on the basis of engineering judgement.

7.7 SAFETY ASSESSMENT

A planned or existing flood defence must be monitored for safety. The classic method (a method still used today) is discussed in section 7.7.1. Subsequently, in sections 7.7.2 and 7.7.3 an indication is given of which methods may be used in a flood (inundation) probability approach.

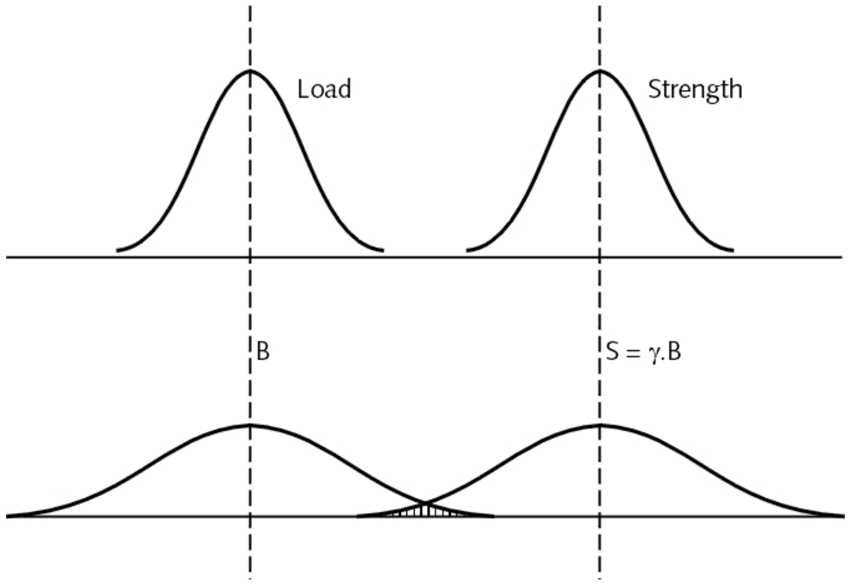


Figure 7.5. The safety coefficient says little about safety

7.7.1 Classic deterministic assessment

In the classic deterministic approach fixed calculation values are used for the load and the strength, with a safety coefficient in between:

$$\text{Strength} = \gamma\,.\text{Load} \quad \text{with } \gamma > 1 \tag{7.3}$$

As every parameter shows a specific spread, γ does not say anything about the failure probability. A completely different probability can accompany the same 'safety coefficient' so that the load exceeds the strength (see figure 7.5). The probability that the strength is smaller than the load, in other words $Z < 0$, is much smaller in the upper case than in the lower case, while the 'safety coefficient' in relation to the average is the same. This is also true if other calculation values are assumed, with a smaller probability of occurrence than the average value for the definition of the safety coefficient.

In a deterministic design the selection of γ is based on experience or intuition. The aim is to prevent failure or collapse, in other words to prevent $Z < 0$. An experienced designer will select a larger γ as the spread of the parameter increases, but γ still says nothing about the failure probability.

7.7.2 Probabilistic assessment

The points of departure in a probabilistic approach are the failure probability and the spreading. The failure probability of the structure calculated in accordance with a protocol laid down by law is compared to a norm value for safety. The norm value follows on from a political/administrative selection on the basis of a consideration of inundation in terms of damage and victims and the costs of the defence.

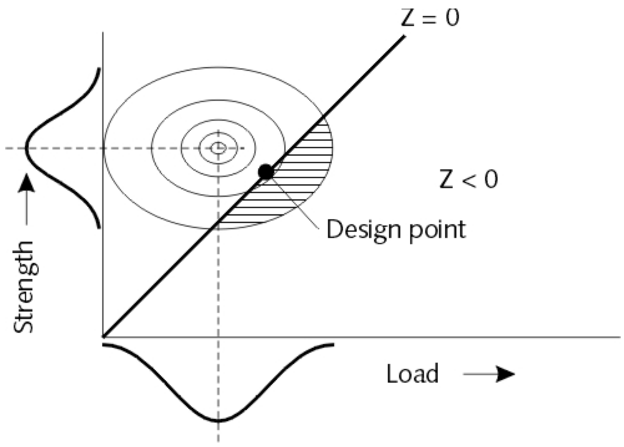


Figure 7.6. 2-dimensional probability strength and load

Of all possible combinations of load and strength the part for which strength < load, that is Z < 0, is the failure probability. That can only be represented in a graph when strength and load are set out on two different axes (see figure 7.6). After all, for every load a strength is conceivable that is smaller and for which Z < 0 and vice versa for every strength a load is conceivable that is greater. It is about the combination of probabilities. The isolines of the 'probability hill' of combinations of strength and load is illustrated in the figure. The content of the shaded part in relation to the total content of the probability hill is the failure probability. The determination of that probability and its rendering into sound calculation values is the main objective of a probabilistic analysis.

The fact that limit state functions consist of various variables, each with its own spread and distribution, makes a complete probabilistic approach complicated and laborious. Methods determining the failure probability from the various possible combinations of strength and load are very laborious and are only use in special cases, for example, where Nature values are very important.

7.7.3 Semi-probabilistic method

A semi-probabilistic method is an assessment using load cases, calculation values, characteristic value and safety coefficients underpinned by probabilistic calculations. In the semi-probabilistic calculation a calculation value is selected for every material characteristic and for every load and there is a check for exceedance of the limit state for the calculation value.

The structure is therefore sufficiently safe if, after interpretation, Z > 0 for the selected calculation values of the relevant parameters.

Theory

The theoretically correct procedure is as follows. The permissible probability per mechanism per part is determined on the basis of the permissible failure probability for a flood defence system. The relationship between the various failure mechanisms for the relevant defence type must be known. The fault tree provides this interrelationship; the contribution of each mechanism to the total failure probability must be determined here. The length effect also pays a role. That is, the length over which a dike section must be considered independent from the rest of the encircling dike for the relevant failure mechanism.

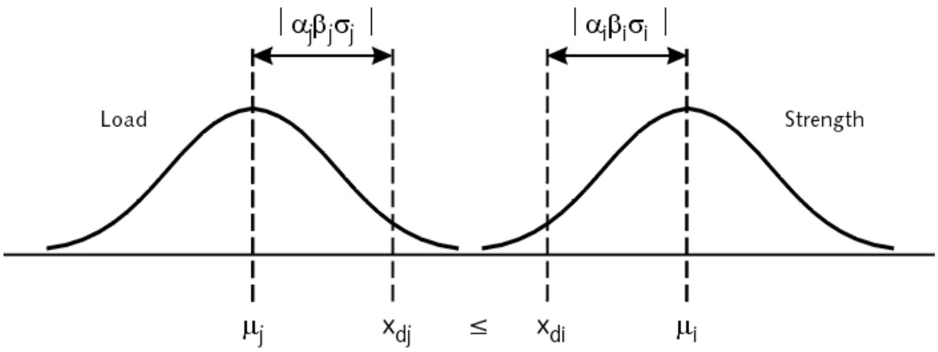


Figure 7.7. Calculation values in semi-probabilistic approach

In the formal semi-probabilistic procedure the calculation value subsequently corresponds to the so-called design value (see also figure 7.6). In the case of normally divided variables, these are provided by (see figure 7.7):

$$X_{di,j} = \mu_{i,j} - \alpha_{i,j}\ \beta_{eis}\ \sigma_{i,j} \tag{7.4}$$

β_{eis} = demanded reliability index;

$\alpha_{i,j}$ = probabilistic influence coefficient;

(load: $-1 < \alpha_j < 0$, strength: $0 < \alpha_j < +1$;

$\mu_{i,j}$ = average value of the stochastic variable $X_{i,j}$;

$\sigma_{i,j}$ = standard deviation of the stochastic variable $X_{i,j}$.

In words: the degree to which the calculation value for every parameter (i,j) differs from the average value depends on: (1) the spread of that parameter (σ), (2) the influence that the parameter exercises on the reliability function (α), and (3) the permissible failure probability for the relevant mechanism and part (via β). The values of μ and σ must be known for every parameter. α and β come from the probabilistic failure calculation.

Where felt necessary, the calculation value can be expressed in a characteristic value with a partial safety coefficient γ:

$$X_{di} = \frac{X_{ki}}{\gamma_i} \text{ or } X_{dj} = \gamma_j\ X_{kj} \tag{7.5}$$

The division occurs for strength variables, the multiplication for loads (see further annex IV).

Practical impediments (limitations)
That is enough about the theoretically correct approach. Practical impediments include the fact that the determination of the interrelationships between the failure mechanisms is not always easy to realise. The same parameter can lead to various calculation values for various failure mechanisms.

Another point is that the norm setting for inundation in the Netherlands was formulated long before there was a full probabilistic approach. The Flood Defence Act offers the opportunity to switch to another formulation of the norm, but it is not meant to lead to another flood defence. The new norm must therefore be oriented to current practice. This is part of the Marsroute.

In hydraulics, the calculation values on the loads side traditionally correspond to the 'normative hydraulic conditions'. The design water level h_d (MHW or normative high water) has an exceedance probability laid down in the Flood Defence Act varying between 10^{-4} to 8×10^{-4} in one year, depending on the safety level of the dike ring area. In the verification of most limit states there is a combination of various loads, such as water level and waves. When calculating these load combinations, it need not be assumed that all loads are at there most unfavourable at the same point in time.

On the strength side, the calculation values in hydraulics are less stringent. For the overload approach it is usually assumed that the flood defence must be 'sufficiently' safe with respect to the overtopping mechanism. Generally, for the overtopping mechanism it can be said that the probability that the strength is smaller than the design value is a maximum of 0.01 to 0.1 for example at normative high water level. But up to now a deterministic strength has been assumed for dike designs for grass revetments. Only dunes can really be designed on a failure probability that is ten times smaller than the exceedance probability of the normative water level.

The failure probability of the other loads should be 'negligible'. Definitive values must be determined when working out the target in the Marsroute. The point of departure is a dike as designed in accordance with the classic points of departure (Delta Committee: sufficiently safe at design conditions). The corresponding spread and the accompanying failure probability must be determined for the mechanism in question. In familiar terms, the norm is outside (this naturally only applies to flood defences that fulfil the test specs in accordance with the Flood Defences Act.).

The expectation is that this will lead to various inundation probabilities for dike ring areas for which the same safety norm currently applies. This is a direct consequence of the deterministically determined strength in the past. A reason for this may also be the switch to another calculation rule for a specific failure mechanism, by which flood defences are relatively safe according to the old rule designs. The same applies to flood defences in the Nieuwe Waterweg (Rotterdam) area that were already improved before the construction of a tidal storm surge barrier there was announced.

7.8 CALCULATION RULES FOR EACH DEFENCE TYPE AND MECHANISM

Failure mechanisms for which generally accepted calculation rules have been developed will be described in special guide annexes (stability of soil bodies, piping, wave overtopping, erosion of the outside slope at set stone and asphalt revetments et cetera). Fault-trees for a specific type of flood defence with the relevant failure mechanism, and where possible the permissible probabilities will be included in the guide for that flood defence type. The calculation rules for the relevant failure mechanisms of flood defences are laid down in the publications, as mentioned in the table below.

The least well developed at the moment is the assessment of objects. For the time being, TAW *Handreiking Constructief Ontwerpen (handouts on structural design)*, drawn up within the framework of the recommendations of the Boertien committee, provides an approach using the so-called assessment profile. This is an imaginary minimum profile of defined dimensions that must fit in to the actual profile. This minimum profile may not be transected by non-water retaining objects (with the exception of pipelines) and must guarantee that the damage to the flood defence as a consequence of the object does not immediately lead to failure of the flood defence. This assessment profile is intended for the assessment of the permissibility of existing buildings and vegetation.

Failure mechanisms	Publications
Dune erosion	*Guide on Sandt Coasts (Leidraad duinen)*
Erosion due to overtopping	*Tecnical Report on Grass and Clay (Gras- en Kleibekleding)*
Macro-instability Soil Structures	*Guide on river Dikes – upper reaches (Leidraad Bovenrivieren)*
Micro-instability Soil Structures	*Guide on River Dikes – lower reaches (Leidraad Benedenrivieren)*
	Technical Report on piping (Rapport Piping)
Piping	*Guide on Retaining (hyraulic) Structures (Leidraad Kunstwerken)*
Non closure hydraulic structure	*Handouts on Structural design (Handreiking Constructief ontwerpen)*
Assessment objects	*Pipeline code/NEN 3650 (Dutch Standards)*
Pipelines	

CHAPTER 8 DESIGN

Chapter 8 provides an overview of what is involved in the design of an improvement of a flood defence, in terms of both content and procedure. All aspects of the previous chapters have a role to play. It is the task of the designer to make these aspects a cohesive whole that, at a given protection level, optimises the other functions and has a sufficient basis of support.

8.1 INTRODUCTION

A flood defence must be designed in such a way that it is able to fulfil the proposed water retaining function during the proposed time line with sufficient reliability, taking into consideration the allocated functions. The necessity of adapting and/or constructing a flood defence follows on from the observation that the flood defence does not fulfil the legal safety norm at a certain moment. Article 3 of the Flood Defence Act (FDA) contains the requirements with respect to safety. Chapter 4 includes a description of the degree to which the safety norm is currently expressed and gives attention to the approach that may be maintained in the future. Chapter 7 provides the technical consequences.

Failure to fulfil the norm may be observed during the five-year determination of the normative high water levels to be maintained by the minister or during the five year monitoring of the hydraulic situation laid down by law. It may also be so that the flood defence in question has yet to fulfil the norm set by the FDA.

Depending on the scale of the measures and the manner of financing, a decision must be taken on whether there is a need for maintenance or improvement. In the case of maintenance, measures will typically be limited and no formal plan procedure need be followed. In the case of improvement article 1 of the FDA applies and that is mandatory.

Article 1 of the FDA obliges the manager to draw up and fix a design plan. The Provincial Executive must approve this plan. It must consist of the following components:
- The provisions to be introduced, oriented to the work for the flood defence;
- The provisions to be introduced, oriented to undoing or limiting the adverse effects of the execution of the work, in so far these provisions are directly connected to the execution of the work;
- The provisions to be introduced to promote the importance of the landscape, nature or cultural-history, in so far these provisions are directly connected to the execution of the work.

Article 1also indicates that all interests in accordance with the recommendations of the *Commissie Toetsing Uitgangspunten Rivierdijkversterkingen* (Boertien I Committee) must be taken into account when drawing up the design plan. Besides the Nature aspects mentioned above the other social functions of the flood defence are also involved. That not only applies to river dikes, but to all primary flood defences (including sea dikes, lake dikes, and suchlike). The design requirements and preconditions are derived from the various functions allocated to a flood defence. The design process is therefore oriented to a spatial and technical design of the flood defence providing for the functions.

8.2 DESIGN ASPECTS

8.2.1 Possible measures

In principle there are various technical possibilities available offering a solution to one or more failure mechanisms. The most important principle solutions tackling various imperfections can be grouped as follows:

A. New flood defence;
B. Improvement using the existing dike or dune profiles;
C. Special Structures.

The first category (A) comprises the solutions in which a new flood defence is constructed, possibly alongside or in the vicinity of an existing one. Bearing in mind the policy of the Directorate-General for Public Works and Water Management with respect to enlarging the winter bed of the river, new river dikes will usually not be constructed outside the dike. In the future relocations inside the dike will become much more prevalent for the same reason. Category B comprises solutions that are used in most cases. The existing flood defence, inside or outside the dike, is improved. In general, the aim is to concentrate improvement measures on one side as far as possible. That prevents damage occurring to nature on both sides.

In the case of dunes sand is introduced for example.

Category C covers the improvement measures in which special structures are used. They are oriented to maintaining the existing cross section or the contours of the profile and to spare the values present as far as possible. In general, it can be said that soil improvement is sought initially. Owing to the often high costs of realisation and maintenance and the limited flexibility for raising in the long run, special structures are only used at bottlenecks. They often take the shape of soil retaining walls (retaining walls, sheet piling).

Dikes

Besides the above mentioned total solution, other measures can be mentioned that help combat specific collapse mechanisms. They include a berm, a seepage ditch, the digging in clay in the foreland or the introduction of drainage on the inside toe of the flood defence.

When determining the improvement measures at a river or sea dike it must be ensured that the permeability of the flood defence increases from the outside to the inside. That means that improvements outside the dike are chiefly carried out with relatively impermeable materials (clay, asphalt) and improvements inside the dike with sand.

A small raising of the crest may sometimes be realised by introducing a few layers of asphalt (thicker road surface), but a greater degree of raising almost always means that they will have to be realised in soil.

If the stability of the inside or outside slope is insufficient, the solution may be to make the slope more gentle by introducing a stability berm. The choice depends on the necessary dimensions of the berm, the possibilities of adapting it to the landscape (including the continuity of the dike profile) and any nature values on the slope among other things. Landscape considerations are important factors in the choice of the shape of a berm.

In some situations it is possible to increase the stability inside the dike by introducing relief ditches.

If the erosion stability of the inside or outside slope is inadequate as a result of a poor revetment, a new revetment must be introduced. For a grass revetment the most usual option is a management method (see section 10.3.1) that results in a better grass cover.

Piping can be prevented by digging in a sufficiently thick clay package in the foreland, by introducing a piping berm or a seepage screen. At sea dikes the probability of piping is typically small due to the relative broadness of such flood defences and the relatively short duration of the rise in water level. A piping berm is a natural choice if a berm is needed due to stability considerations. In that case the two can be combined. A seepage screen (clay coffer, bentonite or foil screen) is usually a good solution if a foreland improvement and a piping berm leads to a great deal of damage to the values present. In a number of situations the introduction of a foreland improvement can be combined with nature development measures.

The occurrence of micro-instability on the inner slope can generally be prevented by introducing a toe drainage or a berm located on the landside of the dike. Here too, the choice of a berm is a natural one when there are also other reasons for application of a berm (stability or piping).

Practical study into loss of stability by overtopping water

Hydraulic structures and objects
If the measures to combat seepage capability and seepage erosion prove inadequate under normative conditions at water retaining hydraulic structures, new screens are necessary. That is usually a complicated intervention and so rather expensive.

If buildings or trees that are deemed important are located on the flood defence, they may be placed outside the assessment profile by means of sheet piling structures in the flood defence. As a result the buildings and trees do not need to be removed. Such structures can also be used if the stability of the inner and/or outer slope is insufficient, and a gentler slope or the introduction of a berm is not possible due to these nature values.

Dunes
In the case of (threatened) erosion of a sandy coast with dunes, sand can be introduced on the beach or on the first bank, depending on the nature and the location of the erosion. If the dunes themselves are too weak they can be reinforced by supplementation. Beach nourishment may be called a soft measure. Hard measures include dune foot protections or underwater dams.

8.2.2 Assessment

The design requirements, wishes and preconditions form the framework within which the solutions for dike improvement measures must be sought. As described above, they are rooted in both the scope of hydraulics and the scope of Nature values and other functions.

Hydraulic assessment
In the design phase the hydraulic assessment is oriented to determining the shortcomings of the current flood defence and the measures deemed necessary (oriented among other things to making the choices A-C as mentioned in section 8.2.1). This assessment comprises the following aspects:

- Determining the soil compositions and soil parameters;
- Monitoring the current crest height and determining the required crest height. The normative water levels and other preconditions laid down by the minister must be used;
- Calculating the potentials in the sand subsoil. For the locations with a varying outside water level this must be done using an non-stationary consideration;
- Determining the required seepage length and monitoring the current seepage length in relation to piping;
- Calculating the stability of the current slope inside and outside the dike;
- Calculating the stability of the adapted dike profile selected inside and outside the dike;
- Determining the necessary measures in relation to piping, micro-stability and erosion stability;
- Studying and advising with respect to the pipelines present;
- Working out the special structures.

In general and initially, simple calculations will suffice. If need be, more accurate calculation methods can be used, for instance if distortions are important, especially in the vicinity of buildings. The design methods to be used for the flood defences are found in the TAW guides. On the basis of the assessment possible variants and options can be developed and the scale of the pace needed determined.

The design of water retaining structures concentrates (see also *Leidraad Waterkerende Kunstwerken en Bijzondere Constructies/Guide on Water Retaining Hydraulic Structures*) on:

- Wave run up and overtopping;
- Strength and stability;
- Reliability of means of closure.

The overload principle is used for wave run up and overtopping. Overloading is said to occur when the wave run up and/or overtopping water causes erosion. This is in accordance with the design criterion for dikes. If no erosion is expected and open water is present immediately inside the hydraulic structure, a permissible rise in the water level can form the design criterion.

The permissible probability of failure, without exceeding the permissible overtopping discharge, is equal to 0.01 times the norm frequency (see annex III). From this it can be derived that the strength of the parts of a hydraulic structure can be calculated in accordance with NEN 6700 series (Dutch Standards), with an adjustment of the water pressures.

The stability of the hydraulic structure, under the influence of piping and any stability of connecting soil bodies, is in principle calculated in the same way as by dikes. For seepage erosion and seepage capability, which leads to piping, the Guide on Hydraulic Structures provides design methods.

The probability of the means of closure failing is set at 0.1 times the norm frequency (see annex III). A risk analysis is used to dimension the means of closure on this, including control procedures.

Assessment other aspects
The assessment of the other aspects (see chapter 5) is oriented, among other things, to:

General
- Collecting and describing relevant plans at various administrative levels;
- Describing administrative history of the dike section;
- Describing procedures and their interconnection.
- Describing autonomous developments.

Nature values
- Collecting and cataloguing current information on landscape elements, fauna, vegetation, cultural-historical elements, and suchlike;
- Determining potentials (description of potential qualities);
- Describing the spatial characteristics of the area, based on the landscape structures and processes;
- Detailed description of local situation at bottlenecks;
- Valuing Nature aspects.

Planning functions
- Describing other existing or desired functions on the flood defence and in the vicinity (housing, traffic, industry, recreation et cetera);
- Describing the current purposes and necessary changes.

In accordance with the LNC-guide (*Handreiking Inventarisatie en waardering LNC-aspecten*), the description of the Nature aspects usually occur on three levels: regional, local and dike level.

8.3 DESIGN PROCESS

8.3.1 Integration and iteration

For the decision making process, the plan procedure in which a dike improvement plan is worked out is founded in the FDA. In the case of dike improvement (so when article 7 of the FDA applies) an environmental impact assessment report (EIA) is mandatory. It is needed (1) to gain good insight into the effects of dike improvement, (2) to enable a well considered choice between variants and options, and (3) to create sufficient support. The legal basis for the EIA procedure is the Environmental Management Act. The aspects with respect to the content of the EIA are handled in chapter 5.

The interaction between the EIA process and the plan process is central to the total approach of plan forming. Choices must be made about the aspects considered important and less important. The necessity of approaching the plan forming integrally means that the activities in the EIA process and in the plan process are integrated to a great degree. There must be an iterative process in drawing up a programme of requirements and the development of options. During the process there is a continual analysis and weighing up of requirements, wishes and interest. This demands an approach in which harmonisation and feedback can occur regularly. It may sometimes prove necessary to modify choices made in the past due to a growing insight into the problems. Both the spatial and structural aspects of the flood defence are accordingly integral parts of the plan development from the beginning.

8.3.2 Legal decision making process

Along the coast almost every flood defence is reinforced on the basis of the 1958 Delta Act. The flooding in 1993 and 1995 resulted in the state governments decision to accelerate the implementation of the river dike improvement programme.

The result was the Delta (Major Rivers) Plan in April 1995, the aim of which is twofold:
- Improvement of the most unsafe dike sections in the years 1995 and 1996 (completed);
- Improvement of the remaining dike sections by 2000 (the so-called second block).

The FDA is to be applied for the improvement of the second block of flood defences. The act harmonises all procedures for flood defences that do not currently fulfil the safety norms set by the Act to those of the improvement of the flood defence (article 17 through 31). One appeal moment is built into the legal procedure where the judge must form an integral judgement of the improvement plan and all interests involved. The procedure is oriented to the improvement of the flood defence no later than the year 2000. The various interests must be addressed and considered to a sufficient degree however. The involvement early in the process of institutions that must take decisions means they can begin the decision making at an early stage. The open character of the procedure also leads to a smaller probability that objections to and appeals against the plan causes a considerable delay; each can exercise an influence on the plan forming at an early stage. The procedure with one appeal moment guarantees a limit is set time-wise. Appendix V gives an overview of the procedure as follows from articles 17 through 31 of the FDA.

For new improvements, once the flood defence of a dike ring area has already fulfilled the safety norm of the FDA, harmonisation stops. Every applicable act has its own appeals procedure, so that the guarantee of a time bound procedure is no longer applicable.

CHAPTER 9 EXECUTION

Chapter 9 provides an overview of the aspects that play a role in the actual execution of the improvement of a flood defence.

Once the decision making on the plan is completed, a start can be made on the acquisition of the ground needed and the execution of the plan. In general, the manager will attempt to acquire the ground in an amicable settlement with the owners. If these attempts fail a judicial compulsory purchase procedure will be necessary.

A plan, in accordance with the 1995 RAW standard, will be drawn up, based on the approved plan, and serving as a contract between the principal and the contractor for the execution. Additional tasks are the generation of the detailed drawings, the consultation with the utilities, the determination of the amounts and the drawing up of a budget. Once the plan is ready the contracting procedure is begun. That usually occurs via a public contract in accordance with the *Uniform Aanbestedings Reglement* (Standard Contracting Regulations, UAR 1986) or via the guidelines for the European contract.

As mentioned above, the total realisation of the dike improvement plans goes hand in hand with a great degree of essential involvement of inhabitants and interest groups. Elements and plans deemed important are discussed down to the fine details and approved. It is also important that these elements are carefully handled during execution. That means that both the manager and the contractor are always up to date on the background of the plan. A thorough preparation and supervision of the execution is necessary.

The method of execution generally influences aspects that are considered important during the plan forming stage. The realisation of the improvement works to the flood defence often consists of making the slopes less steep and introducing baskets and foreland improvements. That always means a temporary reduction in the hydraulic quality of the flood defence, and often a need of more space than for the improvement measures themselves and inconvenience for inhabitants in the vicinity. These factors must be taken into account during the plan forming, so it is important to obtain insight into them at an early stage. A few of them are mentioned below.

9.1 SAFETY DURING EXECUTION

Generally, safety during execution demands extra attention because an existing defence that is undergoing improvement is less strong. This attention may mean that work is executed in a specific period in which the probability of extreme loads is smaller, the summer months for example. The point of departure must be an exceedance probability for the summer period equal to the prevailing MHW exceedance frequency for the area. Another option is the introduction of extra measures to prevent damage or worse.

During and for some time after the execution of improvement works the erosion stability of the revetment may be limited. That is especially so in the case of grass revetments; a good grass cover has not been able to develop after all. As a result, the pursued quality of the flood defence is not fully available. That means that the contractor and/or manager must take measures to prevent erosion when high water develops.

The preservation of landscape, nature and cultural heritage enjoys a great deal of attention at dike reinforcements in the Delta (Major Rivers) Plan.

9.2 WORK STRIPS

Work strips along the flood defence are almost always necessary for the execution of improvement work. They are used for the temporary storage of dredgings and material. This must be factored in to the impact assessment of the various options.

9.3 SUPPLY OF FILL MATERIALS

Clay and sand needed for improvement works is usually transported in from outside. The fill material for river dikes often comes from the river forelands. This typically influences the Nature aspects in the relevant river foreland and is accordingly an important factor in the impact assessment of the various options. When using sea sand the salt problem must not be too great.

9.4 INCONVENIENCE

During the execution there will always be some degree of inconvenience for residents on or along the flood defence and along the transport routes. The to and fro of materials and equipment and the introduction of sheet piling structures for example will usually be the source of road closures, vibrations and excess noise. The choice of supply routes will therefore be accompanied by consultation with municipalities. The inconvenience during execution is unavoidable, but must be minimised. This must be factored in to the design of measures.

9.5 ENVIRONMENTAL PROTECTION ASPECTS

Environmental requirements set by the province, the Directorate-General for Public Works and Water Management and the municipalities involved are applicable for building materials. The remaining building materials must be processed, recycled or disposed of in accordance with the legal frameworks indicated (including the Building Materials Decree).

9.6 NATURE

When executing improvement work it is important to ensure that the damage to existing vegetation considered valuable is minimised. Moreover, the approach must be such that the best possible situation is created to facilitate the recovery of the vegetation. The replacement of the top soil from existing slopes on new slopes usually leads to recovery of the area-specific vegetation. During the execution measures must be taken to this end. Sometimes it must be possible to realise the development of new nature by making a suitable biotope during execution at relatively little expense (a amphibian pool at the foot of the defence for instance).

CHAPTER 10 MANAGEMENT AND MAINTENANCE

Chapter 10 shows what is involved in the management of flood defences. In contrast to the design of an improvement there are no great interventions. The same aspects (safety and other functions) are involved in the search for a workable and sustainable equilibrium between the various functions.

10.1 INTRODUCTION

Chapter 6 discussed management as policy implementation in the total package of flood defence care. The management plan, with the management vision it contains, plays a role here. This chapter discusses how this is worked out, with the emphasis on management and maintenance, also called day-to-day management. The manager of the flood defence is responsible for upholding the safety norm for the dike ring area. The day-to-day management is therefore primarily oriented to this responsibility. In addition, there is a social desire to take account of nature aspects in management. As a result, management is increasingly seen as an nitrated activity to guarantee safety and preserve and reinforce the values in the rivers area..

Management and maintenance instruments include:
- The data-base (*legger*) and the management register;
- The management plan;
- The by-law.

These instruments are part of the foundation for the five-year monitoring of the flood defence.

10.2 MANAGEMENT INSTRUMENTS

10.2.1 Data-base and management register

In accordance with article 13 of the Flood Defence Act (FDA) the manager is responsible for the following:
- A general map showing the location of the primary flood defence;
- A data-base containing a description of the requirements the flood defence must fulfil in terms of direction, dimensions and construction;
- A technical management register containing a detailed description of the characteristic data for the retention of the water retaining capacity of the structure and the actual state.

There is currently insufficient clarity on the precise interpretation of this system. The Union of Dutch Water Boards has set up a model data-base/technical management register (ref. *Uniemodel*), for river, sea and lake dikes in so far as they are designated as primary flood defences.

It is essential that the data-base provides an impression of the flood defence as it must be to fulfil the norm laid down by law (design profile). It is not only about height-related data, but all data of importance for the safety of the flood defence. The management register contains the up-to-date flood defence data.

The Union's model describes which parts are to be included in the data-base and which parts in the management register. The Union has worked out the model in a standard data description for flood defences. In fact, it comes down to the fact that the manager must have general maps at his disposal for the whole management area of the water board, for defined areas, and for the individual dike sections. In addition, medium-scale ('ordinance survey') maps must be made available with topographical and land registry data, boundaries in the sense of the by-law, hydraulic structures and objects, reference lines with respect to which the cross sections (data-base profiles) have been fixed and suchlike. Finally, the manager must have drawings of cross sections and elevations at its disposal.

Rivers are the lifelines of the Netherlands. They are used to transport goods and for pleasure. The banks have many functions such as agriculture and nature

Maps must be made available for the management register, showing the actual location of crest line, toe line, stability line, data on the structural composition and state of flood defences, hydraulic structures and objects. There must also be references to more detailed documentation: soil surveys, design calculations, plans, reports, management agreements and suchlike.

10.2.2 Maintenance plan

In the maintenance plan the management vision is worked out into tangible measures. The manner in which the secondary functions of each individual dike route are made concrete in the management form is decided here. In the determination of the most suitable management form attention is especially given to the technical, organisational and financial aspects of the various management forms in relation to the local conditions.

Important information in this is the slope incline, the presence of a maintenance path, the potential market for dike hay, availability of cattle, the current management and the current make-up of vegetation..

The new management form can generally only be introduced at improved dike sections two years after the execution of the improvement work. During the first two years there must be a mowing regime in place for the slopes to increase erosion stability..

For the regular management and maintenance of the hydraulic structures a maintenance plan must be available, describing the maintenance measures, the inspection schedule and the safety norms. The management activities are oriented to the following aspects:

- The record of all hydraulic structure-related data (design and execution);
- The assessment of the state of the hydraulic structure to determine any decline in strength;
- The assessment of transitional structures and ground surface or ground levels, adjacent to the hydraulic structure;
- The inspection and assessment of all moving parts;
- The regular exercise in accordance with mobilisation and operating procedures.

The regular inspections are usually a condition set in the risk analysis in the design, in order to achieve the required safety level. There can also be a clear link to the design with respect to the other points.

Guide on Water Retaining Hydraulic Structurs (Leidraad Waterkerende Kunstwerken en Bijzondere Constructies) addresses the above mentioned aspects in detail.

10.2.3 By-law

A formal means at the disposal of the manager to guarantee the hydraulic quality of the flood defence is the by-law. The following matters are regulated in this document:

- The method of controlling the flood defences;
- Dos and don'ts with respect to excavations, buildings, cables and pipelines, fencing, vegetation, metalling and suchlike.;
- Obligations with respect to the method of execution and maintenance.

The by-law is the basis for the granting of exemptions and permits to utilities for example. These are based on the boundaries laid down in the data-base (protection zones, stability lines and suchlike).

The Union of Dutch Water Boards established a model by-law in 1991 (*ref. Model-keur*) including sample general conditions. These have been worked into the water board by-laws to a greater or lesser degree.

10.2.4 Five year monitoring

In accordance with the FDA (article 19) the manager must submit a report to the Provincial Executive on the hydraulic state of the flood defence. It conducts the necessary inspections and studies and records its results in a proper and clear manner.

The five year monitoring of primary flood defences occurs in accordance with the provisions in Guide on Safety Assessment (*ref. Leidraad Toetsen op Veiligheid)*, on the basis of the prevailing normative water levels and other preconditions, as laid down by the minister. *Technical Report on Safety Assessment for Drainage Canal Embankments (ref. Technisch Rapport voor het toetsen van boezemkaden)* can be used for the assessment of discharge/drainage canal embankments.

Monitoring is oriented to the main function of the flood defence, that is the safety, and relates to all types of primary flood defences and high grounds. The assessment aspects as included in the guide relate to height, stability, means of closure and limit profile. The manager begins with general monitoring on the basis of simple calculation rules and goes into greater detail if such proves necessary. On the basis of monitoring a qualification is give per flood defence element of 'good', 'satisfactory' or 'poor'. A design profile is usually laid down in the data-base (see section 10.2.1) corresponding to the assessment level 'good'. An assessment of 'satisfactory' means that a level under the data-base level is accepted temporarily. Safety is not compromised however.

Monitoring differs fundamentally from flood defence design on a number of points. The design often starts from a clean situation and a long time is reserved for the optimisation of the construction and maintenance costs within the functions to be fulfilled. Monitoring is about a less all-embracing entirety. The flood defence may have some defect, as long as it does not lead to flooding. That may mean that other requirements are maintained. The aim of a design may be to realise a structure that can fulfil its function for a very long time (fifty years for example). When monitoring a much shorter period, for example five years is applicable.

The possibility of deriving data from the structure is also possible during monitoring. If the design is only available on paper the actual state and behaviour can be mapped in the assessment. As a consequence a number of sources of uncertainty are eliminated. In technical jargon the division of the stochastic functions are updated.

The five year monitoring of hydraulic structures in described in detail in *Guide on Safety Assessment (ref. Leidraad Toetsen op Veiligheid)*. Here too, the assessment is primarily based on general monitoring, complemented by a detailed assessment where necessary. In brief, the monitoring of hydraulic structures must be oriented to the height of the structure (including any means of closure), the strength and stability, the resistance to piping (seepage erosion and capability) and the operation of the means of closure.

10.3 MANAGEMENT AND VEGETATION

10.3.1 Grass slopes

The primary function of the flood defence is oriented to the retention of outside water. For dikes with a grass revetment a good combination of soil type and vegetation is important. Studies show that a deep-rooted spicy vegetation offers good erosion stability. Certain management forms such as mowing without removal and intensive pasturing are harmful to this however. Manuring and a permanently high cattle density have a negative effect on the erosion stability because the vegetation that develops in these conditions have shallow roots and open spots can originate in the vegetation.

In other words, to a great degree erosion stability depends on the management of the slopes. That means that the method of management impacts the primary function of the flood defence.

Furthermore, also as a consequence of unfavourable forms of management, a rapid decline in the ecological qualities of the flood defence can be observed.

The management forms can be determined depending on the secondary functions designated to dike sections. There are four forms of slope management:
- Nature-technical management;
- Modified agrarian management;
- Lawn management;
- Hydraulic management.

Nature-technical management
The nature-technical management may consist of extensive pasturing and hay-making (mowing and removal). A combination of pasturing and hay-making is also possible. Manuring/fertilizing of the slopes is not permitted. The preferred form of use for nature-technical pasturing is the annual maintenance agreement.

Modified agrarian management
Bearing in mind that current forms of agrarian management are no longer desired (in connection with erosion stability, fertiliser legislation and the nature function) a modified agrarian management is usually carried out. This often comprises a rather extensive pasturing regime with sheep or young cattle. Preference is given to periodical pasturing in which pasturing occurs in two or three periods of four weeks during the growth season (April-October). Land lease agreements valid for a few years are generally a good form of use for modified agrarian management.

Lawn management
At the site of the ribbon of buildings management is tailored to the wishes of residents as much as possible. There are restrictions however. In relation to erosion stability, there must be a closed grass lawn; flower and vegetable beds are accordingly not permitted. The lawn management is the responsibility of the residents when the dike slope is part of an estate or a garden.

Hydraulic management
At parts of the slope that cannot be managed in any of the ways outlined above hydraulic management can be carried out that is primarily intended to maintain the erosion stability of the slope. The sections are usually small and the technical degree of difficulty high. The manager will usually carry out a mowing regime with removal.

A detailed description of the management possibilities resulting in an ecologically sound and erosion stable revetment is found in the policy document *Construction and maintenance of grass covers on river dikes (ref. Aanleg en beheer van grassland op rivierdijken)*.

It is also important for the proper functioning of the ecological connection that an unbroken ecological ribbon is formed as far as possible. This is not possible at sites where buildings are found on or against the slope. Many plants and animals can move a short distance from a suitable habitat, and the interruptions become impossible barriers.

10.3.2 Dunes

Dunes demand a separate approach in day-to-day management because they are part of a dynamic system in which sand drifts occur continuously. On the one hand, an attempt is made to minimise this to guarantee the water retaining function as much as possible and avoid problems. On the other hand, a certain degree of sands drifts appears to be important to the vitality of the dunes.

Vegetation plays an important role here. The most well-known dune vegetation is marram. This offers no protection against erosion by waves, but does help catch and retain shifting sand and is accordingly important to the performance of the dunes as flood defence. Marram plays an important role in catching shifting sand. Conversely, the root system of marram will be attacked by mould if it is not covered by sand regularly. Management measures like digging, mowing, burning and manuring are not effective for regeneration of languid marram. If sand drifts cannot be repaired, then species can be considered that follow marram in terms of natural succession. These species are not as sensitive to mould but are more sensitive to salt spray than marram.

In marginal (narrow) dune areas the vegetation must not show any bare spots on the landside.

10.4 CONTINGENCY PLAN

The water levels at which the manager is obliged to establish a dike watch and to undertaken measures to maintain the safety of the flood defence (the alarm levels) are laid down by the minister for a period of five years (Flood Defences Act, article 15). The minister also informs the dike manager in good time of the expected deviations from the published high water levels, if the high water is a threat to ‘a primary flood defence intended for the direct retention of the outside water’. The divisions of the Directorate-General for Public Works and Water Management supplies this information along the rivers and the IJsselmeer (RIZA) and in the tidal area (the department for tidal flood reports, RIKZ).

In general, on the basis of the *Disaster Response Act* (article 1), the Mayor and Aldermen (the Municipal Executive) are responsible for the preparation of disaster response measures in the municipality. They are responsible for a disaster response plan in which plans are included with departments, institutions, organisations and individuals and insight is provided in terms of command and responsibilities. The information flow is also laid down in the emergency response plan.

In the case of extreme high water levels and so a threatened disaster with the flood defence the dike manager, as responsible institution, is obliged to fully inform the Municipal Executive on the state of the flood defence. The manager must have a plan for dike control and a contingency plan, in which all actions to be taken in the case of high water are laid down and including an overview of all parties involved. This plan must be in line with the disaster response plans of the municipalities in the zone. The Union of Dutch Water Boards has provided a framework in *Het waterschap en de rampen- en ongevallenbestrijding (Waterboard and the Disaster Prevention)* for a contingency plan and its relationship to the municipal disaster response plans.

The province has a coordinating and regulating role in the (preparation of) disaster response measures and crisis control. In accordance with article 12 of the *Disaster Response Act* the Queen’s Commissioner can issue instructions on the policy to be implemented by the mayor(s) in relation to the response to a (threatened) disaster of more than local significance (in one or more municipalities). If the mayor requests the assistance of government agencies (military assistance, for example) he can approach the minister of Internal Affairs. The Queen’s Commissioner also coordinates the preparation of the civil protection by government officials working in the province and military personnel, the

Provincial Executive, the Municipal Executive and the water boards. He or she has a seat on the consultation between these parties.

The Queen's Commissioner establishes a provincial coordination plan on the basis of article 10 of the Disaster Response Act. This includes a framework with respect to the leadership and the coordinated efforts of departments and organisations in responding to disasters at provincial level.

After the execution of ongoing improvement plans the probability of the alarm level being reached is relatively small. Factor in frequencies of once every fifty years on average. That is sufficiently low to necessitate extra attention to maintain the level of personnel and equipment. The FDA (article 16) therefore obliges the manager to hold exercises.

Finally, movable hydraulic structures demand special attention, such as cuts and floodgates et cetera. In general, an operating plan must be available for the management of the hydraulic structures in flood defences, in which the tasks, powers and responsibilities with respect to the operation of the hydraulic structure are laid down. It must also include the procedures for closing the defence when high water levels and disasters are ascertained.

Guide on Water Retaining Hydraulic Structures (Leidraad Waterkerende Kunstwerken en bijzondere Constructies) sets requirements on the organisation and the procedures for the closure of hydraulic structures. These requirements are related to the probability of non-closure used in the design of the hydraulic structure.

CHAPTER 11 WHAT NEXT?

Chapter 11 provides an overview of the activities that will take place after the publication of the Fundamentals. Some of these activities are grouped under the TAW umbrella; some are matters that directly follow on from the obligations that the Flood defence Act (FDA) imposes on flood defence mangers and the competent institutions.

The activities for the coming ten years can be roughly divided into two main groups: the monitoring and the Marsroute. Figure 11.1 illustrates both of them.

Starting point for both activities is the current flood defence
In accordance with article 9 of the FDA (published in the Bulletin of Acts and Decrees in 1996) monitoring of the hydraulic state of the primary flood defence must take place every five years. It begins by updating the loads (*ref. Hydraulische randvoorwaarden/Report on Hydraulic Boundary Conditions)*. That is followed by a cataloguing of the strength of the flood defence in the field on the basis of the *Guide on Safety Monitoring/Assessment of Water Defences* (*ref. Leidraad Toetsen op Veiligheid*). Together that delivers a stability test, which is published in a report. First and foremost, the managers report to the provinces and ultimately the minister reports to the Second Chamber of the Dutch government. As the process continues it may be decided to adapt the defence. The first report by the minister to the Second Chamber is scheduled for 2001.

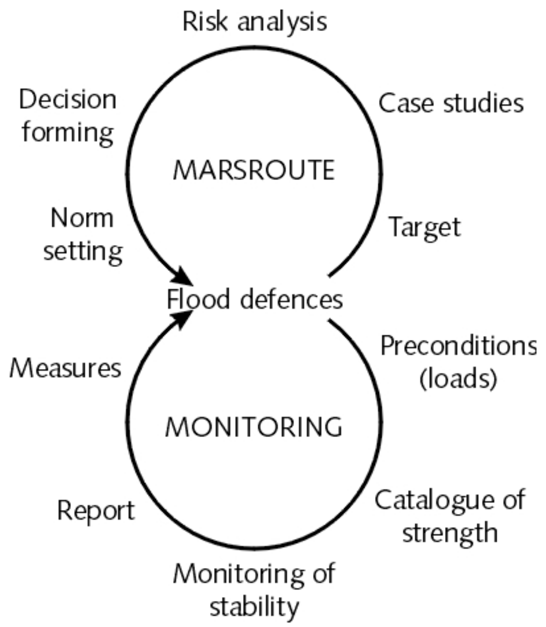


Figure 11.1 Follow on Process (Marsroute)

In the Marsroute (TAW resarch programme) the current flood defences (in so far as they achieve a satisfactory score in the test) play a role in determining the target. Work begins on making the design rules more uniform in accordance with the current safety approach. The results up to now show that there may be some imbalances in the design rules. In the past adaptations were introduced to the rules. The dike section overload approach on parts was cut loose. This led to a non-uniform set of design rules per failure mechanism.

After the case studies that play a role in the formulation of the target, case studies will be generated that are oriented to gaining insight in flooding probabilities, damages and uncertainties. They can be used to draw up a risk analysis and develop ideas on the consequences for norm setting. The possible options can in turn have consequences for the flood defences. Decision making is provided for over a period of approximately ten years.

Besides a content-oriented elaboration of the methodology, social acceptance of the flooding risk approach also plays a role. The first step is publication of the Marsroute brochure (see *Veiligheid van Waterkeringen*). A newsletter has been proposed to keep controllers, managers and interest group up to date in the future.

ANNEX I - BULLETIN OF ACTS AND DECREES OF THE NETHERLANDS

1996

Act of 21 December 1995 containing general rules to ensure protection by dikes against flooding by external water and to regulate certain related matters (Flood Defences Act).

We, Beatrix, by the grace of God, Queen of the Netherlands, Princess of Orange-Nassau, etc., etc., etc.

Greetings to all who shall see or hear these presents! Be it known:
Whereas we have considered that it is desirable that protection against flooding by external water - in particular in the case of high storm surges, high surface water in the major rivers or high water in the IJsselmeer or a combination thereof - is an essential requirement for the habitability of the Netherlands; and that it is desirable to lay down general rules concerning the extent of the protection which must be guaranteed in different areas, and to take procedural measures to ensure that new or reinforcement works can be rapidly implemented, with a view to achieving this degree of protection as quickly as possible;

We, therefore, having heard the Council of State and in consultation with the States General, have approved and decreed as we hereby approve and decree:

Section 1

- The following definitions shall apply in this Act or in provisions made pursuant thereto:
- «Our Minister»: Our Minister of Transport, Public Works and Water Management;
- «dike ring area»: an area that must be protected by a system of dikes against flooding, in particular against high storm surges, high surface water in the major rivers or high water in the IJsselmeer or a combination thereof;
- «primary flood defence»: a structure that offers protection against flooding either because it forms part of the system enclosing a dike ring area, with high ground or otherwise, or because it lies in front of a dike ring area;
- «external water»: the surface water the level of which is directly affected in the event of high storm surges, high surface water in the major rivers or high water in the IJsselmeer or a combination thereof;
- «manager»: the government authority that manages the primary flood defence.

Section 2

1. This Act applies to the dike ring areas and the primary flood defences that are shown on the map attached to this Act as annexe 1.
2. The annexe referred to in subsection 1 may be amended by order in council on the recommendation of Our Minister, after he has heard the provincial executive and managers responsible for the relevant dike ring areas and primary flood defences.
3. An order in council as referred to in subsection 2 shall not take effect until three months after the date on which it is sent to both Houses of the States General.

Section 3

1. The safety standard designated as the average annual overtopping probability of the highest high-water level which the primary flood defence intended to hold back the external water must be designed to withstand, taking account of other factors determining the water-resistance capacity, is shown for each dike ring area in annexe II to this Act.

2. In keeping with and as a replacement of the overtopping rate referred to in the previous subsection, the safety standard for each dike ring area shall be determined by order in council as the average annual probability of flooding as a result of the breach of a primary flood defence.

3. If no safety standard has been determined for the dike ring area to which a primary flood defence that is not intended to withstand the external water directly belongs, the dike must continue to provide at least the same degree of safety as on the date of the entry into effect of this Act.

4. Section 2, subsections 2 and 3, shall apply *mutatis mutandis* to the amendment of the annexe referred to in subsection 1 and to the amendment of the order in council referred to in subsection 2.

Section 4

1. The relationship between high-water levels and overtopping rate that must be assumed by the manager of the relevant primary flood defence in determining its water-resistance capacity shall be determined by ministerial order for the places to be indicated in this connection. Other relevant factors may also be determined at the same time.

2. The capacity shall be determined as referred to in subsection 1 for five years at a time, for the first time within one year of the date on which this Act takes effect.

Section 5

1. Our Minister shall arrange for the preparation and availability of technical guidelines for the design, management and maintenance of primary flood defences and for assessment of their safety. These shall serve as a recommendation to those persons charged with the management or, as the case may be, with the supervision thereof.

2. Our Minister may provide by order published in the Government Gazette that the duty described in subsection 1 is to be performed by a technical advisory committee on flood defences established by him.

3. The availability of guidelines as referred to in subsection 1 shall be announced in the Government Gazette.

Section 6

The provincial executive is responsible for supervising all primary flood defences in its provinces.

Section 7

1. A primary flood defence shall be constructed and any change in the direction, shape, dimension or structure of a primary flood defence shall be made in accordance with the plan adopted by the manager and approved by the provincial executive.

2. The plan shall contain:

(a) the measures to be taken in order to enable the work on a primary flood defence to be implemented;

(b) the measures to be taken in order to negate or mitigate the adverse consequences of the implementation of the work, in so far as such measures are directly connected with the implementation of the work;

(c) the measures to be taken in the interests of the landscape, nature or cultural history, in so far as they are directly connected with the implementation of the work.

3. In the implementation of the plan, account shall be taken of all interests involved in the implementation of the plan, including those of the landscape, nature, cultural history, housing, spatial planning and the environment, in accordance with the recommendations of the Principles of River Dike Reinforcements Review Committee (the Boertien II Committee).

4. The notes on the plan shall indicate the consequences of implementation of the plan and how account has been taken of the interests involved.

Section 8

The manager shall in any event involve in the preparation of the plan the provincial executive of the province and the burgomaster and aldermen of the municipality in whose area the plan is to be implemented.

Section 9

1. Every five years the manager shall report to the provincial executive on the general hydraulic condition of the primary flood defence, in particular on account of its responsibility for maintaining the safety standard within the meaning of section 3. The provincial executive shall report to Our Minister in respect of the same period on each of the dike ring areas in its area, subject to the proviso that where a dike ring area is situated in more than one province the provincial executives of the relevant provinces shall together report to Our Minister. Our Minister shall send the reports of the provincial executive, together with his findings in respect thereof, to the two Houses of the States General.

2. The reports referred to in subsection 1 shall contain a safety assessment. This assessment shall be made *inter alia* in the light of the safety standard determined pursuant to section 3, subsection 1 or 2, the factors determined pursuant to section 4, subsection 1, the technical guidelines referred to in section 5, subsection 1, and the register referred to in section 13 (b).

3. If the safety assessment warrants this, the reports referred to in subsection 1 shall contain a description of the measures deemed necessary within such period as is specified therein.

4. The provincial executive shall on the first occasion send its report before the date determined for this purpose by Our Minister for the relevant dike ring area or dike ring areas, which may not be earlier than two years after the date of the entry into effect of this Act.

Section 10

1. To prevent or counter a landward movement of the coastline, the works that are necessary in the opinion of Our Minister on account of the safety standard to be maintained pursuant to this Act shall be carried out by and at the expense of the central government. Our Minister shall determine the necessity, location and purpose of the works and the period of their implementation.

2. Subsection 1 shall apply *mutatis mutandis* to works which are, in the opinion of Our Minister, necessary in the public interest for some other reason.

3. For the purposes of this article, the coastline shall be deemed to mean the average low-water level. This is shown on the water level chart made available free of charge by Our Minister, which is revised every five years. The availability shall be announced in the Government Gazette.

4. Our Minister shall apply subsections 1 and 2 of his own volition or in response to a written request to him by the manager or the provincial executive. This shall not occur until after the relevant intention or request has been dealt with in a meeting of a consultative body that consists of representatives of the province, the managers and the central government and that is established by the provincial executive in each of the provinces of Friesland, North Holland, South Holland and Zeeland.

5. Our Minister shall decide within six months on a request made pursuant to subsection 4.

Section 11

A manager (other than the central government) of a primary flood defence shall be granted by the provincial executive, at the expense of the province, a contribution towards the costs of management and maintenance, in accordance with rules to be laid down by provincial by-law.

Section 12

1. Where a manager (other than the central government) of a primary flood defence that is not intended to withstand the external water directly is obliged to undertake new or reinforcement works in order to fulfil for the first time the safety standard referred to in section 3, subsection 1, it shall be granted by the provincial executive, at the expense of the province, a contribution towards the costs, in accordance with rules to be laid down by provincial by-law, unless the works come within the definition of section 1 (II) of the Delta Act.

2. Subsection 1 shall apply *mutatis mutandis* to primary flood defences which separate two dike ring areas that are not covered by the same safety standard.

3. The provincial executive shall arrange for the preparation of an annual report on the progress of the works referred to in subsection 1. This shall deal with the way in which the works are implemented. Our Minister shall send the reports within eight weeks of the date of receipt to the two Houses of the States General.

Section 13

The manager shall arrange for the adoption of:

(a) an outline map showing the position of the primary flood defence;

(b) a register specifying the criteria regarding direction, shape, dimension and structure to be fulfilled by the flood defence;

(c) a technical management register specifying the salient data of the structure for the maintenance of the water-resistance capacity and the actual state thereof.

Section 14

1. The provincial executive of the provinces in which one or more dike ring areas are situated shall pass a by-law relating to the subject of this Act and regulating in any event the obligation of the manager as described in section 13 and the period in which this obligation must be fulfilled.

2. A by-law as referred to in subsection 1 for a dike ring area that is situated in more than one province shall be passed by joint order of the provincial executives of the relevant provinces.

Section 15

1. For the purpose of taking timely measures in the event of high water, which may constitute a danger to a primary flood defence intended to withstand the external water directly, Our Minister shall ensure that:

(a) information is available about the expected divergences from the high-water levels published for this purpose by Our Minister;

(b) warnings and further information are given to the managers of the primary flood defences and the provincial executives concerned, as soon as it is expected that the high-water level will exceed the alarm level in the event of a high storm surge, high surface water in one of the major rivers or high water in the IJsselmeer or a combination thereof.

2. Alarm levels as referred to in subsection 1 (b) shall be determined by Our Minister for five years at a time by order published in the Government Gazette.

Section 16

1. The manager of a primary flood defence intended to withstand the external water directly shall hold exercises to test the readiness of personnel and equipment to deal with a situation in which there is a sudden threat to the flood defence in question.

2. The provincial executive may instruct a manager to hold exercises as referred to in subsection 1, if it considers that they are not held sufficiently often. Our Minister may issue such instruction to the provincial executive on the same ground.

Section 17

Without prejudice to the provisions of sections 7 and 8, sections 18 to 31 shall apply to primary flood defences which are intended to withstand external water directly, in so far:

(a) new or reinforcement works are implemented in order to fulfil the safety standard adopted pursuant to section 3, subsection 1;

(b) the Delta Act is not applicable to the major rivers.

Section 18

1. The manager shall ensure that as soon as possible after a draft of a plan as referred to in section 7 has been drawn up, the applications to make orders necessary for the implementation of the plan are lodged with the competent administrative authorities.

2. The manager shall at the same time send the draft plan and a copy of the applications to the provincial executive.

3. A declaration of no objection as referred to in section 19 of the Spatial Planning Act is not required for a request for exemption from a local plan in force under that section.

Section 19

1. The procedure regulated in part 3:4 of the General Administrative Law Act shall apply to the preparation of the plan and of the orders referred to in section 18, subsection 1, subject to the proviso that:

(a) the notices required under section 3:12 of the General Administrative Law Act in respect of the draft plan and the applications to make such orders are combined in a single notice, which is given by the provincial executive;

(b) the period of the deposit for inspection is four weeks.

2. Without prejudice to section 3:11, subsection 4, of the General Administrative Law Act, the draft plan and the applications or drafts of the orders referred to in section 18 shall be deposited for inspection at the offices of the provincial council.

Section 20

1. The provincial executive shall facilitate the coordinated preparation of the plan and of the orders referred to in section 18, subsection 1. If a plan relates to a primary flood defence which is situated in more than one province, the provincial executives of the relevant provinces may order that the coordination of the preparation of the plan and of the orders referred to in section 18 shall be carried out by the provincial executive of one of those provinces.

2. The provincial executive may require the cooperation of the other administrative authorities concerned, in so far as this is necessary for the success of the coordination. Those administrative authorities shall cooperate in the manner required of them.

Section 21

1. The manager shall adopt the plan and the relevant explanatory notes within six weeks of the last day of the deposit for inspection as referred to in section 3:12 of the General Administrative Law Act.

2. It shall send the plan and the explanatory notes within this period for approval to the provincial executive of the province within whose area the plan is to be implemented.

3. The administrative authorities referred to in section 18, subsection 1, shall send drafts of the orders referred to in that subsection to the provincial executive within the same period.

Section 22

1. The provincial executive shall make its approval order within six weeks of the date on which the plan is sent to it by the manager.

2. If the provincial executive intends to withhold its approval of all or part of the plan, it shall consult with the manager within four weeks of the date on which the plan is sent by the manager.

3. If the consultations do not result in agreement, the provincial executive shall give the manager a binding instruction to supplement or alter within two weeks all or part of the plan adopted by it.

Section 23

1. The administrative authorities referred to in section 18, subsection 1, shall make the orders referred to therein within three weeks of the publication of the approval order by the provincial executive and shall immediately send such orders to the provincial executive.

2. The period referred to in subsection 1 shall take the place of the periods for decision specified in or under any other statutory regulation in respect of such orders.

3. If an administrative authority that is competent at first instance to decide on an application as referred to in section 18, subsection 1, fails to send a draft order on the application to the provincial executive or fails to do so in good time, or if it fails to decide or fails to do so in good time

or in accordance with the plan, the provincial executive may take a decision on the application. In such a case, its order shall take the place of the order of the administrative authority competent at first instance. If the provincial executive itself proposes to take a decision on the application, it shall consult with the administrative authority competent to decide on the application at first instance.

4. The orders referred to in section 18, subsection 1, shall be announced simultaneously by the provincial executive.

Section 24

1. An interested party may appeal against an order under section 7 (in so far as the order has been made pursuant to sections 17 to 23) and sections 18 to 23 to the Administrative Law Division of the Council of State.

2. Section 7:1 of the General Administrative Law Act shall not apply.

3. No separate appeal shall lie against an order containing an instruction as referred to in section 22, subsection 3.

4. Notwithstanding section 6:8 of the General Administrative Law Act, the period for the lodging of a notice of objection against the orders referred to in section 21, subsection 1, and section 22, subsection 1, shall start on the day after that on which the publication referred to in section 23, subsection 4, occurs.

Section 25

The Administrative Law Division shall decide within twelve weeks of the end of the appeal period. In special circumstances the Division may extend this period for a maximum of six weeks.

Section 26

If, pursuant to section 23, subsection 3, the decision on an application to make an order as referred to in this section is made by the provincial executive, the administrative authority that was competent to decide on the application at first instance shall transfer the charges received in this respect to the provincial executive.

Section 27

Expropriation pursuant to title II or to title II in conjunction with title IIa of the Expropriation Act shall be carried out in such a way that:

(a) notwithstanding sections 62 and 72a of that Act the Council of State is not heard in relation to the order referred to therein;

(b) notwithstanding section 63, subsection 1, of that Act the committee referred to therein is established by Our Minister and consists of a chairman designated by Our Minister and a representative of the administration of the province and of the municipality in whose area the property to be expropriated - and the property subject to rights to be expropriated - is situated;

(c) notwithstanding section 10, subsection 3, of that Act the committee referred to in (b) above makes a recommendation on this subject to Our Minister within a week of the expiry of the period for inspection of the plan referred to in section 6 of that Act;

(d) the period of deposit for inspection of the application to make the order referred to in (a) above is four weeks.

Section 28

The expropriation referred to in section 27 may be carried out in part to implement the measures to be taken pursuant to the plan and referred to in section 7, subsection 2 (b) and (c).

Section 29

1. The writ of summons referred to in section 18, subsection 1, of the Expropriation Act may be served after the plan has been approved by the provincial executive.
2. The district court shall not make an expropriation order until after the plan has become final.

Section 30

1. If it is absolutely necessary for the purposes of the plan that possession of property is taken immediately, this may be done on the directions of the manager in so far as such property has been designated in the plan. Section 73, subsections 5 and 6, and sections 74, 75 and 76 of the Expropriation Act shall apply.
2. If property as referred to in subsection 1 has been designated in the draft plan, notice thereof shall be given to the persons listed in the land register as the owners of such property or as persons entitled to an encumbrance to which such property is subject. The notice shall form part of the notice referred to in section 19, subsection 1 (a).
3. No appeal lies against a decision of the manager to give a direction as referred to in subsection 1.

Section 31

The law in force before the date of entry into effect of this Act shall apply to a plan and orders as referred to in section 18, subsection 1, which have already been adopted or approved on that date and which have not yet become final.

Section 32

The following subsection shall be added to section 247 of the Provinces Act:

3. The second sentence of subsection 2 shall not apply to the amounts added to the Provinces Fund from 1994 onwards in connection with the maintenance and alteration of the dikes.

Section 34

Our Minister shall send a report on the efficacy and effects of this Act in practice to the States General within four years of its entry into effect.

Section 35

1. This Act shall enter into effect on a date to be determined by royal decree.
2. Section 32 shall have retroactive effect to 1 January 1994.

Section 36

This Act may be cited as the Flood Defences Act.

We order and command that this Act shall be published in the Bulletin of Acts and Decrees and that all ministerial departments, authorities, bodies and officials whom it may concern shall diligently implement it.

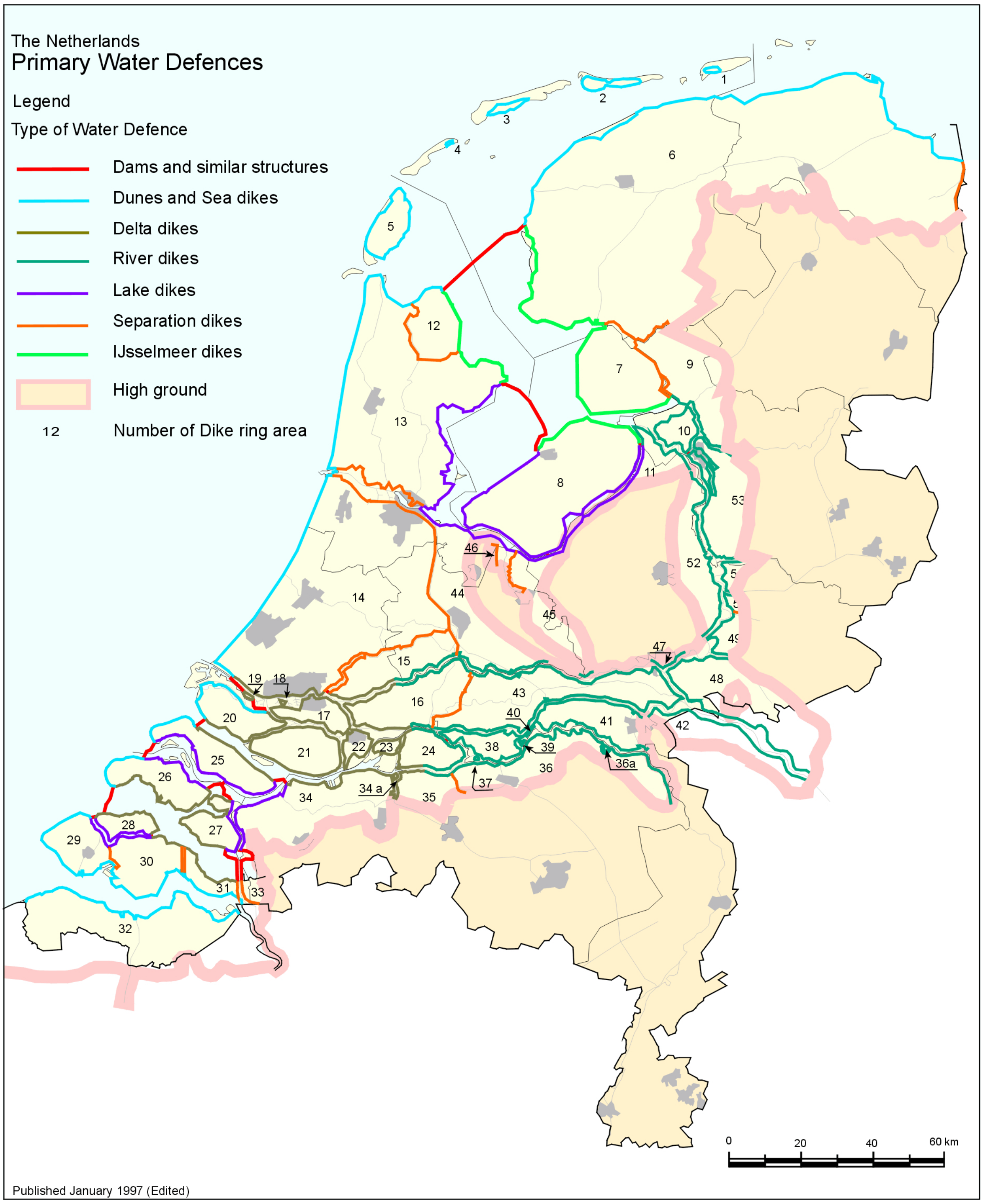
Done at The Hague, 21 December 1995

Beatrix

A. Jorritsma-Lebbink
Minister of Transport, Public Works and Water Management

Published on the ninth of January 1996

W. Sorgdrager
Minister of Justice


The Netherlands
Primary Water Defences
Legend
Type of Water Defence
Dams and similar structures
Dunes and Sea dikes
Delta dikes
River dikes
Lake dikes
Separation dikes
IJsselmeer dikes
High ground
12 Number of Dike ring area
0 20 40 60 km
Published January 1997 (Edited)

ANNEXE II as referred to in section 3

Dike ring areas and safety standards

Dike ring area in accordance with annexe I to the Act	Overtopping probability as referred to in section 3, subsection 1, of the Act
Number	**Annual average**
1.	1 / 2000
2.	1 / 2000
3.	1 / 2000
4.	1 / 2000
5.	1 / 4000
6.	1 / 4000
7.	1 / 4000
8.	1 / 4000
9.	1 / 1250
10.	1 / 2000
11.	1 / 2000
12.	1 / 4000
13.	1 / 10000
14.	1 / 10000
15.	1 / 2000
16.	1 / 2000
17.	1 / 4000
18.	1 / 10000
19.	1 / 10000
20.	1 / 4000
21.	1 / 2000
22.	1 / 2000
23.	1 / 2000
24.	1 / 2000
25.	1 / 4000
26.	1 / 4000
27.	1 / 4000
28.	1 / 4000
29.	1 / 4000
30.	1 / 4000
31.	1 / 4000
32.	1 / 4000
33.	1 / 4000
34.	1 / 2000
34a.	1 / 2000
35.	1 / 2000
36.	1 / 1250
36a.	1 / 1250
37.	1 / 1250
38.	1 / 1250
39.	1 / 1250
40.	1 / 1250
41.	1 / 1250
42.	1 / 1250
43.	1 / 1250
44.	1 / 1250
45.	1 / 1250
46.	1 / 1250
47.	1 / 1250
48.	1 / 1250
49.	1 / 1250
50.	1 / 1250
51.	1 / 1250
52.	1 / 1250
53.	1 / 1250

Bulletin of Acts and Decrees 1996, 8

Known to me,

A. Jorritsma-Lebbink

Minister of Transport, Public Works and Water Management

ANNEX II - DEFINITIONS

Advisory group (adviesgroep); (i.e.,Technical Advisory Committee on Water Defences, TAW)
Organ comprising all governments and interest groups involved that advises the dike manager (initiator in EIA procedure) on an improvement project. The advisory group has no decision making powers.
Assessment profile (beoordelingsprofiel_
A theoretical minimum profile of defined dimensions that must fit inside the actual profile. This profile may generally not be crossed by non-water retaining objects and must guarantee that damage to the flood defence as a result of the presence of the object will not lead to the immediate failure of the flood defence.
Breach (bres)
Hole/cut/breach in the flood defence
By-law (Keur)
Regulation fixing the punishment structure of a water board.
By-law application area (keurgebied)
Area in which the by-law is applicable.
Collapse/failure (bezwijken)
The occurrence of impermissible large-scale distortions of a structure, to such a degree that the cohesion of the structure is lost.
Collapse/failure mechanism (bezwijkmechanisme)
The manner in which a structure collapses (sliding or piping for example)
Committee (commissie)
i.e. Committee Verification of (Design) Starting Points / Commissie Toetsing Uitgangspunten.
(Committee) Boertien I (commissie Boertien)
River dike reinforcements that advised the minister of Transport, Public Works and Water Management.
Competent authorities (bevoegd gezag)
The government institution that is responsible for taking the decision demanded by the EIR (the province in the case dike reinforcement)
Construction level (aanleghoogte)
Crest height of the (parts of the) dike immediately after completion (delivery).
Coupure (cutoff)
Interruption in the flood defence for the sake of a waterway, road or rail track that can be closed at high levels.
Data-base (Legger)
Document in which it is described what the flood defence must fulfil in terms of direction, shape, dimensions and construction, and in which the legal (by-law) limitations are given.
The movement of part of a soil body due to exceedance of the equilibrium capacity.
Design level (ontwerppeil)
Sometimes used as a synonym for MHW (less unambiguous term; it is recommended that only MHW be used).
Dike ring area (dijkringgebied)
An area that must be safeguarded by a system of flood defences against flooding, in particular in the case of high storm tide, in the case of high surface water of the major rivers, in the case of high water on IJsselmeer or in the case of a combination thereof.
Dike section (dijkvak)
Part of a flood defence with more or less equal strength characteristics and load

EIA/EIR (MER)
Environmental Impact Assessment/Report.
Environmental Impact Assessment/Report (Committee); EIA/EIR committee (commissie MER/Cmer)
Independent committee that advises the competent authorities on the guidelines for a planned EIA/EIR and that tests an EIR for correctness and completeness.
Exceedance probability (overschrijdingskans)
Average number of times that a phenomenon reaches or exceeds a certain value in a certain area.
Failure (falen)
No longer meeting the fixed functional criteria.
FDA, Flood Defence Act
Note: the basis for the act was report of the Delta Committee, which was published in 1960 as a result of the disastrous floods of 1953.
Floodplain
The area within the flood embankments..
Floodplain fauna (stroomdalfauna)
Plants from the upper slope of the Rhine that have spread across the floodplain. They usually establish themselves in the drier places, such as bank walls, river dunes and dikes.
Foreland (voorland)
Shallow bottom in front of a dike.
High grounds (Hoge gronden)
Natural high parts of the Netherlands that do not flood at normative high water.
Inundation (inundatie)
Flooding of an area.
Inundation/flooding norm (inundatienorm)
The legal safety norm indicated as the average probability (per year) of a flood due to the collapse of a primary flood defence.
Introductory memorandum (startnotitie)
First formal step in the Environmental Impact Report (EIR) procedure in which the proposed activities are announced and a general indication of options and environmental impact is given that will be worked out in the EIR.
Limit profile (grensprofiel)
The minimum profile that must be present as flood defence after dune erosion during design conditions.
Management (beheer)
The range of activities that are necessary to guarantee that the functions of the flood defence continue to fulfil the functions set and any time-dependent requirements and norms fixed.
Management register (beheerregister)
Documentation in which the maintenance of data characterising the water retaining function of the structure and the actual state of the primary flood defence are described in more detail.
Multi-criteria evaluation (multicriteria evaluatie)
Method of comparing options and variants with each other on the basis of various assessment criteria.
Normative high water level, MHW (maatgevende hoogwaterstand, MHW)
Design level according to the norm of article 3.2 of the Flood Defences Act.

Overloading (overbelasting)
Overloading occurs when the applicable overtopping criterion is exceeded.

Piping (sand boils)

The phenomenon by which a hollow pipe-shaped space originates under the flood defence because the erosion process of a sand boil does not stop.

Plan period (planperiode)
Period (for dikes usually 50 years) for which the foreseen changes in conditions are included in the design of a flood defence.
Policy (beleid)
The whole of administrative choices that have been made
Policy analysis (beleidsanalyse)
Methodology with which systematic alternative solutions are developed and considered
Primary flood defence (primaire waterkering)
A flood defence that offers protection against flooding by either belonging to the system enclosing a dike ring area, with or without high grounds – or situated in front of a dike ring area.
Profile of free space (profiel van vrije ruimte)
Space to be kept free for the continued realisation of the water retaining function of the flood defence
Protection zone (beschermingszone)
Zone indicated in the by-law on both sides of the (legally defined) flood defence.
Reference crest level height (dijktafelhoogte)
The minimum crest height required.
Ring dike (encircling dike) (ringdijk)
The system of flood defences situated around the dike ring area.
River floodplain/foreland (uiterwaard)
Part of the riverbed between the summerbed and main dike (winterbed).
Sand boil (zandmeevoerende wel)
Erosion phenomenon where sand is transported along by exiting seepage water.
Seepage (kwel)
The exiting of groundwater under the influence of a difference in water level over a defence.
Seepage capability (achterloopsheid)
Leakage flow underneath and behind a structure
Seepage erosion (onderloopsheid)
Leakage flow under a structure.
Settlement (zetting)
Sinking of soil, chiefly due to an upper load, own mass and/or the exit of water.
Settlement allowance (overhoogte)
The extra quantity of soil to be introduced to achieve the desired profile after settlement of the undersoil and of the dike body.
Summer bed (zomerbed)
Cross section of the river where the river discharge occurs at normal and low water levels.
Summer dike (zomerdijk)
Boundary of summer and winter bed of the river created by a low dike.
Wake height (waakhoogte)
The actual height of a crest of a flood defence above a water level or the design level.
Water pressure (waterspanning)
The pressure in the pore water.
Wave run-up (golfoploop)
The height above the water level up to which a wave running up to the slope reaches (i.e., the 2% wave run-up is exceeded by 2% of the waves).
Wave overtopping (golfoverslag)

Average amount of water per unit of time that overtops the flood defence by waves per stretching meter.
Winter bed (winterbed)
Cross section of the river between the summer bed and the flood defence.

ANNEX III - SAFETY IN EXISTING GUIDES

1 GUIDE FOR THE DESIGN OF RIVER DIKES: PART 1 – UPPER RIVER AREA

Safety requirements

1. probability of collapse in a dike ring area by wave overtopping, in terms of all high water peaks below MHW, no more than 10% of exceedance probability MHW
2. at water levels equal to or lower than MHW, probability of collapse somewhere along the dike ring area by other causes (sliding, internal erosion et cetera) is negligible, which is interpreted as 10% of the exceedance probability of MHW.

The first requirement with respect to wave run up/overtopping, is rendered as a method to design the crest height and the inclines and the revetments of both slopes per dike section in a cohesive manner by means of a load cases method. The load cases are expressed in wind velocities per wind direction. The crest should be at least 0.5m higher than the MHW. This is a rendering of the Delta Committee's recommendations in the form of a qualitative requirement. For the other mechanisms (second requirement) methods are supplied to determine load and strength. The latter may naturally not exceed the former. Uncertainties are discounted in safety factors.

2 GUIDE FOR THE DESIGN OF RIVER DIKES: PART 2 – TIDAL RIVERS AREA

Safety requirements

1. probability that an overtopping discharge occurs somewhere along the dike ring area that is greater than the permissible overtopping discharge, no more than equal to the exceedance probability of MHW;
2. probability of collapse somewhere along the dike ring area by other causes (shearing, internal erosion, et cetera.) is negligible, which is interpreted as 10% of the exceedance probability of MHW.

The first requirement is rendered as a design procedure (load cases method) in which the crest height and the inclines and the revetments of both slopes per dike section in a cohesive manner for two recorded load cases. The greater load is decisive. The load cases are defined in terms of wind direction, wind velocity, water level at Hook of Holland and Rhine discharge at Lobith. If doubts exist and for a more accurate determination of the results the whole dike ring area may be subjected to the monitoring model, to integrally test against a requirement not yet rendered, mentioned in 1. above. An important characteristic of this method is that the optimisation of the relationship between costs and sacrifices (see end of section 4.2) is made possible by the 'interchange ability' of dike section crest heights, within certain limits. The crest must always be at least 0.5m higher than the MHW.

The second requirement is not explicitly mentioned, but follows on from the fact that the mechanisms in question follow the same design methodology as for the upper rivers, where necessary adjusted to the specific characteristics of the tidal rivers.

3 GUIDE ON HYDRAULIC STRUCTURES AND OBJECT IN, ON AND NEAR TO FLOOD DEFENCES

Safety requirements

1. the probability that the permissible overtopping discharge determined for the dike section in question (hydraulic structure or other structure) is exceeded must be less than the design frequency. The permissible overtopping discharge follows on from the characteristics of the structure and those of the area behind it.
2. the probability of failure by all other failure mechanisms (piping, insufficient strength and stability, non functioning of means of closure), when no overpressures occur, must be very small. In formula form:

   $P\{\text{failure AND } q < q_t\} < 0.1 \text{ norm}$

   q = overtopping discharge, following on from the geometry and the hydraulic boundary conditions;
   q_t = permissible overtopping discharge;
   norm = the design frequency as laid down in the Flood Defences Act.

Both requirements apply to the whole plan period. With respect to maintenance and inspection account must therefore be taken of the accessibility of the various parts. Further specifications for the various requirements areas follow:

The permissible overtopping discharge
If the overtopping water ends up on an unprotected inside slope of the flood defence, the permissible overtopping discharge during normative conditions corresponds to the provisions in the river dikes guide (0.1-1-10l/m/s). If the overtopping discharge ends up in a natural water basin and if measures have been introduced to enable the hydraulic structure and the connections to process a (much) greater discharge, the permissible overtopping discharge is determined by the water storage.

Strength/stability, piping, non closure of a movable defence
The second safety requirement is the basis for the conditions with respect to strength and stability and with respect to the reliability of the means of closure. A considerable part of the total failure space available at structures with means of closures is needed for the closing process, so it is recommended that the probability of loss of strength be fixed a rung lower than the probability of the non closure of the defence. This sets the failure space for the closure process at 0.1 times the norm frequency and that for the strength/stability at 0.01 times the norm.

4 GUIDE FOR THE ASSESSMENT OF THE SAFETY OF DUNES AS FLOOD DEFENCE

Safety requirement
Probability of collapse dune profile no more than 0.1 x exceedance probability of MHW. The safety requirement is rendered as a monitoring method, in which the expected dune profile after a tidal flood is compared to the limit state. In the dune erosion calculation a tidal flood level with an exceedance probability of approx.. 0.2 x the exceedance probability of MHW and the corresponding expected waves is assumed. These design conditions are calibrated to the requirement with respect to the probability of collapse.

5 GUIDE ON SEA AND LAKE DIKES

Safety requirements

1. probability of overload per dike section equal to the norm frequency in article 3.1 of the FDA. Overloading due to a combination of MHW with local wind, wind gusts, wind oscillations and wave overtopping. Permissible overtopping discharge depending on the quality of the grass covering. If the grass cover is good (*ref. Handreiking Constructief Ontwerpe/Handouts on Structural Design* , among others) l0l/m/s is permissible for sea and lake dikes. Lake dikes are still passable at this discharge level, sea dikes are not. If the accessibility requirement is also set for sea dikes then the maximum permissible discharge is 1l/m/s.
2. at water levels equal to or lower than MHW, the probability of collapse somewhere along the dike ring area by other causes (shearing, internal erosion et cetera.) is negligible, which is interpreted as 10% of the exceedance probability of MHW.

ANNEX IV - COMMENTS PROBABILISTIC ANALYSIS

1 INTRODUCTION

To illustrate the theoretical concepts in chapter 7, this chapter covers the overtopping mechanism as an example. The most important parameters are indicated in figure IV.1. The overtopping mechanism, in its simplest form, leads to dike collapse if the acting discharge is greater than the critical discharge:

‘Collapse’ = ‘$q > q_c$’

In this example, simple models will be chosen for both q and q_c. It is emphasised that there are currently better and better founded models available. This does not make a difference for the essence of the comments.

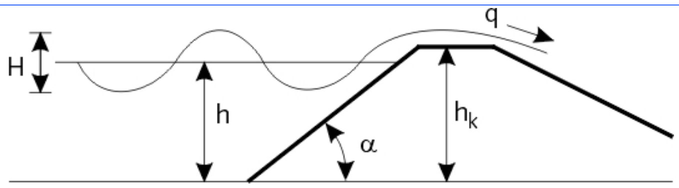


Figure IV.1. The overtopping mechanism

2 LIMIT CONDITION FUNCTION AND MODELLING OF BASIC VARIABLES

The standardised probabilistic analysis asks for a description of limit condition function Z. Per definition, Z < 0 indicates that failure is present and Z > 0 that no failure is present. As such:

$$Z = q_c - q$$

The next step is to express loading q and strength q_c as the so-called ‘basic variables’. These are values that need not be expressed in other units. Basic variables can be both deterministic and stochastic.

The critical overtopping capacity depends on a large number of parameters:
- The duration and development of loading
- The dike’s geometry
- The soil condition
- The water in the dike
- The quality of the grass cover on the inner slope

For didactic reasons, we have chosen not to use further models for the critical overtopping discharge, but to use it directly as basic variable in the model.
The following values are given for grass cover of average quality (nominal strength according to the *Leidraad Benedenrivieren/Guide on River Dikes* equal to 1l/m/s):
- Distribution = log normal
- Mean = $\mu(q_c)$ = 10 litre/m/s
- Standard deviation = $\sigma(q_c)$ 10 litre/m/s

A log normal distribution means that the logarithm for q_c is distributed evenly. The log normal distribution is often chosen as model for strength qualities as values less than zero are automatically excluded. The distribution of q_c is shown in figure IV.2. The distribution indicates that a dike can on average absorb far more than the nominal value. This corresponds with the ages old assumption that a dike must be safe using design conditions.

Next consider the loading side. The acting overtopping capacity depends on:

- The water level
- The crest height
- The significant wave height
- The outer slope's angle

Wind direction is ignored for simplicity's sake. The model chosen for the overtopping capacity is:

$$Q = 0.10 \times 10^{2.85(h+8m_q H_s tg\alpha - h_k)}$$

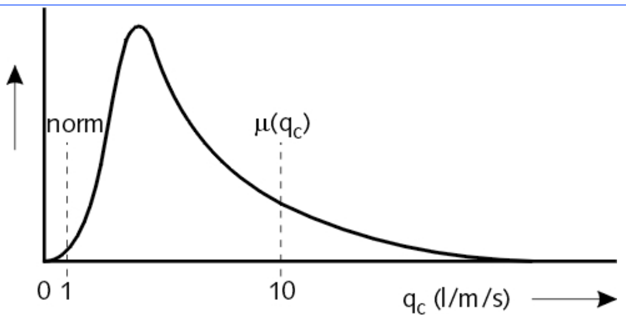


Figure IV.2 Log-normal distribution of q_c

h_k = crest height [m]
h = water level [m]
H_s = significant wave height [m]
$\tan\alpha$ = tangent of the slope [-]
q = overtopping discharge [litres/m/s]
m_q = model factor [-]

The model factor serves to compensate for differences between model and reality. The model factor is mostly stochastic.

It is easy to see that for h_k equal to $(h + 8m_q H_s \tan\alpha)$, the exponent in (IV.2) is equal to 0.0 and q is equal to 0.10 l/m/s. For larger values of H_s, q increases, basically in accordance with annex 11 from the *Leidraad Rivierdiiken* (see Figure IV.3).

On the loading side, the statistical characteristics of these basic variables have to be determined. The following covers the variables individually.

Water level h

In general, water level is one of the variables most often studied in hydraulics. For some time, RWS Departments such as RIKZ and RIZA have with the assistance of various experts invested best efforts to model the rivers and lakes statistically. There are still a number of loose ends, however. The problem is that the measurement sequences are too short to reliably model the tail ends of the distribution. The associated insecurity should also be quantified.

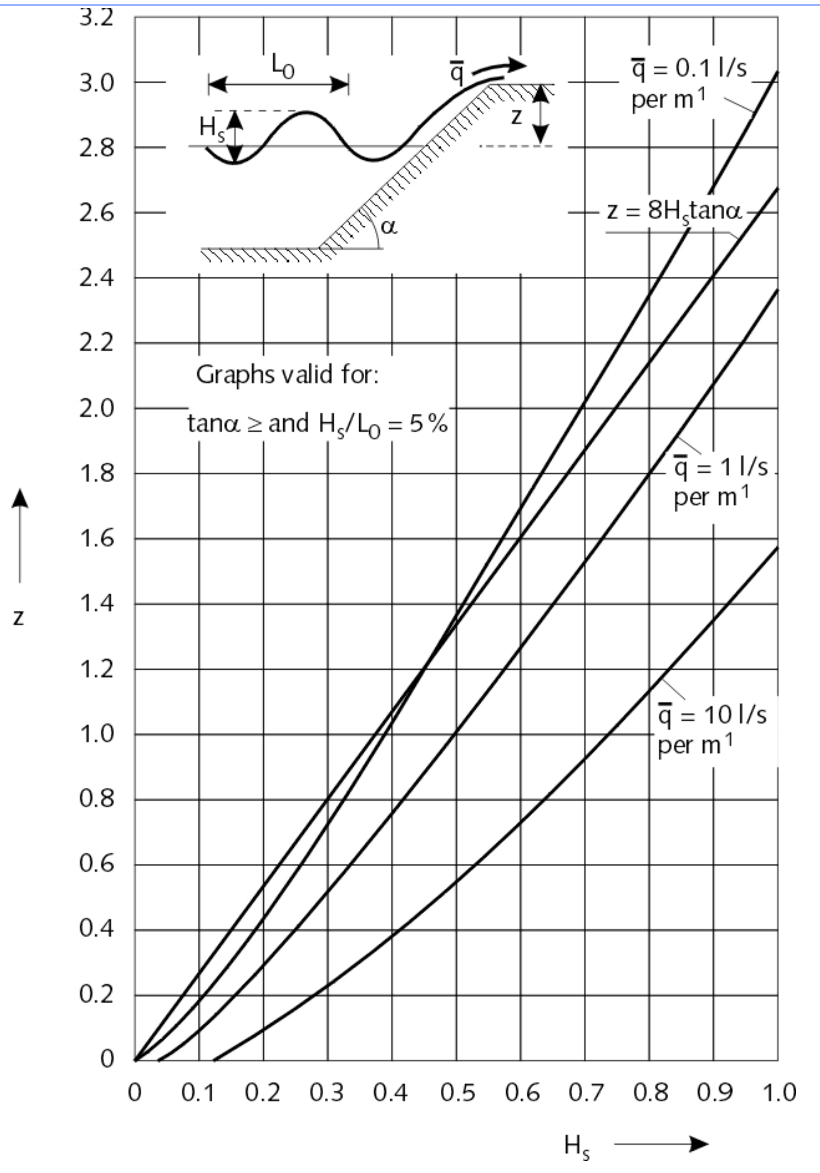


Figure IV.3 Annex II in *Leidraad Rivierendijken (Guide on River Dikes)*, part I

This does not occur in current practice, but is planned as addition to the programme for the future. It is therefore not included in this example for simplicity's sake.

In most cases, water level can be modelled relatively well using an extreme value distribution, such as the exponential distribution

P (h>h) = exp(-(h-A)/B))

A and B are distribution parameters. The relationship between mean and standard deviation is given as:

$$\mu = A + B$$
$$\sigma = B$$

The exponential distribution can be shown as a straight line on one-sided logarithm paper (see figure IV.4). The values for means and standard deviation used in this example can be found in table IV.1.

Comment: it is also possible to define the exponential distribution as a power of 10.

$$P(h>h) = 10^{(h-A)/C} \text{ with } C = 2.3\ B.$$

The Value C given is for the decimation height, the difference in water level in which the probability is reduced by a factor of 10. Analogously, B is also called the decimal height. This is the difference in water level in which the probability is reduced by a factor e = 2.7.

Water levels are time-dependent units. This means that the time scale used needs to be translated. Generally, IV.4 displays annual maximums. This gives the failure probability per year. This annex does not cover the translation process into other time periods. This can generally be done however with sufficient accuracy by means of a simple multiplication: the probability of failure over 50 years is approximately equal to 50 times the probability of failure in a year.

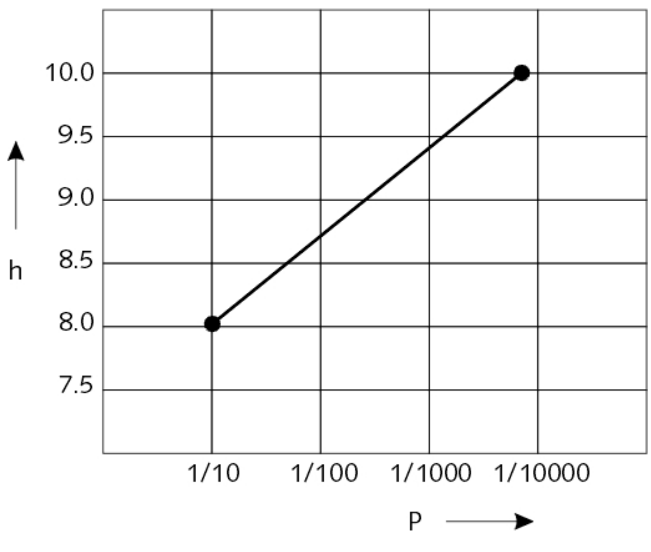


Figure IV.4. Probability of water level h

Significant wave height H_s

The wave height is primarily determined by wind speed. A model for determining the significant wave height should therefore be based on wind fields and strike length (for example, the Bretschneider or Hiswa model). In this simple example, we use the significant wave height as a basic variable.

As for water level, we have access to a large number of observations for waves (wind), but not enough in principle. The distribution of the significant wave height can also with reasonable accuracy be represented as an exponential distribution. This time, however, the Gumbel distribution is used, which has the same tail as an exponential distribution.

$$P(H_s > H_s) = 1 - \exp\{(-H_s - A/B))\}$$

This also provides annual maximums. Assume that for the annual maximum A = 0.51 m and B = 0.12 m. This corresponds to an average value of 0.63 m and a standard deviation of 0.12 metres.

Wave height and water level may be partially or entirely stochastic. At sea, high waves and high water levels generally coincide. This is because the wind causes the high water and the high waves. Water and wind are said to be correlated to a high degree. This is far less true on rivers. Wind and water level are virtually independent there. The example here assumes that wave height and water level are entirely *independent*, a river scenario.

The model has to take the time effect into account. We have taken maximums in a year for both wave and water level. These will generally not coincide precisely as a result of their independence. Various calculation models are available to take this into account. Here we have chosen a simple model. It must be noted that this method is not recommended as it is on the unsafe side.

Assume that high water lasts five days and that the waves plus the lower water levels on the other days of the year do not reasonably pose a threat to the dike. We are therefore not interested in the annual maximum for the waves, but rather in the maximum for a random period of five days.

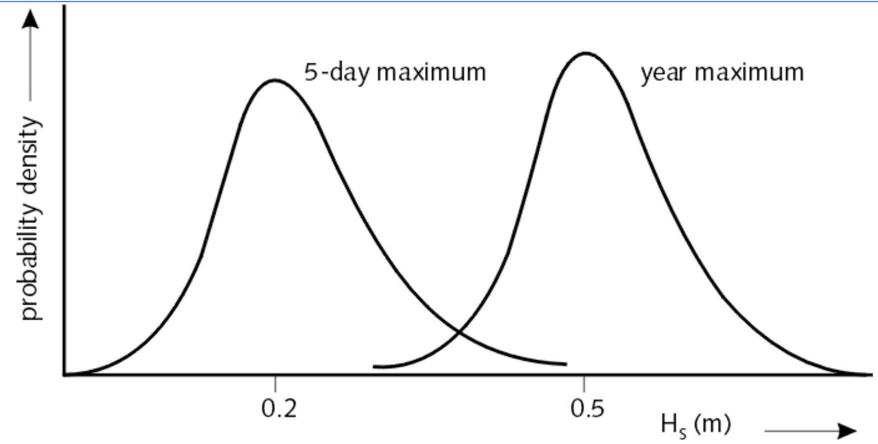


Figure IV.5 Distribution of the annual maximum and the 5-day maximum for H_s

Theory indicates that the Gumbel distribution can still be used for the extremes, and that the same value for B can be used as for the annual maximum. Only value A is reduced as follows:

$$A_{5\ days} = A_{year} - B\ \ln(180/5) = 0.51 - 0.12 \times 3.6$$

The value 180 is the number of days in the winter half-year. This is the only value that is truly important for water levels and wind speeds. Both distributions (annual maximum and 5-day maximum) are represented in figure IV.5.

Dike height h_k

For dike height, the mean is taken as the design height, equal to 10 metres. The standard deviation is set as 0.10 metres. This standard deviation represents the irregularities that will occur over time in the setting.

Slope angle

The slope angle is 1 in 3.

Model factor m_q

Model factor m_q represents insecurity with respect to the model. This factor must compensate for the differences between the model and reality. In this case, we can base a large amount of our estimation on tests of Delft Hydraulics in the Delta Flume. An impression is given in Figure IV.6. Experience has shown that theory models the wave run-up effectively, but that differences occur that are not explained by the model. The standard deviation is approximately 10%.

Note: the WL tests did not assume the simplified formulas used here, but this is not relevant at this time.

3 SUMMARY PROBABILISTIC ANALYSIS

Given the above, the probabilistic probability of failure issue can be summarised as follows:

1. Limit condition function:

$$Z = q_c - 0.10 \times 10^{2.85(h+8m_q H_s tg\alpha - h_k)}$$

2. Characteristics basic variables:

X	Description	Type	μ	σ
H	Water level	Exponential	7,73 m	0,30 m
h_k	Crest height	Normal	10,0 m	0,10 m
H_s	Significant wave height	Gumbel	0,2 m	0,13 m
m_q	Model factor	Log normal	1,0	0,10
q_c	Critical discharge	Log normal	10 l/m/s	10 l/m/s
$tg\,\alpha$	Slope angle	Deterministic	0,330	0

Table IV.1.

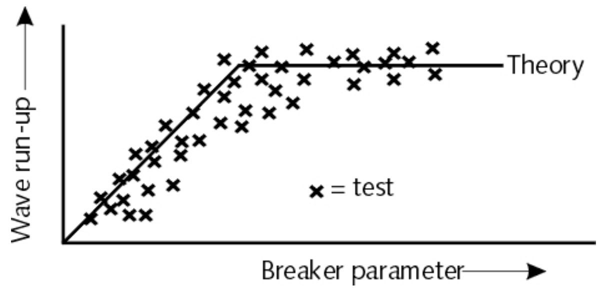


Figure IV.6 Model insecurities wave run-up

4 PROBABILISTIC CALCULATION

Formally, a structure's probability of failure can be defined as the integral of the collective probability density of all stochastic values in the failure domain:

$$P_F = P(Z < 0) = \int\int_{Z(x)<0} \dots \int f_{\underline{x}}\, \underline{x}\, dx_1 \dots\dots\dots\dots\dots dx_n$$

The probability analysis can be implemented using various methods:
- Numeric integration
- Monte Carlo
- FORM (First Order Reliability Method)
- SORM (Second Order Reliability Method)

The first two are level III methods, the latter two are level II methods. In this categorisation, level I is the design values method, but more on that later.

In this example, the result of a FORM calculation is given first. This method is an approach in which the Z-function is made linear and in which all non-standard distributions are replaced by standard distributions. This linearisation occurs at a well-chosen point, the so-called design point. This choice minimises errors. The design point should be seen as the point with the combination of stochastic variables for which 'the probability of collapse is maximal'. In other words, if a collapse occurs, the stochastic values will not differ greatly from those of the design point. This permits the conclusion that for loading, the design point will be higher, while it is lower for strength. Figure IV.7. attempts to illustrate this in a one-dimensional probability space. Figure IV.8. is a two-dimensional probability space. In the calculation, the problem is that the design point is not known beforehand. This is determined iteratively in the calculation process.

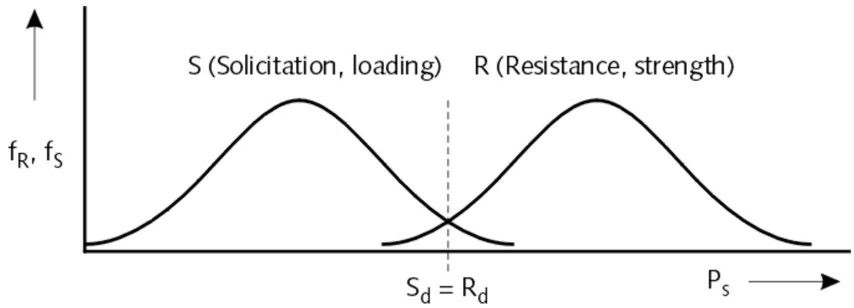


Figure IV.7. Design point in a one-dimensional figure

The FORM analysis for the overtopping problem defined in this annex leads to:

1. Reliability index $\beta = 3.08$
2. Probability of failure P (Z < 0) = 0.001
3. Design point and α-values

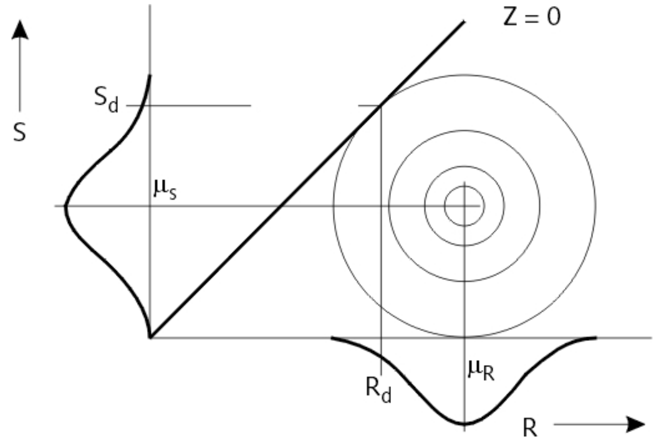


Fig. IV.8. Design point in two-dimensional figure

X	Design value	α	p(X<X$_d$) (strength)	p(X>X$_d$) (loading)
H	9,13 m	0,79	-	0,011
h_k	9,97 m	-,09	0,28	-
H_s	0,53 m	0,59	-	0,036
m_q	1,04	0,13	-	0,034
q	5,2 l/m/s	-0,11	0,42	-

Reliability index β is linked one-on-one to the failure probability via the table for standard deviation. For values of β between 0 and 4, $P(f) = 10^{-\beta}$ applies.

The design point for the overtopping problem is given in the table. These values can therefore be used in a 'regular design calculation'. This will be covered in more detail later. The column with α-values indicates the importance of a variable's uncertainty. The α is dimensionless and lies between -1 and +1. A high positive number indicates an important loading parameter, while a strongly negative number indicates an important strength parameter. In this example, it is clear that wave height and water level are the most important parameters.

Note: the α is linked to the design point via $P(X < X_d) = \phi(\alpha\beta)$. In simple terms, the design point is far from the mean if the stochastic value is important. For stochastic values of little importance, the design point is closer to the mean. Probabilities $P(X < X_d)$ for strength and $P(X > X_d)$ for loading are also shown in the table.
If the safety norm for this mechanism were set at 10^{-3} per year, the dike section would comply precisely. It is also possible that the norm is not set per section or per mechanism, but that a norm applies for the flood/inundation probability or inundation risk of the entire dike. If that is the case, this is only part of the calculation.

5 LEVEL 1 DESIGN (SEMI-PROBABILISTIC CALCULATION)

In many cases, the engineer would probably prefer to design using simple methods, using calculation values and loading data. This is called level 1 design.

The replacement of stochastic values by one or more sets of calculation values is in fact an old habit in engineering. The new introduction of recent years is that the question has arisen as to which calculation values can best be used with a particular reliability in mind. This is where the link with the concept design point is made clear. The design point provides the combination of values for basic variables for which the probability of collapse is greatest. This is therefore the best point on which to base tests for a design if this only has to happen in one point. In short, if the design point is okay, the rest will be fine too.

For another, random dike (other location, other geometry), we could omit the level II calculation. For each basic variable, we simply find the fraction with the exceedance probability indicated and check at that point. As such, the level I calculation is based on a certain degree of safety. This is, of course, not entirely true. These are estimates as the design point may well differ slightly for the other dike. Imagine, for example that the other dike's location means that there is no strike length, and therefore that there is no wave attack of any importance. The α for wind is then zero. Considering the sum for α^2 has to remain equal to 1.0, the other α-values have to go up. This changes the quantities of, for example, water level. It is important to investigate where these deviations are acceptable, and where they are not. The area of applicability can be expanded by the introduction of further loading data. For example, in *Leidraad Benedenrivieren/Guide on River Dikes*, various loading combinations are defined with varying combinations for wind speed, water level, sea level and river discharge. The M&W on the IJsselmeer is a classic example with two sets of loading data: wind (W) with a period of 10 years and a lake level (M) with a 4000 year period, and vice versa.

Before drafting regulations, these issues will have to be investigated. It will then be necessary to formalise the various loading and strength demands. Designers do not enjoy having to work with values for wind speed or water level that differ for each mechanism. For this reason, a fixed water level is generally chosen, for example MHW, as well as reference wind speed. These are then adapted using factors or choices for strength that are different for each mechanism any way.

In the example above, one would therefore choose:

Variable	X_d theory	X_d practice
H	9,12 m	9 m (MHW)
h_k	9,97 m	10 m (nominal value)
H_s	0,52 m	0,50 m (calibrated)
m_q	1,04	1,0 (nominal value)
q	5,2 l/m/s	1,0 l/m/s (nominal value)

The individual drafting the guide also, of course, has the original reliability calculations at his disposal for this type of simplifications in order to ensure that there is not too great a deviation between the safety objective set and the particular set of reference data chosen.

ANNEX V - DIKE IMPROVEMENT PROCEDURE

1 INTRODUCTION

A procedure has been set up by a number of provinces in which the rules for drawing up and submitting the plan are worked out. It concentrates on streamlining the process and content oriented aspects aimed at guaranteeing an integral approach and the participation of interested parties.

The procedure used by the province of Zuid-Holland is used as an example in figure V .1 (*Procedure dike reinforcement)*. Small differences are possible at other provinces. The aim of the procedures is to allow the process to run as smoothly and as transparently as possible. The gearing of the Flood defence act (FDA) plan procedure and the Environmental Impact (EIA/EIR) procedure is an important point for attention.

2 CONSULTATION STRUCTURE

The preparation of the dike improvement plan must be such that there is efficient tuning between the various parties and procedures. The procedure must also have an open character so that all interested parties take cognisance of the plans in good time and have the possibility to exercise influence. The (future) manager must accordingly realise a thorough consultation with the competent authorities (the province), the municipality on whose territory the plan is to be executed, the river manager and other institutions and interested parties (residents, interest groups et cetera).

A consultation structure has been proposed by a few provinces in line with the recommendations of the Boertien I Committee. It proposes the installation of an advisory group in which all those involved have a seat. This proves to be a good structure in the practical situation by working with two separate consultation groups, each with its own status and responsibilities. To streamline the decision making and start it up in good time, a project group has been established in which those institutions have a seat that have a formal decision making function in the process (river manager, province, municipality, water board). In addition, an advisory group is to be established in which the other interested parties have a seat (interest groups, residents, agricultural organisations, companies, et cetera). This group has insight into the interests, provides advisories on the plan forming, the allocation of values and plays a role in creating the social support needed for the dike improvement. To facilitate proper information transfer between the two groups, the members of the project group are usually present at (some of) the advisory group meetings.

3 Environmental Impact (E.I.R.) PROCEDURE

Seven phases can be distinguished in the Environmental Impact Report (EIR) procedure that must lead to the following products:

- Introductory memorandum (drawn up by the flood defence manager; the initiator, IN);
- Guidelines (drawn up by the province (the competent authorities, CA)), based on the advisory of the Environmental Impact Report Committee (*Commissie voor de milieu-effectrapportage*, Cmer));
- Project memorandum/EIR (drawn up by the flood defence manager);
- Acceptance (by the CA);
- Monitoring advisory (by the Cmer);
- Decision (by the CA);
- Evaluation report (by the CA).

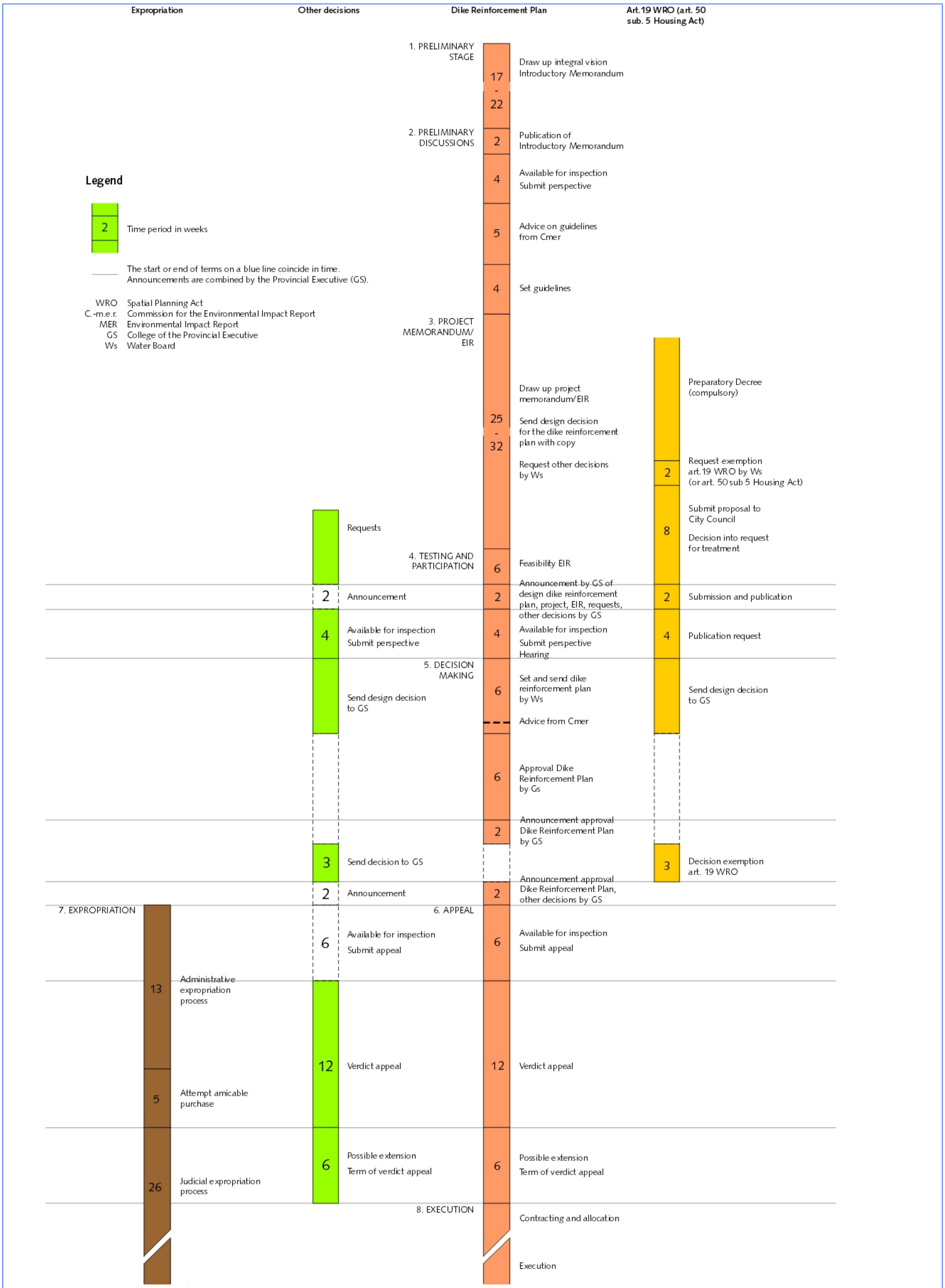


Figure V.1 Timeline for procedures relating to dike reinforcement

As initiator, the flood defence manager is responsible for drawing up the introductory memorandum and the project memorandum/EIR. The advisory by the independent Committee (Cmer) occurs in two stages; first on the guidelines for the content of the EIR and later on its completeness, correctness and quality. In the former case they base their findings on the considerations in the introductory memorandum and the information obtained during the visit to the location. The Cmer advises the competent authorities in both cases (Provincial Executive). The province is ultimately responsible for the decisions. See *Handleiding Milieueffectrapportage/Handouts Environmental Impact* for a detailed description of the EIR procedure.

The introductory memorandum plays an important role in the EIR procedure. The publication of the introductory memorandum formally kicks off the EIR procedure. It is laid down by law that the clear formulation of the objectives of the introductory memorandum will suffice. In practice, the introductory memorandum has been given a much greater significance. This is a consequence of the various TAW publications based on the conclusions of the Boertien I Committee.

One example is the vision of dike improvement that is part of the introductory memorandum and that, based on a cataloguing and allocation of values, usually provides a clear orientation in the search for solutions. As a result the initiator can greatly restrict the number of options, as long as the motivation is strong. At the same time the requirements the dike improvement options must fulfil are made explicit in the introductory memorandum, so that the introductory memorandum can function well as a guide in the rest of the plan forming and design process.

The following are some of the important steps in the realisation of the introductory memorandum:

- Announcement of the initiator and the procedure to be followed;
- Description of the purpose of the proposed activities, and the nature and scale thereof;
- Description of the decision for which the project memorandum/EIR has be drawn up and an overview of relevant decisions made in the past;
- Naming of the essential characteristics and values of the current situation, autonomous developments and potentials for development;
- The requirements for dike improvement laid down by law;
- Naming of the bottlenecks in the consequences for the environment, and a number of other aspects (traffic, agriculture, recreation, costs);
- Selection of the options to be described;
- Short description of the study to be conducted in the scope of the project memorandum/EIR.

As mentioned above, an important step in the selection of options to be included is the development of a vision on dike improvement (see chapter 5). The vision typifies the current and desired spatial quality of the flood defence in the context of its surroundings. The main aim of the vision is to retain the perception of the flood defence as a spatially cohesive whole of values (landscape, nature, cultural heritage) and interests (agriculture, recreation and suchlike). In the vision on dike improvement the spatial and functional main structure, the spatial, ecological and cultural-historical qualities and the policy and plans related to the study area, for both flood defence and stability area, are mapped out. Bottlenecks are also indicated. Those are the situations in which the values and interests named are in danger of being affected by the dike improvement.

The development of options is about obtaining possible solutions for the whole flood defence route. There are two possible methods currently much used. In the first method the possible options are named in one go for the whole flood defence, on the basis of the vision. In the second method the flood defence is first divided into parts and one or more variants are then developed for each part, taking the values and interests into consideration (a variant can therefore be considered to be an option for a limited dike part). On the basis of the vision, the variants can then be used to compile possible options for the whole flood defence. The first method usually leads to a quicker convergence and total overview, whereas the second method realises more local insight into the problems and possible solution orientation at an early stage.

On the basis of the introductory memorandum the Cmer (Commission Environmental Impact) provides an advisory on the content of the project memorandum/EIR in the form of advisory guidelines. These are included in the formal guidelines for the generation of the project memorandum/EIR by the province.

In the project memorandum/EIR there is a further refining of the variants and options on the basis of the description of the effects. In general insight can be more rapidly gained into the scale of the dike improvement and so the size of the effects if a large part of the soil mechanical survey and the exploration of the topography is carried out at an early stage. Insight into the scale of the measures to be taken also enables the restriction of the description of effects. The differences in the effects of the options are compared. Experience shows that this comparison is the best way to realise results, when the differences are concisely named and there is sufficiently broad-based consultation between parties. Extensive multi-criteria analysis techniques are not necessary and even undesirable. It is essential that the options are illustrated in cross sections and situation drawings. The use of (3D) visualisations also proves to be very worthwhile.

In the project memorandum/EIR the compensating and mitigating measures should be named. The compensating measures are oriented to the compensation of river bed reduction and lost Nature values. Mitigating measures are oriented to mitigating the effects of dike improvement. The measures mentioned, which must be an integral part of the plan, are very dependant on the location-specific conditions and the problems.

The project memorandum/EIR defines a most environmental friendly option (NEFO) and generally determines a preferred option (PO). This PO is usually the same as the NEFO, unless great differences is costs lead to the naming of a different option as PO.

The project memorandum/EIR provides more details on the following parts:
- Working out of a vision on dike improvement;
- Description of current situation, autonomous and potential development;
- Further selection of the options to be included;
- Testing against requirements and wishes and the guidelines;
- Determination of space demanded for options;
- Description of effects of options;
- Description of policy framework;
- Comparison of van options;
- Naming of mitigating and compensating measures;
- Working out in a design in principle (including rough costs);
- Determination of NEFO and choice of PO.

4 PLAN PROCEDURE

During the plan procedure a design plan and the ground acquisition documents must be drawn up that are needed for the formal approval procedure in accordance with the FDA. Documents must also be produced for obtaining the permits.

Design plan

The design plan comprises a detailed working out of the preferred option described in the project memorandum/EIR. This is usually reported in a plan document. The flowing parts can generally be distinguished:

- Technical commentary on the plan;
- Drawings with situations and cross sections;
- Landscape harmonisation plan;
- Description of measures for the preservation and development of nature;
- Description of aspects of environment science;
- Description of aspects of execution;
- Estimation of construction costs;
- Description of permits needed.

During plan forming it is essential that a geo-technical report be drawn up alongside the formal documents mentioned (introductory memorandum, project memorandum/EIR and plan document). This is a knowledge document that serves as a basis for the design plan and contains, among other things, a collection of soil surveys and laboratory tests, a description of the technical design principles and the calculations, and a technical underpinning of possible variants as included in the project memorandum/EIR. The geo-technical report will also be a good foundation for the management and the five-year monitoring of the hydraulic state of the flood defence.

Ground acquisition documents

The design plan forms the basis for the ground acquisition documents. These are made up of a ground purchasing plan and expropriation documents showing the purchase/expropriation limits, the areas for temporary seizure and the list of names and land register codes. An impersonal description must also be produced. For a detailed description see 'Expropriation for dike reinforcement' (*Onteigenen voor dijkversterking*) by the Central Department of the Directorate-General for Public Works and Water Management. An emergency expropriation plan may be included in the design plan in certain cases. This is subject to article 30 of the FDA ('immediate seizure'). The areas are indicated in this plan for which expropriation must be possible in the case of disaster at the flood disaster and which are necessary for the introduction of the measures needed.

Permits

The procedure with respect to the permits as included in the FDA is only applicable to the improvement works in the so-called second block and not to future dike improvements post 2000. The FDA (article 18) lays down that Provincial Executive must be in possession of a copy of the various permit requests for the decision making on the design plan for the second block of flood defences. Therefore, other procedures will have to be started parallel to the procedure for drawing up the dike improvement plan if a decision is to be made on the plan. They are the procedure in the scope of the *Spatial Planning Act* (SPA) and various other permit procedures.

In order to allow the procedures to run parallel to each other, the preparatory procedure regulated in section 3:4 of the General Administrative Law Act (GAL) is followed for all decisions.

The coordination of the necessary decisions is the responsibility of Provincial Executive. It announces the design plan, the Project Memorandum/EIR and the requests for the necessary permits in a notice. The manner of requesting the necessary permits required by the FDA demands consultation with the permit granting institutions. The brochure *Proces en Procedure Dijkverbetering van de Provincie Gelderland* (*Process and Procedure Dike Reinforcement of the Province Gelderland*) may be used as a guide.

A general overview of the most important permits is given below (see also section 2.4.2).

Permit requests municipality
- Planning permission;
- Demolition permit (Housing Act);
- Demolition permit (Urban and Rural Regeneration Act);
- Building permit;
- Environmental permits (EMA);
- Felling permits;
- Residential permit;
- Permit Monuments and Historic Buildings Act;
- Conversion of roads to public roads;
- Designated use public roads.

Permit requests province
- Excavation permits;
- Environmental permits (PSW and SPA) for the establishment of depots inside the dike;
- Groundwater permit;
- Exemption municipal windmills ordinance.

Permit requests Directorate-General for Public Works and Water Management
- Permit in the scope of the Rivers Act;
- Environmental permits (PSW and SPA); class IV depots outside the dike);
- Concession KB (Govrnmental Decision);
- Exemption National River Dike Regulations.

Permits will also be needed during execution. They are connected to the execution itself however (traffic measures for example) and need therefore not be requested for the decision making procedure.
An exemption is required for the construction and repositioning of cables and pipelines in the dike profile (on the basis of the by-law (see section 10.2.3)), which must be issued by the dike manager. If a utility company or other interested party suffers as a consequence of the revoking, termination or changing of a permit, it may receive compensation upon request, as far as the compensation is not otherwise insured. The compensation for loss resulting from government decisions with respect to the laying of cables and pipelines (*Nadeelcompensatieregeling inzake het verleggen van kabels en leidingen*) of the Directorate-General for Public Works and Water Management, dd. December 1991 applies to the request for compensation. Others compensation agreements are also applicable (including article 49 SPA).
ANNEX VI - CONTENTS OF SPECIFIC GUIDES

GUIDES AND TECHNICAL REPORTS

The TAW guides per flood defence type or area each form a self-contained unit in the sense that all relevant aspects of flood defence care are handled. In the guides for the design of flood defences with respect to the 'safety' function both the choices and criteria on the one hand, and the manner of dimensioning are addressed. With respect to other functions relevant aspects are addressed in a more general manner. Besides the design, such aspects as management and execution are addressed. The TAW guide '*Guide on Safety Monitoring of Water Defences*' together with the Preconditions book forms the set of instruments for the execution of safety monitoring. '*Guide on Safety Monitoring of Water Defences*' is tailored to the prevailing design guides and also includes rejection criteria and intervention levels . Only in exceptional cases has new knowledge been made operational via '*Guide on Safety Monitoring of Water Defences*'. Guides are explicitly mentioned in the (explanatory memorandum to the) Flood Defences Act. The TAW lays down a draft guide, and it is formally laid down by the minister of Transport and Water Management. Supplementary to the guides, knowledge of a specific mechanism, material or structural component is recorded in technical reports. Technical reports are laid down by working group D of the TAW.

CURRENT PRACTICE AND FUTURE DEVELOPMENTS

In the current generation of guides the size of the chapter 'Dimensioning' proves to be considerable. A great deal of new knowledge is made operation for the first time via the guides. Reference to a number of other guides is also made. This does not stimulate the cohesion and readability of the guide. This means that the most recent guides are fairly concise and that they are accompanied by a detailed design basis memorandum.

To improve cohesion between the various guides and technical reports, to make them easier to maintain and realise a better distinction between the choices to be made and the criteria on the one hand and dimensioning techniques on the other, the TAW aims to continue this trend in the next few years and change the relationship between the guides and technical reports.

The calculation techniques and methods for the design of flood defences will be laid down in technical reports over the coming time. This primarily relates to the methods and (design) instruments. In the guides the emphasis is accordingly place on choices and criteria for the design and the calculation method to be applied. This will lead to a reduction in the size of TAW guides, stimulating the more frequent application of this guides. Parallel to drawing up guides, the generation of technical reports can be given a more continuous character by orienting this report to the method to a greater degree.

CONTENTS OF SPECIFIC GUIDES

Bearing in mind the above, among other things, a TAW guide per flood defence type or area must at least comprise the following.

1. General
- Place with respect to and interrelationship with other guides.

2. Social framework
- Legal and administrative basis in so far as specific for flood defence type or area (including on the basis of relevant policy documents);
- Specific secondary functions.

3. Management
- Relation to spatial planning, plans, procedures, permits.

4. Weighing up
- Valuation, specific problems, options, policy analysis, choice.

5. Dimensioning
- Specific fault-trees, preconditions, possible calculation methods, choices.

6. Execution
- Specific conditions and requirements.

7. (Day-to-day) management and maintenance
- Vegetation management and suchlike.

- **ANNEX VII -** THE REALISATION OF FUNDAMENTALS FOR WATER DEFENCE

The *Fundamentals* were drawn up by a project group, comprising the following members.

ir G.J.Flóriàn (TU Delft/Heidemij, to 1-1-1995)
ir W.A. de Haan (Heidemij, since 1-1-1996)
ing R.J.Houben (Simtech bv)
ir A.Paape (Delft Hydraulics, to 1-1-1995)
ir G.J.Schiereck (TU Delft, chair)
dr J.Th. de Smidt (University of Utrecht, since 1-1-1996)
prof ir A.W.C.M. Vrouwenvelder (TU Delft/TNO, since 1-1-1996)

The results were discussed in an advisory group comprising the following members.

ir P. van de Berg (Union of Water Boards)
ir P. Brolsma (Central Department of the Directorate-General for Public Works and Water Management)
dr ir J. van de Graaff (TU Delft)
ir Tj. de Haan (Central Department of the Directorate-General for Public Works and Water Management, to 1-1-1995)
ir A. Hoekstra (RWS DWW, chair up to 1-1-1995)
ir E. van Hijum
ir J.P.F.M. Janssen (RWS DWW)
ir R.E. Jorissen (RWS DWW)
ir A. Paape (since 1-1-1996)
ing R.J. Termaat (RWS DWW)
prof drs ir J.K. Vrijling (TU Delft)
ir C.J. van Westen (RWS DWW, since 1-1-1996)
ing J. Westerhoven (province of Zuid Holland)
ir J.A. W. de Wit (RWS DWW, chair since 1-1-1996)

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