Working together with water

A living land builds for its future

Findings of the Deltacommissie 2008

Aan de watergang geboren,
aan de grote stroom getogen,
met verholen het vermogen
om zijn tijdingen te horen,
om de maningen van zijn gronden
na te stamelen bij monde,

blijf ik het verbond bewaren.
Bij de wereld in gebreke
blijf ik naar het water aarden;
mag ik met het water spreken,
ademen zijn ademhalen,
zijn voorzeggingen vertalen.

By the water born,
by the current reared,
a hidden power to hear,
its tidings, its demands,
And repeat them, stammering,

I keep the bond.
In this failing world
my roots are in the water;
I converse with the water,
breathing its breaths,
its promptings I translate.

From: Het Sterreschip by Ida Gerhardt
Verzamelde Gedichten II
Athenaeum-Polak & van Gennep
Amsterdam 1992

Working together with water

A living land builds for its future

Findings of the Deltacommissie 2008

DELTA COMMISSIE

Foreword

The coast at Zoutelande, Zeeland

One cannot conceive of the Netherlands without water. Through the centuries, and still today, the inhabitants of our delta have made great efforts to struggle out of the grasp of the rivers and the sea and it is this that sets our country apart. Situated at the mouths of four major, navigable rivers with access to all the seas of the world, in many respects our country is supported by the water. The sea and the rivers have shaped our identity and the country itself: its nature and landscape, its prosperity and economy, and the way it is governed (water boards; the polder model).

The disastrous floods of 1953 are still etched into our collective memory; in the very same month the Minister of Transport and Public Works set up a committee to examine, 'which hydraulic engineering works should be undertaken in relation to those areas ravaged by the storm surge, (and) also to consider whether closure of the sea inlets should form one of these works.'[1] In their advisory report the first Delta Committee introduced the concept of risk-based flood protection, i.e. to consider the probability of flooding as well as the consequences when determining the optimum level of safety. In addition the implementation of the recommendations radically altered the appearance of the south-western Netherlands and secured its long-term safety. Construction of the 'first' Delta Works thus laid a solid foundation upon which to base the present recommendations. In recent decades considerable investments have also been made in the defence of the coastline of Holland, the Wadden Sea coast and the construction of river dikes. In the years to come, work will continue on the 'weak links' in the coastal defences and on the measures to create more discharge capacity for the rivers Rhine and Meuse through the implementation of the *Maaswerken* [Meuse Works] and *Ruimte voor de Rivier* [Room for the River] programmes.

A new Delta Committee

Climate change is now forcing itself upon us: a new reality that cannot be ignored. The predicted sea level rise and greater fluctuations in river discharge compel us to look far into the future, to widen our scope and to anticipate developments further ahead. For that reason the Cabinet appointed a 'new' Delta Committee, the Sustainable Coastal Development Committee, with the mandate to formulate a vision on the long-term protection of the Dutch coast and its hinterland.

Our mandate is broader than that of our predecessors in the first Delta Committee. At that time they were primarily concerned with 'hydraulic engineering works' to counter an acute threat. For us, the second Delta Committee, the threat is not acute, but our mandate is nevertheless urgent. There is absolutely no reason for panic, but we must be concerned for the

Flevopolder near Lelystad

future. If we are to be well prepared for the expected consequences of climate change, we shall have to strengthen our flood defences and change the way our country is managed, both physically and administratively. Our Committee's mandate is therefore unusual: we have been asked to come up with recommendations, not because a disaster has occurred, but rather to avoid it. The nature of the advice requested is also unusual: to present an integrated vision for the Netherlands for centuries to come.

The challenge to the Netherlands in the coming centuries is not primarily a threat; it also offers new prospects. Changing the way our country is managed creates new options; working with water may improve the quality of the environment and offers excellent opportunities for innovative ideas and applications. Where there is water, new forms of nature can arise. Water can be used to produce food and generate energy. Flood defences can be used for roads.

The country we want to live in

The fundamental question, central to this report, is 'How can we ensure that future generations will continue to find our country an attractive place in which to live and work, to invest and take their leisure?' This advisory report sets down the conditions required for that desired future to become a reality. If these conditions are fulfilled, then as far as the Delta Committee is concerned we proceed right away, in both word and deed. After all, 'A living land builds for the future'.

Professor C.P. Veerman,
Chairman of the Delta Committee

1. Rapport Deltacommissie. Eindverslag en Interimadviezen. Deel 1, blz. 15 (1960) [Delta Committee Report, Final Report and Interim Advice, Part 1, p. 15])

Summary

The mandate ...
The government asked the Delta Committee to come up with recommendations on how to protect the Dutch coast and the low-lying hinterland against the consequences of climate change. The issue is how the Netherlands can be made climate proof over the very long term: safe against flooding, while still remaining an attractive place to live, to reside and work, for recreation and investment.

... and its interpretation
The task at hand, then, involved looking further than just flood protection. The Committee's vision therefore embraces interactions with life and work, agriculture, nature, recreation, landscape, infrastructure and energy. The strategy for future centuries rests on two pillars: flood protection and sustainability. The report also emphasises the opportunities for Dutch society/ the Netherlands as a whole.

Water safety
Water safety is at the centre of this report, and includes both flood protection and securing fresh water supplies. Achieving water safety prevents casualties and social disruption, while avoiding damage to our economy, landscape, nature, culture and reputation.

In their report, the Delta Committee assumes that a safe Netherlands is a collective social good for which the government is and will remain responsible. The level of flood protection must be raised by at least a factor of 10 with respect to the present level.

Opportunities for sustainability
The Committee's recommendations place emphasis on development along with climate change and ecological processes; thus, they are cost effective and produce additional value for society. The recommended measures are flexible, can be implemented gradually and offer prospects for action in the short term. Their implementation will allow the Netherlands to better adapt to the effects of climate change and create new opportunities. The recommendations made must be sustainable: their implementation must make efficient use of water, energy and other resources, so that the quality of the environment is not merely maintained but even improved.

Implementation: *The Delta Programme*
The Delta Committee has drafted the *Delta Programme* to implement its recommendations for a climate-proof Netherlands. The programme will be embedded, financially, politically and administratively, in a new *Delta Act*.

The mission is urgent

Implementation of the recommendations is a matter of urgency. The Netherlands must accelerate its efforts because at present, even the current standards of flood protection are not being met everywhere. Moreover, the current standards are out of date and must be raised, the climate is changing rapidly, the sea level is probably rising faster than has been assumed, and more extreme variations in river discharge are expected. The economic, societal and physical stakes in the Netherlands are great and growing still; a breach in a dike has seriously disruptive consequences for the entire country.

The Delta Committee concludes that a regional sea level rise of 0.65 to 1.3 m by 2100, and of 2 to 4 m by 2200 should be taken into account. This includes the effect of land subsidence. These values represent plausible upper limits based on the latest scientific insights. It is recommended that these be taken into account so that the decisions we make and the measures will have a lasting effect, set against the background of what can be expected for the Netherlands.

For the Rhine and the Meuse, summer discharge will decrease and winter discharge will increase due to the temperature increase and changed precipitation patterns. Around 2100 the maximum (design) discharges of the Rhine and Meuse are likely to be around 18,000 m^3/s and 4,600 m^3/s, respectively. Present design discharges are 16,000 m^3/s and 3,800 m^3/s.

A rising sea level, reduced river discharges in summer, salt water intrusion via the rivers and ground water, all put pressure on the country's drinking water supply, agriculture, shipping and those sectors of the economy that depend on water, for cooling or otherwise.

Scientific basis

The Delta Committee sought scientific advice on a number of aspects, which form part of the present recommendations. In summary, these are the findings of a group of national and international experts, including those close to the IPCC and Dutch experts on flood protection and water management. This group of experts has supplemented the latest insights into climate scenarios, and come up with new estimates of extreme values.

Cost

Implementation of the *Delta Programme* until 2050 involves a cost of 1.2 to 1.6 billion euros per annum, and 0.9 to 1.5 billion euros per annum in the period 2050–2100. Coastal flood protection in the *Delta Programme* is mainly achieved by beach nourishments. If this method is intensified so that the coasts of the Netherlands grow say 1 km in a seawards direction, thus creating new land for such functions as recreation and nature, it will involve an additional cost of 0.1 to 0.3 billion euros per annum.

Indicatie extra annual costs [billions of euros]	Period		Average
	2010 - 2050	2050 - 2100	2010 - 2100
Deltaprogramme	1,2 to 1,6	0,9 to 1,5	1,0 to 1,5
Deltaprogramme, with additional coastal space for other functions	1,3 to 1,9	1,2 to 1,8	1,2 to 1,8

Amounts in euros at 2007 price levels, including Dutch Value Added Tax (BTW).

Twelve recommendations for the future

The Delta Committee has developed an integrated vision for the future extending to 2100 and beyond. A long-term vision like this depends on national, European and global developments. Concrete recommendations for the short and medium term must be made, however, since direct action is needed now to raise the level of flood protection and to secure fresh water supply. The Delta Committee has formulated the following twelve recommendations for the short and medium term.

Twelve recommendations for the future

Recommendation 1 **Flood protection level**	Until 2050	The present flood protection levels of all diked areas must be raised by a factor of 10. To that end, the new standards must be set as soon as possible (around 2013). In some areas where even more protection is needed, the Delta Dike concept is promising (these dikes are either so high or so wide and massive that the probability that these dikes will suddenly and uncontrollably fail is virtually zero). With regard to specific or local conditions, this will require a tailor-made approach. All measures to increase the flood protection levels must be implemented before 2050.
	Post 2050	The flood protection levels must be updated regularly.
Recommendation 2 **Plans for new urban development**		The decision of whether to build in low-lying flood-prone areas must be based on a cost-benefit analysis. This must include present and future costs for all parties. Costs resulting from local decisions must not be passed on to another administrative level, or to society as a whole. They must be borne by those who benefit from these plans.
Recommendation 3 **Areas outside the dikes**		New development in unprotected areas lying outside the dikes must not impede the river's discharge capacity or the future water levels in the lakes. Residents/users themselves are responsible for such measures as may be needed to avoid adverse consequences. Government plays a facilitating role by giving information, setting building standards and warning for floods.
Recommendation 4 **North Sea coast**	Until 2050	Build with nature. Flood protection of the coasts of Zeeland, Holland and the Wadden Sea Islands will be continued by beach nourishments, possibly with relocation of the tidal channels. Beach nourishments must be done in such a way that the coast can expand seaward in the next century. This will provide great added value to society. Sand extraction sites in the North Sea must be reserved in the short term. The ecological, economic and energy requirements needed to nourish such large volumes must be investigated.
	Post 2050	Beach nourishments need to be continued with more or less sand, depending on sea level rise.
Recommendation 5 **Wadden Sea area**		The beach nourishments along the North Sea coast contribute to the adaptation of the Wadden Sea area to sea level rise. The continued existence of the Wadden Sea area as we know it at present is by no means assured, however, and depends entirely on the actual rate of sea level rise in the next 50 to 100 years. Developments will have to be monitored and analysed in an international context. The protection of the island polders and the North Holland coast must remain assured.
Recommendation 6 **South-western delta: Eastern Scheldt**	Until 2050	The Eastern Scheldt storm surge barrier fulfils the safety requirements. The disadvantage of the barrier is the reduction of flood and ebb volumes going in and out of the tidal basin and, as a result, the loss of the intertidal zone. This is to be countered by additional sand nourishment from outside (as from the Outer Delta).
	Post 2050	The life span of the Eastern Scheldt storm surge barrier will be extended by technical interventions. This can be done up to a sea-level rise of approximately 1 m (to be reached in 2075 at the earliest). If the Eastern Scheldt storm surge barrier is no longer adequate, then a solution will be sought that largely restores the tidal dynamics of its natural estuarine regime, while maintaining the desired level of flood protection.
Recommendation 7 **South-western delta: Western Scheldt**		This must remain an open tidal system to enable navigation to Antwerp and to maintain the valuable estuary. Flood protection must be maintained by enforcement of the dikes.
Recommendation 8 **South-western delta: Krammer–Volkerak Zoommeer**	To 2050	The Krammer-Volkerak Zoommeer, the Grevelingen and possibly also the Eastern Scheldt must be re-arranged to provide temporary storage of excess water from the Rhine and Meuse when discharge to the sea is blocked by closed storm surge barriers. A salinity gradient (a natural transition between fresh and salt water) in this area is a satisfactory solution to the water quality problem and can offer new ecological opportunities. In this case an alternative fresh water supply must be provided.

Recommendation 9
The major rivers area

Until 2050 — The *Ruimte voor de Rivier* [Room for the River] and *Maaswerken* (Meuse Works) programmes must be implemented without further delays. Subject to cost-effectiveness, measures must be taken already now to accommodate discharges of 18,000 m^3/s for the Rhine and 4,600 m^3/s for the Meuse. In this context negotiations with neighbouring countries have to be conducted under the *European Directive on the assessment and management of flood risks* in order to harmonise the measures. Furthermore, room must be reserved and, if necessary, land purchased so that measures can be taken in the future to safely discharge the 18,000 m^3/s of Rhine water and 4,600 m^3/s of Meuse water.

2050 - 2100 — Completion of measures to accommodate Rhine and Meuse discharges of 18,000 m^3/s and 4,600 m^3/s, respectively.

Recommendation 10
Rijnmond
(mouth of the river Rhine)

Until 2050 — For the Rijnmond an open system that can be closed when needed ('closable-open') offers good prospects for combining flood protection, fresh water supply, urban development and nature development in this region. The extreme discharges of the Rhine and Meuse will then have to be re-routed via the south-western delta.

The fresh water for the Western Netherlands will have to be supplied from the IJsselmeer lake. The necessary infrastructure will have to be built. Room must be created for local storage in deep polders. Further research into the 'closable-open' Rijnmond system should be initiated soon.

Recommendation 11
IJsselmeer area

The level of the IJsselmeer lake will be raised by a maximum of 1.5 m. This will allow free discharge from the lake into the Wadden Sea beyond 2100. The level of the Markermeer lake will not be raised. The IJsselmeer lake retains its strategic function as a fresh water reservoir for the Northern Netherlands, North Holland and, in view of the progressive salt water intrusion in the Nieuwe Waterweg, for the Western Netherlands.

Until 2050 — The measures to achieve the elevated water level can be implemented gradually. The aim must be to achieve the largest possible fresh water reservoir around 2050. The measures needed to adapt the lower reaches of the river IJssel and the Zwarte Water to a 1.5 m higher water level in the IJsselmeer lake must be investigated.

Post 2050 — Depending on the phased approach adopted, follow-up measures may be needed to actually implement a maximum water level increase of 1.5 m.

Recommendation 12
Political-administrative, legal, financial

1. The political and administrative organisation of our flood protection must be strengthened by:
   - ~ providing cohesive national direction and regional responsibility for the implementation (ministerial steering committee chaired by PM, political responsibility lying with the Minister of Transport, Public Works and Water Management, the Delta director for cohesion and progress and regional administrators for the implementation of the (individual) regional assignments);
   - ~ initiating a permanent Parliamentary Committee on the theme.
2. The financial means must be secured by:
   - ~ creating a Delta Fund, managed by the Minister of Finance;
   - ~ supplying the Delta Fund with a combination of loans and transfer of (part of) the natural gas revenues;
   - ~ making national funding available and drafting rules for withdrawals from the fund.
3. A *Delta Act* will embed the political and administrative organisation and funding within the present political system and the current legal framework. This must in any case include: the Delta Fund and its supply; the Director's tasks and authority; the provision that a *Delta Programme* shall be set up; regulations for strategic land acquisition; and compensation for damages or the gradual loss of benefits due to the implementation of measures under the *Delta Programme*.

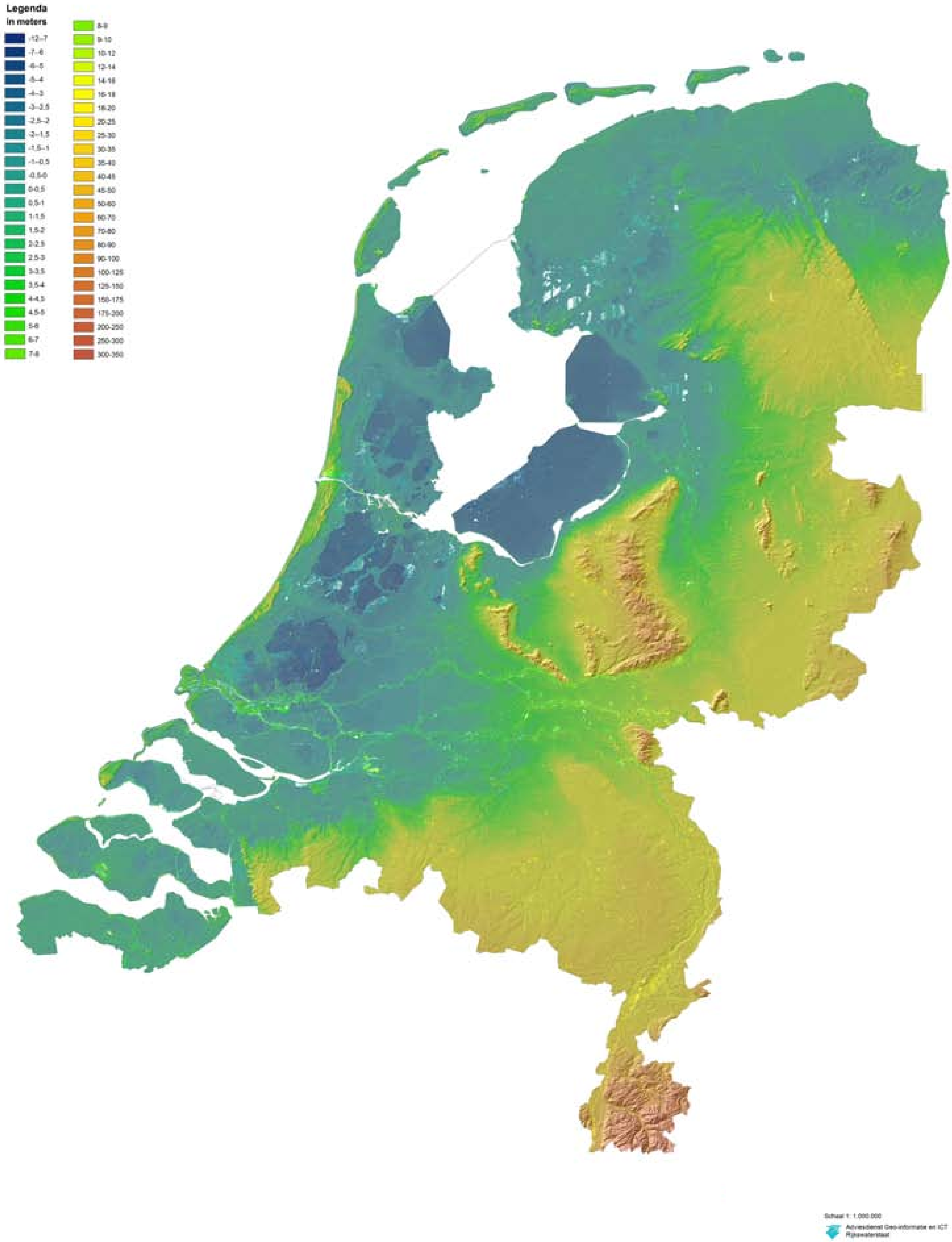

Legenda
in meters
-12–-7
-7–-6
-6–-5
-5–-4
-4–-3
-3–-2,5
-2,5–-2
-2–-1,5
-1,5–-1
-1–-0,5
-0,5-0
0-0,5
0,5-1
1-1,5
1,5-2
2-2,5
2,5-3
3-3,5
3,5-4
4-4,5
4,5-5
5-6
6-7
7-8
8-9
9-10
10-12
12-14
14-16
16-18
18-20
20-25
25-30
30-35
35-40
40-45
45-50
50-60
60-70
70-80
80-90
90-100
100-125
125-150
150-175
175-200
200-250
250-300
300-350
Schaal 1: 1.000.000
Adviesdienst Geo-informatie en ICT
Rijkswaterstaat

Table of contents

Figure 1: Relief map of the Netherlands showing height in metres above Dutch Ordnance Datum (NAP)

North Sea
Wadden area
Groningen – Frisian mainland
Eems
Dollard
High grounds
IJssel delta
IJsselmeer area
Holland Coast
Randstad
IJssel
Rijnmond
Nederrijn
Lek
Haringvliet
Waal
Upper reaches
Lower, tidal reaches
Grevelingen
Meuse
Krammer
Volkerak
Zoommeer
Eastern Scheldt
Southwestern Delta
Western Scheldt
High grounds
Rhine
Scheldt
Meuse

1 The mandate

The Delta Committee's task was to investigate strategies for the future, long-term development of the coast (2100–2200), paying attention to both safety and environmental (spatial) quality. The Cabinet asked the Committee to consider in particular innovative measures to strengthen the coast and to include the interaction with increased river discharge in its recommendations. The Committee was also asked to look at other aspects besides safety: possible synergy between flood protection and other societal functions such as life and work, fresh water supply, nature, recreation, landscape, infrastructure and energy.

On 7 September 2007 the Council of Ministers set down the Delta Committee's mandate in an Appointment Resolution (see Appendix 1).

Defining the mandate

In order to define its mandate in geographical and substantive terms, the Committee pondered how 'wide' the coast is, physically as well as in association with other functions. The Committee takes a broad view of the coast: it includes the sea and the coastal zone as well as the low-lying hinterland, the interaction with the rivers and the IJsselmeer lake, and the cross-border aspects of the rivers and the coastal zone (see Figure 2). This broad interpretation is necessary because to a great extent the system forms a single hydrological, ecological and economic entity.

In substantive terms the Committee concurs with the importance stressed in its Appointment Resolution of the relation between water safety and other societal interests and values. The Committee therefore regards 'water safety' as an integral issue, including not only flood protection and flood risk management, but securing the fresh water supply and conserving the estuaries as well. The Committee's advice concerns mainly the primary system, but is related to and impacts on the spatial planning of the entire country. Administrative responsibility, the legal apparatus and financial guarantees thus make up a substantial part of this report.

Figure 2: Regional divisions used in the Delta Committee's report.

The Committee at work
The Delta Committee is composed of nine members: Professor Cees Veerman (Chairman), Ineke Bakker, Dr Jaap van Duijn, Professor Louise Fresco, Andries Heidema, Professor Pavel Kabat, Tracy Metz, Koos van Oord and Professor Marcel Stive.

The Committee was supported by a secretariat headed by the Secretary to the Committee, Bart Parmet.

The Committee held ten plenary meetings, some of which lasted for several days. Subcommittees were also formed to look in more detail at specific aspects of the mandate: the physical system, its use, future scenarios, and administrative, legal and financial aspects.

Water safety impacts on the entire community; many people are closely involved with it. The Committee found a widespread sense of urgency, one which it shares. The Committee was inspired and enriched by the opinions and creative ideas offered by many people from all sectors of the community. The Committee also received many unsolicited responses, showing that the issue has wide support. At both national and regional level the Committee was provided with extensive information from administrators, community groups and experts on the issues and ideas with which they are concerned. This gave the Committee not just a picture of the national challenge, but also an impression of the challenges, opportunities and possible solutions as they are perceived and experienced in the regions.

The Committee organised workshops with experts and stakeholders, which explicitly involved young professionals (and which later gave rise to a 'Young Delta Committee': see the background report on this initiative). The mandate's international dimension led to exchanges of opinion, knowledge and ideas at different levels with our neighbouring countries and the European Commission2, during bilateral talks, workshops and field trips. The public was kept informed through the Dutch government information line and a dedicated website, and the issues that the Committee addressed received regular media attention.

The Committee consulted experts, research institutes, national assessment agencies, government departments, executive agencies and the like to also provide a scientific foundation for its analyses and recommendations. Information on a number of broad issues was provided in the form of studies that have been published as background reports to this publication (see Appendix 2 for a list of background reports).

The Committee is extremely grateful for their input and involvement to all those persons and institutions that offered their advice and shared their knowledge, whether solicited or not.

Result

The content of this report extends in to a distant future that is most uncertain. We have to work deliberately towards that future right now, though. The Committee does not present a cut-and-dried blueprint but rather indicates a clear direction that leaves room for future refinement. The Committee has formulated proposals for the creation of institutional frameworks that offer guarantees so that the necessary decisions can be taken – timely and at the right level – and so that adequate funding is available for the investments needed. Its recommendations are more concrete for the shorter than the longer term, thus leaving room for possible divergent scenarios and future expectations.

Surely, there are problems that need to be tackled. Above all, however, there are opportunities and new perspectives.

2. Adaptation to climate change is an explicit part of the European Commission's agenda. Currently a White Book is being prepared, to be published in the fourth quarter of 2008.

Results second safety assessment
primary flood defences, 1 January 2006
Legend
complies with the standard
no judgement
does not comply with the standard
diked areas
uplands
Map edition: Road and Hydraulic Engineering Institute of Rijkswaterstaat

2 Foundation of the report: challenges and opportunities

The Dutch coast, a 350 km long strip where sea and land merge, has undisputed value; for the Netherlands, coastal and river flood protection is vital.[3] Being able to live in our delta has never been something we can take for granted. Its maintenance and development demand continuous efforts; the work is never done. Fulfilling this task offers great opportunities for creating additional environmental (spatial) quality.

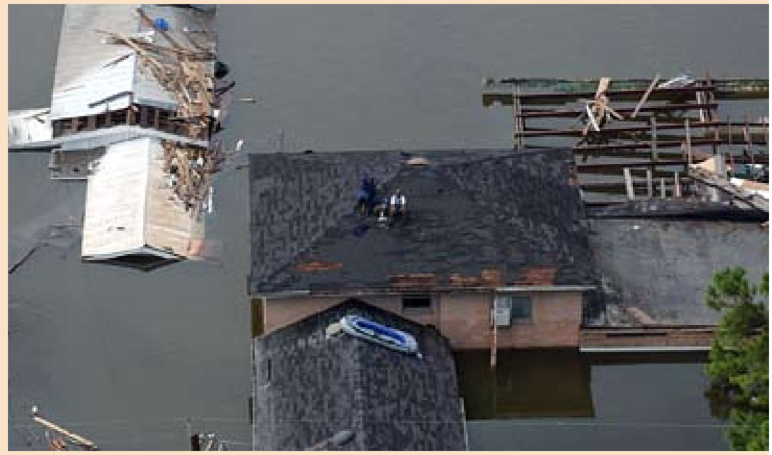
The delta's values

Most of the population lives immediately behind the coast, in the low-lying areas of the Netherlands below sea level. This region is also the centre of the nation's economy. Nearly 9 million people live in this part of the Netherlands, protected by dikes and dunes along the coast, the main rivers and the lakes, while roughly 65% of GNP is generated here.[4] The major docks and airports on or near the North Sea are vital nodes in the international transport network as well as important locations for the goods and services industries.

These are important reasons for the Netherlands to maintain such strict standards for flood protection. The consequences of a flood in our densely populated, intensively utilised country are unimaginable.[5] In her letter to Parliament, Progress Report on National Security 2008, the Minister of the Interior and Kingdom Relations qualified the worst conceivable flood scenarios as '*highly improbable [but with] catastrophic consequences for the entire country*'. If such a catastrophe were to occur, it would not just affect large numbers of people and lead to major social disruption; it would also have serious repercussions on international business investment decisions.

The North Sea, the Wadden Region and the Western Scheldt are the most natural and most dynamic 'landscapes' in the Netherlands. Processes that shape the landscape can proceed undisturbed in these areas. The Netherlands cares greatly about the ecological value and natural landscape along the coast – and rightly so. These values are internationally recognised and are being conserved, partly by allocating large parts of the coast to the National Ecological Network and placing them under the Birds and Habitat Directive. The significance of the North Sea, the Wadden Sea, the IJsselmeer lake and other large bodies of water is largely due to their great natural value as bird breeding grounds, migration and overwintering areas, habitats for marine mammals, molluscs and aqueous flora, and as fish breeding grounds. In short, our delta – the coast and the hinterland – houses great riches: economic, ecological and social. Riches so vast that it would be inconceivable that the Netherlands would ever abandon them.

Figure 3: Results of the second safety audit of the primary flood defences, 2006.

New Orleans

Potential economic damage

In 1997 Statistics Netherlands (CBS, see Glossary) presented an estimate of the national wealth.[1] They found that national wealth was five times the national income. This took no account of ecological, landscape and cultural values. If we take the CBS definition, national wealth at the time of writing would be about 2750 billion euros.[2] Since an estimated 65% of this wealth lies in flood-prone areas, the wealth that is potentially under threat is of the order of 1800 billion euros. This gives an impression of the capital to be insured against flood risk.

The potential economic damage due to flooding has been estimated by the National Institute for Public Health and the Environment RIVM (2004) for all diked areas. The median value between estimated upper and lower bounds is highest in South and North Holland, Friesland and Groningen, as well as a few diked areas along the Rhine and Meuse: between 10 and 50 billion euros per diked area. New calculations show that in practice it is most unlikely that the (major) diked areas will be inundated completely and that the location where a dike is breached will make a marked difference in resultant economic damage. The amount of damage caused by a flood depends on a number of factors, including the size of the area inundated, the water depth in that area, and the duration of the episode. Aerts et al. (2008) have estimated the potential economic damage from flooding through all dike rings as approximately 190 billion euros, based on differentiation according to water depth per diked area. This is made up of direct and indirect damage. The potential damage would increase to 400 to 800 billion euros in 2040 and 3700 billion euros in 2100 in the absence of any measures, given a sea level rise of 24 to 60 cm in 2040 and 150 cm in 2100. The factors that govern calculations of future potential damage are economic growth combined with indirect damage. Calculations like these are still highly uncertain. Further research will give a better idea of indirect flood damage, due for instance to interruptions to business, collapse of the goods supply chain, etc.

Prior to the Hurricane Katrina disaster, potential damage in New Orleans was estimated at US$ 16.8 billion. After the disaster it appeared that just the direct damage to dwellings, government buildings and public infrastructure was US$ 27 billion.[3]

1. Van Tongeren and Van de Veen, *De Nationale Balans en de Overheidsbalans* (The National Balance and the Government Balance], 1997.
2. In 2007 the Netherlands' GNP was 550 billion euros.
3. Interagency Performance Evaluation Taskforce (IPET). *Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System*. Vol. 1 – Executive summary and Overview, 2008.

The water is rising

Flood risk management is a pressing issue right now in a large number of places and will only become only more urgent as the sea level continues to rise, river discharges fluctuate more and more and as interests that need protection increase in value.

The present flood protection standards for the Dutch coast are based on the work of the previous Delta Committee and date from the 1960s. Since that time the interests to be protected have grown enormously; updating these standards would result in higher flood protection levels for numerous diked areas.[6] The latest audit (1 January 2006), however, revealed that 24% of our flood defences did not meet these current (outdated) standards, while nothing could be said about a further 32% (see Figure 3).[7] This report also revealed that 22% of the civil engineering works did not meet these standards whereas 49% of these works could not be assessed. Moreover, one should realise that for the present and the future, large investments in housing, industrial estates, and infrastructure are planned in the low-lying areas of the country. [8] In the short term we thus face many challenges to exploit the opportunities.

Climate scenarios 2006

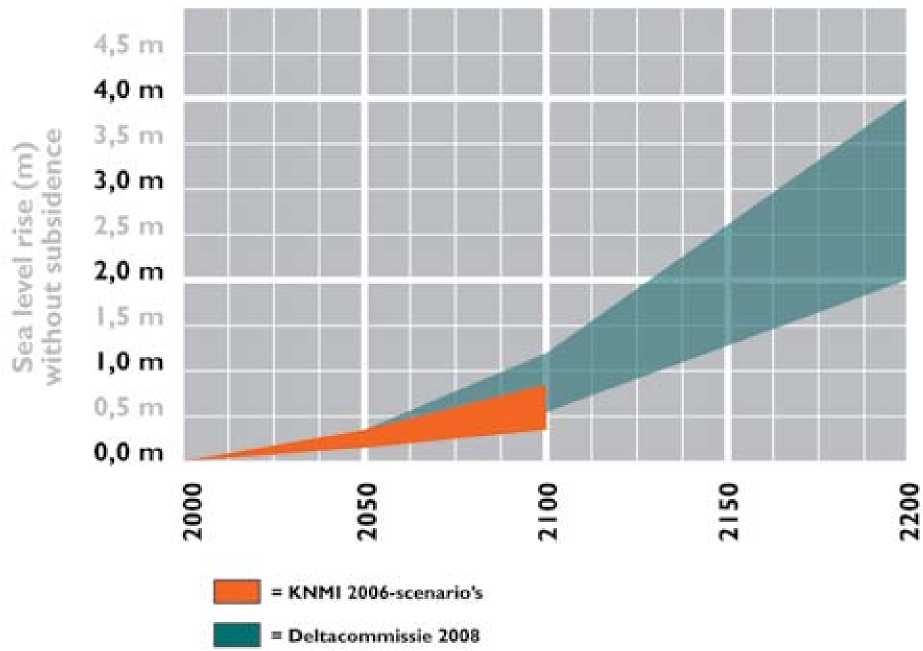
Global warming due to increased greenhouse gas emissions and the fact that this warming will have consequences for sea level and the weather is virtually beyond dispute now. However, there is still a great deal of uncertainty about the severity and rate of climate change, as well as the magnitude of the consequences.

The Royal Netherlands Meteorological Institute (KNMI) has drawn up four scenarios for the Netherlands, varying in terms of mean temperature increase and air circulation patterns.[9] The individual scenarios give temperature increases for the Netherlands from a few degrees to 4°C in 2100. Droughts will become a bigger problem due to increased evaporation and changed precipitation patterns.[10]

In 2006 the KNMI worked out two scenarios for sea level rise off the Dutch coast. KNMI assumes a temperature increase in 2100 of 2°C in its 'low temperature scenario' ('moderate' scenario) and of 4°C in its 'high scenario'('warm' scenario).11 This results in a sea level rise of 15 to 35 cm in 2050 and 35 to 85 cm in 2100. Neither of these cases takes account of land subsidence and the reference year in both cases is 1990 (see Figure 4).

The Delta Committee has sought to base its advice on the most recent scientific insights into a plausible upper limit to global and regional sea level rise, changed storm conditions above the North Sea, and precipitation changes leading to altered discharge in the major rivers. The Committee has therefore commissioned additional research to provide a systematic survey of the most recent information on climate scenarios (see Appendix 3). A score of prominent national and international climate experts, including several IPCC authors, has been commissioned by the Delta Committee to produce scenarios for 2100, supplementary to the IPCC 2007 and KNMI 2006 scenarios. When considering sea level rise scenarios, one of the inputs was the temperature increase calculated by the IPCC on the basis of the IPCC highest emission scenario, called A1FI (see box). Also, estimates have been made of possible climate developments in the year 2200. The following conclusions can be drawn.[12]

Figure 4: Sea level rise scenarios. The sea level increase off the Dutch coast expected in 2050, 2100 and 2200. (Year of reference 1990. Land subsidence is not included in these data.)



Greenhouse gases, rising temperature and sea level

There is a connection between global temperature increase and the expected sea level rise. Temperature increase is caused by greenhouse gas emissions, the most important source of which is fossil fuel combustion. The present concentration of CO_2 in the atmosphere is about 385 ppm. The future progress of this concentration depends in part on future socioeconomic developments, political agreements, and feedback mechanisms in the physical climate system. According to the IPCC, a 6°C temperature increase may occur in 2100 if the atmospheric CO_2 concentration at that time increases to about 750 ppm.

The IPCC A1FI scenario, which the Delta Committee has used as the basis for its estimates of several major components of sea level rise in 2100 / 2200, gives a good picture of general socioeconomic developments that could lead to such an increase. The most important reason why this scenario leads to very high emissions is that investments in new technology concentrate on fossil energy as the motor of the global economy, including the use of abundant supplies of coal and unconventional oil in tar sands and shales, with high CO_2 emissions per unit of energy consumed. This has a greater effect on emissions than improvements in energy efficiency. This scenario is realistic, as witnessed by the fact that actual emissions since 2000 are in line with, or even exceed the IPCC A1FI scenario.[1] At the same time, it should be noted that improvements in the reduction of CO_2 emissions from coal use, as well as CO_2 storage, are developing rapidly. It is at present difficult to determine the total effect of technological advances.

According to the UN Framework Convention on Climate Change, the atmospheric concentrations of greenhouse gases should be stabilised at a level that will allow ecosystems to adapt naturally and to permit sustainable development, while not imperilling food production. At present there is no political consensus on the relevant stabilisation level, but the European Union has agreed as a goal of its climate policy that the global temperature may not rise by more than 2°C above the pre-industrial level. This corresponds to a stabilisation level between 450 and 550 ppm CO_2 in 2100, which, given the state of our present knowledge, will require immense efforts to achieve global emission reductions in 2100 of the order of 80% below the 2000 level. By way of comparison: the Kyoto Protocol envisions for 2012 a mean global reduction of 5.2% below the 1990 level.

1. Raupach, M. et al. Global and regional drivers of accelerating CO_2 emissions. Proceedings of the National Academy of the United States of America, Vol. 104, No. 24, 2007.

Higher sea level

In the past century the sea level along the Dutch coast has risen by approximately 20 cm with respect to Dutch Ordnance Datum NAP. According to the 2007 IPCC report, in 2100 we shall be faced with temperatures from 1.5 to 6°C higher than they are now. In combination with other assumptions incorporated in these scenarios, this means that at the end of the present century, given a temperature increase of 6°C, we may expect a sea level rise of 0.55 to 1.2 m.[13] Mean land subsidence along the Dutch coast, due to glacial isostasy and subsoil compaction,[14] will be well over 10 cm in 2100.[15] On balance this implies a relative 'sea level rise' for the Netherlands of 0.65 to 1.3 m in 2100.[16]

Research conducted for the Delta Committee shows that in 2200 we can expect a global maximum sea level rise of 1.5 to 3 m, depending on the method used, with local values of as much as 2 to 4 m.[17] Uncertainty about long-term climate developments and the fate of the land ice on Greenland and Antarctica, however, are so great that any attempt to translate this upper scenario to the Dutch coast can be regarded as indicative only. The scenarios are more reliable out to 2100 thanks to our knowledge of the present rate of sea level rise and the fact that it is unlikely that this rate will accelerate greatly over a period of several decades. The reliability of predicted sea level rise beyond 2100 is far less. In general terms we can expect that the sea level in 2200 will in any case be higher than in 2100, and that sea level will continue to rise for a long time thereafter as a result of the long-term effects of increased greenhouse gas concentrations.[18]

Following the latest insights into the upper limit of sea level rise in 2100, the Delta Committee concludes that this level may be higher than has been assumed up till now. An upward trend can be seen in the estimates as our knowledge advances.

For 2050 the Delta Committee has utilised the KNMI 2006 scenarios for sea level rise. Given a mean land subsidence of approximately 5 cm, relative sea level will rise by 0.2 to 0.4 m until that time.

The measures developed on the basis of the KNMI 2006 scenarios do not need to be changed in the short term. Given the trend in the estimates, however, there is good reason to implement them fully, in good time, and to future-proof them. The rising sea level must be monitored carefully and policy must be tested against the latest insights, and then modified if necessary. In other words, policy must become *adaptive*.

A climate-proof strategy for water management and flood protection must be based on the possibility that stabilisation at high levels may not be achieved: even if greenhouse gas concentrations were to stabilise at roughly 750 ppm, the global temperature could rise by more than 6°C beyond 2100. This is the level that the Delta Committee has selected as the possible upper limit at the end of the present century.

Growing shortage of sand

In geological terms, the implication of relative sea level rise for the Dutch Delta is a permanent need to deposit sand. Inadequate sand supplies will lead to deficits. On balance, today, hardly any sand is transported to the Dutch coast from the sea and rivers. This is leading to sand deficits in the interlinked system comprising the North Sea coast, Wadden Sea, Western and Eastern Scheldt.[19]

Wind and storm

Climate models are showing a slight, year-on-year increase in the highest daily-mean wind speeds. The force of severe storms, mainly from the south-west, is also increasing slightly over North-western Europe. Such storms occur less than once a year.

The available models and data do not as yet permit clear statements to be made about the period beyond 2100. The Committee regards it as sensible to conduct further research using existing time series and projections based on multiple runs of different climate models.

More water through the Rhine and Meuse

In the KNMI 2006 scenarios, the increasing temperature and changing air circulation patterns result in lower summer discharges and higher winter discharges for the Rhine. In summer the mean Rhine discharge, now 1700 m^3/s, may drop to 700 m^3/s in 2100. In winter, peak river discharges, at present regarded as rare, may occur regularly. For instance, the probability of the 1995 Rhine discharge of 12,000 m^3/s is now 1/50 per year, but this will increase to 1/10 per year in 2100. As a consequence, the discharge that occurs with a probability of 1/1250 per year (the design discharge) rises from 16,000 m^3/s now to 17,000–22,000 m^3/s in 2100.[20] There is great uncertainty, in other words. The available climate models do not permit any sensible scenarios to be developed for the period 2100–2200.

Peak Rhine discharges will lead to widespread flooding in Germany; the state of the flood defences there is such that widespread flooding occurs at rates of 14,000 m^3/s and more. A joint study conducted by the Directorate-General for Public Works and Water Management, the Province of Gelderland, and North Rhine-Westphalia showed that a potential discharge of 19,000 m^3/s, which the scenarios tell us is conceivable in 2050, will result in a peak of 16,000 m^3/s finally reaching the Netherlands. In a climate scenario for 2100 with enough rainfall to generate a potential 22,000 m^3/s, the maximum discharge would be in the region of 18,000 m^3/s. This therefore means an upper limit of 18,000 m^3/s to the discharge that can reach the Netherlands. The design discharge for the Meuse is based on a probability of 1/1250 per year; at present this is 3,800 m^3/s at Borgharen.[21] Climate changes can lead to indicative discharge rates of 4,200 and 4,600 m^3/m respectively around 2050 and 2100. It is not likely that measures in France, Belgium and Germany will lead to a substantial reduction of future discharge volumes through the Meuse.[22]

Anticipating the (plausible) upper limit from climate scenarios

It is unlikely that the maximum values for these years will actually be exceeded. What the Committee finds more important is that the sea level will rise, even if we cannot yet with certainty tell by how much at what time. Certainly, the first problems in our water system will occur before the maximum predicted rises in sea level and river discharge have become a fact. The decisions made and the measures taken must be sustainable, set against the background of what the Netherlands may expect. Future generations must not be confronted with a *fait accompli*, should the effects of climate change be worse than we can or wish to contemplate at this time. For that reason, the Delta Committee has anticipated the upper limits from the climate scenarios and the effects on sea level and river discharge, as set out above.

Higher temperature and fresh water shortage

A rising sea level imperils the fresh water supply in the Western Netherlands as the salt water penetrates further inland via the rivers and through the subsoil. Agriculture, horticulture and other sectors of the economy will suffer harm as a result. There are two threats: salination and – in warm, dry summers – a shortage of fresh water. In the most extreme KNMI scenario for the start of the next century, there will on average be a shortage of water comparable with the driest year to date, 1976. Such a shortage may cause significant damage to agriculture, the natural ecology and shipping.[23]

Higher temperatures and the threats to the fresh water supply change the conditions for animal and plant species in the Netherlands so drastically that we can expect (part of) our natural ecology to take on a very different character. Some species and certain ecosystems will not be sustainable under the changed conditions; others, which were not able to flourish here in the past, can and will become established in our regions. This must have consequences for nature policy; a policy that is concerned to preserve present species will probably be neither sustainable nor desirable in the face of climate change.

Agriculture and horticulture will also encounter changes due to higher temperatures, variability in the fresh water supply, or salt in the soil and ground water. Climate change as such is not a threat to food production. On the contrary, it offers new opportunities for the Netherlands to remain a major food supplier, even in the long term, given sufficient investment and provided the agricultural sciences succeed in developing the necessary knowledge and expertise in time to allow us to take advantage of the changed production conditions.

The high temperatures may give rise to water quality problems. Implementation of the *EU Water Framework Directive* will lead to a considerable improvement in the preconditions needed for good water quality, even with rising temperatures. On this point, climate-proofing rests on a solid foundation.
As temperatures rise, the cooling water for power stations presents a bigger problem. The industrial sector has, however, made provision to cope with the issue as best possible.

Legend

- Attention to coastal dunes
- Attention to flood defences
- Increased flood probability along Meuse
- Landward migration of sea influence
- More frequent cessation of fresh water intake at Bernisse and Gouda
- Free discharge possible
- Shortage of fresh water storage lake IJsselmeer

N

0 km 50 km

Figure 5: Effects of sea level rise and changed river discharge rates on the Netherlands drainage system, 2050.

The Netherlands is unprepared for climate change

Climate change confronts the Netherlands with major adaptation problems, which have consequences for the organisation of the entire country. Spatial planning will have to adapt to different living conditions for both humans and animals. Our country must remain a pleasant place to live, even in times of climate change. This means that under all circumstances there must be space for housing, work, transportation, food production, energy generation, recreation, nature etc. Where possible, these functions must be cleverly combined. In this respect, water is an important guiding principle, and one that will only increase in importance in the future.

The flood risk will increase and the fresh water supply will come under pressure if no extra measures are taken. Our awareness of the interrelations between the various elements of the water system is significant here: everything depends on everything else in our water-rich delta. Figures 5 and 6 show the effects on the water system in 2050 and 2100, respectively. If the Rhine discharge increases, the discharge capacity of the Waal and/or the IJssel will have to be increased. Higher discharges combined with sea level rise have consequences for flood protection at 'critical' locations, such as Rotterdam and other towns in the Rhine delta area, as well as for the land use and spatial planning in the rivers region (where should house-building be permitted, for instance, and what form should it take?), and for fresh water storage in the IJsselmeer lake and possibly in the delta of Zeeland and South Holland. Sea level rise will compel changes to the major flood defences. Such changes will not be without effect on the natural processes and ecological values of the estuarine environments. They will also impact on those sectors of the economy that depend on such environments (tourism, fisheries, etc.).

The storm-surge barriers in the Eastern Scheldt and Nieuwe Waterweg have been designed in anticipation of a sea level rise of 20 and 50 cm per century, respectively.[24] If the sea level rises further, then the storm-surge barriers will have to be modified or replaced. The Maeslantkering (Nieuwe Waterweg) barrier may be closed far more frequently in 2050 and 2100 than the once per decade originally envisaged. If the sea level rises by 85 cm, the Maeslantkering will have to be closed roughly three times a year. A rise of 1.3 m will mean closing the barrier about 7 times a year. If closure coincides with a high river discharge, then for a time the river cannot discharge into sea and its water will accumulate upstream of the closed barrier.[25] The frequency with which the floodplains are inundated will increase as a result, as will the area under water. Moreover, if the flood defences remain unchanged, flood probability in Rijnmond and the Dordrecht region will increase: every 40–60 cm of sea level rise will increase flood probability by a factor of 10 in this region.[26]

The current programme to increase the discharge capacity of the Rhine's tributaries aims at a design discharge capacity of 16,000 m^3/s and, with additional measures (long-term vision presented in *Room for the River*), this can be increased to 18,000 m^3/s. It is important to actually create this capacity increase. The Meuse discharge may increase to 4,600 m^3/s; measures additional to the Maaswerken (Meuse Works) are needed to cope with this discharge.

Lower river discharges in summer could present a problem for fresh water extraction and agriculture. In the most extreme scenario it is anticipated that

Legenda

- Attention to coastal dunes
- Attention to flood defences
- Increased flood probability along rivers
- Retention area for river floods
- Landward migration of sea influence
- More frequent cessation of fresh water intake at Bernisse and Gouda
- Free discharge only possible with raised lake level
- Shortage of fresh water storage lake IJsselmeer
- Increased seepage of brackish ground water

0 km 50 km

N

Figure 6: Effects of sea level rise and changed river discharge rates on the Netherlands drainage system, 2100.

fresh water extraction at Bernisse (near Hellevoetsluis / Spijkenisse) and Gouda will have to cease for nearly 6 months of the year in 2050.27 The process of groundwater salination was set in train centuries ago when the polders were drained and lake beds reclaimed and continues to the present day. A sea level higher than the land means an increase in salt water seepage.

A higher sea level means that water in the polders and drainage ditches will have to be pumped over ever-increasing heights into the North Sea or the inlets and estuaries that drain into it. Added to that, it is anticipated that precipitation peaks will be more frequent and more severe. In combination, this will lead to increased demands for water storage and pump capacity.[28] From 2050 on, free discharge of the IJsselmeer lake into the Wadden Sea will be imperilled and a combination of pumps and/or increased lake water levels will be necessary.

For the Eastern Scheldt it has been calculated that if no measures are taken, the mudflat area will decline drastically due to the constructed storm surge barrier that cuts off almost all sediment transport from the sea into this estuary. This process is amplified by sea level rise. If no action is taken, then in a few decades the mudflats and shallows in the Eastern Scheldt are expected to halve: from more than 11,000 ha in 1986 to approximately 5,000 ha in 2045 (and approximately 1,500 ha in 2100). In that case, salt marshes will only be found in sheltered areas of the Eastern Scheldt in 2050.[29]

Sea level rise will change the natural character of the Wadden Sea. It is assumed that the natural sediment transport (inflow of flood water containing sand and mud) will be able to maintain the intertidal zones against a sea level rise of 30 to 60 cm. The larger the tidal zone, the more sediment it will need and the lower the sea level rise that can be accommodated naturally. The sea level has risen by approximately 20 cm during the last century. If it were to rise faster than 30 to 60 cm per century, possibly from 2050–2100, it is probable that the intertidal zones in the relatively large, most westerly parts of the Wadden Sea will be the first that will not be able to catch up with the sea level rise, thus losing their present form. This will also happen to the salt marshes of the Wadden islands.

Lelystad

The Netherlands in the future

The Netherlands Environmental Assessment Agency (MNP, since 1 January 2008 PBL) has drawn up a report on the Netherlands in the future. This report[1] allows the following picture to be sketched of the demography and economy of the Netherlands roughly 50 years from now. It is assumed that the population in 2050 will lie between 15 million in the lowest population scenario (Regional Communities) and more than 20 million in the highest scenario (Global Economy). It is expected that beyond 2035 only the population in the major cities in the Western Netherlands (the so-called Randstad) will continue to grow slightly (except in the Regional Communities scenario, which shows a decline). In the Randstad, the northern wing will grow faster than the southern one. At the same time, there will be increased migration from this area to adjacent regions such as North Holland, West Brabant, Flevoland and Gelderland. There will be a continuing trend to smaller average households, especially in the cities: it is expected that the number of households will rise from 7.1 million now to 8.1 million in 2035. Between 500,000 and 1.5 million extra dwellings will be built out to 2040. Demands on the living environment will become more severe and varied because prosperity, social individualisation and diversification increase.

According to the scenarios, GNP per head of population in 2040 will be between 30 and 120% greater than it is now. It is expected that the Randstad will absorb more than half of the Netherlands' economic growth. Increased prosperity and population growth will thus greatly increase the potential flood risk in this part of the country.

Global market developments will increasingly displace low-value industrial production (manufacturing) to such countries as China, India, Brazil and Eastern Europe. The services industry and R&D will also relocate outside the EU. The Netherlands, especially the Randstad, will have to rely increasingly on the knowledge economy and the development of high-value technologies. New, fresh enterprise will involve cultural production and the creative economy. The commercial services sector and the care industry will also grow. The significance of agriculture will decline in the Randstad.

1. Netherlands Environmental Assessment Agency (MNP). The Netherlands in the Future. Second Sustainability Outlook. The physical living environment in the Netherlands. The Hague, 2007.

The Netherlands some day

Social, socioeconomic and demographic developments, added to the further growth and distribution of prosperity over the long term, are at least as significant as the physical challenges to water safety. Predictions so far ahead (2100–2200), however, are by definition highly uncertain. We only have to cast our minds back to 1900 or 1800 to see how precarious it is to attempt to predict what the world will look like one or two centuries from now. Would we have been able to explain to our grandmothers' grandfathers what it is like to live in a world of motorised traffic, trans-Atlantic air travel, electricity, space travel, ICT and genetic technology?

Scenarios have been developed out to approximately 2040 by a number of institutions at home and abroad, including planning agencies in the Netherlands. Uncertainty increases immeasurably as the future recedes. The Committee has consulted many authorities on possible long-term future scenarios. In the Committee's view, the dominant long-term variables are pressure on space and the preparedness to invest. Pressure on space determines how easy it will be to find solutions for water safety, and the need to find multifunctional solutions. Preparedness to invest will be the upshot of societal considerations in 2100 or 2200, but will in any case depend strongly on the state of the economy and the level of prosperity we enjoy at that time.

Besides pressure on space and preparedness to invest, the Committee also points to the importance of cross-border co-operation, especially with Germany, and technological developments. The various solutions that the Committee recommends will be assessed in light of how robust they are in the future.

Het Groene Hart [The Green Heart], a polder landscape between the cities of Amsterdam, Rotterdam, The Hague and Utrecht.

3. The Netherlands is protected by a total of 3600 km of primary flood defences. More than three-quarters of this (2767 km) is defined as grade-a defences: primary defences of diked areas that border outside waters (sea, rivers, large lakes). Source: *Toekomst voor het polderconcept* [Future of the polder concept], p. 6.
4. Letter from Vice Minister for Transport, Public Works and Water Management on Progress on exploration of water safety in the 21st century (WV21). Parliament 2006–2007, 27 625, no. 79.
5. The flood that hit the south-western Netherlands on 1 February 1953 resulted in 1836 fatalities, 100,000 evacuees, damage of more than 1.5 billion guilders and a delay of more than a year before the flooded areas could be pumped dry again.
6. Kind, J. *Kengetallen kosten-batenanalyses Waterveiligheid 21e Eeuw* [Cost-benefit analyses for water safety in the 21st century: key figures]. Final draft April 2008. Directorate-General for Public Works and Water Management – Centre for Water Management.
7. *Primaire waterkeringen getoetst*. Landelijke rapportage toetsing 2006 [Primary flood defences assessed. National Report Assessment 2006.]. Inspectie Verkeer en Waterstaat [Transport and Water Management Inspectorate]. 2006.
8. According to estimates from CBS, CPB and RPB (see Glossary), around 400,000 extra dwellings will be built in the coastal conurbation before 2030. Nationally, for the period to 2020, government plans to invest more than 90 billion euros in 'transport' alone. This does not include additional investments in such things as water management, urban and countryside areas, and energy, all of which run into billions. Source: *Kennis voor een Klimaatbestendig Nederland (KBN)* [Knowledge for a Climate-Proof Netherlands]. Een voorstel voor een Kennisprogramma in het kader van de FES investeringsronde [Proposal for a knowledge programme in the context of the FES investment round]. April 2008.
9. *KNMI Climate Change Scenarios 2006 for the Netherlands* [original in English]. KNMI Scientific report WR 2006-01.
10. Het IPCC-rapport en de betekenis voor Nederland [The IPCC Report and its significance for the Netherlands]. IPCC, May 2007.
11. The recent KNMI report *'De toestand van het klimaat 2008'* [State of the climate 2008] clearly shows that the Netherlands is warming, based on a long series of temperature measurements. Since 1950 the Netherlands has warmed twice as fast as the global mean temperature.
12. See Appendix 3: The climate scenarios used by the Delta Committee: explanatory note, and Vellinga's background report, to which the following experts have contributed: Pier Vellinga (Wageningen UR, Free University Amsterdam), Caroline A. Katsman (KNMI), Andreas Sterl (KNMI), Jules Beersma (KNMI), John A. Church (CSIRO, Australia), Robert E. E. Kopp (Princeton University, US) Dick Kroon (University of Edinburgh, Scotland, Free University Amsterdam), Michael Oppenheimer (Princeton University, US), Hans-Peter Plag (University of Nevada, US), Stefan Rahmstorf (Potsdam Institute for Climate Impact Research, Germany), Jeff Ridley (Meteorological Institute, UK), Hans von Storch (GKSS, Geesthacht, Germany), David G. Vaughan (British Antarctic Survey, UK), Roderik S.W. van der Wal (IMAU, University of Utrecht), Wilco Hazeleger (KNMI), Natasha Marinova (Wageningen UR), Ralf Weisse (GKSS, Geesthacht, Germany), Jason Lowe (Hadley Centre for Climate Prediction, UK), Henk van den Brink (KNMI), Reindert Haarsma (KNMI), Erik van Meijgaard (KNMI),Hans de Vries (KNMI), Jaap Kwadijk (Deltares), Rita Lammersen (RWS Waterdienst).
13. Climate change will cause the sea level to rise by 12 to 49 cm due to thermal expansion of the ocean, 7 to 18 cm due to glacial melting, –1 to 41 cm and 13 to 22 cm due to melting of the land ice on the Greenland and Antarctic icecaps, respectively, –5 to 20 cm from local ocean expansion.
    Possible effects from the distribution of melt water from land ice through the oceans, called the gravitation effect, is currently a matter of scientific debate. As such, it has not been incorporated here. The indicated ranges have been translated via nonlinear summation into the final, combined range (see Appendix 3).
14. Isostasy: After the last Ice Age the ice packs melted, so their mass was released, leading the Scandinavian land mass to rebound – a process that is still occurring – with a corresponding tipping of the earth's crust in our own region. North Holland is dropping by approximately 8 cm per century, while South Limburg is rising by about 10 cm per century. Compaction of the soil: sea and river sediments compact under their own weight, as well as by shrinkage and other natural processes. Young sediments can compact more than older, deeper soil deposits.
15. The deepest parts of the Netherlands are no longer sinking much from compaction. These are mainly reclaimed lake beds, which often have a clay base. The peat soils of less deep polders are sinking, but their surface as a rule is 2–3 m higher than the reclaimed lake beds.
16. Recent satellite observations show that the local land subsidence along the coast might be as much as 4 times greater (Deformatiestudie Hondsbossche en Pettemer Zeewering met behulp van radarinterferometrie [Radar interferometric study of Hondsbos and Petten Sea Dike deformation], Hansje Brinker Dijkmonitoring 2008. This corresponds to a relative sea level rise of 0.95 to 1.6 m in 2100. The compaction of the peat soils will continue in the interior if current land use and its dewatering are maintained. In the past century the surface of the peat lands of the Green Lung, the area to the north of Amsterdam, has subsided by an average of 40 cm, with local excursions of more than 1 m.
17. This ignores possible influences of the gravitation effect.
18. Palaeoclimatologists have performed supplementary work to the research commissioned by the Delta Committee. These scientists have been looking at rates of past sea level rises, especially during the start of the previous warm period, about 122,000 years BP. The results of such analyses cannot be compared directly with climate model projections since they were arrived at in a totally different way, using proxy data. They do, however, indicate what has happened in the past in a situation very comparable to the present in terms of global ice cover. The palaeoclimatological estimates of global sea level rise indicate a possible rise of 50–70 cm in 2050, 140–190 cm in 2100 and 310–430 cm in 2200.
19. The sand deficit grows by more than 7 million m^3 per annum for every 1 mm per annum rise in sea level.
20. The changes in design discharge were calculated using the KNMI 2006 scenarios as well as direct output from climate models. This was done because the peak discharge rates are very sensitive to changes in the variability of periodic precipitation and the fact that possible changes in this variability may not have been adequately incorporated in the KNMI 2006 scenarios.
21. Deltares, '*Klimaatbestendigheid van Nederland Waterland, knikpunten in beleid en beheer'* [Climate-proof Netherlands, Land of Water; Tipping points for policy and management]. Delft, 2008.
22. Deltares, '*Klimaatbestendigheid van Nederland Waterland, knikpunten in beleid en beheer'* [Climate-proof Netherlands, Land of Water; Tipping points for policy and management]. Delft, 2008.
23. Rijkswaterstaat / Deltares: *Beantwoording Kennisvragen Deltacommissie, een samenvatting* [Response to Delta Committee's request for knowledge: summary], 2008.
24. Deltares, '*Klimaatbestendigheid van Nederland Waterland, knikpunten in beleid en beheer'* [Climate-proof Netherlands, Land of Water; Tipping points for policy and management]. Delft, 2008.
25. Rijkswaterstaat / Deltares: *Beantwoording Kennisvragen Deltacommissie, een samenvatting* [Response to Delta Committee's request for knowledge: summary], 2008.
26. Kind, J. *Kengetallen kosten-batenanalyses Waterveiligheid 21e Eeuw* [Cost-benefit analyses for water safety in the 21st century: key figures]. Final draft April 2008. Rikswaterstaat Waterdienst.
27. Rijkswaterstaat / Deltares: *Beantwoording Kennisvragen Deltacommissie, een samenvatting* [Response to Delta Committee's request for knowledge: summary], 2008.
28. It should be noted in this regard that most of our polders are oversized. They had to store relatively large quantities of water since they were often designed for windmill pumping.
29. Rijkswaterstaat / Deltares: *Beantwoording Kennisvragen Deltacommissie, een samenvatting* [Response to Delta Committee's request for knowledge: summary], 2008.

3 An integrated vision to create opportunities

Around 1800 the Netherlands had roughly 2 million inhabitants and large parts of the low-lying areas were flooded for months every winter as low-lying pastures filled with surface drainage water. 'Every few years in the decades around 1800 repeated floods occurred as coastal or river dikes were breached'.[30] Now, in 2008, we manage to keep more than 16 million inhabitants dry virtually all the time. Our knowledge of hydraulic engineering and our ability to make the water flow where we want has increased tremendously through the centuries. So we can confidently accept the mandate to keep the Netherlands a prosperous, safe country with sufficient clean water for humans and livestock: we have the time, the knowledge and the means.

A fresh course

The effects of the expected climate change will put far more pressure on water safety in our low-lying delta. Moreover, through the years we have come to regard different values as worth preserving; values that perhaps cannot be expressed in clear monetary terms, like nature and our cultural heritage (landscape, archaeology and buildings). This forms part of the struggle towards sustainable development that is so characteristic of the 21st century. In combination, these factors mean that we have to chart a fresh course for the future. What is wanted is a living environment where people feel at home, where businesses feel welcome, where there is space for nature, and where life, work and recreation are linked comfortably and rapidly by a high-quality infrastructure. This demands more than safety alone.

While history tells us that we often need a disaster before we spring into action, this is not always true. Furthermore, major physical, infrastructural decisions have often been made in the past without any clear knowledge of all the consequences. Consider the decision to construct the ship canals *Nieuwe Waterweg* [New Waterway] and *Noordzeekanaal* [North Sea Canal].[31] Nevertheless, people were convinced that it was a good idea, based as it was on a powerful vision and a clear picture of the future.

It is for an attitude like this that the Committee is pleading; let everybody dare to form a clear picture of what we can expect and think ahead to the way we can cope with these challenges. Even better: how can future opportunities be created?

Dutch coast at Ter Heijde, just north of the mouth of the Rhine

A sustainable view, future opportunities

The Delta Committee has an integral vision of the long-term protection of the delta and the spatial planning of the coast and the hinterland. Regional considerations related to 'specific' issues must always be weighed against an integral, national view. The Delta Committee's advice is therefore concerned with the principal water system. The way the recommendations are translated, though, will often involve the regions. Moreover, the close involvement of all sectors of society is an absolute precondition if the necessary investment decisions are to be supported and sustained. This, too, is an aspect that lends itself to being resolved at the regional scale.

If the country is to be made climate-proof, regional exercises must be approached integrally: resolution of the water issue cannot be seen separately from such related matters as nature, landscape and urban development.

The Committee's vision forms a bridge between the issues with which it is confronted and the solutions it outlines. We should not now, at the start of the 21st century, design a blueprint for the Netherlands at the end of the 22nd century, but we must leave no opportunities unexploited now that will afford later generations the conditions for a good living environment. The Delta Committee is happy to grasp this historical opportunity with both hands and to present its vision, from which a *Delta Plan*, with concrete measures, can be derived.

Administrators and hydraulic engineers in the Netherlands frequently regard new challenges as a fount of innovation. This does not have to change in the future: climate change and sea level rise offer new perspectives. By making well-considered choices now, no actions will be taken that we might regret later. What's more, the odds will increase that we shall achieve our goals.

Our vision of the future

The Committee's vision of the how the Netherlands will look in terms of land use planning in the distant future – i.e. until the end of the next century – can be stated as follows. The entire country will remain an attractive place in which to live, work, invest and take one's leisure. Two pillars on which the strategy for the next century must be based are safety *and* sustainability. The Committee understands sustainability as a determination to use water, energy and other basic materials as efficiently as possible, to maintain or even improve the quality of the living environment. In moving towards this vision of the future, each generation must act in such a way as to provide for its own needs without imperilling the ability of future generations to provide for their own needs. What this means, inter alia, is that government, the business community and households must be frugal with water, energy, sediment and other basic materials, ensuring that materials are re-used (closed recycling).

The country's planning and development will have to be organised as far as possible in accordance with natural processes. New, somewhat different biodiversity and new, attractive landscapes can emerge and flourish if we offer more space to the dynamics of rivers and the sea. Residential areas, suitably adapted, can be created in water storage areas, on new land or on dikes. There are very promising opportunities for various forms of energy generation at sea and along the coast: windmills, tidal and osmotic energy. The development and utilisation of sustainable sources of energy will simultaneously cut greenhouse gas emissions and will permit functions to be combined.

The coastal conurbation of the Randstad remains our country's heart. It is where most of the population lives and where the lion's share of our national income is generated. Also in terms of culture, history and food supply, the low-lying part of our country is internationally significant. Nature, landscape and exceptional architecture are and remain valuable goods, whether they are in the higher or the lower regions of the Netherlands. The major mainports will continue to make a significant contribution to our country's prosperity. The Netherlands will remain an international nexus for goods, services and knowledge. It is not necessary to displace all this, which would anyway destroy an immense amount of capital.

Sufficient (fresh) water will remain available for the most important functions: drinking water, agriculture, nature, industry and transport. Both government and the public take account of water when decisions have to be made; both the opportunities that water offers for work, living, recreation and investment as well as the shortage of water (water as a scarce resource), flooding and the threats of storm surges and river floods.

The best long-term strategy to keep the Netherlands safe and a pleasant place to live is to develop along with the changing climate. Moving with and utilising the natural processes where possible leads to solutions that allow humans and nature to adapt gradually. This further affords better opportunities for combined, multifunctional solutions for functions such as constructing infrastructure, reserving land for housing and business parks, using land for agriculture, recreation and nature. These solutions will commonly also be associated with the lowest long-term construction and maintenance costs. They will also often deliver greater added value to society as they create new possibilities. Changing water levels, for example, offer new opportunities for recreation as well as interesting housing and business environments. Attempts to manage nature will continually demand more (and more expensive) efforts.

First storm barrier completed under the Delta Works: the Hollandse IJsselkering at Krimpen aan de Ijssel

The first Delta Committee's approach to risk management

'A protective system for the entire coastal zone, with attention to well-founded standards and guidelines, is indispensable,' wrote the first Delta Committee. Its safety policy was based on the risk approach: the probability that a flood would occur in a given area, multiplied by the consequences of the flood.

The maximum acceptable risk (the safety standard) was defined on the basis of three analyses:

- an analysis of the highest storm surge level that could have occurred under the worst possible conditions on the night of the disaster in 1953;
- an analysis of storm surge frequency;
- a comparison of the costs of dike reinforcement with the economic value (including the loss of human life and intangible assets) in the Central Holland diked area.

The Delta Committee regarded the interests to be protected in North Holland as having equal value to those in Central Holland and opted for a safety standard of 1/10,000 a year. This means that an extreme water level occurring once in 10,000 years must reasonably be defeated. They considered a safety standard of 1/4,000 a year sufficient for the other coastal regions, in view of the differences in the interests to be protected. Later on, a lower standard of 1/1,250 was derived for the rivers, based on the reduced amount of damage that would be caused by a freshwater rather than a salt-water flood, the importance of landscape, nature and cultural heritage values, and the predictability of high water levels in the rivers. An intermediate standard of 1/2,000 a year was decided upon for the lower, tidal river reaches and for the area around the IJsselmeer lake).

Source: Advies eerste Deltacommissie [First Delta Committee's Advisory Report], 1960, and Waterveiligheid 21e eeuw Synthesedocument [Synthesis report 21st century water safety], 2008.

Basic premises

The Committee has adopted a number of basic premises that can serve as a guide when choosing the paths leading to a future Netherlands.

1. The Netherlands remains the world's safest delta.
2. Where possible we shall move along with the natural developments resulting from climate change and other natural processes. We shall build and develop the country as far as possible in harmony with ecological processes.
3. The Committee has opted for a broad definition of 'water safety', including: people (flood casualties prevention), protection of economic, ecological, and cultural heritage values, preventing harm to our country's international reputation, and preventing social disruption.
4. Flood prevention and flood risk management are important to the entire country: a catastrophic breach in a dike will disrupt the entire country. Water safety is a collective, national responsibility. This was so historically and it will remain so. The government is guarantor. The solidarity principle stems from this collective responsibility: everybody, no matter where they live, has an interest in water safety and therefore contributes financially to it. Concern and care among the present generation increase the opportunities for and cut the risks to future generations. This is why inter-generational solidarity is required.
5. Flood protection is undertaken in collaboration with our neighbouring countries within the frameworks provided by the EU.
6. The Committee has chosen to adopt the previous Delta Committee's risk-based approach. This implies that water safety measures must be concerned with limiting both the probability and the consequences of flooding.
7. The probability of fatalities due to a flood must be reduced substantially below the present level.[32] The probability of fatality due to flooding must not exceed a basic level for any inhabitant of a flood-prone region (a diked area). Moreover, the Committee urges that targeted measures be taken to reduce the probability of a large number of casualties by one flood. The local refinement of this target can differ per region.

A revised approach to risk management[33]

The Committee adheres to the approach to risk management that the first Delta Committee raised to a fundamental premise. Flood risks are managed by a combination of measures that reduce the *probability* (such as high and strong flood defences) and those that limit the *consequences* (such as the regulation of spatial planning, or zoning, compartmentalisation, early warning, crisis management and contingency planning). The combination of measures is adjusted to the nature of the potential disaster and the characteristics of the diked area involved. The approach must be tailor-made. Research conducted in the context of *Veiligheid Nederland in Kaart* [Flood Risks and Safety in the Netherlands][4] offers the necessary facilities. It is proposed that the probability aspect should remain the primary focus, since this has been proved to be most effective.

The level of flood risk management and flood protection is governed by the interests to be protected. The first Delta Committee adhered to a definition of safety related only to economic damage and casualties. It is the opinion of the new Delta Committee that more aspects must be considered. It is the Committee's opinion that the level of protection must be determined by:

- the individual probability of fatality due to flooding;
- the probability of large numbers of simultaneous casualties;
- the potential damage, including more than just economic damage.

Water safety: The highest priority
A human life is worth the same everywhere and the probability of fatality due to flooding must therefore everywhere be fixed at a basic level, to be agreed by society as a whole. 'External Safety Policy'[35] – which deals with protecting people and the environment from incidents with industrial plant, the transport and storage of hazardous materials, railway shunting yards, and air traffic – refers to this as the Individual or Local Risk. It is set at 10^{-6} (one in a million) a year. The Committee proposes that this standard should also be maintained as the basic, universal level of water safety (inside the diked areas). This means that throughout the (flood-prone) areas of the Netherlands the probability that someone will die as a result of a flood must not exceed one in a million per year.

At present the probability of large numbers of simultaneous casualties (the Societal or Group Risk) is many times greater for floods than for the sum total of all external safety hazards. The Committee finds this unacceptable. Large numbers of flood casualties must be avoided. At present there is no accepted measure of Group Flood Risk.[36] For that reason, the Committee urges that further research be done to develop a measure of Group Flood Risk.

In the Committee's view, the third pillar upon which water safety rests is the importance of avoiding flood damage. This damage must be assessed according to our present knowledge and societal considerations. This means that the direct and indirect costs of a flood must be considered, both inside and outside the affected area, as well as the monetary value of landscape, natural and cultural heritage values, damaged reputation and societal disruption. Optimising the costs and benefits (damage avoided) of protective measures will allow a measure to be determined for this element, taking the form of a flood probability.

Together, these three elements must result in a single, amended standard for flood protection for each diked area. This standard would be expressed in terms of maximum acceptable flood probability. The flood protection standard should be reassessed regularly (linked to the *EU Directive on the assessement and management of flood risk*), given the predicted changes in the climate and the potential consequences (due to social and economic developments). Maintaining this approach upholds the spatial differentiation between safety levels introduced by the previous Delta Committee, but with a basic safety level for all. As the three elements are refined, it may turn out that areas will become more differentiated than they are now. In that regard the Committee is of the opinion that equality must be preserved within linked groups of diked areas, and therefore that large regional differentiations are undesirable.

The way these three elements should be combined into a new standard is not yet known with certainty. Further refinement is needed. However, the Committee finds that safety levels cannot be fixed purely as an exercise in calculation. In light of what is known now – and here the Committee once again stresses the large 'societal' or group flood risk – it is the Committee's opinion that the amended standard must in any case lead to a higher level of flood protection than the present one. The Committee wishes to make this point absolutely clear.

It is expected that the flood probability in the diked areas in the rivers region must be cut by a factor of 10 in order that everybody shall enjoy the same basic level of flood protection. Given the present state of our knowledge, the flood probability in several diked areas, both on the coast and in the downstream areas of the rivers, must be cut by *more* than a factor of 10 if large numbers of casualties are to be avoided. After careful consideration, it is the Committee's judgement that the flood probability in *all* diked areas (the amended flood protection standard) must be reduced by at least a factor of 10 below the present standards, i.e. safety levels must be increased by a factor of 10. These present standards are interpreted by the Committee as flood probabilities.[37] It is the Committee's view that further refinement of these three elements of the standard may lead to a factor of less than 10 only if they are based on very solid grounds indeed. In view of the considerable risk of large numbers of casualties,[38] the Committee would rather expect that further refinement will lead to a greater factor for the improvement of safety in a number of diked areas.

30. Auke van der Woud. *Het lege land* [The low country], p. 23.
31. Van de Ven. *De Nieuwe Waterweg en het Noordzeekanaal: een waagstuk* [The Nieuwe Waterweg and the North Sea Canal: a daring feat]. Research conducted for the Delta Committee, 2008.
32. It is impossible to completely rule out all fatalities or any disruption to society.
33. See Appendix *4* for a more extensive explanation of the Delta Committee's view of safety
34. The project Veiligheid van Nederland in Kaart [Flood Risks and Safety in the Netherlands] uses a new method to chart flooding probability and the effects of flooding in the diked areas. Major aspects of the project involve the strength of constructions, knowledge of weak spots in the diked areas, and the uncertainties in our knowledge.
35. The External Safety Resolution (VROM, *2004*) contains the socially acceptable risk standards.
36. At present there are no guide values for Group Flood Risk (Beckers et al., *2008*). It is after all not easy to compare the risk per diked area with the risks from a site or the transport of hazardous materials, where the effects depend on activities at a single location. A flood commonly impacts a substantially greater area. Moreover, floods are of a completely different nature than the hazards due to human activity.
37. The advisory committee on Financing the Primary Flood Defences (the Vellinga Committee) has estimated that improving safety by a factor 10 would cost 9 billion euros.
38. Jonkman, S.N., 2008. *Schatting Groepsrisico ten behoeve van het advies van de Delta-commissie* [Group risk estimates in aid of the Delta Committee's advice]. Memo 9T6387. AO/NN001/902968/Rott

4 Working on the future: developing with the climate

Global warming will continue for centuries even if we were to meet the goals set down in the Kyoto Protocol and its successors, and even if greenhouse gas emissions world wide were to be cut drastically tomorrow. So we are sure that in our low-lying delta on the North Sea we will have to be prepared for the effects of:

~ sea level rise on protecting the coast of Holland, the Wadden region and the South-western Delta;
~ higher river discharges on protecting the rivers region;
~ increased salination and lower river discharges in summer on securing the fresh water supply;
~ sea level rise on the intertidal zone in the Wadden Sea and the South-western Delta;
~ all of these combined with subsidence.

In the Committee's view, 'developing with climate change and other ecological processes' is the most sensible strategy to counter the effects of climate change. Key concepts in this strategy are gradual action, flexibility (ability to guide the activities), a knowledge of natural processes and cost-effectiveness. The best opportunity for both people and nature to stay abreast of changing conditions involves working with natural processes, building with nature, where possible. Over the long term this will bring the lowest costs, too. Generally, it should be noted that if fresh water becomes scarcer in the future, it will be necessary to find more space for storage. It is expected that increased scarcity will drive up the price of fresh water, which will contribute to the innovations needed to handle water more effectively. The Delta Committee underscores the importance of society's close involvement in the country's water safety. The essential approach to flood protection and sustainable fresh water supply will only become a reality if society – the population and the business community – handles its water conscientiously and with care.

The Committee can see three time horizons to which its recommendations apply:

~ concrete measures for the period out to 2050;
~ a clear vision for the period out to 2100;
~ longer term considerations beyond 2100.

For the short term, the Committee believes that it is realistic to extrapolate from the present and the past, using available scenarios. This is more difficult for the medium term (2050–2100), since the trend may well be clear, but the rate of climate change is still very uncertain. But we have to get in position now for what lies ahead beyond 2050, so the Committee thinks it is sensible to

Texel

extrapolate here, too, and has therefore made concrete recommendations for this period as well. The Committee notes in this regard, though, that certain recommendations (post-2050) may be cast in a totally different light if the scenarios develop very differently from present expectations. Extrapolation over the very long term is not realistic and for this time scale the approach should be to look back from possible future scenarios (hindcasting) to test whether measures may be effective in different futures.

Before setting down short and medium-term recommendations in a *Delta Programme*, we sketch the choices that the Netherlands has made in the past, which have lead to our present, interlinked water system. This is followed by a number of possible, preliminary choices for an integral water system in the remote future. All the choices that are to be made are based on the present situation: our present, interlinked water system with the associated design that allows it to fulfil the different use functions. At the same time, the short and medium-term recommendations in this report have been chosen so that as many options as possible remain open in the long term, so future generations will still have room to make their own considered choices, based on the insights and values of their time.

In its report the Committee has indicated which measures are unavoidable in the long term and how we can anticipate them today (‘*no-matter-what*’ measures). Reserving space and money for later is an essential component of this strategy. The challenge is to develop those solutions that will deliver more added value to society as a whole, whenever possible at reasonable cost. The approach to water safety issues, after all, offers opportunities to further develop or unite other interests and functions, such as agriculture, nature, recreation, housing, accessibility and energy supply.

Our water system: product of centuries of work

The inhabitants of the Low Countries started more than 1,000 years ago to adopt such measures as drainage and land reclamation to cut the risk of flooding and to allow or improve agriculture. Over the centuries lakes have been drained, especially in the Holland Provinces, the last being the Haarlemmermeer lake, which was drained with steam pumping engines. In the mid 19th century they chose to connect the dockyards in Amsterdam to the North Sea via locks that cut off tidal flow in the North Sea Canal. In the Rotterdam region at the end of the 19th century they started to build the Nieuwe Waterweg to allow free access to the Port of Rotterdam. The Rhine and Meuse discharge through the Nieuwe Waterweg and the Haringvliet.

The floods in 1916 (Zuiderzee) and 1953 (South-western Delta) led to radical measures to shorten the coastline: construction of the *Afsluitdijk* [IJsselmeer dam] and the Delta Works. The Wadden Sea and the Western Scheldt are now the only two natural systems that remain open to the influence of currents, tides and waves. What characterises the measures of the past century is their multifunctional, integral approach. These brought major advantages to the fresh water supply (via the IJsselmeer lake), agriculture (vast tracts of new land) and flood protection (up to and including Amsterdam). The measures also resulted in the islands in Zeeland being connected to the mainland and each other, and to the development of recreation, water sports and nature reserves. This is how an intensively used, closely regulated water system came into being in the Netherlands. Flood protection is afforded by rings of dikes.

The northern provinces are characterised by control of the fresh water level of the major lakes (IJmeer, Markermeer and IJsselmeer) and by a 'natural' Wadden Sea. The Committee believes that these choices will remain defensible over the medium and even the very long term.

The need to lead the river water via the South-west Netherlands has its origin in the historical design of the water system. The Committee can see that, even in the medium term, routing part of the peak river discharge through the Nieuwe Waterweg will lead to difficult-to-resolve safety problems in Rotterdam and the towns in the surrounding area (the *Drechtsteden*). This is why the Committee makes recommendations to protect the region from extreme conditions both at sea and in the rivers, so peak discharges will be led in their entirety through the South-western Delta. Over the very long term, given a higher than predicted sea level rise and low economic growth, it may become a real option to close the Nieuwe Waterweg permanently. Shipping would then have to pass through locks.

For the period out to 2050 the Committee can see possibilities to reinforce the estuarine nature of the South-western Netherlands, taking into account the routing of peak river discharges, fresh water supply and safety. Naturally, the vulnerable urban areas must be adequately protected. Simultaneously, this offers opportunities for urban development.

For the rivers, the discharge capacity of the floodplain needs to be maintained and increased for as long as possible, and adequate flood protection in adjacent polders needs to be ensured.

In the next chapter the way to finance the investments needed is discussed. This chapter takes the reader on a virtual flight over the Dutch Delta – the coast, the Wadden region, the South-western Delta, the rivers region and the IJsselmeer lake – to determine which possible solutions can be offered to assure our country's protection against flooding and to secure our fresh water supply. The sea and the rivers are interlinked: flood protection and securing the fresh water supply are components of the same system. The different regional problems are all looked at from this broad, integral perspective.

Flood risk management

The flood safety standards date from the 1960s. At present, about a quarter of the flood defences do not meet current standards, while we do not know whether a further third is compliant or not.39 The Flood Protection Programme focuses on catching up on this backlog. Having a backlog is inherent in the present audit methodology: only when an assessment shows that a flood defence does not meet the safety standard – i.e. when there is a backlog – are improvements planned.

The Committee finds that the standards and the audit methodology must be amended (see the previous chapter and Appendix 4). These new standards must be established as soon as possible (according to the water managers, 2013 is a feasible date) and when establishing the new methodology, attention should be paid to the possibility of a more anticipatory audit. This would allow

'Delta Dike' in Japan

Delta Dikes...

are so high, wide or strong that the chance of a sudden, uncontrolled flood is virtually ruled out. The nature of a Delta Dike differs according to the specific situation. They must be tailor-made. They can take the form of an unbreachable dike, an extra high dike, a very wide dike, or a dike with extra internal reinforcement (with dam walls). It's all about the optimum (economic) reduction of risks (either probabilities, or effects). It should be noted that Delta Dikes are only effective if the diked area has no weak links. Preliminary results from recent research indicate that Delta Dikes can reduce the flood probability by a factor of at least 100 at relatively low cost (Silva and Van Velzen, 2008). Practical experiments are being prepared and conducted under the COMCOAST and *Klimaatdijk* programmes.[1,2]

Depending on their shape, Delta Dikes can be combined with other functions. In urban areas, for example, Delta Dikes can be combined with projects to renovate industrial and housing estates. Real space saving and improved physical quality can be achieved by accommodating infrastructure inside or on top of a dike.

1. *COMCOAST* is an experimental research project looking at new ways to plan and manage the coastal zone.
2. *Klimaatdijk* is a project in the research programme *Leven met Water* [Living with Water].

improvements to be signalled before the flood defence is no longer compliant. The measures can then be implemented in good time, so no backlog will occur.

The measures needed to increase the safety level in all diked areas by at least a factor of 10 must be implemented before 2050. The Delta Committee regards it as essential to achieve a deep cut in the probability or the consequences of sudden, uncontrollable floods where further considerations dictate that the safety level will have to be increased (perhaps by a wide margin) to prevent large numbers of casualties. At all times we must avoid large, deep breaches that allow great, violent inflows of water for a long time. For this the Committee recommends the Delta Dike concept: dikes that are so strong, due to their width, height or internal construction, that a sudden, uncontrollable flood is virtually excluded (see box 'Delta Dikes'). The way this concept will work out precisely in practice demands customised engineering, with attention to the consequences to be avoided and the characteristics and possibilities of the local flood defences. In each region a cost-effectiveness analysis must be performed to see how the necessary safety level can best be achieved.

Recommendation 1
Safety level

To 2050

The present safety levels of all diked areas must be improved by a factor of 10. Further refinement of the standards may lead to a higher safety improvement factor. This re-evaluation may lead to a lower factor only on very well substantiated grounds. The amended standards must be established as soon as possible (2013). Where safety needs to be increased by more than a factor of 10 (e.g. a factor of 100), the Delta Dike concept offers promise. This concept will have to be worked out further soon.

The measures needed to increase safety levels must be implemented before 2050. They must also, obviously, take account of anticipated climate change and the Delta Committee's long-term vision.

Post 2050

The safety levels must be regularly updated, linked to the EU Flood Risk Framework Directive. This may lead to a need for supplementary measures.

Temporary flooding nuisance

A higher level of safety can also be achieved by deploying effect-limiting measures besides higher and stronger flood defences and more space for water. These might include amending the building regulations, building on raised foundations, compartmentalisation and directing water away from (residential) centres via low dams. The Committee finds measures like these eminently suitable for countering the effects of flooding from regional waters and severe rainfall.

Building in the deep polders and on soft peat lands demands extra efforts to prevent nuisance and damage due to flooding of the drainage canals. Subsidence and climate change may lead to steep increases in the costs of constructing, managing and maintaining the infrastructure and buildings. The Committee does not unequivocally support a ban on building on these physically unfavourable locations. Space is scarce, after all. Decisions on new building plans, including large-scale reconstruction in these areas, must, however, be undertaken in light of an integral cost-benefit analysis. The costs originating

City wharves, Dordrecht

Urban Flood Management **(UFM)**

The Urban Flood Management project in Dordrecht, Hamburg and London is gathering knowledge about how to apply urban, sustainable flood management, where risk management is seen as part of the urban scene. Some of the basic themes here are building in the floodplains, risk management and cost-effectiveness. ‘Flood-proof’ building in the floodplains will allow innovative, attractive residential concepts to arise. The Dordrecht local authority has recently decided to build 1,000 to 12,000 dwellings along these lines.

from local decisions must not be passed on to a different administrative level, or to society as a whole. They must be borne by those who benefit.

The above considerations play a part in deliberations about site location, the arrangement of large-scale projects, regional development and investment programmes under the *National Space and Climate Adaptation Programme*.[40] The Committee believes that this sort of framework for comparative assessments is suitable and relevant and should be set up for regional and local assessments as well. It is important in this regard that the water manager is involved early on in the spatial planning so there can be no question of obligations being evaded.

Recommendation 2
New building plans

Decision-making on plans to build on physically unfavourable locations should be based on an integral cost-benefit analysis, to include all present and future costs for all parties. The Committee deems it undesirable to pass the costs of local decisions on to another administrative level, or to society as a whole: they must be borne by those who benefit.

In regard to climate-proofing, this principle must be brought within a wider decision-making framework than the provincial or local levels. The water managers must become involved early on so there can be no question of obligations being evaded.

Floodplains

The government can in principle offer no protection in the floodplains. These are after all areas outside the dikes, directly influenced by river discharge or the water level in lakes or the sea. Safety levels have been agreed for those parts of the coastal resorts that lie outside the dikes. These will be maintained by the government. No safety levels have been set down for the floodplains alongside rivers or lakes. It is the responsibility of residents and users themselves to adopt protective measures in these areas. The Committee finds that this rule must hold in any case for all new developments. The government can inform, advise, alarm and (if necessary) evacuate, and can impose building requirements, as has been done in the case of the Maasvlakte, for example. Given the part these areas play in water management, it is from this perspective that activities and developments there must be assessed, as in the *Beleidslijn voor de Rivier* [Policy guidance for the river]: the river's discharge capacity (or a possible future increase in the level of a lake) may not be impeded.

Within these limits, all kinds of different housing and business environments may grow in the floodplains. Artificial mounds in the areas with little flow are a tried and tested option. They can be created with material dredged up while maintaining the shipping channels and floodplain. Other options include floating dwellings or houses on stilts. If flooding is relatively shallow but also quite frequent, dwellings can be made waterproof so the water cannot penetrate into the house.

Recommendation 3
Floodplains

New developments in the floodplains may not restrict the river's discharge capacity or any future increase in the water level in a lake. Residents / users themselves are responsible for protective measures. The government plays a facilitating role in such areas as public information, advice and warnings.

North Sea Coast

The North Sea coast comprises the island headlands in the South-western Delta, the coast of Holland and the Wadden region. The Netherlands can continue to protect itself from rising sea levels by maintaining the coastal defences. In principle there are two possible solutions to this issue: 'hard' flood defences, such as storm surge barriers designed for a particular sea level rise, or beach nourishments to 'naturally' follow sea level rise (where necessary and desirable this can be combined with local, hard measures.)

Beach nourishment lies at the heart of our present coastal management and offers a good opportunity to develop with the climate. If the coast from Zeeland up to the Wadden region is to rise with the sea level, then 7 million m^3 of sand will be required for every millimetre of sea level rise.[41] A rise of 6-12 mm/year (i.e. 65–130 cm in 2100) thus requires 40–85 million m^3 of sand every year.

If this current approach of beach nourishment is intensified, adding more sand than is strictly needed for safety, then the coast will gradually expand. An extra sand volume of 40 million m^3/ year, for example, will widen the Holland and Zeeland North Sea coasts by approximately 1 km towards the North Sea over a century.[42] The beach must emphatically not be widened all at once, but gradually, leaving room for ecological processes and being in harmony with spatial planning.

A wider coast offers more space for nature, the quality of which has degraded greatly in the past 150 years. This could be recouped.[43] For that reason it is important to create open, varied, dynamic habitats for plants and animals, with the saline gradients that were present in the past. There will also be more space for recreation and the land can be used locally for high-grade, flood-proof buildings, so that existing coastal resorts can continue to exploit the advantages of their seaside location. Moreover, it would also be possible to construct an underground infrastructure to open up the coast permanently and relieve the rest of the network. A further advantage of a wider coast is a larger fresh water reserve in the dunes. This will also have a beneficial effect, cutting saline seepage. In short, a wider coast offers new opportunities and can make a significant contribution to an attractive Netherlands.[44]

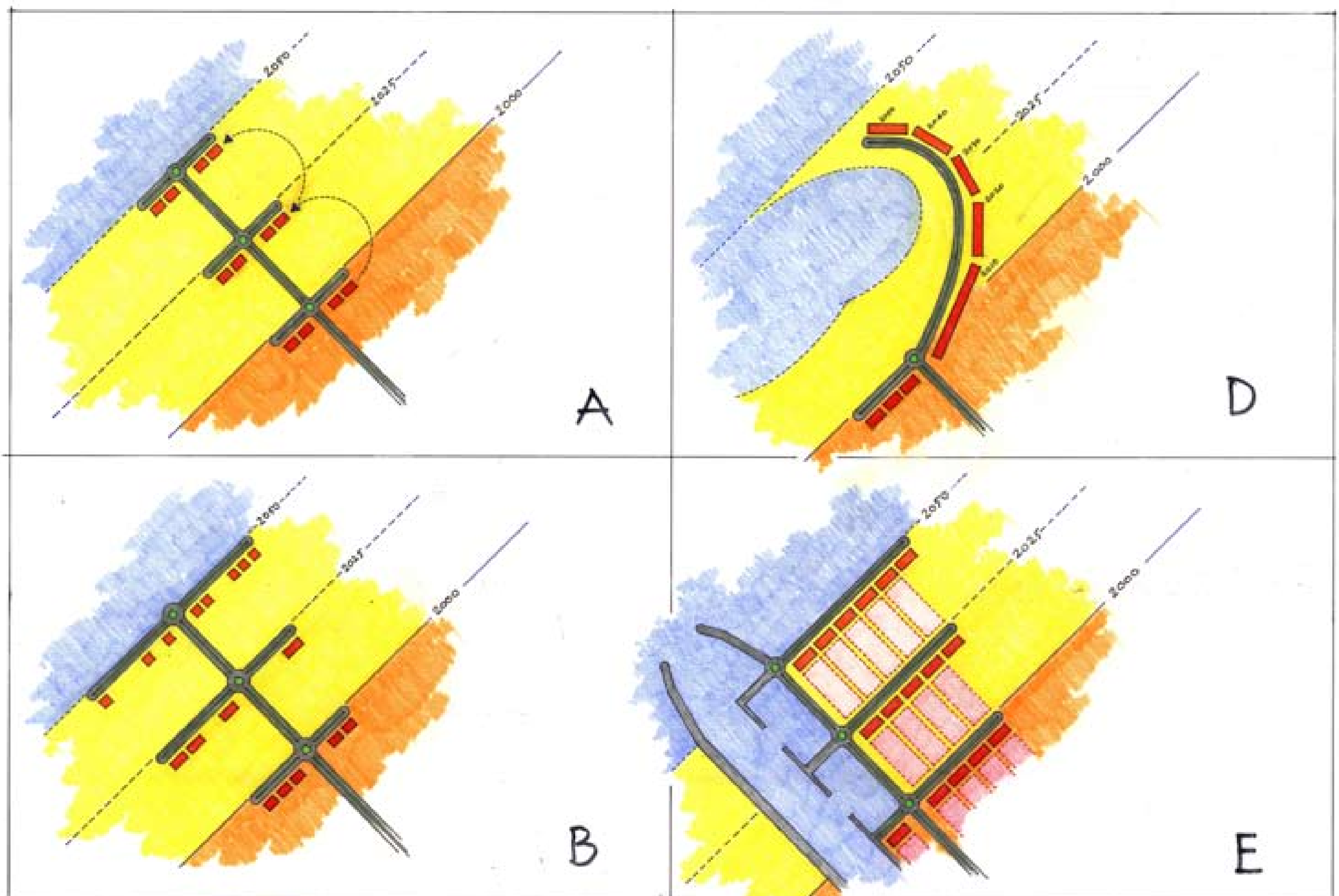
For safety reasons the Committee considers it wise to take a sea level rise of 130 cm in 2100 as a reference for the sand volumes to be nourished. These volumes can be adjusted if sea level rise turns out to be less high.

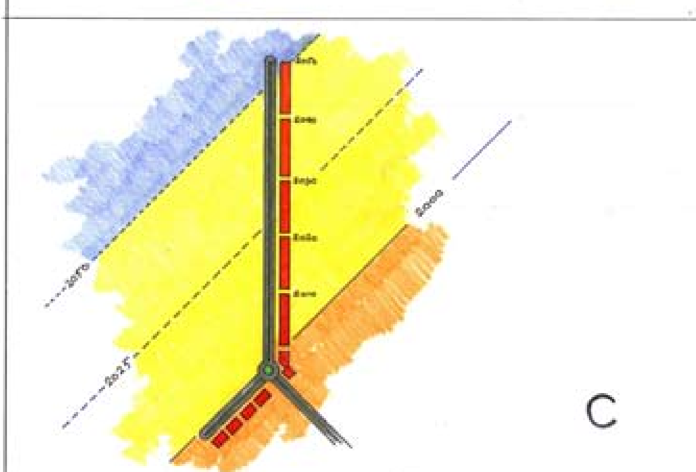
The Dutch part of the continental shelf has plenty of sand for these nourishments but the locations where the sand is to be dredged should be reserved in the next years in view of the ever increasing use of space on the North Sea. It should also be assessed if nourishments can be carried out without damaging nature, in accordance with current national and EU rules. The methods for dredging and transporting the sand could be made more energy saving and more ecologically sound by adopting technological improvements and a large-scale approach. This is particularly important if future nourishments have to be carried out on a large scale and for a long time. The possibilities to do so seem promising and further research, especially into the ecological consequences, is required.

The Committee has, of course, looked at the ideas for building islands off the coast. The Committee considered these ideas from the point of view of flood protection and flood risk management (see Appendix 5, ‘A closer look at islands and artificial reefs’). Islands restrict the wave action and set-up and can therefore have a mildly beneficial effect on coastal safety. Combined with deep channels and a carefully selected location, the height of the storm surge can be cut slightly. But, like the existing coast, the islands too will need protecting, leading to considerably more maintenance of the primary coastal defences. Flood protection must be maintained in areas where there are no islands. Moreover, the construction of islands or artificial reefs disturbs the natural recovery of the normal profile after a storm. It cannot be ruled out that islands may cause the coastal profile to become less stable, thus increasing coastal degradation. These aspects have led the Committee to opt for beach nourishment as the answer to flood protection along the coast.

One common reason for constructing islands is to create extra space, for example for facilities for which it is difficult to find room on shore, such as environmentally burdensome activities or shipping-related services, including an airport or energy storage. In principle, islands can also be used for agriculture and horticulture, as well as recreation, ecological development and housing. ‘Islands off the coast’ can thus create new opportunities. It is more cost-effective, though, to expand the coast via beach nourishment, which also offers possibilities for recreation, ecology and housing (expanding the coastal

Figure 7: 'Growing boulevards'
(Steef Buijs, Spatial development
sketches for the Delta Committee, 2008).





(a) '*Co-moving boulevard'* – movable buildings; collapsible, rolling or floating.
(b) *'Transparent screens'* – new boulevard with transparent buildings; old boulevard retains view and exposure to sun.
(c) *'Turned boulevard'* – bend present boulevard round to the north; carry on extending it to keep end in contact with sea.
(d) *'Bay boulevard'* – coastal expansion takes form of a shallow inland lake, existing boulevard can grow around it.
(e) *'Flight to the front'* – new boulevard laid far into the sea, like a pier that will later be overtaken by coastal expansion.

resorts). This is why the Committee responds to society's demand for more space for nature and recreation by choosing coastal expansion. The Committee has nothing to say about other functions.

Recommendation 4
North Sea Coast

To 2050

The Committee's choice is to 'build the coast with nature'. Coastal safety along the sandy shores of Zeeland, Holland and the Wadden Islands is maintained by beach nourishment. Tidal channels will be relocated where necessary. Until 2050 the Committee assumes that 85 million m^3/year of sand will be needed, i.e. that until 2050 sea level will rise by 12 mm/year.

To meet the needs of society, the Committee advises that beach nourishment be conducted on such a scale that the beach will grow in the coming century. This will deliver great added value to Dutch society.

Sand extraction sites will have to be reserved soon. Research must also be conducted soon to determine how such large volumes can be distributed as efficiently as possible in terms of the ecology, economy and energy efficiency.

Post 2050

Beach nourishment will be maintained or reduced, depending on the sea level rise. If it rises by less than 12 mm/year (1.30 m in 2100), then any surplus sand available at that time will contribute to extra coastal space, offering extra safety for the post 2050 period.

The Wadden Region

A rising sea level will alter the present natural character of the Wadden Sea.[45] This will take place because the large areas of tidal flats in the Wadden Sea can only follow the rising sea level if such a large quantity of sand is imported that is physically not realistic.[46] The Committee's proposed beach nourishment will satisfy part of the need for sediment import into the Wadden Sea basins. This will help the Wadden region and the valuable intertidal zones to grow with sea level rise.

On top of that, though, the Wadden Islands must be kept safe and inhabitable, so the flood defences of the island polders must be improved or else new arrangements must be made to make the area more flood-proof. The flood defences protecting the Northern Netherlands must also be well maintained.

Recommendation 5
Wadden Region

Given that the climate is changing, the continued existence of the Wadden Sea as we now know it is by no means certain. Beach nourishment along the North Sea Coast, however, will help the Wadden Region keep pace. Developments must be carefully observed and analysed. The Committee deems it important that this be done in an international context.

Protection of the Wadden island polders and the Northern Netherlands coast must be guaranteed.

The South-western Delta

The storm surge barrier in the Eastern Scheldt can cope with a sea level rise of 50 cm. Provided it is well maintained, the barrier will protect the hinterland until 2050 or thereabouts. After that time, additional measures will have to be taken, such as different closure schemes and closing the gaps between the gates and the sills, thus improving the barrier's defensive effect and extending its life span. It is expected that, with some modification, the Eastern Scheldt barrier will be able to 'resist' a sea level rise up to 1 m.

An additional point is that the ecosystem suffers from a restricted tidal flow due to the Eastern Scheldt barrier. In the absence of additional measures, the valuable intertidal zone will largely have disappeared under water before 2050 ('sand starvation'). While the Committee agrees that an Eastern Scheldt estuary with a smaller area of tidal flats is also a valuable system, it believes it is important that additional measures should be taken soon. These may take the form of beach nourishment, with sand being brought in from the outside to be spread on the eroding flats or along the dikes.47 The latter option will also make an immediate, valuable contribution to flood protection. In contrast to the Wadden, beach nourishment along the Zeeland coast does not contribute to sand import into the tidal basin, as the natural sand import is hindered by large scour holes seaward and landward of the barrier. To allow the valuable intertidal zones to keep pace in the long term, the Committee would like to see the tidal action in the Eastern Scheldt restored as far as possible. This can be done if safety options are sought that will restore the tidal dynamics as far as possible, at such time as the existing flood defence is no longer adequate. The Delta Committee prefers such an option, but does not wish, even if it could, to move ahead of such technological and ecological advances as may be available at that time. To keep the options for possible solutions open, decisions must be made several decades before the present barrier reaches the point that it no longer adequately protects the hinterland. If an open Eastern Scheldt (no storm surge barrier) is chosen, there will be time enough to reinforce the flood defences of the hinterland after all.

Recommendation 6
South-western Delta: Eastern Scheldt

To 2050 *The Eastern Scheldt storm surge barrier is adequate until at least 2050. The barrier's disadvantages (restricting tidal action) should be alleviated soon by compensating the losses in the intertidal zones with nourishment, bringing in sand from outside (from the shallows seaward of the Delta Works, for example).*

Post 2050 *Extend the life of the Eastern Scheldt storm surge barrier. This can be done up to a sea level rise of around 1 m. Estimates of maximum sea level rise give 2075 as the earliest year when this can occur, but it could happen as late as 2125 or thereabouts. After that time, measures must be taken to guarantee safety.*

At such time as the Eastern Scheldt barrier no longer suffices, the Committee can see good arguments for implementing such safety solutions as will restore (nearly) all the tidal dynamics of the Eastern Scheldt. Choices will have to be made several decades before the barrier reaches that point, so that the full range of options can be employed.

Since the freedom of shipping to Antwerp is a matter of international agreement, the Western Scheldt is the only coastal inlet in Zeeland that remains open to the sea. This makes the Western Scheldt the only completely open estuary in the South-western Netherlands, with valuable natural habitats like the Verdronken Land van Saeftinghe (a large area with brackish salt marshes). As the sea level rises, the defences along the Western Scheldt will have to be raised further to maintain adequate protection against flooding.[48] In this case, all designs will have to take account of possible sea level rise and increased tidal action.

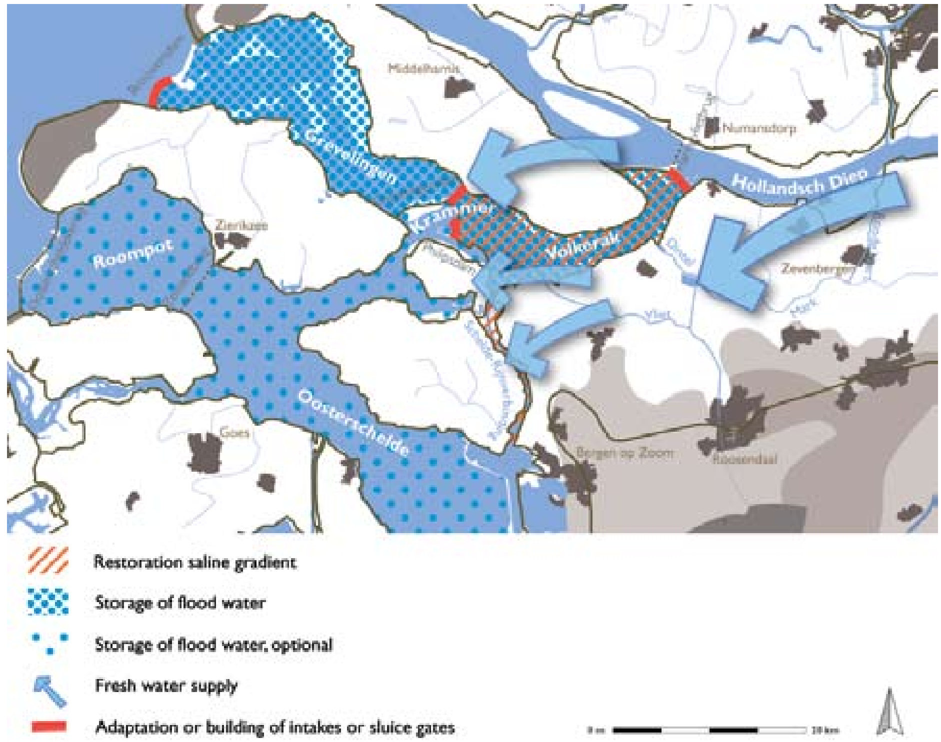
Recommendation 7
South-western Delta: Western Scheldt

The basic premise is that the Western Scheldt must be kept open to conserve its valuable estuarine character and maintain navigation to Antwerp. Safety must be preserved by strengthening the dikes.

Should the Rhine discharge peak simultaneously with a storm surge at sea, it will be necessary to use the Krammer-Volkerak Zoommeer lake and the Grevelingen, and possibly also the Eastern Scheldt, for the temporary storage or immediate discharge of excess water and so to protect the Drechtsteden and Rotterdam from flooding.[49]

The region also fulfils an important function in the fresh water supply for the South-western Netherlands (the agricultural and horticultural regions of West Brabant and the islands of Zeeland and South Holland). In the coming decades, eutrophication will continue to contribute to serious water quality problems, meaning that the fresh water supply function can be realised only to a limited extent. In order to tackle the water quality problem, plans are being considered to connect the lake to the Eastern Scheldt once again and restore the saline gradient. This will represent partial implementation of the *EU Water Framework Directive*.[50] Alternatives will have to be found for those areas that depend on the Krammer-Volkerak Zoommeer for their fresh water.

Figure 8: Measures planned for the Krammer-Volkerak Zoommeer.



Brouwersdam

Grevelingen

It would be better to allow the Brouwersdam on the sea side of the Grevelingen to let water through so that the tidal dynamics can be partially restored, which will improve water quality. This will primarily benefit the recovery of the Grevelingen's ecology, but can also be used to generate tidal electricity. The force of the water flowing in and out can drive turbines with a potential capacity of 60 MW.

Such alternatives can at least involve water savings due to improved irrigation / infiltration, bringing water from the Hollands Diep via the Roode Vaart, Mark and Vliet, and local storage in adjacent polders, possibly in combination with ecological development. The Committee deems the government responsible for realising the fresh water transport routes. These will be needed for the water supply in genuine drought conditions. Consumers may expect to pay a realistic price for this water. The Committee thinks it prudent that a realistic price for this water should be determined when looking at the Krammer-Volkerak Zoommeer situation. The Committee expects that this will encourage innovations not only in agriculture, but in water treatment (by producers and consumers) as well. The knowledge gained can be used in other parts of the Netherlands that are sources of alternative fresh water supplies.

Recommendation 8 To 2050

South-western Delta: Krammer–Volkerak Zoommeer

The Delta Committee recommends that arrangements be made for the temporary storage of river water in the Krammer-Volkerak Zoommeer, the Grevelingen and possibly also the Eastern Scheldt in situations where high river discharges coincide with closed storm surge barriers in the mouth of the Rhine (Rijnmond).

It is the Delta Committee's opinion that a freshwater-saline gradient in the Krammer-Volkerak Zoommeer represents a satisfactory solution to the water quality problems and can create new ecological opportunities. In this case, alternative fresh water supplies must be sought.

Prior to any action it will be necessary to investigate the discharge and inlet works that will be needed to combine this option with water storage and discharge at times of extremely high water levels. A realistic price for fresh water should also be looked at.

Rivers region

The current programme *Ruimte voor de Rivier* [Room for the River], aimed at increasing the discharge capacity of the Dutch Rhine, will result in the safe discharge of 16,000 m^3/s through the Rhine distributaries in 2015. Future (design) discharge of 18,000 m^3/s through the Rhine demands further measures in the river bed and floodplain of the IJssel and the Waal, as well as dike reinforcement along the IJssel, Waal and Merwede.[51] The necessary space has already been reserved. The Committee wants the short-term measures under the Room for the River programme to be implemented with dispatch. The Committee also wants to have the space reserved for greater discharges (based on existing plans for a Rhine design discharge of 18,000 m^3/s, and retaining the associated distribution of the discharge between the Rhine branches), while retaining the primary function of the floodplain, which is to discharge the river water. The necessary land can possibly be reserved under a permanent preference right, which will allow the water manager to actually acquire the land at such time as the owner is prepared to sell it. Besides reservation, the government can also acquire strategic land positions by purchasing land as the opportunity arises.

Where possible, both the current programme and further spatial planning initiatives, where suitable, must now anticipate a maximum river discharge of 18,000 m^3/s. The Committee presumes in this regard that the same physical quality conditions will apply in principle as those in the present Room for the River programme.

Germany will have to implement measures (as yet unplanned and very extensive) to prevent or limit flooding at considerably higher Rhine discharges. Raising the height of the dikes along the entire Cologne–Dusseldorf / Duisburg line, as well as the Upper Rhine, is regarded as unlikely, partly due to technical difficulties. It is more likely that retention areas will be expanded, with individual protection for special objects.[52] In other words, the Committee regards it as very unlikely that discharges greater than 18,000 m^3/s will reach the Netherlands in the medium term. Moreover, the *EU Framework Directive on Flood Protection* demands that Germany and the Netherlands consult before radical measures can be started in Germany. This is important, too, because floods in Germany let water into the Netherlands 'by the back door'. Water that overtops the dikes in Germany flows overland into the Netherlands, leading to considerable damage there. Over the very long term, discharge rates greater than 18,000 m^3/s cannot be entirely ruled out. In that case, the Committee can imagine that the discharge would be led principally through the Waal and the South-western Delta. This would require major modifications, which will have to be considered carefully at that time.

Turning now to the Meuse, measures in addition to the *Maaswerken* [Meuse Works] are needed to cope safely with a design discharge of 4,600 m^3/s. There is a regional vision of the future available (*Integrale Verkenning Maas 2, IVM2:* Integrated assessment of the Meuse 2). Similar to the case of the Rhine and in anticipation of climate change, the Committee deems it necessary to make preparations to develop IVM2 further, both technically and financially, together with the regional parties. Where possible, the Meuse Works must now anticipate the discharge of 4,600 m^3/s.

The River Meuse in Rotterdam

Zandmaas development

The Committee urges the formation of closer links between water safety and other development projects. An example is the *Zandmaas 2 Long-Term Plan*, which covers the region of the Meuse from Roermond to Afferden, in Limburg Province.

This plan, drawn up by Limburg Province, is based on a broad development of the area, in aid of flood protection, flood risk management, ecological development, agriculture, horticulture, recreation, residence and mineral extraction. Where possible the plan links up with private initiatives. If this plan is implemented, the long-term goals of the *Integrale Verkenning Maas* [Integral Exploration Meuse] – a design discharge through the Meuse of 4,600 m^3/s – can be achieved at far lower costs to the government.

A pro-active approach like this can save significant costs in the long run, while being able to count on wider support as it achieves other, different social objectives as well.

This sort of anticipatory approach, however, does not fit in with the national government's financial policy. At present, government only make funds available when a high water incident – whether or not it is accompanied by flooding – leads to an increase in the standard (after which, the standard must be met within a very short period of time).

Flood risk management plans

The *EU Directive on the Assessment and Management of Flood Risk* went into effect in Autumn 2007. The *Directive's* goal is to reduce the numbers of casualties and the financial consequences of floods. One way this has to be done is by drafting flood risk management plans, which set down for every river basin 'adequate targets for management of the flood risks' plus the measures that have to be taken to achieve the agreed level of protection. An important precondition is that measures must not lead to an aggravated flood risk in areas either upstream or downstream.

The flood risk management plans must be complete by 22 December 2015 at the latest. Thereafter, the plans must be assessed every six years and amended if necessary.

Ecopolder, an innovative way to deal with salination

The salination of surface and ground water is a problem for present users. In its report, the Committee envisions good quality surface water. However, saline seepage and salination of the ground water is difficult to combat. Innovative work is being done here in the Ecopolder project, which is part of the *Leven met Water* [Living with Water] project. An Ecopolder is being created to the south of Amsterdam, based on the *cradle-to-cradle* principle. A variety of technologies and processes are linked together in an integral, multifunctional approach to provide cost-effective solutions in such areas as water, the environment, waste, and energy.

In the Ecopolder, saline seepage water is pumped up through wells and desalinated to give grey water. This means the water board has to flush less frequently (saving money) and the water quality improves. The energy for desalination is extracted from the Amsterdam Waste Incinerator. The desalination residue (brine) is evaporated using residual heat to give dry salt, which can be used on icy roads. Biogas (methane) from the ground water can also be used to produce energy. The methane can also be extracted from domestic waste (and agricultural waste) via a fermentation plant.

Recommendation 9 **Rivers region**	To 2050	*The Room for the River and Meuse Works programmes must be carried out without delay. Where it is cost-effective, measures must be immediately implemented to cope with discharges of 18,000 m³/s through the Rhine and 4,600 m³/s through the Meuse.* *It is necessary to consult with neighbouring countries to co-ordinate measures under the EU Directive on the Assessment and Management of Flood Risk.* *Space must be reserved and, where necessary, strategic land positions must be taken to allow the river system to cope safely with discharges of 18,000 m³/s and 4,600 m³/s through the Rhine and Meuse, respectively. The possibility of establishing a permanent preference right must be looked into.* *Similar to the case of the Rhine and in anticipation of climate change, the Committee deems it necessary to make preparations in co-operation with the regional parties to develop IVM2 further*
	2050 - 2100	*Completion of extra measures needed to allow the Rhine to cope with 18,000 m³/s and the Meuse with 4,600 m³/s.*
	Post 2100	*It cannot be ruled out that the Rhine discharge may rise above 18,000 m³/s over the very long term. In such a case the Committee can envision using the Waal and the South-western Delta to discharge the excess water volumes.*

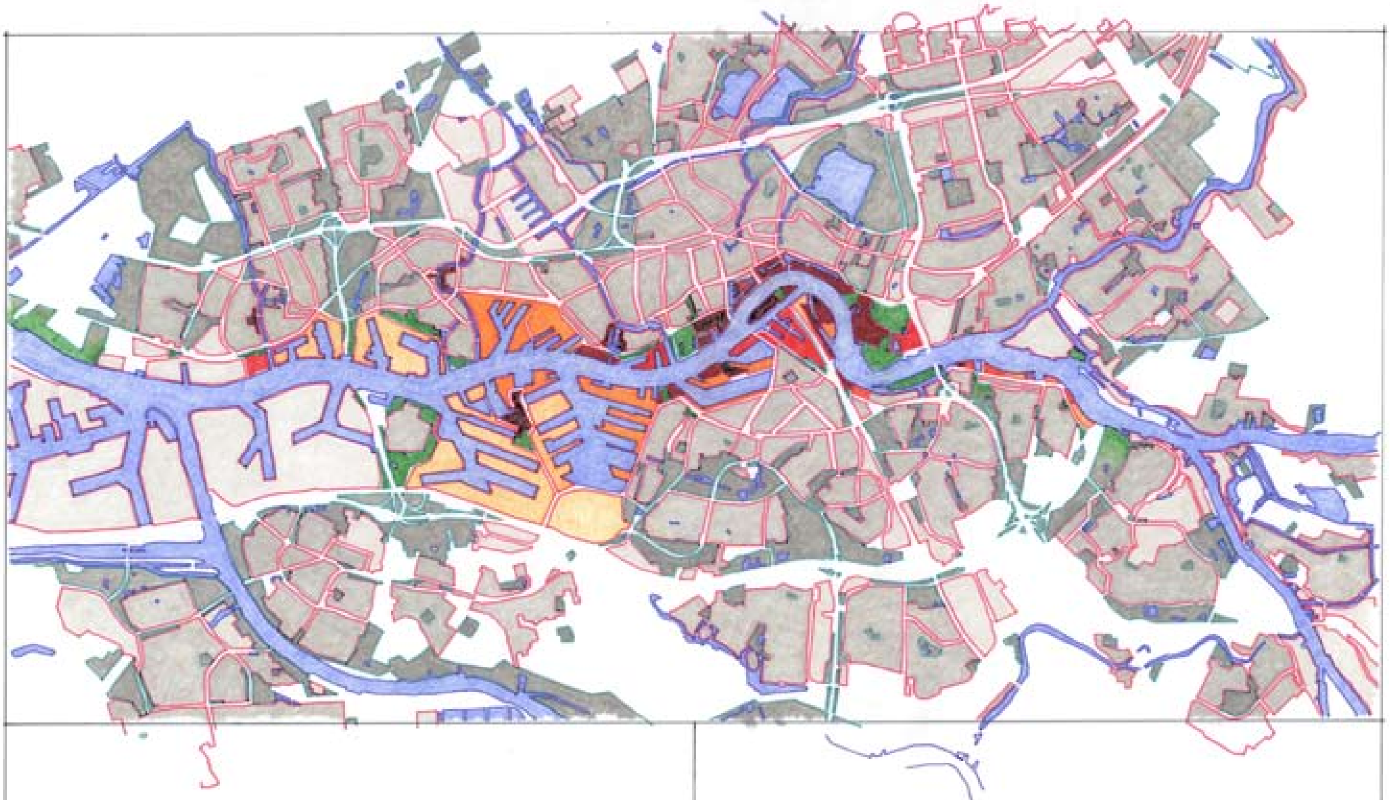
Rijnmond

The task in the Rijnmond and Drechtsteden region (the area around the mouth of the Rhine and its hinterland) can be simply summarised: how can the region be protected against floods in both the rivers and the sea and how can the adverse effects of salination be avoided? The Maeslantkering storm surge barrier has been designed to cope with a 50 cm sea level rise. There is no safety problem envisaged until 2050. Thereafter the closure frequency may rise, with an increasing probability that closure will coincide with high river discharge, which will in turn lead to more frequent high water levels in the downstream region (behind the barrier).

Future flood safety can be assured in this region in a number of ways. One option is to reinforce the dikes, possibly combined with a completely open Nieuwe Waterweg and Haringvliet. Recent history has shown that this is very difficult and expensive in this highly urbanised area. Moreover, it does not help to protect the floodplains, of which there are many here, which are used for housing and other activities. One might also choose to close the Nieuwe Waterweg permanently. This would be very beneficial to the fresh water supply and urban development. It also offers a prospect for osmotic energy generation. This option is not beneficial to the natural system, though, and would be a great hindrance to shipping.

The Committee can see a third option: one that combines the advantages of the other two while limiting their disadvantages. This variant involves keeping the Rijnmond region 'closable open'. At extremely high storm surge levels at sea the region would be closed off by the Maeslant and Hartel storm surge barriers

Figure 9: Waterfronts (Steef Buijs, Spatial development sketches for the Delta Committee, 2008).



Redevelopment of the obsolete docks and industrial areas along the Nieuwe Maas in Rotterdam started as long ago as 1970. The ‘closable-open’ option that was chosen retained the dynamic relationship between these areas and the water, while redevelopment of the Waalhaven-Eemhaven area, the Merwedehaven, and the docks in Schiedam and Vlaardingen could be continued according to plan. This marked the start of a new era, offering ample capacity to continue developing at the same pace for another 40 years, with new facilities for creative industries and the ‘leisure’ market. Today, these are crucial segments of the economy for the city as a whole, and they flourish extraordinarily well in such areas, with great industrial heritage sites, proximity to the city centre, excellent accessibility and a wide-open panorama over the river.

historical waterfronts and water related centres

waterfront (re)development
mainly development area for urban renewal

broader function for urban renewal – next to housing also much working

increasing focus on creative sector

depending on further westward harbour development

river related parks

and the Haringvliet sluices, possibly combined with additional, closable flood gates in the Spui, Old Meuse, Dordtse Kil and Merwede. This would need less dike reinforcement, while the entire system would function as a diked area, thus offering new prospects for high-quality development in the region.

Under such conditions the river water will have to be stored in extra retention areas in the Krammer-Volkerak Zoommeer and possibly the Grevelingen. Since the Port of Rotterdam will develop increasingly on the Maasvlakten, this variant will offer many new prospects in the Rijnmond region for urban waterfront developments (attractive housing environments, see Figure 9) and natural areas in the floodplains. Ways to divert the Lek waters will have to be looked at, as will the closure of the Rijnmond, to see whether it can remain partially open or will have to be closed off completely, in combination with the water storage available in the Rijnmond region.

Salt water intrusion via the Nieuwe Waterweg will no longer be counteracted with great quantities of river water. Fresh water intakes will be moved where necessary, whereas innovative ways to treat salt water may contribute to fresh water supply. Fresh water for the Western Netherlands will then have to be supplied from the IJsselmeer lake and possibly from local storage.

This option will afford more room for the natural tidal dynamics in the Rijnmond region, while also recalling that the area is a vulnerable one, which cannot be left exposed in an uncontrolled way to storm surges at sea and high river discharge. This 'closable open' Rijnmond has many advantages and there is no need to wait until 2050 to start construction. Further research should be initiated soon to develop possible plans and carefully document the benefits and disadvantages. This should also look at possible management and maintenance strategies. Figure 10 illustrates one possible design of the 'closable open' variant.

Recommendation 10
Rijnmond

Tot 2050

A 'closable open' Rijnmond offers good prospects for future-proofing the area in a number of ways, including flood protection, fresh water supply, urban development and nature. The Committee recommends that this should be examined soon.

The water needed for the Western Netherlands will have to be drawn from the IJsselmeer lake, which will require modifications to the infrastructure. More space will also have to be found for water storage in deep reclaimed lake beds. The fresh water supply for the Rijnmond region must be part of the investigation.

Figure 10: Possible design for the 'closable-open' option in the Rijnmond region (Ties Rijcken, Delft University, 2008)

Closable open

The Rijnmond region (mouth of the Rhine area) will be protected by flood defences from both the sea and the river. Figure 10 sketches a possible design. Further research will have to determine the best way to implement the 'closable open' option.

In this variant, the sluices in the Haringvliet are normally open, except during storm surges. This will allow the fresh-saline water gradient to return in the Haringvliet to such an extent that the Spui remains available as a fresh water inlet when the river discharge is low. Combined with tidal water level changes, this offers good prospects for ecological recovery. It would be possible to generate tidal energy at the Haringvliet sluices.

When the river discharge is low, the salt wedge in the Nieuwe Waterweg will penetrate further inland, threatening South Holland with salination. Agriculture and horticulture can be compensated by admitting water from the IJsselmeer lake, but this will require the infrastructure to be modified. In addition to the possibility of drawing fresh water from the Spui, other supplies will have to be found, as necessary. The fresh water may also possibly be supplied by local storage in old, deep polders. This sort of storage can also be used to relieve flooding and can be combined with house building and ecological development.

IJsselmeer region

The closure of the Zuiderzee, which lead to the creation of the IJsselmeer lake in the first half of the 20th century, involved a strategic choice in favour of an integrated water management system in the Netherlands, one that has brought great benefits. The IJsselmeer region can continue to perform its role as strategic fresh water reserve provided, of course, that the *Afsluitdijk* [IJsselmeer dam] remains closed, the IJsselmeer lake is filled to capacity early in the year, and the management strategy is changed. This, combined with a higher summer level than the present one, provides more fresh water to those areas that depend on the IJsselmeer lake. There will be no need to discharge extra Rhine water through the IJssel and the existing low-water discharge distribution over the Rhine branches can be maintained. A more dynamic water level is also good for nature. The first problems become manifest when the summer level sinks by about 20 cm below the present summer target level. This hinders the intake of water from the IJsselmeer region into the surrounding areas, North Holland in particular, which is then no longer possible without pumping. If the level were to drop even further there would be problems for shipping and recreation, the shallower system would become more sensitive to water quality problems, and problems might arise in connection with the stability of the flood defences.

In the most extreme KNMI scenario, after 2050 the present variable-level strategy will not be adequate to continue to supply the Northern and Western Netherlands with enough water for their needs (this excludes the South-western Delta). While the situation will not occur frequently, climate change does increase the probability of water shortages. The Committee's preference is to allow the water level in the IJsselmeer lake to rise with the sea level in order to retain the maximum possible future flexibility for the strategic freshwater reserve. The most extreme summer drought will require a 'water slice' of at most 1.1 m in the IJsselmeer region. If the Markermeer lake is omitted, this works out at 1.5 m. Placing all our bets on a drop of 1.1 or 1.5 m gives less flexibility, however, and also brings a number of significant disadvantages for the economy (recreation and shipping) and ecology (water quality).[53] Higher levels also have their disadvantages: modifications must be made to flood defences, docks, pumping stations in surrounding areas, and existing buildings outside the dikes. The costs of pumping to drain the surrounding areas will also increase.

Maintaining the IJsselmeer lake as a body of fresh water implies that the Afsluitdijk must be maintained as a hard boundary between fresh and salt water. This offers prospects for energy generation: the Committee encourages the planned experiments, provided they do not greatly influence the IJsselmeer lake's storage function.

An elevated water level is also important in regard to coping with excess water in the IJsselmeer lake. Currently, the IJsselmeer lake discharges freely into the Wadden Sea at low tide. Extra discharge capacity (sluices in the Afsluitdijk) in view of sea level rise will allow this to be continued until at least the middle of this century. The choice thereafter is either pumping or raising the water level in the IJsselmeer lake and thus following sea level rise. Pumping will allow the present level to be maintained. The lake level cannot rise without limit, as this will affect the surrounding areas, so pumping will inevitably have to be started at some point.

The IJsselmeerdam at Den Oever

Fresh-Salt Energy

A new development, combining sustainable energy with water, generates energy from the difference between salt and fresh water. This can generate electricity due to the charge difference between salt and fresh water, using osmosis. The technique uses a membrane to separate fresh from salt water. The membrane allows water through, but not ions. The differences in ionic concentration can be used to generate electricity. The only waste product is brackish water, which is discharged into the sea. Two conditions are needed for a power station based on this principle. First, both fresh and salt water must be present; second, there must be a guaranteed, adequate supply of fresh water (the plant needs about 2 m^3/s of fresh water per MWh). If these preconditions are satisfied, then this sustainable source of energy in principle offers the great advantage of a continuous, on-demand electricity supply. A study is now being conducted into the possibility of a future 'fresh-salt' generator (200 MW max.) near the IJsselmeer dam. If this were to be built, it would supply approximately 1% of all power generated in the Netherlands, which would be enough, for instance, to cover the electricity demand of the entire water management sector: pumps, dikes, and pumping stations. It is an inviting prospect: the flood defences as a source of energy.

Starting to pump right now, though, so the IJsselmeer lake level does not have to be raised, has significant disadvantages. Pumping while maintaining the water level is not a satisfactory answer to the IJsselmeer lake's function as a strategic fresh water reserve. Furthermore, starting pumping operations now would result in new developments throughout the entire region being planned based on the present water level. At some future point this would lead to even greater problems if it were decided to raise the water level anyway. Moreover, pumping costs increase considerably as sea level rises. Nor does this strategy fit in with the Committee's vision of developing with natural events as far as possible, i.e. rising with sea level for as long as possible and thus allowing for free discharge at low tide into the Wadden Sea.

What a higher level does mean is that the entire IJsselmeer region (both inside and outside the dikes) will have to develop simultaneously: areas outside the dikes (including some beautiful little harbours) will flood more frequently, for which flood-proofing arrangements will have to be made. Building regulations will be needed for areas outside the dikes (new buildings must float or be flood-proof). Flood defences must be raised and the diked areas will suffer more from phosphate-rich seepage water. They will also experience greater difficulty in draining their excess water into the higher IJsselmeer lake. This will demand extra pumping capacity and/or storage areas in the surrounding polders.[54]

An elevated water level in the IJsselmeer lake will require extra measures to manage high water levels in the downstream reaches of the IJssel and the Zwarte Water. A lake level rise of more than 1.5 m will require radical, expensive dike reinforcement along long stretches of the IJssel's lower reaches (as far as Zwolle).

In terms of water management, the Markermeer is separated from the IJssel and IJsselmeer lake by the Houtribdijk and its sluices, so it plays only a subordinate role in coping with excess water. There is no need to raise the level of the Markermeer as well. This has the advantage that, once the backlog of flood defence measures has been cleared, the defences in that part of the North Holland coastline (which have high landscape value) will not have to be reinforced again. The salination problem in North Holland will also be kept under control.55 Furthermore, a clearly defined water level in the Markermeer will afford clarity for urban development in Amsterdam and Almere.

All in all, the Committee opts for a water level rise in the IJsselmeer lake only. The importance of a strategic fresh water reserve and the ability to discharge into the Wadden Sea for as long as possible without depending on pumps, in the Committee's view, outweighs the disadvantages (and higher costs) of the higher water level. A 'water slice' of at most 1.5 m is needed as a fresh water reserve. If the level were to rise by more than 1.5 m, it would have major disadvantages for the downstream reaches of the IJssel and the Zwarte Water. To create the greatest possible flexibility, the Committee therefore opts for 1.5 m as the maximum water level rise.

Recommendation 11
IJsselmeer region

The Committee's preference is for a higher water level in the IJsselmeer lake of at most 1.5 m so that discharge into the Wadden Sea can be continued for as long as possible without pumping. This will help retain the greatest possible flexibility in respect of the fresh water supply.

The IJsselmeer lake will retain its function as fresh water reservoir for the Northern Netherlands and North Holland. In the face of the penetrating salt wedge in the Nieuwe Waterweg, it will also supply the Western Netherlands. The level in the Markermeer lake will not be raised.

Tot 2050

A study should be made of the measures needed to adapt the lower reaches of the IJssel and Zwarte Water to a 1.5 m higher water level in the IJsselmeer lake.

The goal is to have the greatest possible fresh water reserve available around 2050. The measures needed to facilitate the water level rise can be implemented gradually. A phased approach may be chosen, with a combination of raised and lowered levels.

Measures planned for the near future, such as improving the Houtribdijk, must be carried out according to the Delta Committee's vision.

Post 2050

Depending on the phased approach, the measures leading to a 1.5 m water level rise will have to be completed.

If sea level rises by more than approximately 2 m, the water will have to be pumped from the IJsselmeer lake into the Wadden Sea. This situation will not arise before 2100 in any case.

Shipping

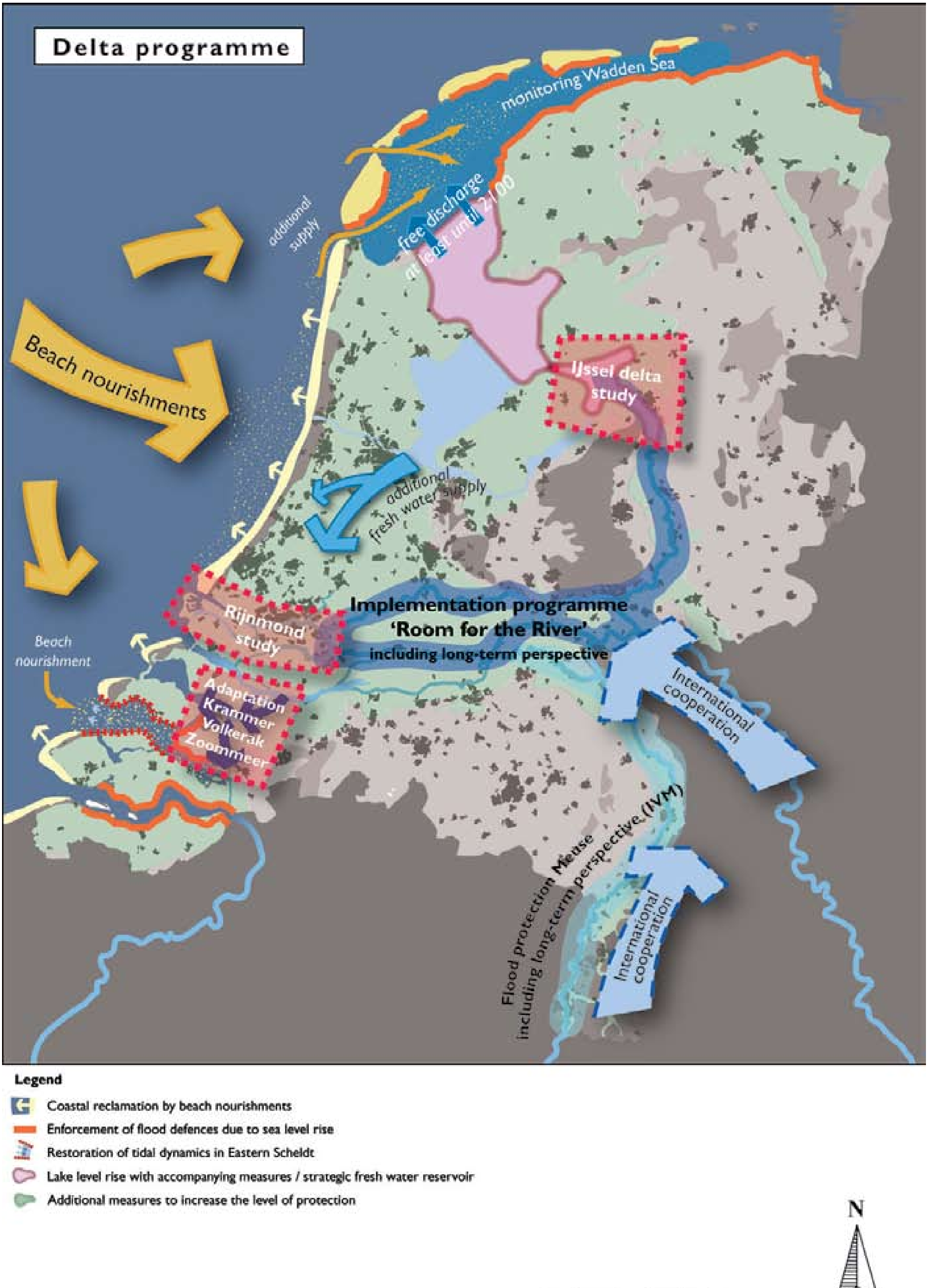
Under extreme climate scenarios with long periods of drought, shipping will experience frequent difficulty from low river discharges. Droughts like that of 2003 might become average summers, which will pose problems. The channel depth can be improved by laying down longitudinal dams along the groynes, thus narrowing the shipping channel. In addition, the Committee deems it sensible that shipping and (other) sectors of the transport industry should prepare for long periods of drought by building ships of shallower draft and adopting other technological measures. Furthermore, the Committee thinks it is sensible to move towards combinations of multimodal transportation facilities. This can be anticipated when new entrepot docks and transfer facilities are built, where possible in association with flood risk management measures.

Even far into the future, the Netherlands will remain a major European port of entry. The Committee deems it sensible to study this topic in greater detail, preferably in an international context.

Drought on high ground

Water from the rivers and the IJsselmeer lake cannot provide all of the Netherlands with sufficient fresh water. In the future, fresh water will increasingly become a far scarcer good than it is now, especially in summer. This requires society to change the way it treats water. As with all scarce goods, we shall have to be far more frugal in our use of it. The potential rewards are great. The Committee's desire to see a realistic price for water should be seen in this context, specifically where measures have to be taken to secure the fresh water supply.

In addition, local and regional (rain) water storage must be improved on the high ground in the Eastern and Southern Netherlands. This can be done by constructing local basins or by rearranging dales so that water is retained longer in the valleys. This will also create space for nature and recreation. Nature will thus be made more 'resistant' to extreme conditions. This is important, certainly in times of climate change, when vulnerable ecosystems come under pressure from higher temperatures, different patterns of precipitation, and changes in the (ground) water budget. Appropriate measures are contained in the programmes *Investeringsprogramma Landelijk Gebied* [Countryside Investment Programme] and *Kaderrichtlijn Water* and *Waterbeheer 21e Eeuw* [Water Framework Directive and 21st Century Water Management]. In time of drought the local storage can also fail. In aid of agriculture and horticulture it therefore appears sensible to the Committee to look at existing water transport routes to see if they can be improved or brought back into use.



Delta programme
monitoring Wadden Sea
free discharge
at least until 2100
additional supply
Beach nourishments
IJssel delta study
additional fresh water supply
Rijnmond study
Implementation programme
'Room for the River'
including long-term perspective
Beach nourishment
Adaptation Krammer Volkerak Zoommeer
International cooperation
Flood protection Meuse including long-term perspective (IVM)
International cooperation
Legend
Coastal reclamation by beach nourishments
Enforcement of flood defences due to sea level rise
Restoration of tidal dynamics in Eastern Scheldt
Lake level rise with accompanying measures / strategic fresh water reservoir
Additional measures to increase the level of protection
N
0 km
50 km

Figure 11: Measures under the Delta Programme

North Sea

The North Sea offers many opportunities for integrated development, such as energy generation from tide or wind, or seaweed and algal production. The sustainable development of fish farming and aquaculture also offers promise. Islands may possibly play a role in these functions. The Committee recognises the possibilities of integrated development in the North Sea, but given its mandate makes no further recommendations on the subject.

As already indicated, though, sand extraction locations must be reserved so that sufficient sand is available for beach nourishment.

Cost

Implementation of the entire package of measures proposed by the Delta Committee – the *Delta Programme* – will cost 1.2–1.6 billion euros per annum to 2050 and 0.9–1.5 billion euros per annum in the period 2050–2100. This is on top of the budgets already reserved for bringing the flood defences in order so they comply with the present flood safety standards. The Committee assumes that the present programmes *Ruimte voor de Rivier, Zwakke Schakels, Maaswerken, Zeeweringen* and *Hoogwaterbeschermingsprogramma* [Room for the River, Weak Links, Meuse Works, Sea Defences and the Flood Protection Programme] will be carried out.

The summary does not include the annual sums for maintenance and management in relation to flood protection and the fresh water supply. At present, these add up to approximately 1.2 billion euros per annum for central government, the water boards and the provinces.[56] The total costs of growing with the climate and ensuring improved protection are 2.4–2.8 billion euros per annum up to 2050.

A supplementary sum of 0.1–0.3 billion euros per annum will be required if the *Delta Programme's* beach nourishment for flood protection is expanded so that a hundred years from now the North Sea coast of Holland and Zeeland is widened by, for instance, 1 km to create space for recreation, nature and other functions. This brings the costs of the *Delta Programme* for the period 2010–2050 to 1.3–1.9 billion euros per annum, while for 2050–2100 it is 1.2–1.8 billion euros per annum. Including management and maintenance, the total costs of growing with the climate and ensuring improved protection add up to 2.5–3.1 billion euros per annum to 2050.

It should be noted, though, that all the sums mentioned are only an indication of the costs of the *Delta Programme*.[57] The rate and the effects of climate change must be monitored. New knowledge may lead to changes in the way the measures are implemented, which can impact on the costs presented here.

Indicated extra cost per annum [€ billion]	**Period**		**Average**
	2010 - 2050	**2050 - 2100**	**2010 - 2100**
Delta Programme	1,2 to 1,6	0,9 to 1,5	1,0 to 1,5
Delta Programme with extra space for other functions on the coast	1,3 to 1,9	1,2 to 1,8	1,2 to 1,8

Monetary amounts in 2007 euros including BTW [Dutch Value Added Tax]

Decision making needs both vision and cost-benefit analysis[I]

Many a politician, lobbyist, civil servant and scientist believes that social cost-benefit analyses[1] leave too little room for human creativity and daring. Such critics emphasise the importance of vision. They contend that important decisions cannot be based solely on lists of costs and benefits expressed in cash terms. Major projects like the Afsluitdijk, the Nieuwe Waterweg and the North Sea Canal would never have got off the ground if they were decided on the basis of a cost-benefit analysis.[2] Another objection is that major social interests – such as casualties and loss of landscape, culture and ecological value, and the value of freshwater in 2100 – are difficult to express in cash terms and so are not adequately expressed in a cost-benefit analysis.

These ‘visionaries’ are opposed by the proponents of cost-benefit analysis: the ‘accountants’. Their criticism is that visions often rest on wish-fulfilment (dreams), presented as facts. A project’s proponents are not clear about the problem the project is supposed to solve. They are insufficiently aware of alternatives, many of which may be more efficient. A cost-benefit analysis with an adverse outcome is often rejected a priori.

What this contradiction fails to make clear is that visions and cost-benefit analyses both have their own role to play in decision-making. Visions of the future development of the Netherlands generate ideas for possible projects, while cost-benefit analyses force one to be concrete, thus allowing projects to be compared and assessed according to their costs and benefits to society. Thus can one distinguish between opportune ideas and castles in the air. But a cost-benefit analysis cannot be used as a hanging judge. Good political choices depend on both visions and calculations.

1. Taken from Savelberg, ‘t Hoen and Koopmans, 2008: *De schijntegenstelling tussen visie en kosten-baten analyse* [The apparent contrast between vision and cost-benefit analysis].
2. A cost-benefit analysis (CBA) lists all benefits and disadvantages to society. These are expressed in cash terms as far as possible, for both tangible and intangible goods and services, such as an unpolluted environment. A CBA answers the question whether prosperity resulting from a project is an increase over autonomous development (positive balance of benefits over costs). A CBA helps to assess whether a project is sensible (useful and necessary), to compare projects / variants, and to improve projects.
3. Cost-benefit analyses have their limitations if they are applied over a period of 50–100 years ahead. A CBA is actually a simple sum, where costs and benefits are expressed in market value. To do this, the project needs to be worked out in sufficient detail and it must be possible to set the sum off against a future in which the project is not undertaken. This is fundamentally difficult if we look at a Delta time frame of one to two centuries. The prosperity accruing from a project represents the difference between growth with and without the project. The calculation fails when the path to growth, in this case the *Delta Programme*, changes. Secondly, there are major uncertainties, even over a decade; even more so for a century. It is practically certain that unforeseen events will occur and it is impossible to cover all the complex interrelationships and forces at work. Thirdly, projects cannot suddenly be stood on their heads. If circumstances turn unfavourable it is not easy to recoup investments already made. Fourthly, one must also anticipate the sizeable physical and financial reserves needed to offer the possibility to take advantage of new, possibly unexpected developments. Such reserves can only be used once, and thus they too influence the future.

39. New insights into the Hydraulic Boundary Conditions for the Wadden coast in 2011 may soon necessitate a further round of reinforcements of the Friesland-Groningen mainland flood defences, meaning that the backlog will only increase.
40. The Nationaal adaptatieprogramma ruimte en klimaat [National Space and Climate Adaptation Programme] involves co-operation between central government, the provinces, local authorities and water boards. It seeks to develop a strategy for climate-proofing the spatial planning of the Netherlands.
41. Rijkswaterstaat / Deltares: *Beantwoording Kennisvragen Deltacommissie* [Response to Delta Committee's request for knowledge]. Summary, 2008.
42. Derived from *Economische analyse Kustbeleid* [Economic analysis of Coastal Policy], rapport fase 2 verkenning ex ante [Report phase 2, ex ante assessment], drafted by Rebelgroup, Witteveen & Bos and Rijkswaterstaat RIKZ, 2007.
43. See also *Kust, ruimte voor mensen én vogels* [The Coast, room for people *and* birds]. Volgelbescherming, 2008.
44. Rijkswaterstaat / Deltares: *Beantwoording Kennisvragen Deltacommissie* [Response to Delta Committee's request for knowledge]. Summary, 2008.
45. Van Goor, M.A., Zitman, T.J., Wang, Z.B. and Stive, M.J.F., 2003. 'Impact of sea level rise on the morphological equilibrium state of tidal inlets.' *Marine Geology*, 202 (3–4), 211–227.
46. In smaller tidal basins, such as the Eierlandse Gat, a sea level rise of 1 m a century implies a 30% linear reduction of mud flat area. The shallows in larger basins, such as the Amelandse Zeegat, even decrease linearly by as much as 40% with a sea level rise of 0.6 m a century. In both small and large basins, mudflat area declines exponentially thereafter. Mudflats will disappear altogether if the sea level rises by a further 0.5 m a century (in excess of the 1.0 and 0.6 m a century already named).
47. In the Committee's view this would involve a sand volume of 3 million m^3/year, based on Rijkswaterstaat / Deltares: *Beantwoording Kennisvragen Deltacommissie* [Response to Delta Committee's request for knowledge]. Summary, 2008.
48. It has been estimated that raising these dikes by 50, 150 and 300 cm would cost 3.5, 5.5, and 10 million euros a kilometer, respectively. Total length involved: 140 km.
49. This will also require drainage conduits in the form of sluice gates from the Krammer-Volkerak Zoommeer to Grevelingen (and the Eastern Scheldt). In the rare cases when these have to be opened, the inflow of large quantities of fresh water into the saline Grevelingen or Eastern Scheldt estuary will have a marked ecological impact. The Committee regards this as acceptable when seen in the light of flood protection, the infrequency of occurrence, and the fact that the ecosystem will be able to recuperate.
50. This can be done by opening the dams at the Krammer sluices into the Eastern Scheldt, allowing salt water to flow once again. This would also to some extent restore the original tidal dynamics (insofar as permitted in view of the shipping between Antwerp and Rotterdam).
51. It is estimated that this will cost 6.5 to 7 billion euros (excluding unforeseen of several tens per cent), according to Rijkswaterstaat, 2008: Memo W. Silva in response to questions of the Delta Committee.
52. Information gained from a German–Dutch expert meeting held under the auspices of the Delta Committee, 2 July 2008.
53. The fishing industry in the IJsselmeer is relatively small. The effect of changed water levels on the fishing industry has not specifically been examined. Possible water quality problems arising from lower levels will have adverse effects.
54. Unie van Waterschappen, 2008. *Financiële consequenties peilopzet IJsselmeer* [Water Boards' Association, 2008. Financial consequences of increased IJsselmeer water level].
55. The cost of building and operating a pumping station in the Houtribdijk and alterations along the rest of the IJsselmeer are 700 million to a billion euros.
56. Central government flood defences 150 million euros per annum; water board flood defences 200 million euros per annum; Water quantity management water boards 760 million euros per annum; water defences and ground water provinces 85 million euros per annum. (Source: Het Hoofd boven Water [head above water] , Nyfer, 2008)
57. Costs are based on expert estimates by Rijkswaterstaat, Unie van Waterschappen and Ingenieursbureaus [Directorate-General of Public Works and Water Management, Water Boards Association and Consultant Engineers]. The upper and lower cost limits are related to the way the measures are implemented, their nature, the time they are needed, and the unit cost limits used.

5 Decision-making: from vision to action

The Committee realises that its message is a difficult one: after a disaster there tends to be a widespread feeling of urgency, that something must be done to prevent a repetition of events. The aim of the recommendations in this advisory report, though, is to stay ahead of future threats, which also requires immediate action. Climate change compels us to think about and plan for an exceptionally long period. This, coupled with the many, very different measures that need to be implemented to secure our safety from flooding and to preserve the fresh water supply, makes what we have in mind a unique project: a *Delta Programme*, encompassing numerous investment projects over a period of more than a century.[59]

Staying on track

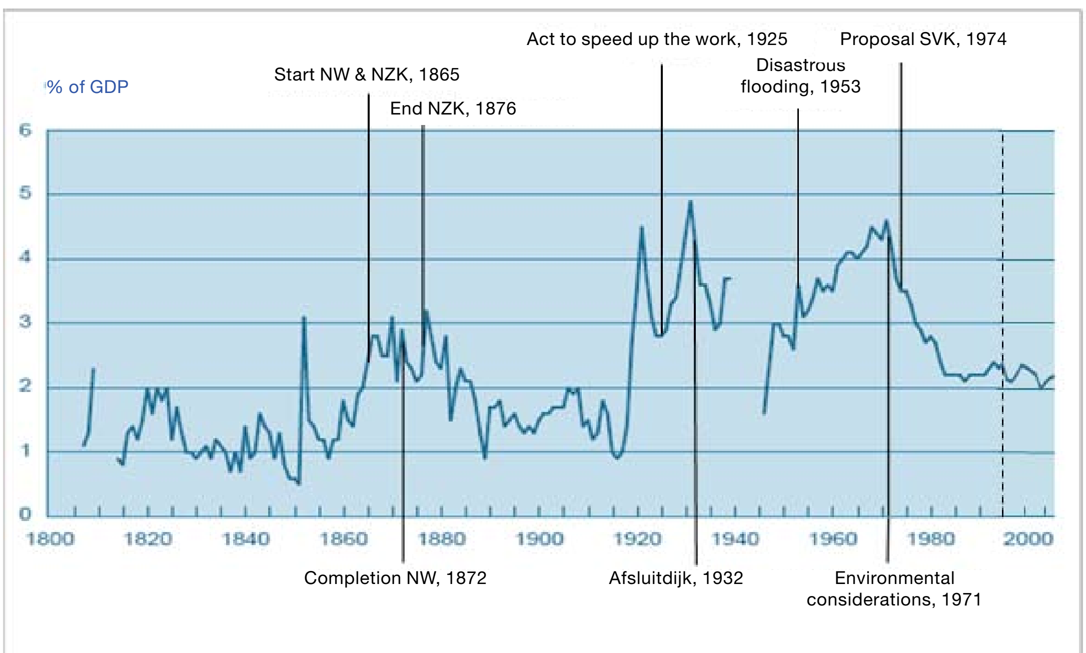
The general public takes it for granted that government guarantees its protection against flooding, but the public does not see the matter as urgent, or of high political priority. The people of the Netherlands are not apprehensive of a natural catastrophe; the risks of climate change are only gradually becoming manifest and there is a general feeling that effects will only be felt in the distant future. How can we make sure that the Netherlands will remain on course, continuing to work on the issues that the Delta Committee has sketched out here, and along the lines the Committee has indicated? And how can one ensure that plans and measures can be adequately financed, both now and in the remote future?

Water safety is an indispensable precondition for social and economic development in the Netherlands, but many factors may intervene to impede the energetic pursuit of the *Delta Programme* that the Committee proposes. These include the following:

~ When building infrastructure – even when the national interest is at stake – the Dutch consensus model requires that broad public support be gained for any decision; and public opinion is increasingly in favour of the protection and expansion of nature and areas of ecological value.
~ Decisions on water safety require a planning time frame of 50–100 years, while spatial planning decisions often look no further ahead than 10–25 years.
~ Many sectors of government and society are responsible for water safety. They often have competing interests and take different positions, so there is a risk that no one ultimately accepts final responsibility and no one has the authority to take a decision across the board.[60]
~ The *Delta Programme* encompasses many different facets, which, at many different levels and promoted by different 'players' over many decades, must be implemented with a high degree of coherence.
~ Investments in water safety, with benefits in the distant future, compete with other forms of government expenditure, which have visible, short-term benefits.

Eastern Scheldt storm surge barrier

Infrastructural investment, 1800–2007 (% of GNP)[1]



1. Total infrastructural investment (wet and dry).

* NW = New Waterway (Nieuwe Waterweg)
NZK = North Sea Canal (Noordzeekanaal)
SVK = Eastern Scheldt storm surge barrier

Source: 1800–1995 based on Groote (1999); 1995–2007 based on CBS Statline

19th Century vision

In the latter half of the 19th century there was a conviction that it was necessary to improve the infrastructure to bring greater prosperity to the Netherlands. An analysis of national government expenditure reveals that the construction of the North Sea Canal [*Noordzeekanaal*] and the New Waterway [*Nieuwe Waterweg*] cost considerably more than all remaining expenditure in the sector. Even the considerable cost overruns in the 1880s were accepted, even in the absence of a disaster. In 1880 the government did not hesitate to invest in dredging works. In the same decade, too, the Canal Company [*Kanaalmaatschappij*, set up in anticipation of the North Sea Canal's construction] was nationalised at considerable cost. This was because there was a clear awareness that the competition with Hamburg and Antwerp would be lost unless the North Sea Canal and the New Waterway were constructed.[1]

1. *De Nieuwe Waterweg en het Noordzeekanaal, een waagstuk* [The New Waterway and the North Sea Canal – a hazardous enterprise] , Prof. Dr. G.P. van de Ven, April 2008.

Unambiguous, national direction and co-ordination: powerful, devolved action

Securing the nation from the risks of flooding and protecting the fresh water supply far into the future demands great decisiveness and unambiguous direction. For that reason, both the long-term vision and the national goals are fixed at national level.

Decision making on and the implementation of regional tasks require a national decision making forum. National government can then enjoy confidence as both key player and participant in the way regional tasks are implemented. At national level there must be horizontal co-ordination and this needs to be translated into decisive direction and decision making. To accomplish this the Delta Committee proposes that a Ministerial Steering Committee be set up, chaired by the Prime Minister, with representation from at least those ministries most closely involved: Housing, Spatial Planning and Environment (VROM); Agriculture, Nature and Food Quality (LNV); and Finance.[61] Ultimate political responsibility for the implementation and execution of measures remains with the Minister of Transport, Public Works and Water Management.

A Delta Director should be appointed as secretary to the Ministerial Steering Committee.[62] The Delta Director will make preparations for the decisions made in the ministerial steering committee, while also holding responsibility for the progress and co-ordination of the process. To this end, the ministers must confer on him[63] the necessary (mandatory) powers. In consultation with the appropriate ministers and regional administrators, he will translate national tasks (set down as measures in a *Delta Programme*) into concrete regional tasks for the next 25 years. If necessary, he will intervene, using, for example, such instruments as are laid down in the new Planning Act, all the while maintaining the flexibility and manoeuvring room necessary to be able to deal with the inherent uncertainties involved.

The Delta Director keeps the *Delta Programme* on course, creates a national frame of reference, facilitates, encourages (nationally and in the regions) and, where necessary, is the one to take decisions. He connects the various administrative layers (national, provincial and local government, the water boards), as well as involving NGOs, business and the general public, while always bearing in mind the national interest, partly by assuring Dutch participation in EU forums on flood risk management and by translating EU guidelines into national legislation. The Delta Director's tasks and authority will be set down in a new *Delta Act* (see below). The Delta Director reports to the Ministerial Steering Committee and (through them) to the Cabinet and Parliament.

The suggestion is offered to Parliament that it might consider appointing a (permanent) Theme Committee to underscore Parliament's insistence on adequate control of the *Delta Programme*'s execution during the 21st century.

The *Delta Programme* can only be effectively pursued if the regional tasks are linked into local initiatives, knowledge and networks. This also necessitates the continuous, active involvement of NGOs, business and the general public in the regional tasks.[64] This, obviously, is why regional responsibility is needed for the planning and decisive implementation of regional tasks (analogous to the existing practice in the Room for the River programme, for instance). These tasks must contribute to the national vision and must be executed under the nationally agreed preconditions. The ultimate responsibility for the various regional tasks will in general rest with a regional administration, with practical matters devolved to a regional development organ, while still making use of the experience and practical abilities of the Directorate-General for Water Management and Public Works and the water boards. The regional administrator deploys the authority and powers already available under existing legislation, partnered on the national level by the Delta Director.

Money must not be an impediment

The Scientific Council for Government Policy in a recent publication pleaded for a strategic reorientation in respect of long-term infrastructural investments. The Council quite correctly calls the infrastructure that protects us from floods 'vital'.[65]

Costs and Benefits of the Zuiderzee Works

Under the *Zuiderzee Act* a separate fund was set up to finance the Zuiderzee works because the government regarded these works as an exceptional project. This allowed the project to remain outside the government's normal budget policy. The Zuiderzee Fund provided finance until the work was completed. Other matters provided for by the fund were the costs of military works related to the damming operation, the *Visserijzeesteunwet* [Marine Fisheries Support Act], the *Zuiderzeeraad* [Zuiderzee Council] and costs of interest and capital repayment. The fund received an annual contribution of 2 million guilders from the Water Management Directorate budget, supplemented by contributions from the War Budget, special loans, Treasury notes, income from land leases and sales, and certain benefits from the previous accounting year.

Cost-benefit projections for the Zuiderzee works were regularly updated over the years. For example, Lely (originally in charge of the works) estimated the costs in 1891 as approximately 190 million guilders. He looked only at the direct costs and benefits, which is one reason why he did not realise that the Afsluitdijk would recoup its own costs.1 The Lovink Committee, with more detailed calculations, estimated in 1925 that total costs were double, putting them at 380 million guilders. The ultimate costs of the Zuiderzee works are estimated at approximately 3 billion guilders. Earlier estimates did not envision this sort of price escalation. As the engineer Thijsse stated in 1972, "In 1925 they had no idea of what it means to create new land, nor how large the agricultural yield from that land might be." After all, such a great project as the Afsluitdijk had never before been undertaken. With hindsight, both the costs and the benefits were many times greater than could have been predicted at the project's inception.

1. Thijsse*: Een halve eeuw Zuiderzeewerken* [Half a Century of Zuiderzee Works], 1972.

The first Delta Committee's advisory report stated that the Netherlands should devote about 0.5% of GNP to flood protection and flood risk management. The new Delta Committee would underscore this target: The Netherlands must devote at least 0.5% of GNP66 to water safety.[67] The operations recommended in the previous chapter require extra funding, roughly estimated to be between 1.2 and 1.9 billion euros per annum until 2050, on top of the present expenditure by national government and the water boards for the construction and maintenance of the flood defences. This extra funding is necessary. It must be acquired and guaranteed by:

- distributing the extra burden over a number of generations: the social benefit of infrastructural projects also accrues to several generations;
- allowing every resident of the Netherlands to contribute to measures that make our country climate-proof;
- noting that the total amount needed does not have to be available immediately. But the size of the Delta Fund (to be set up, see below) must follow the expenditure pattern;
- regarding current legislation (such as the 3% norm under the Stability and Growth Pact[68]) as a point of departure. It must, however, be applied in such a way that it does not impede long-term funding.

The Delta Committee also points to the tension between 'short-term expenditure' and 'long-term benefits': investments in flood protection, flood risk management and the security of the fresh water supply result in benefits in the future, but compete with other expenditure on matters that command immediate attention. It is noted in this regard that public-private co-operative funding should be seen in the light of the government's primary responsibility for flood protection and the security of the fresh water supply. However, if combined forms of funding should arise, with combined interests, it would be worth investigating the opportunities for public-private partnership. This might involve such matters as developing extra land for housing, recreation, energy generation, nature reserves etc.

Delta Fund to secure finance

In view of the position set out above, the Delta Committee proposes that a Delta Fund should be set up for the realisation of flood protection and fresh water supply security measures. The fund would be run by the Minister of Finance, but would be kept 'at arm's length' from the national budget and other funds, such as the Infrastructure Fund and the Economic Structure Improvement Fund (FES), which, in part at least, serve different purposes.[69] This will retain the means where they are needed: flood protection, flood risk management and security of the fresh water supply. The fund will produce the means when needed: expenditures follow the pace of the work on the physical infrastructure. This will provide surety for the means needed to guarantee flood protection and the security of the fresh water supply, while avoiding competition with the short-term agenda.

The finance for proposed Delta Fund can be supplied through a combination of borrowing and (part of) the natural gas revenues. Creating a link between natural gas revenues and water safety will give expression to the connection between fossil fuel consumption (such as natural gas), climate change, the rising sea level and the Committee's recommendations. The Committee can see other good arguments for channelling (part of) the natural gas revenues to the Delta Fund: no increase in public debt (either national or that of the water boards), no increase in the pressure on the general public, while multiple generations enjoy the benefits.

There are political implications to the use of (part of) the natural gas revenues, though. True, we shall 'transform underground capital into above-ground safety' in the form of infrastructural projects, but setting up a reserve in the Delta Fund might soon lead to competition with consumption and investment expenditure which is currently funded from natural gas profits.[70]

It is for this reason that is it impossible to supply the fund entirely from the natural gas profits. Nor is this necessary, because it is entirely possible for the Delta Fund to attract external capital from the market – in the form of government long bonds, for example. This would allow government to respond rapidly to changing circumstances, such as the interest rate: the pace of work can be increased when interest rates are low. Other advantages to this option are:

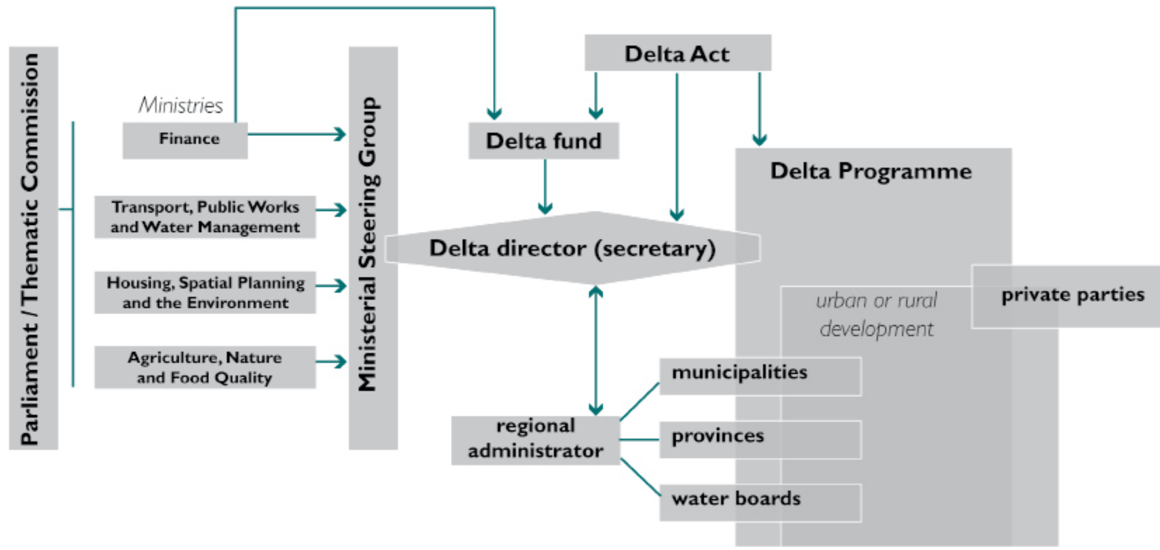
- it will be possible to supplement the fund from time to time, which expensive projects may require;
- the burden will be spread evenly over a number of generations (each generation pays interest and part of the capital), even though there may be (extreme) peaks in expenditure;
- expenditure can follow the same rate as the projects;
- it is relatively simple to adhere to the 3% EMU norm[71];
- long-term loans are attractive investments to pension funds, certainly when they are inflation proofed.

Other uses for (part of) the natural gas revenues, such as technological innovation, would not be short-changed.

The Minister of Finance is responsible for financing and managing the Delta Fund. Final responsibility for the Fund's expenditure lies with the appropriate minister in the Ministry of Transport, Public Works and Water Management. One precondition for the pursuit of a *Delta Programme* is that decisions on how the funds are to be allocated must be taken nationally: drawn up by the Delta Director and settled in the Ministerial Steering Committee. The Delta Director then makes budgets available to the parties responsible for implementing the (regional) measures, such as water boards, the Directorate-General for Water Management and Public Works, etc. If a measure is incorporated into the *Delta Programme*, it will be funded from the Delta Fund, even if it serves wider interests than flood protection and/or securing the fresh water supply.

It is crucial that local governments become involved with the regional tasks in the *Delta Programme*. The Delta Committee emphatically proposes that local governments should contribute financially where specific regional interests are served, with specific regional advantages. Co-financing is also possible, with the involvement of NGOs and private parties in cases where extra added value to the community and/or the economy is generated.

Figure 12: Administrative/political/legislative structure.



The keystone: a new Delta Act

In the short term, the Committee's recommendations can be implemented within the ambit of existing legislation, such as the Water Act, the new Planning Act, and the Water Boards Act.[72] The spatial aspects of the water-safety tasks will be worked out in spatial plans. The planning section of the Water Act already contains a (statutory) link to the planning section of the Planning Act, which will improve efficiency.

For such matters as are not already regulated under existing legislation, the Committee advises that a *Delta Act* be introduced, which will provide a statutory basis for these recommendations.[73] In the first place, a (new) *Delta Act* expresses the integral nature of the measures to be adopted. Moreover, a separate Act emphasises the importance attached to the *Delta Programme*, and that 'normal' decision-making is in some respects inadequate to achieve such ends. A *Delta Act* makes it quite explicit that adequate procedural, substantive and financial guarantees must be available, far into the future, going beyond 'normal' legislation:

- procedural: the tasks and authority of the Delta Director (who is secretary to the Ministerial Steering Committee), as well as regulations needed for strategic land acquisition, damages, and loss of financial advantage – including private parties – would be set down in the *Delta Act* (insofar as this is not covered in existing legislation);
- substantive: it is the *Delta Act* that stipulates that a *Delta Programme* will be drafted. This comprises a list of delta works that must be undertaken (with an outline, general description of the works and an outline of their cost, plus financing);
- financial: the institution of the Delta Fund, as well as the cash flowing into and out of it. This shall explicitly mention the measures' objectives, as well as the conditions to be fulfilled by the measures financed.

These political-administrative, financial and legislative measures must be prepared during the present Cabinet's period of office, with concrete details to follow in the coming years. This is why the Delta Committee regards the present administration's own political organisation and attitude as the point of departure: 'let the regions do what they can; let the nation do what it must'.

Recommendation 12

Political-administrative, legislative and financial

The Delta Committee's recommendations are:

1. To reinforce the political and administrative organisation of water safety by:

- *providing a unifying national direction and regional responsibility for the execution:*
  - *appointing a Ministerial Steering Committee, comprising the ministers of (at least) Transport, Public Works and Water Management; Agriculture, Nature and Food Quality; Finance; and Housing, Spatial Planning and Environment, to be chaired by the Prime Minister;*
  - *said steering committee to be responsible for decision-making, direction and horizontal, national co-ordination;*
  - *single, ultimate political responsibility to be carried by the minister of Transport, Public Works and Water Management, who bears ultimate responsibility for the programme and the national goals for flood protection and securing the fresh water supply;*
  - *the steering committee to have a secretary, the Delta Director, who reports to the Ministerial Steering Committee and (thereby) to the Cabinet and Parliament;*
  - *the Delta Director to translate national tasks for the coming century into regional tasks for the next 25 years;*
  - *final responsibility for the planning and performance of the regional tasks shall in general be devolved upon a (regional) administrator, one per task. According to the nature of the task, this administrator may be chosen from local or provincial government, or the water boards. This administrator can count on the Delta Director as central government partner;*
  - *the Delta Director takes a collective, national view of all regional tasks (including their planning and progress) together, guiding their direction where necessary; he facilitates the process, encourages developments and decision-making, bringing together the parties and their knowledge as needed. If necessary he uses his authority to take decisions;*
  - *appointing a permanent Theme Committee in Parliament, thus assuring close parliamentary involvement.*

2. To guarantee finance for flood protection and fresh water security measures by:

- *setting up a Delta Fund;*
- *supplying the Delta Fund with a combination of loans and deposits from (part of) the natural gas revenues;*
- *national government to make funding available for measures and to draft rules for withdrawals from the fund.*

3. To draft a Delta Act to embed the political and administrative organisation and the surety of funding within the present constitutional system and current legislation.[74]
The new Delta Act[75] *must contain at least the following:*

- *institution of a Delta Fund, including deposits and withdrawals therefrom;*
- *the Delta Director's tasks and authorities;*
- *provision that a Delta Programme shall be drafted;*
- *regulations for strategic land acquisition, compensation for damage, including loss of financial advantage, occurring as a result of measures under the Delta Programme.*[76]

59. See also the background report, *Bouwstenen voor de Deltacommissie* [Building blocks for the Delta Committee], Nyfer, 2008.
60. See also *Sneller en Beter* [Faster, Better], the report of the Elverding Committee, 2008: 'The need in our consensus-based culture to unite the virtually irreconcilable in many cases […] strands due to the administrative and political incapacity to take decisions or, once a decision has been taken, to actually implement it.'
61. The 'Ministerial Committee chaired by the Prime Minister' has been used a number of times in the past for major projects.
62. In constitutional terms, 'a government commissioner' according to section 69, para. 3 of the Constitution.
63. Obviously the Delta Director may also be of the feminine gender.
64. See also *Sneller en Beter* [Faster, Better], the report of the Elverding Committee, 2008.
65. WRR, *Sturen op infrastructuren* [New Perspectives on Investment in Infrastructures], 2008.
66. In 2007 GNP was approximately 550 billion euros.
67. The Committee views water safety as composed of flood protection, flood risk management and the security of the fresh water supply. The estimated cost, including management and maintenance, comes out at between 2.4 and 3.1 billion euros per annum (see Ch. 4), approximately 0.5% of GNP.
68. The size of deficits within the EMU have been agreed and set down in the Maastricht Treaty and the Stability and Growth Pact. For example, in a single year a country's EMU deficit may not rise above 3% of GNP.
69. The Delta Committee is aware of the recent confirmation of the Cabinet's resolve (letter to Parliament from Ministries of Economic Affairs and Finance, 1 July 2008) that the FES's domain of investment should be expanded to include water management, inter alia. The Committee's advice is that an independent Delta Fund should be set up precisely to offer surety to the means needed for water safety and the fresh water supply, rather than allowing them to compete with other areas of investment.
70. Wierts en Schotten *De Nederlandse Gasbaten en het Begrotingsbeleid*: Theorie versus praktijk [Dutch gas revenues and budgetary policy: Theory vs. practice]. Occasional Studies vol. 6, No. 5, Amsterdam, 2008.
71. Based on the assumption that Europe will follow the 'Golden Rule' (article 104), which states that is it 'permitted' in certain cases (major infrastructural investments) for the government to violate the 3% norm.
72. Nyfer Report: *Eb en vloed wachten op niemand* [Time and tide wait for nobody], 2008.
73. Professor Bruil: *Naar een nieuwe Deltawet* [Towards a new Delta Act], 2008.
74. Existing legislation, such as the new Planning Act, the Water Act and the Water Boards Act, remains in full force when measures are implemented.
75. The Act, which functions as outline legislation, concerns the objectives of measures (flood protection and securing the fresh water supply) and their realisation, together and at national level – sometimes even internationally.
76. If necessary, a *Delta Act* can contain provisions for vertical and horizontal co-ordination and decision-making (insofar as this is not adequately safeguarded under current legislation).

6 Future-proof advice: conclusions

The Committee's mandate

The Committee was asked by the government to come up with advice on how to go about the planning and development of the Netherlands so that our country can be protected against flooding over the very long term, while still remaining an attractive place in which to live. Furthermore, the Committee was asked to look at consequences extending further than safety alone. It was also asked to investigate possible synergy with other societal functions, such as living and work, agriculture, nature, recreation, infrastructure and energy. The Committee can see an ocean of opportunities for combining different functions and interests with an approach to water safety.

The Committee has interpreted 'the coast' in very broad terms as comprising the entire low-lying area of the Netherlands. The Committee's advice concerns mainly the principal water system, in relation to and co-operating with spatial planning throughout the entire country.

An urgent matter

Given the state of a number of diked areas, the safety issue is urgent right now and, with rising sea levels, greater variation in river discharge, and a further growth of interests that need protecting, it will only become more so. A disastrous breach in a dike anywhere in the country would disrupt the entire country.

The current legal standards date from the 1960s. Currently about a quarter of all flood defences do not comply with the present standards, while we do not know whether a further 30%, roughly, are in compliance.

In the Delta Committee's view we should anticipate a sea level rise of 0.65 to 1.3 m in 2100 and from 2 to 4 m in 2200. This includes the effects of land subsidence. These values represent possible upper bounds; it is sensible to work with them so that the decisions made and the measures adopted will be sustainable over the long term, set against the background of what we can possibly expect.

Rising temperatures and possible changes in air circulation will lead to declining summer discharges and increasing winter discharges in the Rhine and the Meuse. There is a limited discharge capacity for the Rhine in Germany, which means that the upper Rhine discharge limit that the Netherlands can expect around 2100 may reach 18,000 m³/s. For the Meuse we should anticipate a design discharge of at most 4,600 m³/s around 2100.

Eastern Scheldt

Water intake and with it the country's fresh water supply come under pressure when the sea level rises and salt water penetrates further inland via the rivers and ground water. Dry summers, like that of 2003, will occur more frequently, leading to damage to agriculture and shipping. Other economic sectors will also be harmed as a result.

A coherent vision and a national perspective

It is the Committee's view that all of the Netherlands must remain an attractive country in which to live, work, invest and take leisure. The two pillars on which the strategy must rest in the coming centuries are safety and sustainability. The best strategy to keep the Netherlands safe and a pleasant place in which to live over the long term is to develop along with climate change and other ecological processes.

Water safety is of utmost importance to the whole of the Netherlands. A safe delta is a collective societal good for which the government is and will remain responsible. It is upon this collective societal interest that the principle of solidarity is based: everyone contributes to water safety since everyone has an interest in a safe Netherlands, both now and in the future.

Innovative approach to risk

The Committee has remained true to the risk management approach upon which the first Delta Committee based its actions. On top of this, however, the new Delta Committee has paid explicit attention to reducing the probability of fatalities, while maintaining a broad definition of the concept of safety, where damage involves more than just economic harm.

Assessment of the safety level of various diked areas must be based on three elements:

- The probability of fatality due to flooding. A human life is worth the same everywhere and the probability of a fatality due to a disastrous flood must therefore be assessed on a common basis, to be agreed throughout society. The Committee proposes a probability of one per million, which is comparable with other (external) safety risks, such as those associated with industrial plant and the transport of hazardous materials.
- The probability of large numbers of casualties in a single flood episode. This probability is currently far greater than all other external safety hazards combined. The Committee finds this unacceptable. There is as yet no measure for the 'societal (group) risk' due to flooding. It is the Committee's urgent advice that such a measure be developed as soon as possible.
- Possible damage, involving more than economic harm alone. It is the Committee's view that damage to the landscape, nature and cultural heritage assets, societal disruption and a harmed reputation must be explicitly incorporated.

In combination, these three elements result in a single, amended standard for water safety.

Water safety highest priority

Our understanding of the way these three elements can be combined into a new standard is not yet complete. It needs further refinement. The Committee believes, however, that safety levels should not be determined purely on the basis of calculations. After careful consideration, it is the Committee's judgement that the present safety level for all diked areas must be improved by a factor of at least 10. In the Committee's view, further refinement leading to a factor lower than 10 can be justified only on very substantial grounds. In view of the considerable likelihood of large numbers of casualties, the Committee rather expects that further refinement will lead to a still higher factor for a number of diked areas, to improve safety yet further. The Committee has considered the concept of Delta Dikes for such diked areas.

A sustainable strategy ...

The Committee considers that safety comes first. The solutions that the Committee proposes, though, make a substantial contribution to the physical quality of the Netherlands and thereby to its attractiveness as a location to live and work. The Committee's proposals:

- are to harmonise as far as possible with natural processes: 'building with nature and other ecological processes';
- are as far as possible integral and multifunctional; solutions deliver added value to society;
- are cost-effective;
- are flexible and can be implemented gradually to take advantage of long-term developments;
- contain prospects for action in the short term;
- are rooted in Dutch tradition and can serve as a beacon to the rest of the world.

The Committee emphasises that government must remain responsible for climate-proof planning and development. The recommendations made also offer room for active market involvement: where possible, private parties may be invited to co-invest in sustainable planning and development for the Netherlands, especially where investments in water safety are accompanied by the reinforcement of other interests and values, such as nature, recreation, industry, agriculture, infrastructure, energy and housing.

... for the entire Netherlands

The Delta Committee has arrived at a number of recommendations for a *Delta Programme*, which demands a coherent, comprehensive package of investments running over more than a century. These recommendations ensure that the Netherlands can absorb the effects of climate change while still remaining an attractive, safe country over the long term. In this regard the Committee has made choices based on a view of the nation as a whole, tested against an overarching national interest, to which factional interests are subservient.

The Committee's point of departure is our present, interlinked water system, which is organised in such a way as to allow it to serve a variety of functions. At the same time, the short and medium-term recommendations we make have been chosen so that different options remain open over the longer term. This will allow future generations to form their own judgements, based on their own insights and values. Flexibility is essential: it is important to stay abreast of developments, to keep our knowledge up to date, continually assessing our plans and modifying them where necessary.

The Committee distinguishes between three time horizons and has set its recommendations in that context:

- concrete measures out to 2050;
- a clear vision out to 2100;
- opinions on the very long term, beyond 2100.

Safety level

The backlog of work needed to make the flood defences in the Netherlands comply with present safety standards must be remedied quickly. This also holds for setting new water safety standards, so that the present safety level will be improved by a factor of 10. New standards can be set before 2013. The measures needed to increase the safety level must be implemented before 2050. These must take account of the predicted sea level rise and increased river discharges, as well as the Delta Committee's long-term vision. The Committee stresses the importance of combining water safety with the exploitation of opportunities for nature, housing, agriculture and other activities.

Plans for the construction of new buildings

The Committee does not recommend an unequivocal ban on building on physically unfavourable locations. Space is scarce, after all. Decision-making on planned new building in these areas (on soft peat lands, for instance) must be based explicitly on an integral cost-benefit analysis. The costs arising from local decisions must not be passed on to another administrative tier, or to society as a whole; rather, they must be carried by those who profit from them.

This principle must be incorporated into the wider context of decision-making on climate policy, which can be applied regionally and locally. Water managers must become involved in this process at an early stage.

Areas outside the dikes

New development in areas outside the dikes must not impede the river's discharge capacity or the future levels of water in the lakes. Residents/users themselves are responsible for such measures as may be needed to avoid adverse consequences. Government plays a facilitating role in such areas as public information, advice and warnings.

North Sea coast

For the North Sea coast (Holland, the Zeeland headlands and the Wadden Islands), the accent lies on maintaining coastal safety by continuing the practice of beach nourishments, which will offer permanent safety until far into the next century. The Committee advises that nourishments must be carried out in such a way that the coast can grow in the next century to meet the needs of society. This vision should allow the 'weak links' to be dealt with. A growing coast in fact creates extra space for nature and recreation (including seaside resorts). Islands off the coast have a beneficial effect on coastal safety, albeit only a limited one compared with that of beach nourishments. They can be constructed for other functions, but coastal expansion is more cost-effective for nature and recreational functions.

Wadden area

Large-scale beach nourishments along the North Sea coast will have a beneficial effect on the Wadden area, allowing it to grow with rising sea levels. Developments in the Wadden area must be observed with care. The sea defences in the Northern Netherlands and the Wadden Islands will be brought up to strength and maintained.

South-western Delta

The Committee can see good arguments – primarily ecological ones – for completely restoring the tidal dynamics in the Eastern Scheldt when the life-span of the Eastern Scheldt storm surge barrier can no longer be extended, which is expected between 2075 and 2125. A solution must be chosen in good time, because if a completely open variant is selected, the flood defences around the Eastern Scheldt will then have to be brought up to strength. To maintain the estuarine character the sand starvation in the Eastern Scheldt must be tackled by sand nourishments in the short term.

The Western Scheldt must remain open to preserve both the valuable estuary and the navigation to Antwerp. Safety must be maintained by dike reinforcement.

Provisions must be made so that the Krammer-Volkerak Zoommeer lake, combined with the Grevelingen, can store large quantities of river water temporarily when river discharge is high. A freshwater-saline gradient in the lake will rapidly improve water quality. The water supply from the South-western Delta for agriculture and industry must be guaranteed by fresh water supplied from the Hollands Diep. When the details of this plan are developed further, the Committee's advice is to investigate whether water pricing may be applicable.

Rivers region

In the short term it is imperative for the river basin that the programmes *Room for the River* and *Maaswerken* be implemented. For the time being, the Committee assumes that the maximum discharge that can reach the Netherlands via the Rhine is 18,000 m^3/s. The design discharge for the Meuse is 4,600 m^3/s in 2100. It is essential to harmonise measures with neighbouring countries under the European *Directive on the assessment and management of flood risks*. It will be necessary to reserve the space needed to accommodate these maximum flows, possibly by establishing a permanent preference right and, if necessary, by strategic land acquisition. The peak discharges expected in 2100 must be anticipated, if possible, before 2050 for both the Rhine and the Meuse.

Rijnmond
The Committee recommends that a study be made of the 'closable-open' variant for the Rijnmond area immediately: the area can be closed off by barriers when faced with extremely high water levels. This offers safety, while at same time allowing the development of attractive living environments (city water fronts) and nature reserves. A 'closable-open' variant will need the Maeslant and Hartel Barriers, and the Haringvlietdam with its sluices (all of which will need replacing between 2050 and 2100), possibly supplemented with other closable barriers on the Spui, Oude Maas, Dordtse Kil and Merwede.

Salt intrusion via the Nieuwe Waterweg will no longer be counteracted with large quantities of river water. The fresh water supply for the Western Netherlands will be drawn mainly from the IJsselmeer lake and local storage where possible. The Committee recommends that this be implemented before 2050. The fresh water supply to the Rijnmond area, including possible innovative water management options, must be incorporated into studies of the 'closable-open' approach.

IJsselmeer area
The Committee has opted for a water level rise of at most 1.5 m in the IJsselmeer lake. The importance of the strategic fresh water reserve and the need to be able to discharge into the Wadden Sea without pumping for as long as possible are more important, in the Committee's view, than the disadvantages (extra costs) of the increased water level. Related to expected climate change, from 2050 onwards, a 'water slice' of 1.5 m will be needed in the IJsselmeer lake in years of extreme drought. A water level rise of more than 1.5 m would have significantly adverse effects on safety in the lower reaches of the IJssel and the Zwarte Water, which is why the Committee advises a maximum 1.5 m water level rise to afford the greatest possible flexibility. A phased approach may be adopted, but the aim must in any case be to have the largest possible fresh water reserve available around 2050.

The water level in the Markermeer lake will not be raised. A clearly defined water level offers clarity for urban development in Amsterdam and Almere. After the safety backlog has been remedied, the flood defences, with their prized landscape along the coast of North Holland, will not need to be reinforced again.

Cost
Implementation of the *Delta Programme* will require a sum of 1.2 to 1.6 billion euros per annum until 2050, and 0.9 to 1.5 billion per annum between 2050 and 2100. Under the *Delta Programme* coastal safety will be maintained by means of beach nourishments. Extra nourishments to expand the coasts of Holland and the Zeeland area into the North Sea by 1 km, for instance, and thus to create space for such functions as nature and recreation, will require an additional 0.1 to 0.3 billion euros per annum. These sums are merely an indication. New insights may lead to different measures, with cost implications.

Funding and implementation

The Delta Committee points out that the measures it advises will impact on the planning, development and use of physical space throughout large areas of the country. The Committee's proposals will have consequences at a variety of scales and will thereby have an impact on many functions and interests. Improving water safety – protection from flooding and water nuisance, and securing the fresh water supply – forces choices about land use and therefore affects the development of agriculture and nature, urban development, infrastructure, shipping, ports and other sectors of the economy. Implementation of the Delta Plan, therefore, demands an integral, harmonised interface with other facets of spatial planning, touching on such aspects as the economy, energy, nature and landscape, etc. The need for such an integrated approach leads the Committee to urge the appointment of a ministerial steering committee led by the Prime Minister. Final political responsibility for implementation and execution remains with the minister of Transport, Public Works and Water Management.

The political and administrative organisation can be further reinforced by the appointment of a Delta Director who can serve as secretary to the ministerial steering committee and thus assure horizontal and vertical communication. The Delta Director will translate the national task into regional ones. Responsibility for development and implementation of the regional tasks would generally rest with the regional administrators. In practical terms, the Committee advises the use of the water managers' experience and expertise. Finally, the Delta Committee proposes that a permanent, dedicated Delta Theme committee be instituted in the Parliament to assure parliament's supervision of the *Delta Programme's* implementation and execution.

The measures the Committee proposes are so important for our nation's water safety and fresh water supply that their financing must be independent of short-term political priorities and economic fluctuations. The Committee advises, therefore, the establishment of a Delta Fund, to be supplied from (part of) the natural gas profits and long-term loans.

Those political-administrative and financial recommendations that are not already set down in current legislation will be embedded in a new *Delta Act*.

The Delta Committee emphasises the importance of society's close involvement with the water safety in our country. Only if the general public – residents and industry – is careful with and aware of the way it uses water can the necessary approach to flood protection and a sustainable fresh water supply be realised.

The *Delta Programme* must be a sustainable one, which the Committee interprets as an enduring attempt to use water, energy and other basic materials as efficiently as possible to preserve and even improve the quality of the living environment. The Committee can see innumerable opportunities, the key concept being multifunctionality. Biodiversity can flourish if we offer more room for the dynamics of the sea and rivers. Residential environments (suitably adapted) can be created in water storage areas, on new land or on Delta dikes. Development and utilisation of sustainable energy supplies near to or using the water can simultaneously cut greenhouse gas emissions while combining functionalities.

Future-proof advice

The Delta Committee's report consists of integral recommendations, with a clear direction indicated. However, this is report is not intended to be a cut-and-dried blueprint of what the Netherlands will look like in a century or two. Our recommendations are based on the latest scientific knowledge of the consequences of climate change; they tie recommendations for water safety and fresh water supplies to solutions that will permanently improve the physical quality of the Netherlands.

Assuring water safety demands a long-term approach and considerable stamina. For that reason, the Committee believes it is essential that its recommendations must be future-proof. This the Committee has achieved with its combination of a flexible, partly multifunctional package of suggested solutions for planning and developing the Netherlands, coupled with a sturdy package of guarantees: political-administrative, financial and legal.

In the Committee's view, one important source of uncertainty for the future is prosperity and, related to it, the willingness to invest in the protection and quality of our country. We recommend the creation of a Delta Fund to survive less prosperous times and to avoid the danger of non-investment. Furthermore, the political-administrative and legal components of the report are aimed at maintaining the necessary focus on the *Delta Programme*: a powerful role for a ministerial steering committee chaired by the Prime Minister; a Delta Director, tying in both horizontal and vertical communication while also being responsible for progress and co-ordination; strong regional responsibility; legislation embedded in a *Delta Act*; and a Theme Committee in the Lower House. This future-proofs the recommendations against uncertainties arising from political, economic and societal developments.

Another important factor is pressure on space. Despite uncertainties about demographic developments, the Committee expects that pressure on space in the Netherlands will persist. The Netherlands will remain densely populated, come what may, while agriculture, water storage and other functions will demand a great deal of space. The Committee's proposed solutions bear a close relationship with spatial planning. Coastal expansion offers extra space. Multifunctional solutions, such as wide Delta dikes combined with dwellings and infrastructure, aim at an efficient redistribution of space. Water safety costs space, but the space is regained, with better quality. Under any and all circumstances, it is vital to reserve space now.

International co-operation plays a part in the recommendations, certainly for the rivers area. Cross-border co-operation within the European Union is increasingly commonplace. Even if matters were to change in the future, the recommendations are future-proof with provision in the major river basin for 18,000 m^3/s for the Rhine discharge and 4,600 m^3/s for the Meuse discharge, and the strategic fresh water supply in the IJsselmeer lake.

The recommendations here do not anticipate future technological advances, which will certainly be significant. The development and utilisation of new materials, for instance, will permit the construction of new types of dike. New forms of energy and food production will undoubtedly become possible, with consequences for the use of space. Information and communication technology will come to offer new facilities for risk monitoring, allowing the population to be informed and brought to safety when disaster threatens. Developments like these will only be beneficial to the execution of the recommendations.

Now suppose that the sea level rises by 4 m in the year 2200: will the Committee's recommendations still stand? What is important here is that we adopt no measures in the coming centuries that leave us with no way out. In this respect, too, the recommendations are future-proof. It will be possible at any time to erect a barrier in the Western Scheldt, or to close off Rijnmond with a lock, as at IJmuiden. The choice will be made at any moment to pump excess water from the IJsselmeer lake, while over the long term, the decisions made for the Krammer-Volkerak Zoommeer can all be reversed. Continuing beach nourishments along the coast and strengthening the flood defences – whether in the form of Delta dikes or not – can continue to protect us, even if the sea level rises by 4 m. If investments continue beyond 2100 in the order of magnitude proposed by the Committee, then our country will remain a safe place to live for many, many years.

And now to work!

The challenges facing the Netherlands are immense and it is no use closing our eyes to the task ahead. But we have the means, the knowledge and the time to take up the challenges and grasp the opportunities. That we have the time does not mean that we can wait. Using the Delta Committee's recommendations, the Netherlands must set to work today: not just on the coast and along the rivers, but also around the seat of government in the Hague and everywhere in the country where politicians, administrators, professionals and scientists are working on water safety and shaping the Netherlands.

The recommendations in this report are devoted to the issue of water safety in its entirety and impact on the spatial planning of the Netherlands. In that regard they offers prospects for other areas of policy and create preconditions for developments in these areas. It goes without saying, then, the possibilities for co-operation offered by the *Delta Programme*'*s* implementation must be utilised to the full. In this regard, the Committee has in mind ties with the national Adaptation Space and Climate programme, with the future of the coastal conurbation of the Randstad, with the policy for the rural area and the countryside, with the achievement of nature goals, with the work on a sustainable energy supply, and with the further development of the Netherlands as a transport country and a business location.

Implementation timetable
***Working* together with water**

A start can be made on this timetable during the present Cabinet's term of office; in the Delta Committee's view this is an ambitious agenda. The very short-term needs are:

- *the installation of a ministerial steering committee chaired by the Prime Minister, the secretariat to be headed by a Delta Director;*
- *drafting a Delta Act and setting up a Delta Fund so that the Delta Programme can get under way.*

The Committee would like to see at least the following items on the agenda before 2020:

- *Continue to cut the backlog in reinforcing the primary flood defences. Anticipate future sea level rises and changes in river discharge as investigated by the Committee and according to the Committee's long-term vision;*
- *Implement the programmes Room for the River and Maaswerken in full. Where cost-effective, anticipate a Rhine discharge of 18,000 m³/s and a Meuse discharge of 4,600 m³/s;*
- *Reserve space with a permanent preference right and/or acquire strategic land positions that will in time be needed to increase the discharge capacity of the Rhine and Meuse to 18,000 and 4,600 m³/s, respectively;*
- *Tackle the 'weak links' accordance with the Delta Committee's vision;*
- *Set down new standards for water safety in a new Water Act, in accordance with the Delta Committee's proposal;*
- *Develop instruments that can be used to create climate-proof spatial planning at local and regional scale. These must not be voluntary in respect of building on unfavourable locations and the early involvement of the water managers;*
- *Make a start on:*
  - *expanded, gradual beach nourishments along the North Sea coast, looking always for innovative concepts;*
  - *sand nourishments in the Eastern Scheldt to compensate for sand starvation in the area;*
  - *admitting salt water into the Krammer-Volkerak Zoommeer lake and constructing alternatives for areas that depend on the lake for their fresh water supply;*
  - *preparing the Krammer-Volkerak Zoommeer and the Grevelingen so that they can be used for water storage at times of high river discharge.*

The Committee believes it is important that before 2050:

- *measures will have been implemented to improve the water safety of the Netherlands according to the Delta Committee's proposals: i.e. by a factor of at least 10;*
- *the Rijnmond will have been developed in such a way that the area is no longer exposed to the influence of storms and extreme river discharges in an uncontrolled manner;*
- *fresh water transfer will have been made possible from the IJsselmeer to the Western Netherlands;*
- *arrangements will have been made for a 1.5 m higher water level in the IJsselmeer lake.*

Grasping the challenges offered by climate-proofing the Netherlands demands the development of integrated knowledge: knowledge that ties in 'green', 'blue', and 'red'. Moves towards this sort of integration are already afoot in the academic world and the Delta Committee's recommendations only serve to increase the need. The Netherlands forms an ideal test bed for experiments in this area, even from a global perspective. The Committee envisages an explicit, structural role for Dutch research institutions, assessment agencies and universities in support of the *Delta Programme*.

Knowledge timetable

***Working* together with water**

The following knowledge timetable is needed to get the Delta Committee's recommendations off to a good start:

~ *building with nature; innovative ways to carry out large-scale, gradual sand nourishments on the coast and in the Eastern Scheldt;*
~ *monitoring developments in the Wadden Sea and the intertidal zones;*
~ *necessary modifications to the Krammer-Volkerak Zoommeer lake, including a realistic price-fixing for water;*
~ *innovations in water treatment and water use by industry and agriculture; experiments with sustainable energy, linked to the possibilities offered by water;*
~ *realisation of a 'closable-open' Rijnmond, including the fresh water supply to the Rijnmond area;*
~ *taking the necessary measures to enable raising the water level in the IJsselmeer lake;*
~ *the Delta Dikes concept, including possible multifunctionality, in relation to diked areas where the new standards specify a more than 10-fold improvement in their safety level.*

Finally, the work is never done. That is characteristic of living in a delta. Circumstances and outlooks will always change. For that reason it will be necessary to keep knowledge up to date and to modify the plans continually in light of the latest developments and insights. In the meantime, it will remain sensible to be prepared for possible disastrous floods and, as a society (government, the public and business), to have our disaster planning and crisis management in order, no matter how small the chance of a catastrophe may be.

We can master the long-term challenge of keeping the Netherlands a safe, attractive country. Moreover, we have many opportunities and new prospects, particularly to make our country more sustainable, to expand our knowledge and expertise yet further, spreading it and putting it into practice in the rest of the world. Given the Delta Committee's ambitious timetable for implementation, the Netherlands can and must start work today. In our interaction with the water we, the country's residents, can ourselves shape the Netherlands of the future – just as our forefathers have always done throughout the centuries.

Appendices

Maeslantkering

Appendix 1

National Committee for Sustainable Coastal Development; Appointment Resolution and membership

Members of the National Committee for Sustainable Coastal Development:

- Prof. dr. C.P. Veerman, Mr. (Chair)
- Ir. I.M. Bakker, Mrs.
- Dr. J.J. van Duijn, Mr.
- Ir. A.P. Heidema, Mr.
- Prof. dr. ir. L.O. Fresco, Mrs.
- Prof. dr. P. Kabat, Mr.
- T. Metz, Mrs.
- Ing. Jac.G. van Oord MBA, Mr.
- Prof. dr. ir. M.J.F. Stive, Mr.
- Ir. B.W.A.H. Parmet, Mr. (secretary)

Members of the Committee's secretariat:

- Drs. J.S.L.J. van Alphen, Mr.
- Ir. P.J. van Berkum, Mr.
- Ir. B. van Bussel, Mr.
- A. van den Hurk, Mrs.
- L. Hurts, Mrs.
- Drs. E. Rijken, Mrs.
- Drs. T.J. Verhoef, Mr.
- Drs. C.D. Vlak, Mr.
- M. Wismeijer, Mrs.
- Ir. F.T. van Woerden, Mr.

Ministerie van Verkeer en Waterstaat

Ministry of Transport, Public Works and Water Management

Date
07 Sept. 2007
Number
HDJZ/WAT/2007-1020
Subject
Regulation for appointment of a
Committee on Sustainable Coastal Development

CHIEF DIRECTORATE LEGAL AFFAIRS

THE SECRETARY OF STATE FOR TRANSPORT, PUBLIC WORKS AND WATER MANAGEMENT AND THE MINISTER OF THE INTERIOR AND KINGDOM RELATIONS,

Acting in accord with the sensibilities of the Council of Ministers;
Having regard to Article 6, 1st paragraph of the Framework Legislation on Advisory Organs;

HAVE RESOLVED:

Article 1
There is a committee on sustainable coastal development, hereinafter: the committee.

Article 2
The committee's task is to advise the Secretary of State on:

a. expected sea level rise, the interaction between that rise and the discharge in the major rivers in the Netherlands and such other developments, climatological and societal, until 2100–2200 as are important for the coast of the Netherlands;
b. the consequences of such developments for the Dutch coast;
c. possible strategies for an integral approach leading to sustainable development of the Dutch coast, based on a) and b) and
d. to indicate the additional value to society of such strategies, in addition to the safety of the hinterland, in both the short and long term.

Article 3
The committee shall comprise a chairperson and at most eight other members.

Article 4
1. The advice shall be presented to the Secretary of State for Transport, Public Works and Water Management before 1 April 2008.
2. The committee shall be dissolved after its advice has been presented.

HDJZ/WAT/2007-1020

Article 5

1. The committee shall have a secretary who shall be appointed, suspended and dismissed by the Secretary of State for Transport, Public Works and Water Management after consultation with the chairman.
2. After the committee's dissolution, or earlier as circumstances may dictate, its documents shall be archived in the Ministry of Transport, Public Works and Water Management.

Article 6

1. This present regulation shall pass into effect upon the second day after the date of its publication in the Government Gazette [Staatscourant] and shall be retrospective up to and including 11 September 2007.
2. This present regulation shall cease to have effect on 1 September 2008.

Article 7

This present regulation shall be cited as: Regulation for appointment of a Committee on Sustainable Coastal Development

This present regulation and explanatory note shall be placed in the Government Gazette [Staatscourant].

THE SECRETARY OF STATE FOR TRANSPORT, PUBLIC WORKS AND WATER MANAGEMENT,

mw. J.C. Huizinga-Heringa

THE MINISTER OF THE INTERIOR AND KINGDOM RELATIONS

mw. dr. G. ter Horst

2

HDJZ/WAT/2007-1020

Explanatory note

Introduction
The fifty years since the Delta Committee, appointed by the then government after the disastrous floods of 1953, have witnessed radical changes in the Netherlands, accompanied by great population growth. Moreover, the Netherlands is increasingly becoming confronted with global climate change. The programme 'Room for the River' already anticipates the expected climate changes until 2100. No similar strategy exists for the coast.

In the short term it is sufficient to reinforce the weak links and adopt beach nourishments. Over the longer term (to 2100–2200), however, one may question whether the present way of flood protection is the best strategy.

To avoid surprises it is extremely important that problems and possible policy options be explored now. The longer the delay, the fewer options (in spatial planning terms) there will be for sustainable adaptation. Action now will avoid the need for very radical, expensive solutions for society in the long term.

The Cabinet will consider the committee's advice in its coastal vision, to be incorporated in the first National Water Plan (2009).

The committee's tasks
The committee is to use recent studies and advice to list future opportunities for and threats to the coast resulting from rising sea levels. Relationships will be described with other possible consequences of climate change (more severe storms, river discharge increase, and the increase of flooding and water shortages) as well as with societal, ecological, economic and international trends. The committee will consider the long-term consequences of these developments for the physical living environment along the Dutch coast.

These findings will be used in the formulation of sustainable policy strategies for the coast. Every policy strategy will be accompanied by a description of how the water safety options chosen will improve, or possibly degrade, the quality of the environment, both temporally and spatially. This involves the relationship between water safety on the one had, and water management, residential and industrial planning, nature, leisure, landscape, infrastructure and energy on the other. The advice will also consider possible innovative measures to improve the sustainability of these areas. The desirability of a range of policies is related to the degree and rate of sea level rise.

The study will consider the entire coastal zone, from Zeeland to the Wadden Islands. If necessary, the study will also be extended to the coastline of other countries bounded by the North Sea. The interaction with the rivers forms part of this mandate since sea level rise influences the capacity to cope with possibly increased river discharges, or because such increases may demand a different discharge distribution. Advice on the rivers as such, however, is not the primary substance of this mandate, in view of the measures already implemented under the "Room for the River" campaign, which has already given effect to a future-oriented strategy, and also to keep the committee's task manageable.

HDJZ/WAT/2007-1020

Why institute a new advisory organ?
The subject of the mandate is highly important both to society and politically. It demands broadly oriented expertise and experience as well as creativity, imagination, and the ability to think outside existing contexts.

In view of the mandate's breadth, input from a variety of disciplines is needed. An integral advice has been requested, describing the interrelations between numerous policy disciplines. Finally, the mandate's horizon (2100–2200) is more remote than usual for existing political advice.
The combination of qualifications needed is not available within existing advisory organs.

For the reasons set out above and given the short period of time within which the advice has to be ready, we have chosen to institute a separate committee.

The committee's mandate embraces all aspects of a sustainable living environment. This places the mandate directly in line with the Cabinet's desire to strive for greater interconnections between separate policy fields.

The committee is an ad-hoc one and shall be dissolved according to law after it has issued its advice. The committee shall therefore not interfere with the process of restructuring national advisory bodies.

The chair and other members of the committee are appointed by the Secretary of State for Transport, Public Works and Water Management. The members receive compensation for their work, in conformity with the provisions set down in the Decree on Compensation for Advisory Bodies.

THE SECRETARY OF STATE FOR TRANSPORT, PUBLIC WORKS AND WATER MANAGEMENT

mw. J.C. Huizinga-Heringa

THE MINISTER OF THE INTERIOR AND KINGDOM RELATIONS,

mw. dr. G. ter Horst

4

Appendix 2

Background documents

Aarts, J, Sprong, T and B. Bannink (eds)
Aandacht voor Veiligheid. [Attention to safety] BSIK Leven met Water, BSIK Klimaat voor Ruimte, DG Water, 2008.

Arcadis
De Deltacommissie legt haar oor te luisteren; verslag van de workshops, 2008. [The Delta Committee has a listening ear: Workshop report].

Bruil, D.W.
Naar een nieuwe Deltawet. Onderzoek in opdracht van de Deltacommissie, 2008. [Towards a new Delta Act. Investigation commissioned by the Delta Committee].

De Haan, Tj, Kind, J., Van Stralen, M., Kok, M. and J. Stijnen
Globale kostenschatting van alternatief Deltacommissie. Rijkswaterstaat-Waterdienst en HKV-Lijn in Water, 3 juli 2008. [Global estimation of costs of the alternatives of the Delta Committee. Directorate-General for Public Works and Water Management – Centre for Water Management and HKV Consultants].

Jonge Deltacommissie
'Nederland veilig, nu en later'. Ideeën voor de Deltacommissie. 2008. [Young Delta Committee. "Netherlands safe, now and later". Ideas for the Delta Committee].

Jonkman, B.
Schattingen Groepsrisico t.b.v. advies Deltacommissie. Memo in opdracht van de Deltacommissie 9T6387.A0/NN0001/902968/ Rotterdam 2008. [Group risk estimates w.r.t. Delta Committee advice. Memo commissioned by the Delta Committee].

Kok, M., B. Jonkman, W. Kanning, T. Rijcken en J. Stijnen
Toekomst voor het Nederlandse polderconcept. Technische en financiële houdbaarheid. TU Delft, HKV-Lijn in Water, Royal Haskoning. Studie in opdracht van Deltacommissie, 2008. [Future for the Dutch polder concept. Technical and financial sustainability. Delft Technical University, HKV Consultants, Royal Haskoning. Study conducted for Delta Committee].

Ministerie van Verkeer en Waterstaat - Waterdienst en Deltares
Internationale benchmark. Onderzoek in opdracht van de Deltacommissie, 2008. [Ministry of Transport, Public Works and Water Management – Centre for Watermanagement and Deltares. Research commissioned by the Delta Committee].

Nyfer
Eb en vloed en wachten op niemand. Bouwstenen voor de Deltacommissie. Onderzoek in opdracht van de Deltacommissie. 2008. [Ebb and Flood and waiting for no-one. Building blocks for the Delta Committee. Research commissioned by Delta Committee].

Nyfer
Het hoofd boven water. Tweehonderd jaar investeren in waterwerken. Onderzoek in opdracht van de Deltacommissie. 2008. [Heads above water. Two centuries of investment in water works. Research commissioned by Delta Committee].

Rijkswaterstaat/Deltares
'Beantwoording Kennisvragen Deltacommissie, een samenvatting'. Rijkswaterstaat en Deltares. 2008. [Response to Delta Committee's Request for Information, a summary"].

Vellinga, P., Katsman C.A., A. Sterl and J.J. Beersma, (eds)
Exploring high end climate change scenarios for flood protection of the Netherlands: - an international scientific assessment. 2008.

Ven, G.P. van de
De Nieuwe Waterweg en het Noordzeekanaal: een waagstuk. Onderzoek in opdracht van de Deltacommissie. Nijmegen, 2008. [The New Waterway and the North Sea Canal: A hazardous enterprise. Research commissioned by Delta Committee].

Wageningen IMARES
Werken aan Deltanatuur: compenseren of versterken? Onderzoek in opdracht van de Deltacommissie. Wageningen, 2008. [Working on delta nature: compensate or reinforce? Research commissioned by Delta Committee].

Witteveen + Bos
Economische waardering imponderabilia. Overstromings-schadekaarten. Achtergronddocument opgesteld in opdracht van de Deltacommissie. Rotterdam, 2008. [The economic valuation of imponderables. Flood damage maps. Background document commissioned by Delta Committee].

Appendix 3

The climate scenarios used by the Delta Committee: explanatory note[77]

Introduction

This appendix summarises the background to climate scenarios, placing the climate scenarios used by the Delta Committee in relation to the IPCC's (2007) global climate scenarios and the KNMI (2006) regional climate scenarios.

The Delta Committee's advice is based on the most recent scientific insights into expected global and regional sea level rise, changing wind conditions over the North Sea and changes in precipitation, leading to changed discharge patterns in the major rivers. The Delta Committee has commissioned additional research to systematically chart the most recent information on climate scenarios (Vellinga et al. 2008). This research, conducted by 20 leading national and international climate experts, including several IPCC authors, supplements the scenarios for 2100 produced by the IPCC (2007) and KNMI (2006). These experts have based their exploration of sea level rise scenarios on a global mean temperature increase of 2 to 6°C in 2100, which corresponds to the IPCC high economic growth scenario with widespread global use of fossil fuels, coal in particular. This scenario is named A1 FI. The research has given detailed consideration to upper limits to future sea level rise. The scenarios developed should be regarded as upper values; in other words, values that can serve as a reference for long-term tests of the robustness of future measures and investments.

The international research team has also estimated the upper limit of sea level rise for the year 2200. These estimates may well be surrounded with great uncertainty, but they would appear to be the best estimates that can be made based on our current knowledge and insights. The team of international experts has indicated that these estimates may be adjusted as and when our knowledge of inter alia the melting of the Greenland and Antarctica icecaps improves and as additional observations become available.

The IPCC emission scenarios

In 2000, the Intergovernmental Panel on Climate Change (IPCC) has drafted scenarios for possible socioeconomic developments in the world and related greenhouse gas emissions. These scenarios have been used inter alia for the third (2001) and fourth (2007) IPCC Assessment Reports, and as the basis for scenarios describing climate change and its impacts. The time horizon of the scenarios stretches to 2100. At that time the world will have changed in ways we can now only imagine with difficulty, just as it would have been difficult for anyone at the start of the 20th century to imagine today's world. Nevertheless, it is not only possible for us to develop such images of the future; we must do so if we are to make meaningful statements about possible climate changes over a century or more.

The IPCC has opted for four scenario 'families', with different assumptions selected for each family in terms of changes in demographic, economic and technological developments, leading to increased divergence over time. The long timescale means that these are explicitly not extrapolations of present trends, but possible, plausible pictures of the future. Since the future is in principle unknowable, IPCC makes no explicit statements on the scenarios' probability. None of the scenarios assume any form of climate policy that goes further than what has been established in 2000. The scenarios do not pretend to give a full picture of all projections of the future. Extreme scenarios with major discontinuities in socioeconomic development – such as war, disaster or utopian scenarios – have not been incorporated, for example. The scenarios developed do embrace a great deal of what the authors regard as plausible.

These are multidimensional scenarios, so it has been decided that they should not bear one-dimensional names, but rather combinations of letters and numbers (A1, B1, A2 and B2), based on two axes: on one hand an emphasis on materialistic economic growth or else sustainability, and on the other an emphasis on international convergence (globalisation) or else fragmentation (regionalisation). The A scenarios emphasise economic growth as the most important driver, but differ in respect of the degree of social and economic convergence, especially between poor and rich countries. The B scenarios emphasise sustainable development as the most important driver, differing once again in respect of the degree of social and economic divergence.

The A1 scenario family describes a world of rapid economic growth, a global population reaching a maximum in the middle of the present century and declining thereafter, and the rapid introduction of new, more efficient technology. The most important themes in this world view are convergence and increasing interregional interactions, social and cultural, resulting in substantial declines in income differences between the regions. This world view is highly dynamic and for it the IPCC has chosen various possible directions for technological development, especially in the energy sector. These technological developments might be distinguished by a continuing focus on accessing and exploiting fossil fuel sources (A1 FI – Fossil Intensive, see box), as well as by a rapid growth of non-fossil sources (A1 T). Nor would the energy supply have to concentrate especially on a single form of energy generation, under the assumption that the same pace of improvement would hold for all energy generation and consumption technologies (A1 B).

The A2 scenario family describes a much more heterogeneous world. Here the accent lies on regional self-sufficiency and the preservation of local identity. In this scenario the regional fertility levels converge far more slowly, resulting in a steady growth of global population. Economic development is primarily regional, while income growth and technological development display a far more fragmentary pattern. They are also slower than in the other scenarios.

The B1 scenario family describes a convergent world with a population that, just as in A1, increases until mid-century, after which it declines. In these scenarios, however, the world moves in a less materially intensive direction, the stress being on a service and information economy, accompanied by a steep decline in material intensity, coupled with the introduction of clean, efficient technologies. In B1 the principal role is played by international solutions to economic, social and environmental problems in a struggle towards sustainable development, which includes narrowing the income gap between rich and poor, but excluding a solution to the climate problem.

In B2, too, the significant drivers of socioeconomic change are social, economic and ecological sustainability, but only local and regional solutions are sought. While the global population may well increase, it will do so far more slowly than in A2. The rates of economic growth are higher than in A2 but lower than in A1 and B1. This also holds for technological development, which is more diverse and a little slower than in A1 and B1.

A1FI: gematigde bevolkingsgroei, snelle technologische ontwikkeling, toch hoge emissies

The Delta Committee has used the A1F1 emission scenario and the related worldwide temperature increase of at most 6 °C in 2100 as one of the starting points for additional scenarios for upper boundaries of sea level rise. Just like the other A1 scenarios this scenario is characterized by fast economic growth, a preference for solving problems through the market, high investments in education and technological developments (including energy efficiency), and international mobility of ideas, people and technology. The most important reason why this scenario still results in very high emissions, is because the investments in new technology focus on fossil energy as the driving force behind the world economy, including the use of abundant coal supplies and unconventional oil supplies in tar sands and oil shales, with high CO_2 emissions per unit energy consumption. This has a larger effect on emissions than the positive effect of energy efficiency improvements. The fact that the actual emissions since 2000 are in line with or even exceed this highest scenario of the IPCC emission scenarios shows that the A1F1 is not unrealistic (see figure 1).

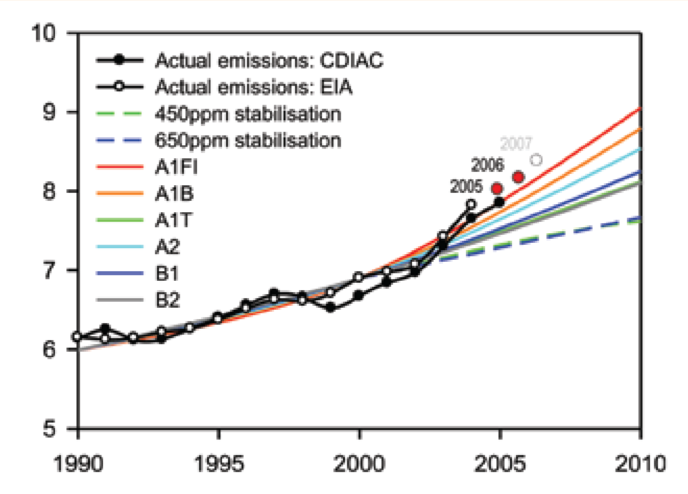


Figure 1: Realised global fossil fuel emissions compared with the IPCC SRES scenario. The A1FI scenario assumes 2.71% annual growth. Average growth over 2000–2006 was 3.3%. (Modified from Raupach et al. 2007, PNAS).

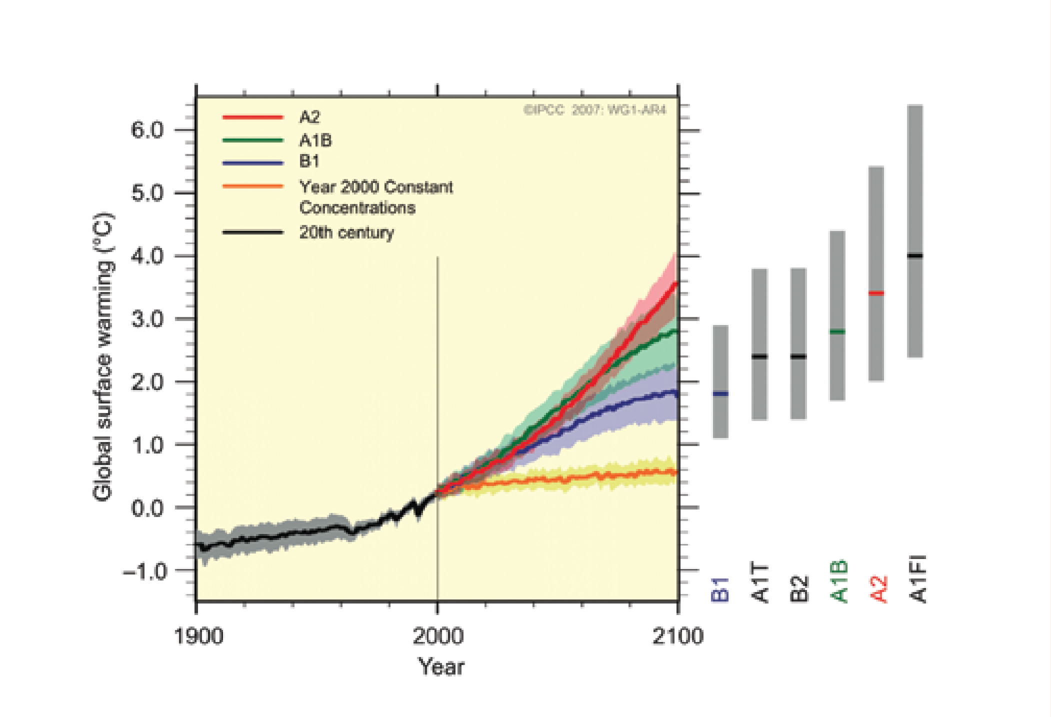


Figure 2: IPCC climate scenarios

The IPCC climate scenarios

IPCC has described the scenarios indicated above, including four in the A family (A1B, A1T, A1FI and A2) and two in the B family (B1 and B2) as illustrative. These emission scenarios have then served as input to calculations of changes in the climate system using 23 global climate models, which indicate a range of outcomes, covering a large part of the uncertainty. In both its Third (2001) and Fourth (2007) Assessment Reports, IPCC has reported results of the most important variables out to 2100, including temperature, precipitation and sea level rise (see figure 2). The range of expected global warming before the end of the 21st century is 1.1 to 6.4°C (figure 2). This range is determined in part (especially after 2050) by the different emission scenarios, but also by the differences between the climate models used, particularly in terms of climate sensitivity (calculated degree of warming resulting from a given increase in the atmospheric concentration of the greenhouse gases).

The KNMI 2006 scenarios in relation to the IPCC scenarios

In 2006 the KNMI has presented four climate scenarios for the Netherlands. These are based on the results of climate model computations, conducted throughout the world in aid of the Fourth IPCC Report. The computed changes of global temperature and the air stream above Western Europe have been used as point of departure. These projections have then been 'translated' into more detailed changes in temperature, precipitation, evaporation, wind and sea level in the Netherlands.

The decisive factor governing the precipitation (and, related to it, drought and the discharge of the major rivers) is the air circulation patterns in our region. The present generation of climate models either show little change in the air circulations, or else clear changes. To cope with this uncertainty the KNMI has chosen both a scenario that includes and one that omits a changing air circulation under global warming of +1°C and +2°C in 2050 (+2°C or +4°C in 2100).

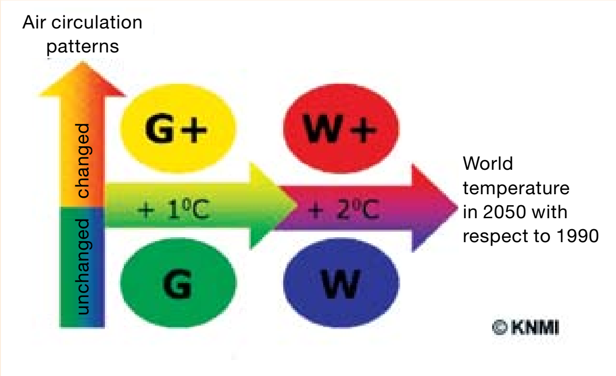
The KNMI has charted the uncertainty about our future climate as well as possible by basing the calculations on a large number of different climate models rather than a single one, which is common in our neighbouring countries. The four scenarios (see figure 3) together embrace a wide range of possible changes. Given the current state of our knowledge, we cannot indicate which of the four scenarios is most likely. The fact that the IPCC report gives possibly lower or higher values for global warming than those used by the KNMI (e.g., +6.4°C in 2100 as the upper limit of the probable range in the A1 FI scenario) is less significant for climate change in the Netherlands out to 2100. The difference is important in relation to sea level rise because this is related, inter alia, to the global mean temperature. Until 2050 (the target year on which the KNMI 2006 scenarios primarily focus), the projections of global mean temperature reported by the IPCC are practically independent of the emission scenario selected. The KNMI 2006 scenarios for 2050, together with the related sea level rise scenarios, encompass almost the entire range of projected global mean temperatures.

The four scenarios show that the changes in extremes in the Netherlands will probably differ from the changes in the mean climate. For instance, in scenarios incorporating changed air circulation, the temperature during heat waves increases far more than the temperature on an average sunny day. Summer showers also occur less frequently, but when they occur they are more severe. This has major implications for climate adaptation issues. Similarly to the IPCC method, new scientific knowledge is being incorporated into the next generation of KNMI climate scenarios, which are planned for 2012 or thereabouts.

Sea level rise scenarios

The Delta Committee has requested an investigation of global sea level rise and the rise along the Dutch coast for the years 2100 and 2200. The sea level rise scenarios presented here have a different basis than previously published scenarios for global (IPCC 2007) and regional (KNMI 2006) sea level rise. Here the analysis is explicitly concerned with the

Figure 3: KNMI 2006 scenarios



upper limit of the possible values under certain assumptions, rather than the bandwidth of most probable values. In relation to the Delta Committee's work, therefore, the scenarios presented represent an essential complement to existing scenarios (IPCC 2007; KNMI 2006).

Given the gaps in our knowledge of current sea level changes and the uncertainties involved in modelling them, the scenarios presented must be regarded as plausible upper limit scenarios, which are regarded as possible by the group of sea level experts consulted, based on current scientific knowledge. In common with all long-term (climate) scenarios, these upper limit scenarios may change as a result of advances in scientific knowledge.

a. Global 2100

The upper limit scenario for global sea level rise assumes a global temperature increase of 2 to at most 6°C, in agreement with the IPCC Assessment Report 4 (AR4) emission scenario A1 FI (2007). An estimate has also been made of the possible effects of rapid ice dynamics on the contribution of the Greenland and Antarctic icecaps to global sea level rise.

Table 1: Assumed most significant contributions to global sea level rise scenarios in the year 2100, as presented by the Delta Committee and IPCC AR4 (2007, A1FI-scenario).

	IPCC AR4 – A1FI (including extra discharge from icecaps[1])		**Delta Committee upper limit scenario**		**reason for different approach / outcome**
total[2]	**+0.25 to +0.76 m**		**+0.55 to +1.10 m**		
ocean expansion	+0.17 tot +0.41 m	Climate model results	+0.12 to +0.49 m	Analysis of simple relation between expansion and air temperature as simulated by climate models (Katsman et al., 2008; Rahmstorf, 2007)	A wider temperature increase bandwidth has been taken than that given by the climate models[3]
glaciers	+0.08 to +0.17 m	Simple relation between ice loss and air temperature, based on observations	+0.07 tot +0.18 m	cf. IPCC 4AR	Minimal differences due to small differences in assumptions about rates of temperature change
Antarctica	-0.14 to -0.03 m	(i) increased snowfall based on climate models (ii) estimated ice discharge	-0.01 to +0.41 m	(i) cf. IPCC 4AR (ii) continuation or accelerated ice discharge, as recently observed in the Amundsen Sea, Eastern Antarctica and the Antarctic peninsula	- (ii) The icecap in these areas is vulnerable due to geography. Recent observations show that the icecap is now in motion. We cannot now predict whether this motion will slow, continue, or accelerate.
Greenland	+0.02 to +0.12 m	(i) volume change based on icecap models (ii) discharge observed between 1993 and 2003 (iii) increased summer melt	+0.13 to +0.22 m	(i) cf. IPCC AR4 (ii) accelerated flow of glaciers at the edge of the icecap into the sea (iii) cf. IPCC AR4	- Recent measurements show that these glaciers can respond very rapidly to changing conditions -
extra icecap discharge	-0.0 to +0.17 m	Extrapolated discharge based on recently observed relation between discharge and temperature increase	-	-	

Figure 4: Contributions of the major components and totals in the scenarios for global mean sea level rise in the year 2100, presented by the Delta Committee (black) and IPCC AR4 (2007, A1 FI scenario including extra icecap discharge, blue).

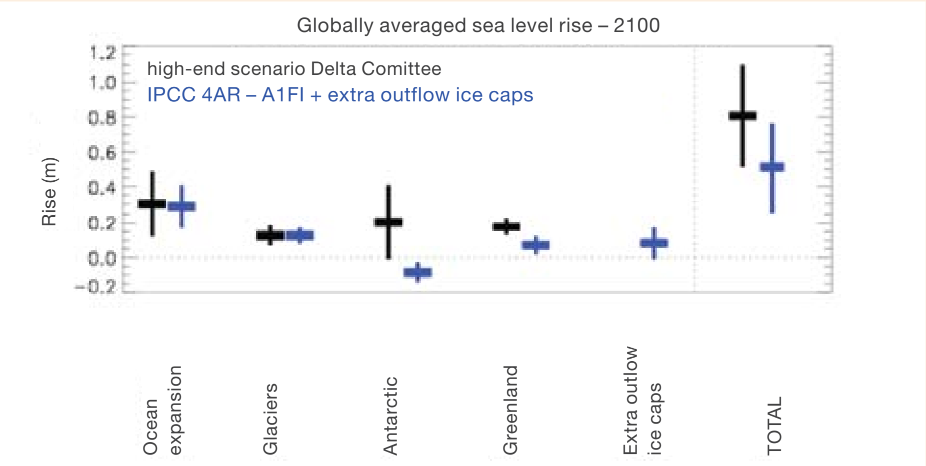


Figure 5: Contributions of the major components and totals given by the scenarios for local sea level rise along the Dutch coast in 2100, as presented by the Delta Committee (black continuous line: excluding gravity effects; dotted line including gravity effects) and KNMI 2006 'warm' scenario (blue: excluding gravity effect). All scenarios exclude land subsidence.

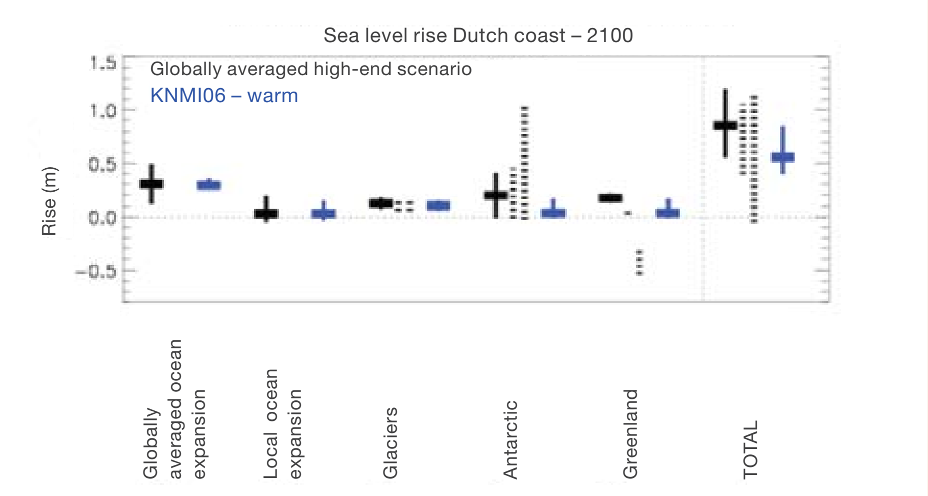
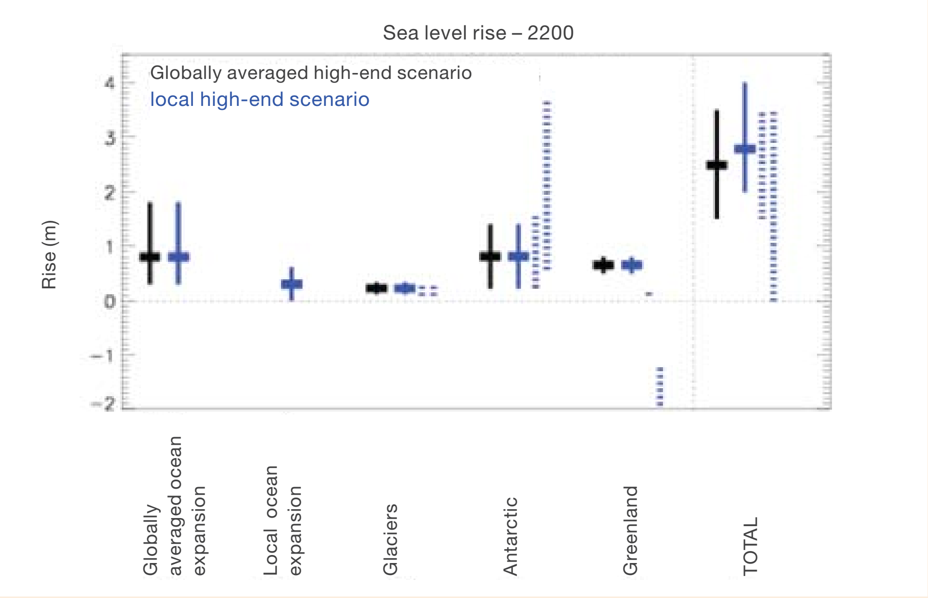


Figure 6: Contributions of the major components and totals given by the scenarios for local sea level rise along the Dutch coast in 2200, as presented by the Delta Committee (black: global mean; blue: along the Dutch coast; continuous line: excluding gravity effects; dotted line: including possible gravity effects). All scenarios exclude land subsidence.



b. The Netherlands coastal region – 2100

The local sea level rise can differ greatly from the mean rise. Two local effects have been incorporated into the scenario for the Dutch coast, as set out in the background report.[5] First of all, account has been taken of possible extra local expansion of the ocean as a result of changed ocean currents. A second important factor is the distribution over the ocean of melt water from land ice.[6] The quantification of this effect, called the gravity effect, is currently a matter of scientific debate. To a significant degree it determines the local contribution of the Greenland and Antarctic icecaps and is therefore very significant in determining the final sea level rise scenario obtained. The discussion of the gravity effect is a technical one, but the underlying physical principles governing the distribution of melt water are clear.

The background report (Vellinga et al., 2008) describes scenarios based on two methods for calculating the gravity effect. These results are also reproduced in figures 5 and 6. The fact that the upper limits of the two scenarios are similar is a coincidence. At present no preference can be given to one of the two methods and more research is needed. For that reason, the Delta Committee has opted to present an upper limit scenario that excludes the gravity effect. KNMI 2006 sea level rise scenarios also ignore this possible effect.

Table 2: Assumptions about the major contributions to scenarios for local sea level rise along the Dutch coast in the year 2100, as presented by the Delta Committee (excluding the gravitation effect) and KNMI 2006 'warm' scenario. Both scenarios exclude land subsidence.

	KNMI 2006 ('warm' scenario)		**Delta Committee upper limit scenario (excluding gravity effect)**		**reason**
total	**+0,40 to +0,85 m**		**+0,55 to +1,20 m**		
ocean expansion	+0,27 to +0,35 m	Analysis of simple relation between expansion and air temperature computed by climate models	0,12-0,49 m	Extrapolation of this simple relation between expansion and air temperature based on two methods (cf. KNMI'06 and Rahmstorf, 2007)	Wider temperature increase bandwidth considered than in KNMI'06[7]
local ocean expansion	-0,04 to +0,15 m	Analysis of simple relation between expansion and air temperature computed by climate models	-0,05 to +0,2 m	Extrapolation of this simple relation between expansion and air temperature	Wider temperature increase bandwidth considered than in KNMI'06
glaciers	+0,06 to +0,15 m	Simple, observed relation between ice decline and air temperature, based on observations	+0,07 to +0,18 m	cf. Table 1	Method compatible with IPCC AR4; wider temperature increase bandwidth considered
Antarctica	-0,01 to +0,17 m	Schatting op basis van recent waargenomen ijsverlies en modelberekeningen van de gevoeligheid van de ijskap voor veranderingen in de atmosfeertemperatuur	-0,01 to +0,41 m	cf. Table 1	New insights based on recent observations; takes account of possible effects of rapid ice dynamics, not directly related to changing air temperature
Greenland	-0,01 to +0,17 m	cf. Antarctica	+0,13 to +0,22 m	cf. Table 1	New insights based on recent observations

c. Global and regional along the Dutch coast – 2200

The upper limit scenarios for 2200 presented here give an indication of the *possible* sea level rise, not the most probable. The scenarios for the 21st century are bounded because we know the current rate of sea level rise from observations and because a rapid acceleration of this rate is unlikely on a time scale of several decades. No such limits exist for the 22nd century.

	global mean upper limit scenario		**local upper limit scenario (excluding gravity effect)**	
total	+1,5 to +3,5 m		+2,0 to +4,0 m	
global mean ocean expansion	+0,3 to +1,8 m	Extrapolation based on simple relation between expansion and air temperature calculated by climate models	cf. global mean	
local ocean expansion	-	-	0,0 to +0,6 m	possible local effects of changed ocean circulation
glaciers	+0,1 to +0,3 m	extrapolation of simple relation between ice decline and air temperature based on observations	cf. global mean	
Antarctica	+0,2 to +1,4 m	continuation of changes in the melting rate assumed for 2100 (Table 1)	cf. global mean	
Greenland	+0,5 to +0,8 m	based on same assumptions as 2100 (Table 1)	cf. global mean	

Table 3: Assumptions about the possible contributions to the upper limit scenarios for global mean sea level rise and local sea level rise along the Dutch coast (excluding gravity effect) for 2200 as presented by the Delta Committee.

d. Estimated upper limit scenario for global sea level rise based on palaeoclimatology

Palaeoclimatological studies offer us an insight into past changes in our climate system. Changes in global sea level can be reconstructed inter alia from isotope concentrations (which indicate the balance between water stored on land and that in the oceans) and coral growth rings. Sea level reconstructions for periods that compare closely with the present or expected future state of the climate form a useful complement to the sea level rise scenarios discussed above.

During the last interglacial (the Eemian: 125,000 y BP) the global mean temperature was a little warmer than at present, and large icecaps existed only in Antarctica and Greenland. During the Eemian the sea level rose globally at a rate of roughly 1 to 2 meters per century. The reconstructions are not sufficiently detailed to offer any certainty about how long such a rate of sea level rise may persist, nor how fast the climate system can switch from a situation with barely any sea level rise (comparable to the present climate) to such a rapid rate. Based on historical reconstructions, a switch like this could occur over a period of a few decades at the fastest.

An alternative upper limit scenario for global sea level rise can be formulated based on these palaeoclimatological data. If it is assumed that the present sea level will start to rise at a rate of nearly 2 meters per century within a few decades (when it is expected that the global mean temperature will be just as high as it was in the Eemian), this will result in almost 1½ meters of sea level rise globally in 2100, with almost 3 meters of global sea level rise in 2200. The upper limit scenarios for global mean sea level rise based on palaeoclimatological reconstructions of the past are thus higher than the upper limit sea level rise scenarios discussed above (see table 4).

Method /assumption Estimated sea level rise in 2050 (m)	**Estimated sea level rise in 2050 (m)**	**Estimated sea level rise in 2100 (m)**	**Estimated sea level rise in 2200 (m)**
~ 1.7 m sea level rise per 100 y, based on palaeo-data from Red Sea	~ 0,5	~ 1,4	~ 3,1
~ 2.4 m sea level rise based on last interglacial	~ 0,7	~ 1,9	~ 4,3

Table 4: Estimated upper limit scenarios for global mean sea level rise based on palaeoclimatological reconstructions (Vellinga et al., 2008)

Storm scenarios for the North Sea

The research into possible changes in wind strength and direction, waves and water set-up in the southern North Sea and along the Dutch coast is based on the following sources:

a. the IPCC Fourth Assessment Report (AR4);
b. the KNMI 2006 scenarios;
c. recently published research using regional climate models; and
d. recent results from the ESSENCE project, which computed 17 iterations of future climate developments under the A1b scenario, linked with a North Sea water set-up model (WAQUA/DCSM98).

These sources are not independent; rather, they supplement each other. The KNMI 2006 scenarios are based on the same models as the IPCC AR4, while the regional climate models use results from the same IPCC AR4 models as preconditions. Finally, the climate model used in ESSENCE, ECHAMS/MPI-OM, is one of the IPCC AR4 models. The regional models give greater regional detail than the global ones, while the ESSENCE and ESSENCE-WAQUA/DCSM98 integrations provide a reasonably solid statistical basis for determining the 10,000 year repeat values, as prescribed by the Delta Act. The ESSENCE-WAQUA/DCSM98 computations have been performed specifically for the Delta Committee. The results of recent research (regional modelling and ESSENCE) confirm the results of the KNMI 2006 scenarios and make them more precise.

To summarise the results concerning wind conditions and waves:

1. The projected future changes are small relative to natural variability as well as the inherent uncertainty involved in the statistical processing of relatively short observational series;
2. each model gives different patterns of change over the North Sea;
3. the scenarios used show no clear dependence on future greenhouse gas emissions;
4. there is a trend towards more frequent (south-) westerly winds, but no indication of more frequent or stronger northerlies. Northerly winds cause the largest water set-up against the Dutch coast.

The observational series is too short to afford precise estimates of the 10,000 year repeat values for water set-up. This also holds for the time series from climate models, which are based on a single model integration of the 20th and 21st century. Currently, only the 17-member ESSENCE-WAQUA/DCSM98 ensemble contains sufficient data to determine the 10,000 year repeat values of water set-up with a statistical accuracy of ±0.5 m. The results of this research indicate that extreme water set-up in the future will be no higher than it is now. Since the other IPCC AR4 models also show no increase in northerly winds, this result is probably unrelated to the climate model used in ESSENCE.

Rhine discharge scenarios

Changes in the Rhine's mean discharge

Changes in mean discharge (Table 5) are based on the KNMI 2006 climate scenarios, combined with hydrological models of the Rhine. Under all climate scenarios there is an increase in mean winter discharge, but for the summer the possible discharge effects vary between no change to a sharp decrease. In 2100 the changes are roughly double those of 2050. What is most striking, compared to earlier climate scenarios (e.g. WB21), is the sharp decrease in mean summer discharge (in the KNMI 2006 climate scenario, in which the air circulation patterns change).

Changes in the Rhine's design discharge

The scenarios for changes in the design discharge are based on the KNMI 2006 climate scenarios in combination with individual climate models, due to the great sensitivity of peak Rhine discharge to changes in the variability of periodic precipitation and the fact that a possible (but highly uncertain) change in this variability has not been incorporated in the KNMI 2006 climate scenarios. Statistical extrapolation to a return period of 1250 years gives a 95% confidence interval of 13,000 to 18,500 m^3/s for the present design discharge of 16,000 m^3/s.

The projected changes in design discharge for 2050 and 2100 (Table 6) have an upper limit (19,000 and 22,000 m^3/s, respectively) which exceeds the upper value of the confidence interval under present circumstances. It is important to note that the results in Table 6 take no account of the damping effect that flooding in Germany has on peak discharges at Lobith, which makes these results rather theoretical.

Given the present state of the dikes, very large peak discharges will lead to flooding in Germany, which will drastically lower the peak discharge at Lobith. At present there can be no clarity about the state of the dikes in Germany in 2050 and 2100. The effect of flooding in Germany on the peak discharge at Lobith can be computed, though, based on the state of the German dikes in 2020 (which is known quite accurately). The effects of combining the state of the German dikes in 2020 with the climate projections for 2050 and 2100 to give peak discharges at Lobith are given in Table 7. There is a considerable reduction in peak discharge. Ultimately, the peak discharges at Lobith will depend on the actual state of the German dikes in 2050 and 2100. What can be stated now, however, is that considerable changes will be needed in Germany to permit peak discharges of around 22,000 m^3/s to pass Lobith.

Cross-border floods are also possible. Given the state of the German dikes in 2020, the discharge capacity of the northern region of the Lower Rhine in Germany will be about 17,500 m^3/s. Under a changed climate, and given higher dikes upstream in Germany, peak discharges may exceed 17,500 m^3/s in the northern region of the Lower Rhine in Germany, leading to uncontrolled flooding in the area. Cross-border flooding via ancient river beds will then in turn lead to uncontrolled flooding in the Eastern Netherlands.

Table 5. Mean Rhine discharge (m^3/s) at the end of the 20th century, with projections for 2050 and 2100 (meaningful results are not available for 2200). Summer = August–October; Winter = January–March.

	1968-1998	2050	2100	2200
Mean summer discharge (m^3/s)	1700	1100 – 1700	700 – 1700	n.c.
Change in mean summer discharge (%)		-35 – 0	-60 – 0	n.c.
Mean winter discharge (m^3/s)	2750	2950 – 3200	3100 – 3600	n.c.
Change in averaged winter discharge (%)		+5 – +15	+15 – +30	n.c.

Table 6. Peak discharge at Lobith (m^3/s) in 2050 and 2100. Reference discharge corresponds to design discharge of the Rhine. Uncertainties in the hydrological models and hydraulic effects (including floods in Germany) are not included.

	Reference discharge	2050	2100	2200
Peak discharge (m^3/s)	16.000	16.500 – 19.000	17.000 – 22.000	n.c.
Change in peak discharge %		3 – 19	6 – 38	n.c.

Table 7. Peak discharge at Lobith (m^3/s) in 2050 and 2100 (from Table 6), taking account of the effects of flooding in Germany, assuming the state of the German dikes in 2020.

	Reference discharge	2050	2100	2200
Peak discharge (m^3/s)	16.000	15.500 – 17.000	16.000 – 17.500	n.c.

77. This appendix has been written under the editorship of P. Kabat, based on contributions from W. Hazeleger C. Katsman, A. Sterl, J. Beersma and A. Klein Tank (all of KNMI), and P. Vellinga, R. Hutjes and R. Swart (all of Wageningen UR).
78. The local, vertical movement of the ground (land subsidence) is considered separately.
79. When land ice melts the melt water does not distribute evenly over the earth. Gravity attracts seawater towards an ice mass on land. This is associated with a relatively large sea surface area in the neighbourhood of an icecap. When (part of) the land ice melts, then (part of) the attractive effect on the seawater also vanishes. The changed loading of the earth's crust due to ice or melt water also influences the local sea level.

Tablenotes

1. In IPCC AR4 this extra ice discharge is called *'scaled-up ice discharge'*
2. The totals have been rounded to 5 cm and are calculated as follows. First, the central estimate is determined for each component (usually the mean of the given bandwidth. The central estimate of total X is the sum of the central values of the components ($X = \Sigma x$). The total bandwidth, dX, follows from the quadratic sum of the indicated bandwidth of the components: $dX^2 = \Sigma (x-X)^2$. The total indicated bandwidth is (X-Dx, X+dX). This is the correct procedure when it is assumed that the uncertainties in the individual components are independent of each other. It is used both in IPCC AR4 and this report.
3. The Delta Committee's upper limit scenario considers global mean temperature increases of 2– 6°C.Climate models show global mean temperature increases of at most 5.2°C under the A1FI emission scenario, but take no account of possible feedback between climate and the carbon cycle.
4. The analysis takes account of declining glacier sensitivity to temperature change (the most vulnerable parts melt fastest) and the drop in the total ice volume (higher parts of the remaining glacier disappear more slowly than low-lying areas).
5. The bedrock on which these glaciers rest is below sea level and slopes down to the edge of the icecap. Theoretically, such marine glaciers can disappear entirely, albeit over a century or more.
6. The contribution due to rapid ice dynamics has been incorporated into the individual contributions from Antarctica and Greenland. The Delta Committee scenario estimates a higher contribution from rapid ice dynamics as a result of changes in the Antarctic icecap than in IPCC AR4.
7. The Delta Committee's upper limit scenario considers global mean temperature increases of 2– 6 °C. The KNMI 2006 "warm scenario" assumes a global mean temperature rise of 4°C. Climate models show global mean temperature increases of at most 5.2°C, but ignore possible feedback between climate and the carbon cycle.
8. KNMI 2006 uses a rather simpler relation than IPCC AR4.

Appendix 4

The vision of water safety explained

The basic issues of water safety upon which the Delta Committee has based it advice are essential to the nature and magnitude of the measures proposed. The Delta Committee's statements set the standard for what the Committee regards as a desirable level of water safety. In other words, a socially acceptable risk. Here the Committee takes further steps along the path first embarked upon by the previous Delta Committee.

Firm foundation for present policy

The first Delta Committee has laid the foundations for the present flood risk management policy, the core of which is their approach to risk. This implies:

- The magnitude of a risk is determined by the probability multiplied by the consequences. Low-probability occurrences with major consequences may have the same risk as high-probability occurrences with minor consequences.
- the risk is managed by a combination of measures that limit the probability (prevention) and those that limit the consequences (proactive, preparative and responsive).[80]

In current practice the risk approach is operationalised in the form of a control of flood probability. This means that the water safety standard is expressed as a maximum acceptable probability (see box). In terms of practical water management this means inspecting the dike ring to see if it meets the standard. If not, then measures – primarily preventive ones – are taken within or on the dike ring. In fact, a great deal of research and many case studies indicate that every euro invested in prevention is almost always most effective. In principle, supplementary consequence-limiting measures would also merit

Flood protection

Looking at the organisation of flood protection, one can discern an Anglo-Saxon style, based on a great deal of individual responsibility and the operation of the market, and a Continental style with the government taking responsibility. Lessons from the USA and the UK teach us that leaving responsibility to individuals does not always mean that they accept it. This can lead to great harm with legal procedures as a result. Flood protection often remains confined to local 'postage stamps' based on local cost-benefit considerations and so do not always form a consistent whole. In the Dutch situation, with vast flood-prone areas and an extensive system of diked areas, flood protection is a paramount collective good.

Among all nations, the Netherlands has established these measures in law best, in the form of standards, quinquennial audits and political reporting. Damage control and disaster management (and insurance) are better organised in countries with poorer levels of protection (and more frequent flooding), such as the UK and the USA. Japan has the best coverage of the entire safety chain, from spatial planning and prevention (flood defences) to disaster management and recovery. The emphasis in the Netherlands is primarily on prevention, while in the USA and the UK it lies mainly on disaster management. Japan has also instituted its own 'Delta Committee' to advise on climate-proofing the Japanese flood defences. There they aspire to 'zero casualties' from flooding.

Source: *"Beantwoording Kennisvragen Deltacommissie, een samenvatting" [Response to Delta Committee's request for knowledge].* Directorate-General for Public Works and Water Management and Deltares, 2008.

attention – which is what the previous Delta Committee also stated. These would involve spatial planning restrictions, zoning, compartmentalisation, early-warning, evacuation plans, evacuation routes and evacuation locations.[81] The optimum combination of measures must then be in accordance with the nature of the disaster, the properties of a dike ring and the effect (cost-effectiveness) of the various types of measures. A custom-tailored approach, in other words.

Explicit concern for casualties

The current water safety standards count casualties only indirectly, expressing them in monetary terms and thus allowing their inclusion in the costs and benefits (damage avoided) of protective measures. The Delta Committee finds that casualties must also be explicitly incorporated when determining water safety standards.

The risks of flooding, as an inescapable natural phenomenon, are not acceptable to modern society; they are rather seen as a phenomenon against which government affords protection (even though society does accept that there is no such thing as 100% safety). In this regard, the risk of flooding can be compared with other external safety hazards, such as those from industrial plant, the transport and storage of hazardous materials, railway shunting yards and air traffic.

The Delta Committee finds that every citizen inside a diked area may expect the government to provide a basic level of flood protection. The probability of fatality due to flooding can be no higher than a certain level, acceptable to society. Moreover, the Delta Committee finds that the safety level must reflect the population's aversion to 'large numbers of simultaneous casualties' due to flooding.

Interests worth protecting: a broad definition

The Delta Committee considers that the interests to be protected embrace more than just costs and damage. In the Committee's view, the cost-benefit analysis underlying the standards to be set must include aspects that were not previously cast in monetary terms, such as landscape, nature and cultural-historical values (LNC values), societal disruption and damaged reputation. The last Delta Committee shared this conviction but at the time there were no satisfactory data on the economic worth of LNC values, nor on how to cope with casualties. In its valuation of these imponderables, as they are called, the last Delta Committee used a factor of 2 to multiply the direct damage. This did justice to the added protection of such interests.

Research[82] has become available in recent years on the valuation of:

- landscape, nature and culture (history);
- societal disruption and damaged reputation;
- direct and indirect damage

The Committee advocates their explicit inclusion in present considerations. Furthermore, the risk aversion aspect must also be given a place in society's cost-benefit analysis. Risk aversion is the preparedness to pay added costs to reduce uncertainty about extreme levels of damage.

The first Delta Committee and the Flood Protection Act

The core of the Delta Committee's advice in 1960 is to achieve a level of protection that agrees with the value of the interests to be protected. This level of protection is translated into a storm surge sea level and a high water level in the rivers. The flood defences must be able to contain these levels with a high degree of certainty. The more capital, population and cultural-historical heritage behind the flood defences, the greater the level of protection should be. Thus the highest level of protection was advised for Central Holland: protection against a storm surge level with a probability of 1/10,000 per annum. Elsewhere along the coast and along the lower reaches of the rivers we maintain lower levels of protection (1/4,000 and 1/2,000 per annum). Standards for the upper reaches of the rivers came later, as 1/1,250 per annum.

The level of protection in the Flood Protection Act (1996) is defined as the probability of occurrence of the highest water levels that need to be safely contained by the flood defences. This water level is known as the Design High Water level [Maatgevende Hoogwaterstand: MHW]. The probability is called the threshold probability [overschrijdingskans]. This is very different from the flooding probability [overstromingskans], which is the probability that the land behind the flood defence actually gets inundated. The flooding probability is also determined by the strength of the dikes and the extra height of the dikes above the Design High Water level. The probability of a flood is in principle less than the (threshold) probability that the water level exceeds the design height. We can now use flooding probabilities to guide us rather than threshold probabilities because we now know more about flood defence failure mechanisms than was known at the time of the first Delta Committee.

Source: *Onze Delta. Feiten, mythen en mogelijkheden. [Our Delta. Facts, myths and opportunities]* Deltares, 2008, pp. 12, 13

A broad interpretation of safety

The Committee has opted for a broad definition of 'safety', to include: human life, economic value, landscape, natural and cultural (historical) (LNC) values, social components and the reputation of the Netherlands abroad.

People can experience flood damage in a variety of ways and to different degrees. In the worst case people die or get hurt. Evacuees and material damage may also be involved. Direct economic damage can occur within the affected area: damage to capital goods (structural, infrastructure etc.); costs of emergency assistance, evacuation, aftercare; loss of income. Indirect damage is possible outside the affected area: added pressure on utilities, loss of income (evacuee reception, less consumer expenditure, unemployment).

Ecological and cultural (historical) values relate to vulnerable and irreplaceable buildings, objects and areas, involving a societal – sometimes ethical – choice about what must be included as essential areas. What is important to society is that superregional 'lifelines' (gas and other fuels, water, electricity, roads and bridges, sewage systems, water treatment, telecommunications and ICT networks etc.) must remain operational. If they were to fail for more than a few days, then we would experience societal disruption. This has effects on public governance, health care, financial traffic and more. The reputation of the Netherlands benefits if a flood is not associated with enduring, catastrophic consequences, leading to a decline in international investor confidence and weakening the economy.

The interests to be protected determine the water safety standard

In the Delta Committee's opinion, the water safety standard must give expression to:

1) the basic level of flood protection afforded to each citizen living inside a dike ring. In other words, a probability of fatality due to flooding no higher than a level to be agreed by society as a whole – the personal risk;
2) a socially acceptable upper limit to the probability of large numbers of fatalities due to flooding – the societal (group) risk;
3) damage avoided set against the costs involved. This is an economic optimisation, taking the form of a societal cost-benefit analysis, which should include both direct and indirect costs of flooding within and outside the flooded area, as well as the monetary value of LNC values, casualties, societal disruption, risk aversion and damaged reputation.

In combination, these three aspects embrace both economic damage and casualties, taking account of the distribution of risks among individuals (the equality principle, related to basic safety) and the balance between societal benefits and costs (efficiency, related to societal cost-benefit analysis and group risk). Naturally, the final degree of protection must at least be the same as the present one according to the present state of safety of the diked areas: the safety of these areas must not be allowed to degrade under the new standards.

In the Delta Committee's opinion, these three aspects must be translated into a single water safety standard, which should be set down in law. This aids the maintenance of water safety over the long term. It is recommended that the standard be regularly reassessed – every 12 years, for instance – since both the climate (and flood probability) and the consequences of a possible flood, due to social and economic developments, are changing.

This approach maintains the principle of spatial differentiation in safety levels, introduced by the last Delta Committee, but with a basic safety level for all.

Developing these three elements further may result in a yet more spatial differentiation than there is at present. If so, the Committee's view is the equality principle must be guaranteed in interlinked groups of dike areas, so large regional variations in safety levels are not desirable.

Casualties part of water safety standards

When looking at casualty prevention, the Committee has chosen to seek a link with existing external safety policy for protecting persons and the environment against accidents in industrial plant, the transport and storage of hazardous materials, railway shunting yards and air traffic. The measure of risk in external safety is the individual or Local Risk (LR) and the Group Risk (GR).[83]

The local risk (LR) is the probability of a fatality due to flooding at a given location inside a diked area. The LR is calculated from the probability that the dike ring will flood, multiplied by the probability of fatality, should a flood occur at that location. The flooding probability for the diked areas with the lowest level of safety is roughly 1/1,400 a year.[84] The probability of fatality due to flooding is of the order of 1/100. This means that the expected LR for flooding in most locations in the Netherlands is less than $10^{-3} \times 10^{-2} = 10^{-5}$. The Delta Committee proposes a safety level of 10^{-6} a year as the minimum flood protection level for every inhabitant of the Netherlands. This is comparable with other areas of

Societal or Group risk (GR) is the annual probability of a disaster with a certain number (N) of casualties, or more. The group risk is represented by an FN curve (a graph of probability against number of casualties). In 2004 the RIVM estimated the group risk of flooding,[85] showing that the probability of large numbers of fatalities (group risk) due to flooding is far greater than the group risk of all recognised external safety hazards together (see graph). In the Committee's view this is unacceptable. Especially for the large number of casualties the estimated group risk of flooding is a factor of 10 to 1000 larger than the summed group risk of external safety hazards, because the inundation of a diked area impacts a large number of people. Moreover, extremely high water levels along the coast and the rivers could cause simultaneous flooding of a number of diked areas.

Figure 1: Societal or group risk of flooding in the Netherlands compared with the sum total of societal (group) risks of all other external safety hazards in the Netherlands studied by RIVM thus far (RIVM, 2004).

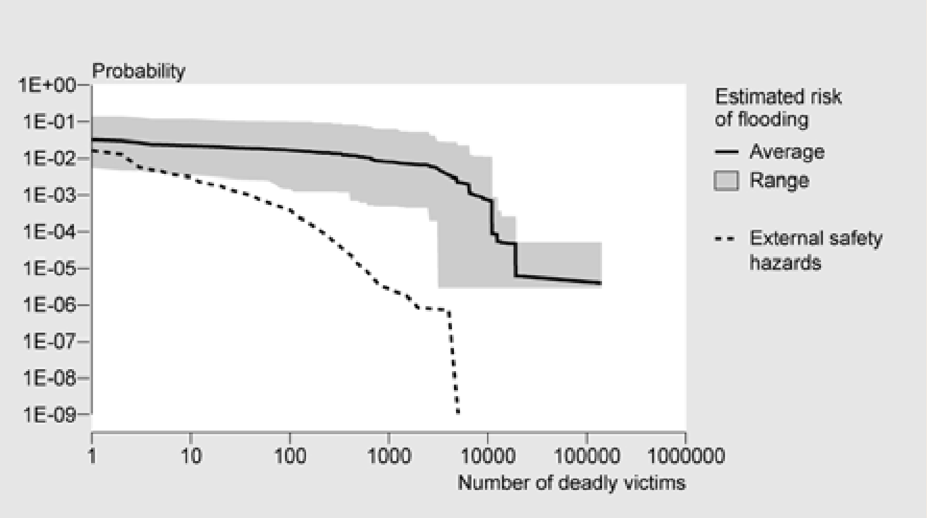
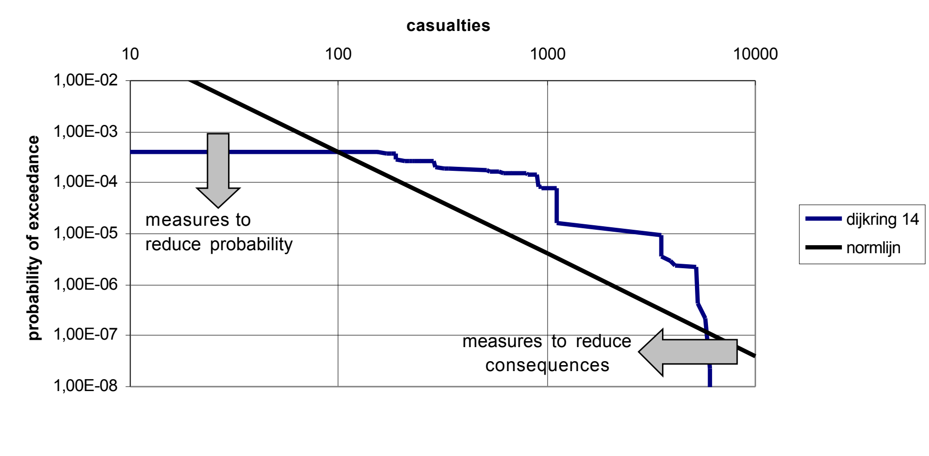


Figure 2: The effect of probability-limiting and effect-limiting measures on the FN curve and its relation to the norm line (Jonkman, 2007, MSc Thesis).



There is at present no ready-made methodology nor standard for the group risk of flooding. The Delta Committee urges the development of such a measure for group flood risk in order that measures can be targeted to avoid large numbers of flood casualties. This should preferably be based on a so-called norm line with a quadratic gradient. This norm line expresses an acceptable flood probability for all numbers of casualties. Using a quadratic-slope norm means that an incident involving 10 times more casualties must have a 100 times lower probability of occurrence. This is also used in other safety areas; it expresses society's aversion to incidents involving large numbers of casualties. It is recommended to base considerations of group risk on the total, national group risk.[86] A practical consideration of group risk can be based on the calculated group risk for each diked area. A group risk measure per diked area can be derived from the level of ambition as defined at national level (the national GR standard).

After the GR standards have been fixed, the FN curves for each diked area can be compared with the norm line to see whether extra measures are needed. Risk-limiting measures, such as improved flood defences, will shift the line as a whole downwards: the probability of a given number of casualties is reduced. This can also be achieved by effect-limiting measures, so that the same probability will result in fewer casualties. This deflects the line to the left (see Figure 2). It is also possible to combine probability and effect-limiting measures.

The Delta Committee's choice

There is at present no complete insight into how these three elements should be worked out in terms of a new standard. More work is needed. However, the Committee believes that fixing safety levels is not something that should take the form of a mere exercise in calculation. In light of what we already know, whereby the Committee must once again emphasise the far greater flood risk to society, the Committee is of the opinion that the amended standard must in any case lead to a greater level of safety than the present one. The Committee wants to be very clear about that.

After careful consideration, the Committee's judgement is that the flood probability for all diked areas (the amended water safety standard) must be reduced by a factor of 10, so increasing the safety level by a factor of 10 in comparison to the present standard. In this regard, the Committee has interpreted the present standards as flooding probabilities. To afford everyone the same basic level of safety, it is expected that the flood probabilities of the diked areas in the rivers region will have to be reduced by a factor of 10. According to the present knowledge flood probability of several diked areas along the coast and the lower river reaches must be reduced by a factor of 10 as well in order to avoid large numbers of casualties. In the Committee's view, further refinement of these three ingredients into a standard may lead to a factor of less than 10 only when this can be justified on very substantial grounds.

In view of the considerable risk of large numbers of casualties, the Committee expects that further refinement for a number of diked areas would rather lead to a greater improvement in the safety factor.[87] In these cases the Delta Committee believes that it is essential to drastically reduce the effects of sudden, uncontrollable flooding, since large breaches, open for a long time, will create havoc, admitting vast quantities of water. Here the Committee recommends the concept of Delta Dikes: dikes built so wide, high or strong as to virtually rule out a sudden, uncontrollable flood. The way this concept will work out precisely in practice will require tailoring to local circumstances, taking account of the effects to be avoided, and the properties and opportunities offered by the local flood defences.

80. Preventive measures are dike reinforcement and river widening. Proactive measures are those concerned to avoid hazardous situations, such as zoning in spatial planning and building regulations. Preparation involves the organization of disaster management (exercises). Response is the actual response to a disaster during the flood.
81. The Fransen Committee (Flood Management Task Force) is mandated to ensure that disaster management is in order by the end of 2008.
82. Witteveen and Bos, 2008. *Economische waardering imponderabilia*, Achtergronddocument in opdracht van de Delta Commissie [Economic valuation of imponderables. Background document commissioned by the Delta Committee].
83. The External Safety Order (Besluit Externe Veiligheid, VROM, 2004) contains the socially acceptable risk standards. For Local Risk this is a probability of 1 in 10^{-6} per annum. For Societal or Group Risk, the probability that an incident will cause 10, 100 or 1000 fatalities must not be more than 10^{-5}, 10^{-7} and 10^{-9}, respectively. The collective risk standards are not absolute thresholds, rather guide/checkpoints. The proper authorities must be held accountable for any departure from these values. External safety policy in the Netherlands aspires to a probability for an incident with 100 fatalities that is a factor 100 lower than that for an incident with 10 fatalities. The acceptable probability of a disaster is thus inversely proportional to the square of the number of fatalities. This second power is also called the aversion factor.
84. This ignores the Meuse Embankments. Rijkswaterstaat 2008, *Kengetallen kostenbatenanalyse (KBA)* [Cost-benefit analysis, key data] *WV21*, final draft 29 April 2008.
85. RIVM, 2004. *Risico's in bedijkte termen*. [Dutch dikes, and risk hikes.] De Bilt.
86. The choice of a national GR standard is recommended because: a) water safety policy is concerned with protecting the Netherlands against flooding; b) the impact of a major flood is also felt outside the flooded diked area.
87. Jonkman, S.N., 2008. Schattingen groepsrisico t.b.v. advies Deltacommissie. [Group risk estimates for Delta Committee's advice]. Memo 9T6387.A0/NN0001/902968/Rott. The diked areas associated with large number of simultaneous casualties and a reasonable chance of flooding, which for that reason exert a dominant influence on the group risk at national level, are IJsselmonde (17), South Holland (14), Dordrecht Island (22), West Brabant (34), Voorne-Putten (20), Alblasserwaard & Vijfheerenlanden (16), Hoeksche Waard (21), Lopiker- en Krimpenerwaard (15), Friesland and Groningen (6) and Flevoland (8).

Appendix 5

A closer look at islands and artificial reefs

Introduction

Climate change will cause the sea level to rise and possibly will lead to a change in the storm and wave climate, which will impose a greater burden on the flood defences along the Dutch coast. This burden can be alleviated in a number of ways. One option is to construct islands off the coast, since an island can influence the direction and strength of water currents, as well as breaking waves and reducing their impact. In this way an island can help defend the coast (locally) and contribute to the safety of the Netherlands. The effect depends on the island's shape and size and the distance from the island to the coast.

An island off the coast can also perform other functions that can help resolve societal problems while affording economic opportunities. Such functions can be water-related, for example, or may offer space that is not available or perhaps too vulnerable on shore. The Delta Committee has received many detailed proposals for such options, so it seems to us a good idea to give a general description of their advantages and disadvantages in this appendix.

The problem

The coast of the Netherlands is sometimes hit by severe storms. The combination of high tides and storm set-up can then result in water levels more than 5 m above Dutch Ordnance Datum NAP. Sea level rise will increase these water levels. Combined with long, high waves, this can result in large-scale erosion of the beaches and dunes with consequent damage to the sea defences. In extreme cases the hinterland may be flooded.

Possible measures

The measures must affect the storm set-up and/or wave action in order to reduce the erosion of beaches and dunes as well as general damage to the sea defences under such conditions. A reef or island off the coast in the North Sea will resist wind-waves and storm surges to a greater or lesser degree. During a severe storm, coastal damage is mainly caused by long waves from the sea. These waves can be observed down to great depths and it is known that they are reflected if they collide with steep inclines in the sea bottom. An artificial reef or island, or a series of them, can amplify this sought-after effect. In deep sea waters (10 to 15 m below NAP) the long waves are weakened while the short waves pass through.[88] This damping effect is either absent or greatly reduced at coastal locations without an island or reef. Other means of coastal defence must be used there. So, even with an archipelago of artificial islands, parts of the coastline will still have to be given extra protection.

An alternative way of limiting coastal erosion is dredging the sea bed, which reduces storm set-up. This should preferably take the form of long, extended channels so that the water set up by the storm can flow back along the sea bed. The greatest effect is expected with a north-westerly orientation, which is the direction with the severest storms and highest set-up. Exploratory calculations show that a water level drop equivalent to the 1953 storm can be achieved along the coast of Holland.[89]
Both measures – reef or island and dredging the sea bed – can be combined with a series of islands outside a contour 20 m deeper than NAP, with channels between and along the islands from which the sand has been extracted. Exploratory calculations[90] show that it is

possible to achieve a reduction of the design water level of 20 cm at the Hook of Holland and 10 cm along the remainder of the Holland coastline. In the Western Scheldt a 50 cm reduction of the design storm surge level that occurs once in 4000 years can be achieved. This reduction consists of a drop in daily tide (20 cm) and a cut in wind set-up (30 cm). Exploratory calculations for the construction of an island on the Vlakte van de Raan, which is on the landward side of the 20 m depth contour below NAP, give the impression that this may increase design water levels, especially in the Western Scheldt, because the island changes the nature of the tidal wave.

The most significant way to achieve a drop of storm surge water levels along the Dutch coast is to dredge large, deep channels between the islands, in a north-westerly direction. The position of the islands along the coast must also be streamlined to avoid a funnelling effect on the tide or wind set-up. Creating such channels would also seem to counteract the formation of mud flats since the tidal flow is invigorated.

Islands off the Holland coast will reduce the size of extreme waves. The islands' influence on the waves depends closely on wind direction. A reduction of the order of 25% in both height and period could be achieved under a north-westerly wind that raises roughly 7 m waves under present circumstances.[91]

Implementing the measures: what is needed?

Constructing islands requires vast quantities of sand. Given a water depth of 20 m (within the 12 mile zone but out of sight of the beach) and a construction height of at least 5 m above Dutch Ordnance Datum NAP, this means an island 25 m higher than the surrounding sea bed. Constructing an island (or archipelago) with a total length of 100 km and a mean profile width of 6 km would require 15 to 20 billion cubic meters.

Since the island would be exposed to the sea on all sides, it would need to be well protected against waves and currents, so would need expensive, hardened construction or, if this is rejected, it would require regular maintenance, taking the form of beach nourishments. So, an island with a total coastline of 200 km, which itself would require maintenance, would have to be laid in deep water to reduce wave action along 100 km of coastline. Of course, one should note that waves obviously attack the seaward side of an island mainly. The island will have to rise along with the sea level to secure the wave reducing effect for the future, which will demand even more sand. In the meantime, the unprotected part of the North Sea coast (the remaining 250 km) would still need regular maintenance.

Sand extraction from channels would deliver additional beneficial effects, reducing water levels (see also[92]). Further research is needed to see whether the principle of sand extraction from channels may be viable as the optimum type of sand extraction for coastal nourishments.

What side-effects do these measures have?

Locally, in the short term, the wave damping effect of the islands can be beneficial to coastal safety. But it is important to look at effects on the large scale. First of all, it appears that the shelter does offer reduced erosion or even sand accretion locally. But this local gain is often at the cost of increased erosion elsewhere, in locations to which the sand would otherwise be transported by the currents.

Furthermore, the changed wave climate would have consequences for the behaviour of the coastal profile. Long waves along a natural coastline actually change the coast's profile temporarily, causing a steeper high area with a less inclination in the lower region. Under calm conditions the coastal profile can restore itself thanks to natural wave action. Constructing islands or coastal reefs not only disturbs the coastal profile but also the natural recovery to the original profile after a storm season. Over the long term this leads to a net adverse effect: stability of the coastal profile is reduced and the coast degrades more rapidly. This does not hold for the natural reefs along the coast, the breaker banks, as they are called. These actually transmit sand to shallower water, in contrast to artificial reefs.

Islands not only influence the wave climate during storms; a calmer climate is created under normal conditions, too. The Wadden Sea shows where that can lead. The calmer environment creates conditions for the sedimentation of fine material; there is less energy to displace sand towards the coast. Over the long term this can lead to the development of a mudflat environment, while beach and dune formation stagnate along the old coastline. As indicated earlier, dredging channels may prevent this.

Generally, an important reason for constructing islands is to create more land, possibly for functions for which no space can be found on shore, such as environmentally harmful or shipping-related activities. An island can be used to transfer and store goods. This requires docks and terminals. If a seaport were to be combined with an airport, then the island would house a distribution centre linked to facilities on shore, thus reducing spatial pressure and the environment there. In principle, islands can also be used to live on. The island might probably also be used to house fish farms, algae cultures and other forms of aquatic business such as tourism (beach, marina, recreational facilities). It might possibly be used for agriculture, too, but that would place specific demands on soil quality and the water supply. Depending on use, links with the coast would be needed, in the form of roads, bridges, tunnels or ferries, with the complementary infrastructure on shore.

The waters surrounding an island can be used to generate energy (tidal, wave-generated) as well as to store and transmit it (LNG terminal). Other energy-related functions can be housed on the island, too, such as windmills or a dock for windmill delivery, assembly and maintenance, drilling platforms and other offshore activities.

Islands can have beneficial ecological effects due to the formation of extra shallows or intertidal environments along the periphery in less turbid (light-limited) surroundings than the coastal waters. This would possibly create breeding grounds for fish, bird foraging areas, and aquaculture. These ecological advantages, however, must be weighed against the loss of ecological values from the construction and presence of an island where previously there was only sea bed.[93]

International examples

The construction of islands off the coast for residence and recreation has recently become relatively common in the Arabian Gulf, Dubai especially. Japan and Hong Kong have airports on islands. Large-scale land reclamation in Singapore takes the form of islands and coastal expansion, especially for housing and industrial applications. At the time of writing, little is known about the effects on coastal protection.

Matters are different for artificial reefs. Above-surface and underwater reefs have been laid down around the world to protect the coast behind them. They all lie relatively close to the coast (out to a distance of less than 500 m, within the surf zone under extreme conditions) and success has been very mixed. They are more successful where the tidal amplitude is relatively small. Sedimentation sometimes occurs directly behind the reef and the reef can sometimes even attach to the coast (tombolo effect). Given the distance from the coast and the length of the reef, empirical formulae can predict tombolo formation. The probability of adverse effects is very high on both sides of the reef. The sedimented sand comes from somewhere. Not much information is available about these additional adverse effects at greater scales.

It has been found in Spain and Italy that reefs can lead to local sand accumulation, but the overall sediment balance is negative. This is mainly due to the fact that the reefs lead to horizontal circulation, with a net sediment transport out of the system. In Spain this has led to the removal of as many reefs as possible from the coastal system, followed by beach nourishments. The same strategy is needed in Italy, but there are reservations there due to the scale on which reefs have been created, coupled with economic considerations.

88. The principles of this action for the Dutch coast have been confirmed by laboratory and model experiments. During an extreme storm, an exploratory study at Scheveningen revealed that a reef at 10 m depth cut wave height by 30 to 40% (Jacobse, S., M. Meijerink and J. de Ronde (2007), Verkenning kustrif Scheveningen; fase rapport technische haalbaarheid [Exploratory study of a coastal reef off Scheveningen; Phase report on technical feasibility]. WINN samenwerkingsverband Rijkswaterstaat & Royal Haskoning. Report 9R8885.B0/R0005/SJAC/SSOM/Rott1). Wave height in the breaker zone at a depth of 6 meters declines by more than 1 meter. The wave period at that point is also roughly 1 second less. Model calculations show that the dune erosion would be significantly reduced as a result (indicative value: 15–20 m).
89. F. Groenendijk, 2008. *Kustveiligheid en eilanden, een eerste oriënterende verdiepende studie*. (Coastal safety and islands, a first orienting and exploratory study].
90. Svasek en Boskalis, betreffende onderzoek naar effecten ruimtegebruik van de Noordzee, rekening houdend met morfologie en ecologie [Re. research into the effects of using space in the North Sea, taking account of morphology and ecology]. Unpublished.
91. Svasek en Boskalis, betreffende onderzoek naar effecten ruimtegebruik van de Noordzee, rekening houdend met morfologie en ecologie [Re. research into the effects of using space in the North Sea, taking account of morphology and ecology]. Unpublished.
92. F. Groenendijk, 2008. *Kustveiligheid en eilanden, een eerste oriënterende verdiepende studie*. (Coastal safety and islands, a first orienting and exploratory study].
93. Wageningen IMARES, 2008. *Werken aan Deltanatuur, compenseren of versterken* [Working on Delta Nature: compensate or strengthen]

Appendix 6

Glossary

BZK (Ministry) Ministry of the Interior and Kingdom Relations

CBS Statistics Netherlands (Government statistics office)

CPB Netherlands Bureau for Economic Policy Analysis

Design discharge River discharge that is related to the probability of the safety standards (1/1250 a year for the Rhine and the embanked Meuse) and that determines the design high water levels which the dikes must be able to withstand in any case.

Dike ring region / diked area Area protected against flooding by connected primary flood defences, such as dikes, dunes, pumping stations or high ground. There are 95 dike rings (diked areas) in the Netherlands, as set down in the Flood Protection Act. The flood protection afforded by the dike rings is managed by the water boards and the Directorate-General for Public Works and Water Management.

EMU European Monetary Union

Estuary Wide, tidal, often funnel-shaped river mouth where fresh river water and salt sea water mix to form brackish water. It is called a delta when a river discharges into the sea through a system of branches.

FES Economic Structure Improvement Fund

GNP Gross National Product: total worth of all goods (and services) produced in a country over a given period.

Groyne Short, stone dam in a river bed at right angles to the summer bank. Restricts river's flow profile, thus preventing river meander, and improves river navigability as the shipping channel remains deep and in a fixed position.

Hydraulic preconditions (boundary conditions) Load imposed on a flood defence by hydraulic conditions (water levels, currents, wave height and length). As prescribed in the Flood Protection Act, the hydraulic boundary conditions for the safety standards are revised every 5 years.

ICT Information and Communication Technology

IPCC Intergovernmental Panel on Climate Change

KNMI Royal Netherlands Meteorological Institute

Lagoon Shallow body of salt or brackish water separated from deeper sea by shallows, in the Netherlands usually a sandbank.

Littoral zone Zone where active sand transport occurs, now and in the long term, due to accretion and erosion by currents and waves. The littoral zone is composed of dunes, sea dikes, beach and underwater moles out to a depth contour of 20 m below Dutch Ordnance Datum NAP.

LNV (Ministry) Ministry of Agriculture, Nature and Food Quality

LNC (values) Landscape, natural and cultural heritage values

Longitudinal dam Guard dam parallel to the river. Prevents the shipping channel from silting up.

Lower river region The region of the lower, tidal reaches of the rivers Rhine and Meuse, west of the line Vianen, Gorinchem, Heusden, including the Hollands Diep and Haringvliet, but excluding the Hollandsche IJssel. High water levels in this area are caused by a combination of storm surges at sea and river discharge.

MNP (PBL since 1 January 2008) Netherlands Environmental Assessment Agency

Mudflat Shallow in the intertidal zone of relatively quiet tidal waters, made up largely of fine-grained sediments.

NAP Dutch Ordnance Datum: the reference water level for the entire Netherlands.

National Ecological Network Connected network of major nature reserves in the Netherlands (existing and yet to be developed). Forms the backbone of nature in the Netherlands.

Palaeoclimatology Climate study using data retrieved from geological formations. Climate data can be derived from a wide variety of materials using many research methods.

PKB Key planning decision

Retention Temporary storage of water so that downstream areas do not flood.

RPB Netherlands Institute for Spatial Research

Salination Gradual increase of salt concentration in soil or water.

Salt marsh Vegetated shallow in the intertidal zone attached to the dikes.

Salt wedge Salt water that flows into a coastal outlet (canal, waterway, river channel) underneath the lighter river discharge during a flood tide.

Seepage Ground water that reaches the land surface due to a pressure gradient between relatively high water levels on sea or in rivers or lakes, and the relatively low-lying land behind the dikes.

Settling Compaction of the soil due to drying or extraction of ground water. Occurs mainly in peat and to a lesser extent in clay soils. Leads to subsidence.

Upper rivers region River IJssel and the Rhine and Meuse east of the Vianen, Gorinchem, Heusden line. Here, high water levels are only governed by river discharge and local wave action.

V&W (Ministry) Ministry of Transport, Public Works and Water Management

VROM (Ministry) Ministry of Housing, Spatial Planning and Environment

Appendix 7

Overview used literature

Adviescommissie financiering primaire waterkeringen (Commissie Vellinga)
Tussensprint naar 2015, Rotterdam 2006

Adviescommissie Water
- *Recommendationen van de Adviescommissie Water inzake verzekeren tegen wateroverlast.* Advies 2006/002. Den Haag, 2006.
- *Advies veiligheid tegen overstromen. Advies 2006/103.* Den Haag, 2006

Advies Commissie Versnelling Besluitvorming Infrastructurele Projecten (commissie Elverding)
Sneller en Beter. Den Haag, 2008

Aerts, J. B. Kolen, H. v.d. Most, M. Kok, S. v.'t Klooster, B. Satijn en A. Leusink
Waterveiligheid en klimaatbestendigheid in breder perspectief (Routeplanner 2050). 2007.

Andriesse, L.A. e.a.
Natuurlijke klimaatbuffers voor een klimaatbestendiger Nederland. (Definitiestudie Royal Haskoning i.o.v. Natuurmonumenten, Waddenvereniging, Staatsbosbeheer, Vogelbescherming Nederland en ARK Natuurontwikkeling) Rotterdam, 2007.

Alterra
Transitie en toekomst van de Deltalandbouw. Alterra rapport 1132, Wageningen, 2006

Braakhekke, W. e.a.
Hoogtij voor Laag Nederland. (Geschreven in opdracht van het Wereld Natuur Fonds). Zeist, 2008.

Brinke, W. ten
Land in Zee, de watergeschiedenis van Nederland, Diemen, 2007.

Bureau de Ruimte
Kenniskaarten IJsselmeergebied, opgesteld in opdracht van Rijkswaterstaat RIZA. Utrecht, 2007.

Buuren, M. van en P. Schengenga
Randstad in zicht. Lange termijnperspectieven voor water en ruimtelijke ontwikkeling in de randstad. (Rijkswaterstaat Waterdienst en H+N+S Landschapsarchitecten i.o.v. ministerie van V&W). 2007.

CPB
Optimal safety standards for dike-ring areas (discussion paper 62). Den Haag, 2006.

DEFRA
Fisheries 2027. Towards a contract for the future of marine fisheries. London, 2007.

Deltacommissie
Eindverslag en interimadviezen. Den Haag, 1960.

Deltares
- *Klimaatbestendigheid van Nederland Waterland, knikpunten in beleid en beheer*. Delft, 2008
- *Onze Delta. Feiten, mythen en mogelijkheden. Staat en Toekomst van de Delta 2008 – Eerste stap*. Delft, 2008.
- *Grenzen aan de gevolgen van een overstroming? Discussiestuk voor Waterveiligheid 21e eeuw*. Delft, 2008.

Europese Commissie
- *Recommendation concerning the implementation of Integrated Coastal Zone Management –ICZM*. Brussel, 2002.
- *Groenboek Maritiem Beleid. Naar een toekomstig maritiem beleid voor de Unie, een Europese visie op oceanen en zeeën*. Brussel, 2006.
- *Directive 2007/60/EG on the assessment and management of flood risk*. Brussel, 2007.
- *Groenboek Aanpassing aan klimaatverandering in Europa – mogelijkheden voor EU-actie {SEC(2007)849}*

Ecorys
Quick scan van kosten van waterbeheersvarianten voor het IJsselmeergebied. Verandering peilbeheer 2050-2100. Rotterdam, 2008

Flyland
Missie van Flyland naar Azië, 21 mei –31 mei 2002. Den Haag, 2002.

Goor, M.A. van, Zitman, T.J., Wang, Z.B. and Stive, M.J.F.
Impact of sea-level rise on the morphological equilibrium state of tidal inlets. Marine Geology: 202 (3-4): 211-227, 2003.

Inspectie Verkeer en Waterstaat
Primaire waterkeringen getoetst. Landelijke rapportage toetsing 2006. Lelystad, 2006.

Instituut SMO
Startnotitie Toekomstverkenning Afsluitdijk. Naar een toekomstbestendige en duurzame Afsluitdijk (in opdracht van Rijkswaterstaat). Den Haag, 2007.

Internationale Commissie ter Bescherming van de Rijn (ICBR)
Ministerieel communiqué MIN07-02 van de Rijnministersconferentie Bonn, 18 oktober 2007.

InnovatieNetwerk
Het zout en de pap. Een verkenning bij marktexperts naar lange termijn mogelijkheden voor zilte landbouw. 2007.

Jeuken, A. en H. van Waveren
Drie perspectieven voor een klimaatbestendig NL. Adaptiemaatregelen voor het Nederlandse waterbeheer. (Tussentijdse rapportage tbv de Deltacommissie). (Deltares), Delft, 2008.

Jonkman S.N.
Loss of life estimation in flood risk assessment - theory and applications. PhD thesis. Delft, 2007.

Kennis voor een KlimaatBestendig Nederland (KBN)
Een voorstel voor een Kennisprogramma in het kader van de FES investeringsronde. Den Haag, 2006.

KNMI
Klimaat in de 21^{e} eeuw, 4 scenario's voor Nederland. De Bilt, 2006.

Landelijk Bestuurlijk Overleg Water
Water in beeld. Voortgangsrapportage over het waterbeheer in Nederland 2008. Den Haag, 2008.

Milieu- en Natuurplanbureau
Nederland Later. Tweede duurzaamheidsverkenning, deel Fysieke leefomgeving Nederland. Bilthoven, 2007.

Ministerie van Binnenlandse Zaken en Koninkrijksrelaties
Voortgangsbrief Nationale Veiligheid 2008 aan de Tweede Kamer. Den Haag, 2008.

Ministerie van Landbouw, Natuur en Voedselkwaliteit
Kiezen voor landbouw. Een visie op de toekomst van de Nederlandse agrarische sector. Den Haag, 2005.

Ministerie van Verkeer en Waterstaat
- *Zeespiegelrijzing, worstelen met wassend water*. Den Haag, 1986.
- *Ruimte voor de Rivier, PKB deel 4*, Den Haag, 2006
- *Integrale Verkenning Maas (IVM) II*, 2006
- *Beleidslijn kust*. Den Haag, 2007.
- *Water in de Randstad.* Den Haag, 2007.
- *Een ander IJsselmeergebied, een ander beleid*. Den Haag, 2007.
- *Nederland veroveren op de toekomst (Watervisie*), Den Haag, 2007.
- *Van Lobith en Eijsden naar zee. Aanspraak op ruimte en afvoercapaciteit in het rivierbed op de lange termijn vanuit de veiligheid tegen overstroming*. Concept mei 2007. Rijkswaterstaat RIZA*,* Lelystad, 2007
- *Rode Delta's, overstromingsrisicobeheer in verstedelijkt gebied, de praktijk in het buitenland*. Rijkswaterstaat RIZA, Lelystad, 2007
- *Systeemanalyse Rijn-Maasmonding*. Rijkswaterstaat Zuid Holland, Rotterdam 2008
- *Waterveiligheid 21^{e} eeuw, synthesedocument 17 april 2008*. Den Haag, 2008.
- *Kentallen kosten-batenanalyse waterveiligheid 21^{e} eeuw. Concept 29 april*, Rijkswaterstaat Waterdienst Lelystad, 2008.
- *Coastal flood risk and trends for the future in the North Sea region. Synthesis report*. Safecoast project team. Rijkswaterstaat Waterdienst,Den Haag, 2008

Ministerie van Verkeer en Waterstaat, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, Ministerie van Landbouw, Natuur en Voedselkwaliteit.
- *Integraal Beleidsplan Noordzee 2015*. Den Haag, 2005.
- *Beleidsnota IJsselmeergebied*, concept 13 juni 2008. Den Haag, 2008.

Ministerie van VROM.
- *Besluit Externe Veiligheid.* Den Haag, 2004.
- *Randstad 2040 facts & figures. Wat komt er op de Randstad af?* Den Haag, 2007
- Reactie op motie van Bochove/Depla *over ruimtelijke gevolgen 'worst-case' klimaatscenario*. Brief aan Tweede Kamer (2007)
- *De Wet ruimtelijke ordening. Beantwoording van gestelde vragen over nieuwe Wro*. 2008

Ministerie van VROM, LNV, V&W en EZ.
- *Nota Ruimte*, *Ruimte voor ontwikkeling, deel 4*. Den Haag, 2006.
- *PKB Waddenzee deel 4: Ontwikkeling van de Wadden voor natuur en mens*. Den Haag, 2007.

Ministerie VROM, V&W, LNV, EZ, IPO, VNG en UvW.
Maak ruimte voor klimaat. Beleidsnotitie nationale adaptatiestrategie. Den Haag, 2007

Molenbroek, dr. E.C.
Energie uit zout en zoet water met osmose. Rotterdam (Ecofys), 2007.

Natuur- en Recreatieschap De Grevelingen e.a.
Ontwikkelingschets Zicht op de Grevelingen. 2006.

De Nederlandse Bank
- *Gevolgen van klimaatverandering voor de Nederlandse overheidsfinanciën.* Kwartaalbericht DNB september 2007. Amsterdam, 2007
- *De Nederlandse Gasbaten en het Begrotingsbeleid: Theorie versus Praktijk*. Occasional Studies Vol.6/No. 5. , Wierts en Schotten. Amsterdam, 2008

Nienhuis, P.
Environmental History of the Rhine-Meuse Delta An ecological story on evolving human-environmental relations coping with climate change and sea-level rise. 2008

Office of Science and Technology
Foresight Future flooding. Executive Summary. London, 2004.

Platform Communication on Climate Change (PCCC)
Het IPCC-rapport en de betekenis voor Nederland. De Bilt/ Wageningen, 2007.

Provincie Friesland
Streekplan, Leeuwarden, 2007.

Provincie Gelderland
Waterveiligheid Gelderland, Gelderse visie klimaatbestendige hoogwaterveiligheid 21^{e} eeuw. Arnhem, 2008.

Provincie Groningen
- *Provinciaal Omgevingsplan 2*. Groningen, 2007.
- *Kustvisie provincie Groningen*. Groningen, 2008.

Provincie Zeeland
- *Omgevingsplan Zeeland 2006 –2012*, Middelburg, 2006.
- *'Nieuwe verbindingen'*, coalitie-akkoord. Middelburg, 2007.

Provincie Zeeland, Zuid-Holland en Noord-Brabant
- *Kracht van de Delta, de agenda voor een Deltaprogramma*. Middelburg, 2006

Provincie Zuid-Holland
Coalitie-akkoord, Den Haag, 2007.

Raad voor het Delta
Onderzoek Strategische Deltavraagstukken, 2007.

Raad voor Verkeer en Waterstaat
Investeren in de Noordzee. Den Haag, 2005.

Raupach, M. et al.
Global and regional drivers of accelerating CO_2 emissions. Proceedings of the National Academy of Sciences of the United States of America. Vol. 104, no. 24, 2007

RIVM
Risico's in bedijkte termen. Den Haag, 2004.

Royal Haskoning
- *Investeringsruimte voor toekomstige droogte. Verkenning van de hydrologische effecten en economische schade in de KNMI'06 klimaatscenario's.* Studie in opdracht van Rijkswaterstaat RIZA. Amsterdam, 2007
- *Overstromingsrisicozonering. Naar een groter risicobewustzijn in ruimtelijke afwegingen*. In opdracht van ministeries van V&W en VROM. Rotterdam, 2008

Royal Haskoning, HKV-Lijn in Water, Jongejan Risk Management Consulting en TU Delft.
Verkenning slachtofferrisico's in het hoogwaterbeschermingsbeleid. Rotterdam, 2008.

Ruimtelijk Plan Bureau, Milieu- en Natuur Planbureau, CBS
Welvaart en Leefomgeving. Den Haag, 2006.

Ruimtelijk Plan Bureau
Overstromingsrisico's als ruimtelijke opgave. Den Haag, 2007

Saeijs, H.L.F.
Turning the tide. Essays on Dutch ways with water. Delft, 2008.

Silva, W en E. van Velzen
Quick scan doorbraakvrije dijken (concept juli 2008).

Sprong, T.A.
Achtergronddocument Case Business as Usual: kostenschattingen. Eindversie maart 2008. www.adaptation.nl

Staatsbosbeheer en Natuurmonumenten
Dans met de zee. Duurzaam leven in laag-Nederland. Arnhem, 2008.

(Japanese) Subcommittee on Climate Change Adaptation for Flood Control
Climate change adaptation strategies to cope with water-related disasters due to global warming. Draft policy paper June. Tokyo, 2008.

TNO Bouw en Ondergrond
Eilanden voor de kust van Nederland. Pre-feasibility verkenning. TNO-notitie 2008-IenR-N007-RSTA-PEM. Delft, 2008.

Twynstra Gudde
Quick scan alternatieve veiligheidsmaatregelen. Amersfoort, 2007.

Unie van Waterschappen
Financiële consequenties peilopzet IJsselmeer. Inbreng t.b.v. Deltacommissie. Den Haag, 2008.

Vogelbescherming Nederland
*Kust, ruimte voor mensen én vo*gels. Zeist, 2008.

VROM Raad
De hype voorbij. Klimaatverandering als structureel ruimtelijk vraagstuk. (advies 60) Den Haag, 2007.

Waaldijk, C.
Grondwet voor het Koninkrijk der Nederlanden. (bewerking) Koninklijke Vermande BV, Lelystad 1991.

Waddenvereniging
Natuurlijke klimaatbufffers, oktober 2006

Waterloopkundig Laboratorium
- *De Rijn op termijn, een veerkrachtstrategie*. Rapp. R 3124.10. Delft, 1998
- *Afvoerverdeling Rijntakken: een vast gegeven?* Rapp. R 3294.95. Delft, 1999.

WL/Delft Hydraulics
- *Overstromingsrisico's in Nederland in een veranderend klimaat.* Verwachtingen, schattingen en berekeningen voor het project Nederland Later. Delft, 2007.
- *Risky places in the Netherlands: a first approximation for floods*. Delft, 2007.

Wetenschappelijke Raad voor het Regeringsbeleid
- *Waterbeheer en waterveiligheid*. Den Haag, 2007.
- *Sturen op infrastructuren. Een investeringsopdracht*. Den Haag, 2008.

Witmond, B. en J. Bovens
Quick scan van kosten van waterbeheersvarianten voor het IJsselmeergebied. Verandering peilbeheer 2050-2100. (rapport Ecorys Nederland BV i.o.v. Geodelft en het deskundigenteam Beleidskader IJsselmeer) Rotterdam, 2008.

Woud, Auke van der
Het lege land - de ruimtelijke orde van Nederland 1798-1848, 1987

DELTA COMMISSIE

Colophon

Responsible for editing:
Secretariat Delta Committee

Responsible for production and layout:
Synergos Communicatie, Coen Mulder

Responsible for photos:
Jos van Alphen, Esther Rijken, Rob Stroeks
www.katrinadestruction.com

Translation:
Ian Priestnall, Sara van Otterloo

Editing:
Wilfried ten Brinke

Illustrations:
H+N+S Landscape Architects

Further information:
www.deltacommissie.com
A DVD with background reports
and a movie is available as part
of this advice

Printer:
Hollandia Printing

First edition September 2008
Second edition November 2008