Rijkswaterstaat
Ministry of Infrastructure and the Environment

Water Management in the Netherlands

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Preface

Having the right amount of water for water users, at the right time, in the right place, and at socially acceptable costs is one of the key targets for the Ministry of Infrastructure and Environment.
Today's ground rules for the distribution of water in the Netherlands originate from the 1980s, more specifically from the second Policy Document on Water Management. At the time, the entire water infrastructure was reviewed. The conclusion was that large-scale investments in the water infrastructure were not necessary and that good management would suffice to optimise the benefits of our water distribution system.
Our infrastructure and the ground rules still suffice, but the capabilities have been stretched to the limits. Climate change and sea level rise prompt a re-examination of our water management. The resilience of the main water system, the water infrastructure and the ground rules are up for reconsideration. Water usage has also changed and new facilities are needed. We can only respond to the forecasted climate changes if we are fully conversant with the way the main water system works. The question is, are we still familiar with the background, the operation and the rules of our water management? This booklet seeks to contribute to answering that question. This is also an excelent opportunity to offer our collegues from abroad an overview of the specific situation of water management in the Netherlands, a country that would not be inhabitable without our flood defences and water management structure.

I hope you will enjoy reading it.

Luitzen Bijlsma
General Director, Rijkswaterstaat, Centre for Water Management

Introduction

Water management in the Netherlands is a complicated issue. Also,water distribution throughout the country is far from straightforward. The challenges for water policy makers are significant and the discussions about these challenges frequent. That is precisely why it would be practical if the parties involved could share an unequivocal body of knowledge and a vocabulary that everybody understands.

As the work of many water management authorities and water users is usually limited to only one part of our water system, it is often difficult to understand the system as a whole and all its interconnections. There is also sometimes a distorted perception of the possibilities that exists in channelling water. The need to have an overview of our water management system and its functioning is indispensable in present discussions. It is important to know why things are organised the way they are and to understand the aspects closely related to the distribution of water, such as safety, excess of water and shortages, drought and salinisation. It is also important to know which issues and bottlenecks to expect if climate change persists.

This booklet describes water management and water distribution in the Netherlands as well as the problems related to flooding, water shortages, safety, drought and salinisation. The description of our water management system includes a short history of the geological creation of the Netherlands and an account of the interventions that took place over the centuries to protect the country from highvolume river discharges or storm tides. Land reclamation and other hydraulic engineering projects, such as the excavation of channels to the sea and the canalisation of rivers, are also briefly discussed.

We also look at water distribution, focusing on the main water system, the regional system and the interaction between them. Water distribution under normal circumstances is distinguished from water distribution in the event of flooding or water shortage.

The relation with safety and salinisation is explained as well. Finally, we discuss the current bottlenecks and the problems we can expect as a consequence of climate change and soil subsidence. Where relevant, the various themes will be related to the designated users.

This booklet may be used by everyone involved in organisational issues of water management in the Netherlands: water management authorities and policy staff of municipal councils, provinces, water boards and central government, as well as people who use our water system, and other interested parties. The aim is to provide basic knowledge on water management and water distribution in the Netherlands. Hopefully this knowledge and information will contribute to a clear discussion on solving current and future bottlenecks. We hope it will also contribute to insight and understanding of those abroad, who are interested in the particularities of water management in the Netherlands.


Ems
Groningen
Dollard
Leeuwarden
Assen
Lake
IJsselmeer
Overijsselse
Vecht
Lake Markermeer
Lelystad
Zwolle
Noordzeekanaal
Haarlem
Amsterdam
Amsterdam-
Rijnkanaal
Den Haag
Utrecht
IJssel
Nieuwe Waterweg
Neder-Rijn
Arnhem
Rotterdam
Haringvliet
Lek
Waal
Rhine
Merwede
Maas
Grevelingen
Bergsche Maas
Oosterschelde
Middelburg
Den Bosch
Westerschelde
Scheldt
Roer
Maastricht
Meuse

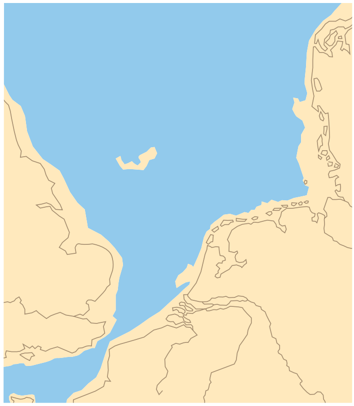
1 The development of watermanagement in the Netherlands

The history of the formation of the Netherlands

At the end of the last Ice Age, around 10,000 years ago, the North Sea was a large lowland plain. As temperature increased the sea level rose and after a few thousand years, the North Sea was on the doorstep of what we now call the Netherlands. River water came to a halt behind barrier bars that the sea had created. Silt settled and plants flourished in the warmer climate, forming a layer of peat on windborne sands deposited during the previous period.

For centuries these layers of peat accumulated, particularly where the barrier bars formed a continuous line, as it did in Holland. However, storm tides washed away entire areas of peat, after which marine clay deposits were formed. This happened mostly in the southwest of the Netherlands. In the east and south the coarse and fine sand deposits from the ice ages still occur on the surface. Here we also find the hilly areas of the Veluwe, the Utrechtse Heuvelrug, the Hondsrug and Salland, which are formed by lateral moraines left behind by the ice ages. These high grounds are criss-crossed by a multitude of streams that provide natural drainage. In the north we also find boulder clay.

7000 BC



5500 BC

This mixture of boulders, gravel and loam was so heavily compacted by the glaciers of the last ice age that it became impermeable, which has its effect on today's water management.

The history of water management in the Netherlands

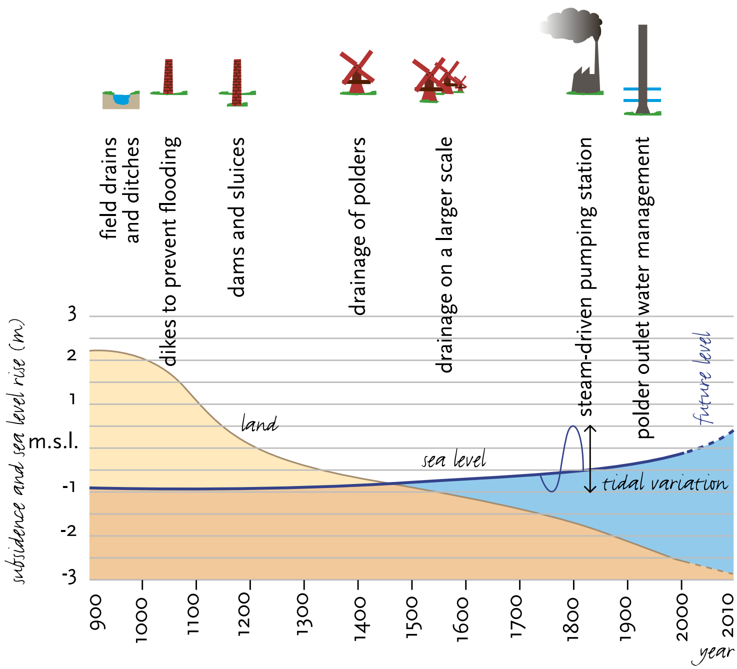
Living on the edge of land and water offers many benefits, which is why our ancestors stayed here despite the intrusive sea, trying to learn to live with water. Excavations near Vlaardingen in the late 1990s proved that water management was already part of life before the Common Era began. Dams, sheet piling and culverts were uncovered that are clearly indicative of water management interventions. People in the north erected artificial dwelling mounds called terps several centuries before the Common Era began.
Gradually, we became more enterprising. The Middle Ages saw the reclamation of the peat bogs. Channels and ditches were dug from the levees into the elevated bogs in order to drain them. As an unintended effect, exposure to air caused the bogs to set and oxidise.
While this was a slow process, in time the surface level dropped until it lay beneath the level of the river on the other side of the levee. Dikes and mills became necessary to drain the excess water into the rivers.
In the southwest, the bogs were not drained but excavated for their salt deposits. This type of surface level reduction gave easy access to the sea: large parts of the bog were washed away, for instance during the St. Elisabeth Flood of 1421, which created the Biesbosch. Large estuaries were formed around the cores of islands.
In the north, this had already happened several centuries before. Here the sea had breached the barrier bars in 1170, washing away the bog situated behind them, and thus creating an internal saltwater lake: the Zuiderzee. Shortly afterwards, in the 13th century, the inhabitants of the salt meadows in Groningen and Friesland decided to link the mounds or 'terps' on which they lived by building a series of dikes.

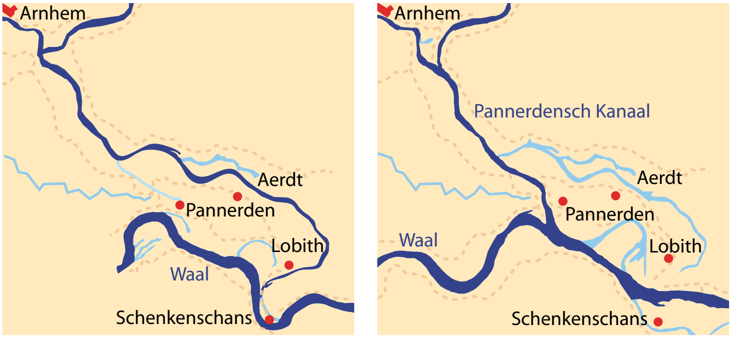
Even after the Middle Ages, sea levels continued to rise and land continued to subside. Dikes had to be raised continually. But water management at times also took the offensive: in the early 17th century, we started draining the lakes and ponds that had been created by extracting peat. The last of the inland lake reclamation projects, Haarlemmermeer, was drained around 1850. By then, powerful steam-driven pumping stations had been developed that enabled us to drain this large lake.

Soil map of the Netherlands: high grounds with wind-borne sand deposits drain into low-lying grounds with Holocene deposits.

Diking in the southwest and north (the Dollard) reclaimed large stretches of land from the sea, undiscouraged by disastrous setbacks in the form of periodic storm surges. The area along the major rivers of the Netherlands was also subject to regular flooding, often caused by ice dams: ice floes snagged on the shore, impeding subsequent floes until the blockage became so great that the water forced its way over or through the dikes.
In the course of the 17th century, the Waal became the main distributary of the Rhine. Almost 90 percent of the Rhine's water discharged through the Waal to the sea. This drastically reduced the discharge of the Rhine itself and of its other branch, the IJssel. In order to stop this process, as well as for military and socio-economic reasons, the Pannerdensch Kanaal was dug in 1707.

The succession of evermore powerful water-related interventions resulted in continual subsidence of low-lying areas of the Netherlands, while the sea level continued to rise ever faster (mean sea level [m.s.l.]).

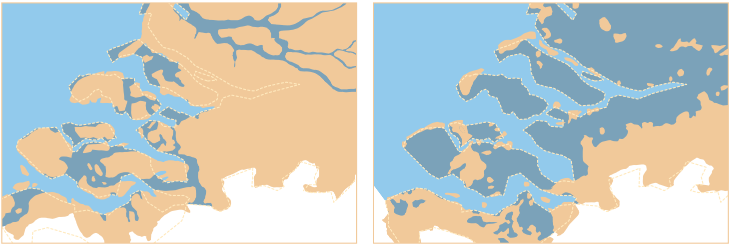




How the Pannerdensch Kanaal restored the discharge through the Neder-Rijn and IJssel.

In the 18th century, the rivers started to have difficulties discharging into the sea. The Maasmond at Brielle silted up and shallows were also formed upstream. Yet it would still be another century before this was corrected by river intervention works.
The 19th and 20th centuries saw more drastic interventions, such as the digging of the Nieuwe Merwede, the Bergsche Maas and the Nieuwe Waterweg, and the construction of weirs in the Neder-Rijn designed to create a different distribution of the Rhine's water over its distributaries.

The Netherlands earned international renown with the Zuiderzee Project, which began with the Afsluitdijk (1927-1932) and the reclamation of the Wieringermeer, the Noordoostpolder, Oostelijk Flevoland and Zuidelijk Flevoland. Equally impressive is the Delta Project, built in response to the disaster that hit the southwest Netherlands in 1953. The Delta Project in particular confirmed our reputation as controllers of the sea, especially once the planned dam in the Oosterschelde was altered in such a way that the sea will only be kept out if there is the threat of a repeat of the 1953 disaster.
Many of the interventions, however, have a downside which we only started to understand in retrospect such as, for example, the ecological consequences of the Delta Project. This understanding was incorporated into the integrated water management policy launched in the 1980s. Meanwhile, all these interventions have caused us to forget that the sea actually intended to continue shifting our coastline further eastwards. Where it would have ended up by now is difficult to say.



Southwestern Delta below sea level (dark blue). Right: situation in the event of flooding; left: situation in the event of flooding if no interventions had been made in our water system.

The intrusion of the sea would have been counteracted by the rivers, which would have continued building up their deltas. But evidently the Netherlands would have looked very different had these interventions not taken place.

Fact is that the coast now lies where it is. And that we decided in 1990 to try and maintain the coastline there. This is why we have been so busy ever since with sand replenishments, both on the beach, the foreshore and in the littoral zone. Moreover, at the turn of the millennium some events occurred that turned our views on water management upside down. High discharge volumes from the rivers Rhine and Meuse in 1993 and 1995 led to the Space for the River programme. In addition, exceptional droughts in 2003 and early 2005 underlined the importance of designating areas where water can be stored as a buffer capacity.

Water Boards

In the early Middle Ages, the western part of the Netherlands was a boggy peatland. For people to work and live on that land, it had to be drained. In those days, the villagers did that themselves by digging a ditch, building a dam or constructing a dike. From the 11^{th} century onwards, this gradually changed. The people who owned the land were often no longer villagers but large landowners who lived in cities, castles or estates. Moreover, there was a growing insight that the construction of dikes and water drainage were matters that went beyond the realm of a village.
In the 13th century, people with common interests in safe water management formed co-operatives, resulting in the first water boards. Their co-operation not only involved working together, it also implied participation in governance, which makes the water boards the oldest form of democratic government in the Netherlands. The water board Hoogheemraadschap van Rijnland, established in 1232, is the oldest water authority that is still in function.
There used to be several hundred water boards, but in the last century their number has been reduced considerably. Nowadays there are 26 left.

Rijkswaterstaat

At the end of the 18^{th} century, parliament decided to establish a powerful central organisation to prevent the country from being flooded by the sea and rivers. Shipworms were attacking the wooden seawalls and quaysides, harbour mouths were silting up, and ice dams were causing flooding. Countermeasures were taken, but they often only provided solace on a very local scale and caused new problems elsewhere. It was time for centralised water management on a national level. On March 27, 1798, an 'Agency for Public Works and Water Management' was established, comprising a president, an assistant and a draughtsman.
Nowadays Rijkswaterstaat is the implementing agency for the Ministry of Infrastructure and Environment. Rijkswaterstaat administers the national road network (3,260 km), the national waterways network (1,686 km) and the water system (65,250 km^2), including the Dutch part of the North Sea.
The legal instruments at the diposal of our water authorities are presented in chapter 10.

Overview of the area administered by the 26 regional water boards.

Bifurcation point ('T-junction') at IJsselkop, seen from the south.
The ship is approaching from the IJssel.

2 System and functioning

The Netherlands could be considered as a gateway for water. All the water that is carried across its borders by streams and rivers must be discharged into the sea. The same applies for rainwater, which makes its way to the sea overland or underground. In the east and south, this happens naturally. Due to the relief of the land, water on high ground finds its own way down. But in the flat low-lying areas that also lie below sea level, water needs a helping hand.

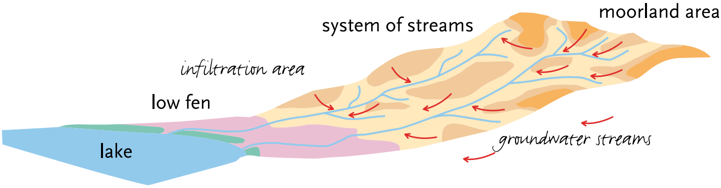
We gradually tried to turn this gateway into a control panel: a pumping station here, a lock there, dams, dikes and weirs everywhere. This has resulted in a mosaic of rivers, canals, lakes and (dammed) estuaries, interlaced with a system of ditches, town canals and channels. Generally we manage the operation of our main water system quite well. We direct water from the Rhine and Meuse to locations of our choice. A substantial amount is stored in Lake IJsselmeer, so that it can be used later on for the production of drinking water, irrigation purposes and much more. We make sure that there is sufficient water in the canals to allow shipping to continue and we use it to combat saline intrusion of groundwater and to keep seawater at bay.

Management of the freshwater element of our water management system

However small our country is, it still is part of four international river basins: Rhine, Meuse, Scheldt and Ems. All the water that flows down these rivers passes through our country on its way to the Wadden Sea and the North Sea.
As this booklet focuses only on the freshwater element of these river basins and on the transitional area (the southwestern Delta), the Scheldt and Ems will not be discussed. The discussion of our water management system will address the following:

- rivers with accompanying canals in the same river basin,
- IJsselmeer area,
- southwestern Delta, and
- the smaller, regional waterways on high grounds and in low-lying areas.

In order to understand how our water management system works, the water systems themselves need to be explained. A water system comprises various components which interconnect to a high degree, particularly in the water management system of the Netherlands. They influence each another, they are co-dependent and moreover they are sensitive to transfer of problems related to water quality and quantity. To understand that interconnectedness properly, this paragraph will first describe the nature and character of the various components.



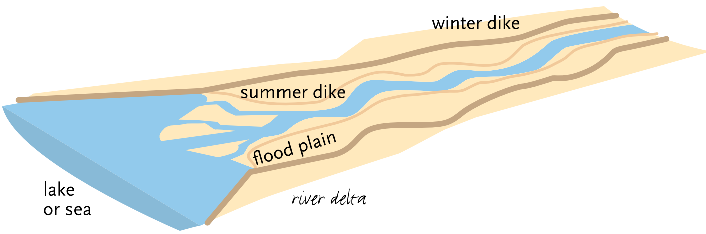
Water from high grounds flows to the sea as surface water as well as via groundwater streams.

High grounds

Rain that falls onto high grounds partly infiltrates where it fell, while the remainder flows to lower-lying areas by way of streams. The infiltrated water also seeps down, which causes marshland to develop at the foot of the high grounds. These areas react differently in summer and winter. In summer, the groundwater level is low as a result of the evaporation surplus, which causes the ground to absorb most precipitation, and run-off is limited. In winter, the soil is saturated and rainwater is discharged immediately.

River

A river can be fed by meltwater, precipitation and groundwater. In summer (with zero or only a small precipitation surplus and little meltwater), the river stream is narrow. In times of a large precipitation surplus and/or a lot of meltwater, the river can become so wide as to cover the entire flood plains (the area between the summer dike and the winter dike).



The 'river system' component.

Polder

A polder is an area that is protected from outer water by a dike and that has a controlled water level on the inside of the diked area. Any water entering the polder (rain, seepage water) that is not used or stored, has to be pumped out. To do this, the water is first pumped into the polder outlet.

Lay-out of our water management system.

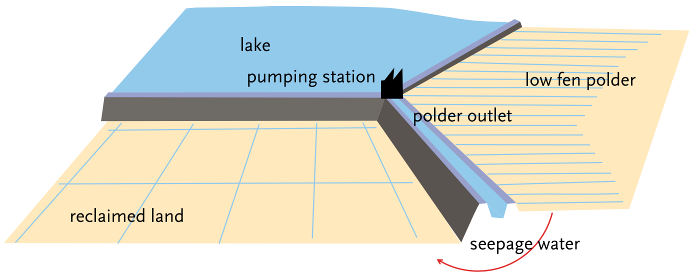


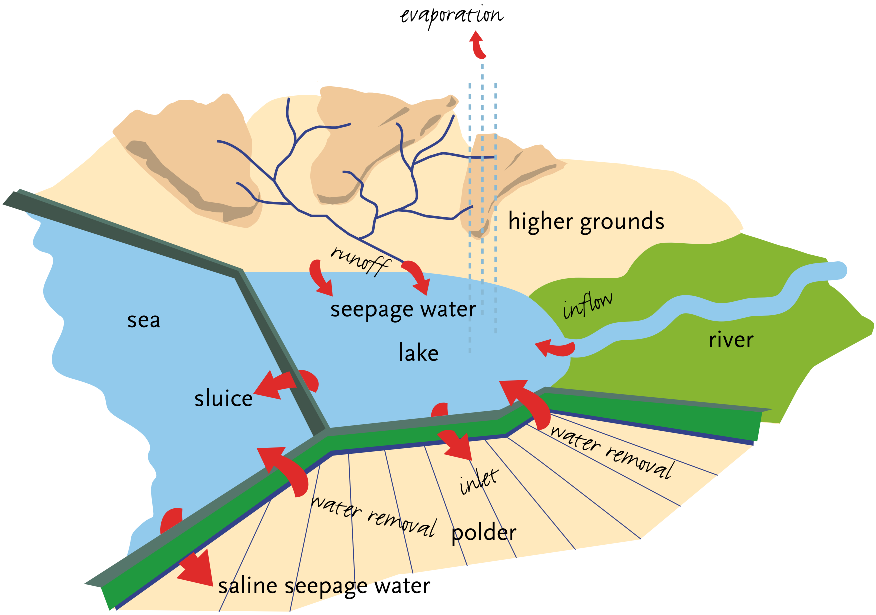
Diagram of the components 'polders' and 'reclaimed land'.

Streams between components

The different components (high grounds, polders and rivers) cannot be seen in isolation from one another. There is constant interchange: the river supplies water to the lake, the lake discharges water into the sea and the polder drains water into the lake, as well as absorbing it in the summer. The water level in the lake influences the seepage water and groundwater flows. In short, everything is interconnected.

Interconnectedness

This interconnectedness is the basis for management of our main water system. Under normal circumstances, it seams obvious that water in every component is at the level we want it to be and that it flows where it is needed. However, in periods of excess rainfall in our own country and in countries upstream, or during prolonged periods of drought, we have to constantly control and manipulate the system to continue serving all water-related interests. We do this according to scenarios and agreements, which will be discussed in detail in the following paragraph.



The interconnectedness of the water system components.

Components of our water management system

Rivers and canals

The days when the rivers could determine their own course are long gone. We have taken various measures to control water distribution.
Key tools are the weir at Driel, which determines to some extent how much Rhine water flows to the IJssel, the Neder-Rijn and the Waal; the sluice gates in the Afsluitdijk, which enable us to regulate the water level in Lake IJsselmeer; and the Haringvliet and Volkerak sluice gates, which allow us to determine through which 'exit' the water will flow into the sea.

The Meuse

The Meuse is a rain-fed river and, as a result, it often goes through periods with little discharge. In order to retain what water there is and to maintain shipping, seven weirs were constructed in the 20th century: at Borgharen,

Linne, Roermond, Belfeld, Sambeek, Grave and Lith. They are almost always in operation, being opened only when the discharge volumes are high. This mostly occurs in winter, when there can be so much rainfall in the river basin that the Meuse cannot cope with this discharge. This happened, for example, in 1993 and 1995.
Where the Meuse crosses the border at Eijsden, it is almost immediately divided into three channels: the Zuid-Willemsvaart, the Julianakanaal and the Grensmaas (the stretch of Meuse in the border region of the Netherlands and Belgium).
In the Grensmaas, we aim at a minimum flow of 10 m^3/s for ecological reasons, but in dry periods this cannot be maintained. Shipping along the Julianakanaal must remain possible at all times, requiring 20 m^3/s to compensate for losses at the locks at Born and Maasbracht. In dry periods, water that is used through operation of the locks is pumped back again.

The canals in Midden-Limburg and Noord-Brabant

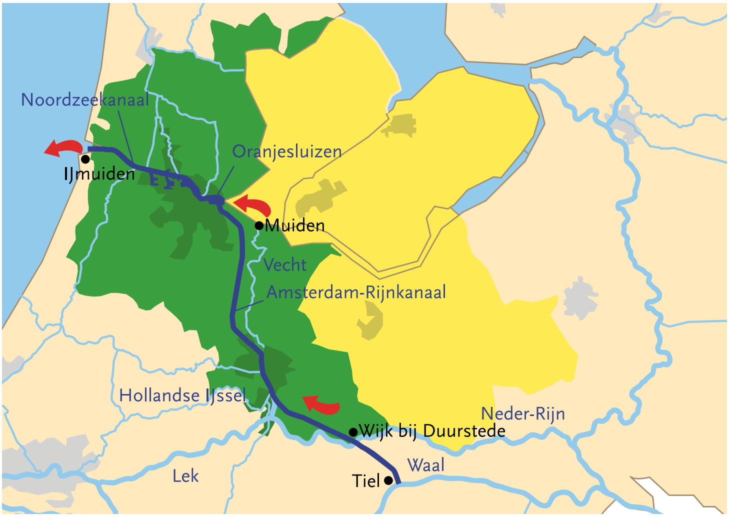
The provinces of Limburg and Noord-Brabant rely on the Meuse for their water supply. According to several treaties with Belgium since 1863, the Netherlands is obligated to discharge a minimum of 10 m^3/s into the Zuid-Willemsvaart via the supply culvert at Maastricht. In return, Belgium is obligated to redirect 2 m^3/s, plus anything exceeding the obligatory 10 m^3/s that is discharged to the Netherlands at Lozen. Incidentally, part of the Meuse water is already diverted near Liege, which Belgium uses to supply the Albertkanaal.
Water management of the canals in Midden-Limburg and Noord-Brabant is laid down in a water agreement that aims to ensure that the supply and discharge of water is distributed equally among the areas managed by the regional water boards.

The Rhine and its distributaries

The Rhine crosses the Dutch border at Lobith. The first bifurcation point is near the Pannerdensche Kop. Here the river splits into the Waal and the Pannendersch Kanaal, which flows into the Neder-Rijn.
East of Arnhem, the IJssel branches off from the Neder-Rijn. The weir in the Neder-Rijn near Driel is operated in such a way that Rhine water can be discharged into the IJssel for as long as possible at 285 m^3/s and that there is always 25 m^3/s left for the Neder-Rijn. The remainder goes to the sea through the Waal.

Detail of the subsystem of the Meuse and the canals in Midden-Limburg and Brabant.

This distribution of water discharge guarantees a reasonable navigation depth on the three river branches. In addition, the power station Harculo near Zwolle receives sufficient cooling water and there is enough water available in Lake IJsselmeer to meet agricultural requirements in the north of the Netherlands during dry periods.
This ideal scenario can be maintained on average for at least nine months per year. However, if the discharge at Lobith is less than 1,300 m^3/s, it is impossible to direct 285 m^3/s to the IJssel. Even so, a discharge of 25 m^3/s is still maintained over the Neder-Rijn.



Catchment area of the subsystem of the Amsterdam-Rijnkanaal and Noordzeekanaal. Green drains directly, yellow indirectly

As the discharge rises above 1,300 m^3/s, the weirs at Driel, Amerongen and Hagestein are gradually opened and the discharge through the Neder-Rijn increases, while approximately 285 m^3/s continues to flow through the IJssel. If the Rhine has a discharge over 2,400 m^3/s, the weirs are fully opened and the distribution of water discharge can no longer be manipulated.

The Amsterdam-Rijnkanaal and the Noordzeekanaal

The Amsterdam-Rijnkanaal and the Noordzeekanaal are of major importance for shipping connections between IJmond, Amsterdam and Germany and for regional water management. The canals must be considered as a single system. The map shows the catchment area for this system. The green area is drained directly, the yellow area can also be drained indirectly through the Noordzeekanaal by way of the inlet Oranjesluizen (locks) near Schellingwoude. On average, 60 percent of the water in the system is supplied by regional water discharged by the water boards (the green area). The system drains into the North Sea at IJmuiden. When the sea level is low, the water flows through discharge sluices (maximum 500 m³/s). When the sea level is high, the IJmuiden pumping station, which is the largest in Europe (maximum 260 m³/s), is put into operation.

Water can be supplied through locks at Wijk bij Duurstede and Schellingwoude. The quantity supplied by Lake IJsselmeer depends to a large extent on the flushwater management for the Lake Markermeer. The amount that is supplied at Wijk bij Duurstede in dry periods in its turn depends on the amount of water that can be subtracted from the Waal at Tiel, as the discharge in the Neder-Rijn is needed to maintain the water levels downstream.
Water is withdrawn from the Amsterdam-Rijnkanaal and the Noordzeekanaal, for regional water supply and drinking water purposes.
This is taken into account in the management of the system as navigable depth is to be maintained. If the level of Lake Markermeer permits flushing of the Vecht and water supply via Muiden, water can also be directed into the Amsterdam-Rijnkanaal. In that case, less water has to be diverted from the Waal through the Neder-Rijn.
Many ships are locked at IJmuiden. This causes saltwater to flow into the Noordzeekanaal, creating a saltwater gradient from IJmuiden to the connection with the Amsterdam-Rijnkanaal. Ecologically, this saltwater gradient provides the Noordzeekanaal with unique ecological characteristics. Because there is an inlet point for drinkingwater in the Amsterdam-Rijnkanaal we must ensure that saltwater incursion does not advance any further. To that end, a minimum flow of approximately 30 m³/s is aimed for at Diemen. If possible, water from Lake Markermeer is also used at Schellingwoude to halt saltwater incursion.
In prolonged periods of drought, water from the Amsterdam-Rijnkanaal is also used to combat salinisation of the polders in the province of Zuid-Holland. During dry periods water from the Hollandsche IJssel is too saline for this purpose, because the saltwater tongue has advanced too far into the Nieuwe Waterweg. This arrangement to provide the polders in the province of Zuid-Holland with water from the Amsterdam-Rijnkanaal was made in the late 1980s in a Water Agreement entitled Small-scale Water Supply Provisions. It stipulates that a system of pumps and pumping stations direct approximately 7 m³/s of freshwater to the polders of Zuid-Holland during periods of water shortage.

IJsselmeer area

This water system comprises lakes IJsselmeer, Markermeer, IJmeer and Randmeren. This is the largest freshwater basin in Western Europe and functions as a buffer which, during periods of drought, can supply water to many of the northern parts of the Netherlands.
It is also a nature reserve of national and international importance.
Its primary function is to discharge water from the river basins of IJssel, Overijsselse Vecht and Eem.
Lake IJsselmeer – and in the summer months, Lake Markermeer – is primarily fed from the IJssel. From April to September, the target level on these lakes is 0.20 m below mean sea level (m.s.l.), while during the rest of the year a level of 0.40 m below m.s.l. is maintained. There is usually enough water to maintain this level. In the winter months, Lake Markermeer discharges the majority of its excess water into Lake IJsselmeer, while in the summer most of it flows westwards to flush the Noordzeekanaal. In spring and autumn the direction of the water discharge changes depending on the weather conditions and the water levels.
Excess water from Lake IJsselmeer is discharged into the Wadden Sea via sluice gates at Den Oever and Kornwerderzand.
Lake IJsselmeer provides significant water volumes to the provinces of Friesland and Groningen, as well as the northern part of Noord-Holland and large parts of Drenthe and northwest Overijssel. In addition, water inlet points for the production of drinking water are located at Andijk and Enkhuizen. However, the quantities involved here are relatively small.
The key water inlet points for the Schermerboezem are located on Lake Markermeer at Lutje-Schardam, Schardam and Monnickendam. Finally, water from Lake IJsselmeer can be let in at Muiden and Zeeburg to flush the Vecht and the Amsterdam canals, respectively. During periods of drought, a sequence of priorities comes into operation (see page 52), which determines the order in which the scarce supply of water will be allocated to the users. For the IJsselmeer area this sequence has been laid down in the regional sequence of priorities entitled ‘Water distribution in the Northern Netherlands’.

Southwestern Delta

The southwestern Delta is demarcated by the Nieuwe Waterweg/Nieuwe Maas, the Biesbosch and the Scheldt estuary. It is a complex system of interconnected and mutually influential fresh- and saltwater waterways.

Detailed map of the southwestern Delta.

Some waterways are stagnant, others are tidal.
The Rhine, Meuse and Scheldt converge here. Water distribution is largely regulated by the Haringvliet sluice gates, which are operated in such a way that the Nieuwe Waterweg can discharge 1,500 m^3/s for as long as possible. In this way, we attempt to counteract saltwater incursion and prevent salinisation of the Hollandse IJssel, the most important water inlet point for the mid-western part of the Netherlands of which is located at Gouda. Moreover, the operation of the Haringvliet sluices aims to ensure a minimum water level in the Hollandsch Diep of 0 metre Amsterdam Ordnance Datum (NAP), in order to sustain navigation to and from the seaport of Moerdijk.

During discharges at Lobith up to 1,100 m^3/s, the Haringvliet sluice gates are completely closed, except for the salt drains and fish passages.
When the Rhine discharge is between 1,100 and 1,700 m^3/s, the gates are open at low tide for 25 m^2 if the sea water level is lower than the water level

on the landward side. In this way, an average flush rate of some 50 m^3/s per tide is maintained in the western part of the Haringvliet.

At discharge rates between 1,700 and 9,500 m^3/s, the sluice gates are gradually opened and at discharge volumes over 9,500 m^3/s, the gates are fully opened. However, these operation rules are not always sufficient to maintain a target discharge of 1,500 m^3/s at Hoek van Holland. During periods of low flows and when the Haringvliet sluices are completely closed, the Nieuwe Waterweg receives the discharges from the Lek, the Waal and even the Amer, minus the water that is drained at the Volkerak sluice gate and the flush rate of the Haringvliet.

At the moment, the Haringvliet sluice gates still form a solid barrier between the sea and the Haringvliet, and as such they block the passage of (migratory) fish such as salmon and trout. The Haringvliet sluice gates will be left ajar in 2010 in order to create a more natural delta. This means that the gates will no longer close during rising tides, but will remain ajar on the condition that the freshwater inlet points do not become salinated. In this way, a gradual transition from seawater to river water will develop. Moreover, migratory fish will be able to pass through the sluice gates. This measure is in line with the implementation of the Water Framework Directive and the Bird and Habitat Directives (Natura 2000).

With the excavation – and subsequent deepening – of the Nieuwe Waterweg to ensure access to the port of Rotterdam, saltwater moved further and further inland, which compromised the water supply to Delfland. To supply fresh water to Delfland, a pipe with a capacity of 4 m^3/s was installed from the Brielse Meer to Delfland, passing underneath the Nieuwe Waterweg. In combination with the existing capacities for leading 10 m^3 through the Lopikerwaard or Krimpenerwaard, the area can now meet its own water demands.

Lake Volkerak-Zoommeer was created in 1987 as a result of the decision to keep the Oosterschelde in an open connection to the sea.
To retain sufficient tidal range, the surface area of the Oosterschelde was reduced with the help of the Philipsdam and the Oesterdam. By disconnecting the Lake Volkerak from the Haringvliet and flushing the system with freshwater from the Hollandsch Diep and the rivers in the province of Brabant a fresh water lake was created.

Since 1994, excessive amounts of nutrients and a long retention time in this lake have created optimal conditions for blue-green algae blooms. Blue-green algae adversely affect the aquatic environment by producing toxins. In addition, when they die off in late summer, they produce a terrible smell. This causes inconvenience to residents, holiday-makers and tourists almost every year, while farmers cannot use freshwater from the lake for irrigating their crops. In 2004, a study was initiated to identify solutions to this problem. The research results led to the conclusion that the necessary improvement in water quality cannot be obtained if Lake Volkerak-Zoommeer remains a freshwater lake. Only if the lake is salinated again and limited tidal dynamics are restored, water quality will improve sufficiently for the algal blooms to disappear.

Overview of all 'water valves' in the main water management system.

Regional waterways

In addition to the main water system, there is also a dense network of ditches, streams and canals in the Netherlands that belong to the regional water system. The main water system and the regional water systems are interconnected at several locations. In the event of excessive rainfall, the regional system drains into the main system, while the regional system can be fed by the main system in periods of drought.
In low-lying parts of the Netherlands, the water that enters the system has a variety of functions, the most important of which is maintaining the water level to prevent subsidence of peat bogs. In addition, flushing is used to guarantee good water quality. In higher areas, the water is supplied primarily for irrigation purposes. The map on page 35 provides an overview of the 'water valves' in the main and regional systems.

Limits to water management in the event of extreme discharge volumes

Under normal circumstances, our water system works well.
Problems such as safety, water shortages, flooding, waterlogging and salinisation usually only occur under extreme circumstances. The fact that problems occur is no surprise given that the margins for water distribution in and between the various elements of the system are small. In the event of extremely low river discharges, every weir along the Neder-Rijn is opened and the sluice gates on the Haringvliet and Afsluitdijk remain closed, but that is all we can do to regulate or direct the distribution of water. The same is valid for extremely high discharges, when we can do nothing else but open all the sluice gates as wide as possible.

The following chapters deal with safety, flooding, water shortages and drought, salinisation and water quality in the current situation.
Chapter 8 provides a glimpse into future developments and their potential consequences, and Chapter 9 discusses the policy and management documents that indicate how we intend to adapt our water management system to climate change effects.

3 Safety

Dunes, dams, dikes and the Delta Project enable us to live safely in our low-lying country. The standards that the water defences have to meet are laid down by law. Ironically, the gradual development of the system with which we gained control over the water created a safety risk in itself. River water that is forced to remain in a limited space between dikes can only rise in the event of higher discharge rates.

We have exchanged as it were the inconvenience of a large area of wetland for a virtual guarantee of land that is permanently dry, but at the risk that water levels will be much higher than before in the event of a flood. This threat has increased even more by subsidence and sea level rise. As the population behind the dikes has grown and investments in housing and businesses run into the billions, the consequences of a dike burst would be disastrous. In the distributaries of the Rhine, water distribution relates to safety in yet another way. The 'regulatory valves' in the main system are operated in such a way that the chance of flooding is equally high in all distributaries. Management and maintenance of the river beds and winter beds must ensure that this continues to be the case.

What is safety?

Dikes and dunes ensure that we may feel safe. All the dunes and the most important dikes are called primary water defences, because they protect us from flooding by the sea, the main rivers or Lake IJsselmeer and Lake Markermeer. The secondary defences are also important, but if a dike in this category collapses, the consequences are not as dramatic – although the inhabitants of Wilnis may think differently. There, the ring dike of the Groot-Mijdrecht polder burst in August 2003 and the streets in the Veenzijde estate were covered by half a meter of water. Yet, in terms of safety, Wilnis is of a different order than what we are discussing here. If the primary water defences were breached, the consequences would be considerably greater, Just how safe we are behind the water defences depends on where we live. The Flood Defences Act indicates the safety standards for every dike ring area. The standard is higher if more economic activities take place within the ring and if the number of inhabitants is high. Other important factors are the size of the area liable to flooding; the height to which the water may rise and whether the flood water will be fresh or saline.

The standard is expressed in a probability per year that a critical water level will occur, e.g. 1:1,250 per year. The requirements for a flood defence structure in terms of height and strength are derived from that standard.

How is safety determined?

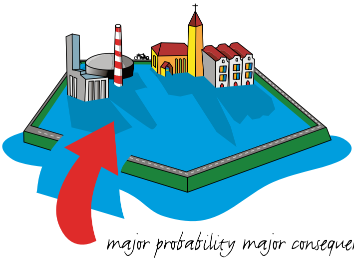
The safety of lakes, rivers, the river delta and the sea are each determined by different factors:

Lakes	water level, wind (wind action and wave run-up)
Rivers	water discharge and, to some extent, wind (wind action and wave run-up)
River delta	river inflow, sea level, wind (wind action and wave run-up)
Sea	tide and wind (wind action and wave run-up)

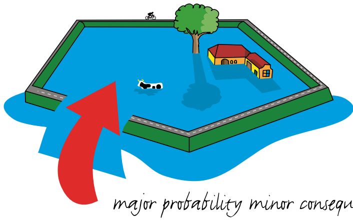
Safety, for whom?

The Delta Committee, established after the disaster of 1953, has laid down our current protection policy. However, since then, a number of issues have changed. Considerable investments were made in the areas behind the dikes and the number of people living there has increased significantly. These developments are not likely to stop any time soon. In addition, all climate scenarios forecast by the Royal Netherlands Meteorological Institute (KNMI) show a rise in sea level and river discharge volumes. In short, the threat and the potential consequences of a flood are on the increase. A large-scale flooding will cause widespread damage and long-term disruption of our society.

That is why there is growing support for an alternative approach to safety. We should no longer focus on the probability of a failure of our water defences, but on the risk (i.e. probability multiplied by consequences) of actual flooding. This provides greater insight into the possibilities of limiting the consequences of flooding. The riskbased approach shows that, despite all our efforts, the risk can never be reduced to zero. By implication, the national government cannot be held solely responsible for protection against flooding. However, the preventive approach of high-water protection remains pre-eminent in water management policy. In order to map the risks of flooding, the government, provinces and water boards are implementing the programme Flood Risks and Safety in the Netherlands. For each dike ring, the probability of flooding and the flood damage is expected to be mapped out by 2010 – taking the present situation as the basis for calculating probabilities.



major probability major consequences



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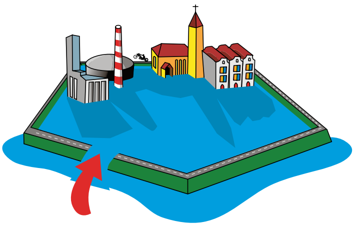

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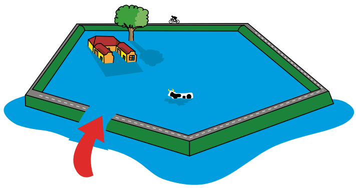


minor probability minor consequences

4 Excess of Water

A cellar full of water is upsetting. A layer of water on the road is a nuisance. No more and no less. In any case, our safety is not at risk.
We have caused part of the problem ourselves, by gradually paving or asphalting more land and continually choosing to build residential estates at locations where water also likes to 'reside' now and again. The National Administrative Agreement on Water (NBW) includes an agreement that water management must be in order by 2015, indicating how often flooding or waterlogging may occur.

What is excess of water?

Excess of water is the collective term for situations in which we are faced with large amounts of water in the form of precipitation or groundwater, but without it endangering our lives. In most cases, the problem is temporary, such as after a heavy rainstorm or flooding.

Excess of water caused by rain

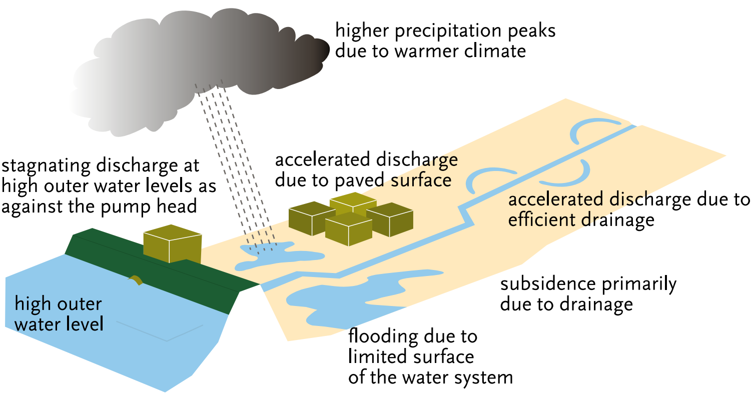
Heavy rainfall occurs mostly between September and March. This is also the period when the rivers carry more water. Excess of water that occurs as a combined effect usually affects low-lying areas, where the water gathers and from where it is difficult to pump out because of high water levels. The same is valid for polders. In salt meadows, the problem is worse because the water also comes up through the ground.

Excess of water caused by groundwater

In areas with high groundwater levels, excess of water can occur whenever there is insufficient drainage and the water gets into crawl spaces or basements. A frequent problem is spontaneous seepage under dwellings, which is difficult to solve without drainage or pumps.

What is waterlogging?

Waterlogging is a specific term used for a state of the soil whereby the water content in the soil prevents enough aeration for specific activities. Ground may be regarded as waterlogged when the water table of the ground water is too high to conveniently permit an anticipated activity, like agriculture. Waterlogging can also be cased by excessive rainfall.



Overview of interconnected causes of flooding.

What causes water flooding and waterlogging?

Flooding and waterlogging are caused by:

- insufficient ability to store rainwater; reasons include more intensive use of land, increase of paved surfaces, reduced storage capacity.
- the excessive level of outer waters, making it impossible to drain water swiftly from the upstream area which leads to stagnation.
- alterations in spatial layout. Sometimes we built residential areas at locations that used to be storage basins. In that case, higher groundwater levels alone can cause damage.
- subsiding ground levels caused by shrinkage, setting and oxidation of peat bogs. The result is that water level and ground level more rapidly coincide with one another. In addition, the height difference between groundwater and surface water in higher-lying waterways or lakes increases, resulting in more seepage water.

As for regional waters, flooding occurs when water levels are so high that the streams, lakes or waterways bursts their banks. In the main water system, floods are deemed to occur if national waterways are not sufficiently capable of storing or discharging regional water discharges. Given that national waterways are the final link in the discharge chain, it is important that they are not the weakest links, otherwise they will cause excess of water in upstream regional water systems. On the other hand, it is equally undesirable that regional water boards should shift their drainage problems onto the national waterways. Agreements between water authorities concerning such matters are laid down in so-called water agreements. National waterways can cause flooding and waterlogging in two ways. Directly, when water flows over its banks, and indirectly, when high water levels on national waterways block discharges from regional waters. There are different causes of flooding and waterlogging in polders, on high ground, in urban areas and in areas between the rivers and the dikes.

Weir in the Neder-Rijn at Driel.

Polders

In polders, excess of water can be caused by:

- limited storage capacity, which means that water cannot be collected
- overly rapid discharges into storage basins, that cause these to overflow
- insufficient drainage capacity to pump water to larger storage basins. This causes problems if large amounts of water need to be drained and/or if the receiving water has a high level and the discharge head increases
- extra seepage water caused by high water levels behind the dike, which causes waterlogging.

High ground

On high ground, flooding and waterlogging are caused by:

- stagnation in discharges due to high water levels downstream or in receiving waters
- overly rapid discharges, resulting in increasing water discharge levels. This increase is temporary, because the water then flows to low-lying areas.

Urban areas

Floods caused by rainfall often occur in cities or industrial estates, where almost all rainfall drains into the sewer. This is usually a combined sewer for waste water as well as rainwater, even though segregated sewer systems for separate rainwater discharges are gaining ground. During heavy rainfall, sewers cannot cope with the amount of water and overflow, resulting in streets being flooded. Much worse, sometimes cellars are flooded as well. Moreover, if a combined sewer overflows, public health may become an issue.

Areas outside the dikes

In areas outside the dikes, floods are simply caused by high water levels. It is sometimes necessary to accept excess of water. If the operation of the main system requires 'closing the tap of the regional drainage system', local flooding will occur. This will, however, prevent potentially less controllable flooding elsewhere and thus jeopardizing safety.

Who is affected by floods?

In order to determine whether the systems operate as they should, it is necessary to know the requirements for water systems.
Management goals have been set for this: a particular water level must not be exceeded more than once in a certain period of time. An assessment of whether the system is functioning properly does not so much focus on the extent to which the level is exceeded but on the frequency with which this occurs and, particularly, for how long.

Regional water boards assess their water systems according to the operating standards stipulated in the National Administrative Agreement on Water, on the basis of which they can determine whether measures are required to keep damage due to flooding and waterlogging at an acceptable level.
The operating standards indicate how often flooding is allowed to occur statistically. Different standards apply for different designated land uses. Grassland, for example, may be waterlogged once every 10 years, land on which greenhouses are built only once every 50 years and in built-up areas flooding is not to happen more than once every 100 years.

Weir in the Meuse at Roermond.

5 Water shortages and drought

Even this boggy land near the sea experiences water shortages once in a while. That is to say, freshwater shortages. The very dry summer of 2003 and the dry spring of 2005 are the most recent examples.
Plants withered in the fields, ships could only be partially loaded, power stations were limited in their intake of cooling water, nature suffered from drought. In order to prepare for the next period of drought, the "sequence of priorities" – which indicates the order in which water will be allocated to specific users – was adjusted.

What is water shortage and drought?

We speak about drought when there is a long-term shortage of areaspecific water, which causes every process that is dependent on the water cycle to suffer. Drought manifests itself in a shortage of moisture in the soil's root zone, in extremely low water levels in rivers, and even in dry waterways.

What causes a water shortage?

A water shortage can be caused by a severe lack of rainfall or low river discharges. The lack of sufficient infrastructure to supplement the shortage in rainfall may also be a cause. Occasionally, available water is not properly distributed. Finally, the water can be of inferior quality: too saline (for agriculture, drinking water and industrial processes), too warm (to be used as cooling water) or too polluted.
Aside from all this, shortages can arise even when there is no drought, simply because demand exceeds supply.

Who is affected by water shortages?

Water shortages manifest themselves in three ways. A shortage of moisture in the soil is most common. This means that there is not enough water for plants, stunting their growth. Secondly, a shortage can occur in the surface water, meaning that water levels cannot be sufficiently maintained. This results in a lack of water for agricultural purposes and flushing. The inability to maintain water levels can have a negative effect on the stability of dikes, engineering structures and foundations. Bogs can become oxidised. In the third place, a consequence of insufficient water of the correct temperature and quality is that power stations have no cooling water, drinking water companies have to close their inlet points and farmers and horticulturalists cannot irrigate their crops.

The diagram besides features drought regions and their characteristic drought-related problems.

Northern Netherlands
Salinisation along the Wadden Sea coast, drought-related problems on the islands.

Northeastern Netherlands
Dry areas due to a lack of water supply infrastructure.

Centraleastern Netherlands
Groundwater related drought.
Supply from the IJssel and the Vecht in cases of drought.

Eastern Netherlands
Presence of hilly areas where water supply is impossible.

Central Netherlands
Shortage of cooling water in the Amsterdam-Rijnkanaal/ Noordzeekanaal, no other drought-related problems.

Northwestern Netherlands
Few drought-related problems, occasional deficiencies of the water supply system.

Western Netherlands
Salinisation and small-scale water supply.

Southwestern Netherlands
Salinisation.

Southeastern Netherlands
Presence of hilly areas where water supplyis impossible.
Supply from Germany and Belgium.

Southern Netherlands
Water shortage in hilly areas where water supply is impossible. Dependent on water supply from Belgium, though no agreements exist to that end. In dry periods, therefore, the water supply is significantly limited.

Area around the major rivers of the Netherlands
Few drought-related problems, occasional deficiencies of the water supply system.

sufficiently maintained. This results in a lack of water for agricultural purposes and flushing. The inability to maintain water levels can have a negative effect on the stability of dikes, engineering structures and foundations. Bogs can become oxidised. In the third place, a consequence of insufficient water of the correct temperature and quality is that power stations have no cooling water, drinking water companies have to close their inlet points and farmers and horticulturalists cannot irrigate their crops.

Shortages are sometimes characterised by large regional variations. Differences in soil moisture can be due to meteorological conditions, soil type, land use, management of surface water levels and seepage water. Shortages in surface water are mostly down to limited possibilities in freshwater supply. In the downstream river areas, this is directly related to salt incursion.

A shortage of water affects almost every sector:

Agriculture

Water shortages lead to lower production. Crop yields can be down by 10 percent in an average dry year. However, this does not necessarily equate to economic damage. Damage caused by salinisation only accounts for one percent of the overall drought-related damage. This is due to heavy flushing and to the fact that farmers and horticulturalists opt for drought-related damage rather than salt damage. A substantial part of the losses caused by water shortages are the indirect result of choosing to prevent moisture damage. By opting for deep drainage, farmers and horticulturalists implicitly accept that they will sometimes lose crops due to water shortages.

Shipping

Low water levels mean that ships can carry less cargo. These limitations become relevant if the Rhine's discharge level falls below 1,250 m^3/s. This occurred recently in 2009.

Energy sector

Production is usually limited once every two years. However, the reason for this is high river water temperatures rather than low discharge levels.

Nature

Choices in spatial development and subsequent adjustments to water management have occasionally created artificial situations that have made ecosystems vulnerable to drought. Moreover, fragments of nature already suffering from drought are facing even harder times as they barely have any reserves to draw on.

How do we respond to periods of drought and water shortages?

Periods of drought can sometimes last so long that it is no longer possible to serve every designated use. This forces us to choose: who or what takes priority in the distribution of scarce supplies of river water? This choice is not made all over again each time but criteria are laid down in a 'sequence of priorities'. These priorities were drawn up in response to the exceptional drought of 1976, and updated after the summer of 2003 when drought was almost as intense (see box on page 52).

Unfortunately for shipping and the other sectors in category 4 the water level in rivers, canals and harbours is the least of our concerns when water is in short supply. If needs be, farmers and horticulturalists who cultivate capital-intensive crops and factories using process water (category 3) are also ignored, so as to allocate only water to the production of drinking water and to power stations (category 2). Ultimately, all that remains are the interests of the first category: safety and the prevention of irreversible damage.

The sequence of priorities in the form of a diagram:

Category 1 **Safety and the prevention of irreversible damage**

1 stability of flood defence structures
2 settling and subsidence of peat bogs and moorland
3 nature dependent on soil conditions

takes precedence over:

Category 2 **Utilities**

1 drinking water supply
2 power supply

takes precedence over:

Category 3 **Small-scale high-quality use**

1 temporary spraying of capital-intensive crops
2 process water

takes precedence over:

Category 4 **Others (economic considerations, also in terms of nature)**

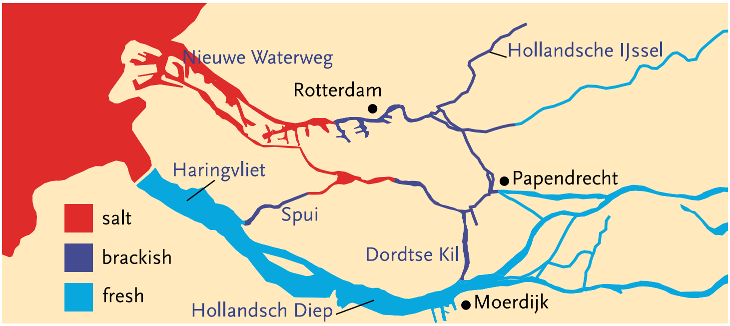
1 shipping
2 agriculture
3 nature, as long as no irreversible damage occurs
4 industry
5 water recreation
6 lake fishing

6 Salinisation

‘Salt enters the Netherlands through the front door and underneath the doormat.’ As long as the Rhine carries sufficient amounts of water, the front door (the Nieuwe Waterweg) will remain closed, but underneath the doormat, which is as wide as the coastline is long, there are many gaps that allow saltwater to come to the surface. Salinisation is a problem for many sectors.

What is salinisation?

Ground water in the northern and western parts of the Netherlands is slowly becoming saltier. This insidious process called salinisation takes place in two ways. The salt forces its way inland via surface water, known as external salinisation, or it works its way up through the soil in groundwater, which is called internal salinisation.



Extend of salinisation during the drought of 2003.

What causes salinisation?

External salinisation

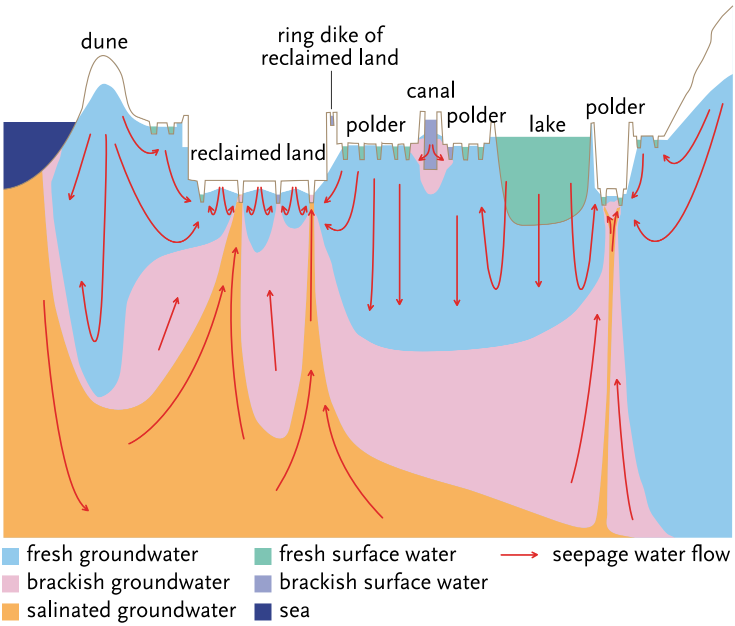
There is only one location where fresh and saltwater are in direct contact with each other: Hoek van Holland. The extent to which seawater can force its way inland depends primarily on the relation between the river discharge and the sea level. With an average discharge level of the Rhine and an average tide at sea, the saltwater tongue reaches the Willemsbrug in Rotterdam. Extreme events of salt water incursion will only happen when the sea level is high while the Rhine carries a limited amount of water. Incidentally, some inlet points already become salinated if the water level of the Rhine is low and the sea is at a regular level.

The Haringvliet sluice gates play a key role in counteracting external salinisation through the Nieuwe Waterweg. By keeping the gates closed even at low tide and when the Rhine discharge is low, all river water is directed to the Nieuwe Waterweg. As long as there is a minimum flow to the sea of 1,500 m^3/s past Hoek van Holland, the mouth of the Hollandsche IJssel will not become salinised. However, it is not possible to guarantee such a minimum discharge. Under exceptional conditions, external salinisation can occur in the Haringvliet and the Hollandsch Diep, even if the Haringvliet sluice gates are shut tight. The salt forces its way through the 'back door' via the Nieuwe Waterweg and then through the Spui and the Dordtsche Kil. This extreme event of salinisation occurred in the autumns of 2003 and 2005, when river discharge levels were very low while the sea level was significantly higher due to a storm.

During dry periods, however, the discharge from the rivers will decrease, which results in an increase in external salinisation. And this in turn reduces the capacity to keep internal salinisation under control.

Internal salinisation

In most parts of the Netherlands, deep groundwater is brackish to salty. With the exception of the coastal zone, this is caused by sea water that remained in the underground when the sea retreated. Originally, this marine groundwater was practically immobile, but as a result of land reclamation and drainage groundwater started to move. In their turn, batches of groundwater were brought out of their stable situation and started to move in an upward direction, in certain places breaching through the surface or entering into the surface water. This form of salinisation is a process that is virtually irreversible. Even if the sea level remains the same,



Cross-section of the western part of the Netherlands, highlighting how seawater and deep brackish groundwater seep into surface waters in deep polders.

the process will continue for centuries. Sea level rise and soil subsidence will only accelerate this process. It is most prevalent in the western and northern parts of the Netherlands. Further inland, the influence of sea level rise is less pronounced. For example, in polders as Groot-Mijdrecht in the province of Utrecht, which do suffer from internal salinisation, sea level rise has no impact on the water system.

In deep parts of polders and reclaimed areas such as the Haarlemmermeerpolder, saline groundwater can end up as seepage water in canals and breach through the surface as natural artesian wells (see figure page 55). To combat internal salinisation, freshwater is pumped into the polders. On the one hand, this is carried out to provide counter pressure to saline seepage water and on the other hand, to flush the watercourses. In this way, water in regional systems is maintained at a certain chloride concentration. However, this requires sufficient good-quality water in the main water system. During dry periods, however, the discharge from the rivers will decrease, which results in an increase in external salinisation. And this in turn reduces the capacity to keep internal salinisation under control.

Who is affected by salinisation?

Salinisation is only a problem if users are hindered or damaged by the fact that the chloride content in the water rises above a certain concentration.

Agriculture

Salinisation is a direct threat to agriculture. Agriculture is best served by water with a low chloride content. What farmers or horticulturalists will accept, depends, however, on the crops they grow. For example, fruit trees are more sensitive to higher chloride content than sugar beet or grain. Halophyte farming is, of course, indifferent to salinisation, but this sector only accounts for a limited market. Within the sector, there are possibilities of making use of brackish water, for instance to produce crops that are rich in protein as an alternative to imported animal fodder. In areas where salinisation is already a problem, alternative sources of freshwater are being considered to combat further salinisation.

Shellfish fishing

Mussel seed fishing requires the presence of freshwater/saltwater transitions and estuarine conditions. Otherwise spat fall will decline significantly. In general, shellfish cultivation depends on good quality saltwater, which is why shellfish cultivators benefit from the salinisation of freshwater bodies and the restoration of estuary dynamics.

Drinking water companies

Drinking water companies need water with low chloride content in order to produce good quality drinking water. In areas where salinisation is imminent, they spread the risks as widely as possible by using both surface water and groundwater sources, or by desalinating high-chloride content water.

Energy companies and industry

For energy companies and other industries, the availability of fresh cooling water is essential for their production processes.
Installations are built on the basis of freshwater intake, which is a condition for the selection of construction materials. Salinisation increases treatment costs of process water.

Freshwater is not always good and saltwater is not always bad

What a user calls fresh or saline water depends on the purpose water has to fulfil, and on how users appreciate the quality of the water.
For the drinking water sector and for industry, water quality standards are high. The Dutch standard for the chloride content in drinking water is 150 mg/l, while the European standard is 250 mg/l and the standard adhered to by the World Health Organisation is 300 mg/l.
While there is no evidence that levels in excess of these standards constitute a public health risk, these limits are based on organoleptic judgement by taste panels. Industry also employs a 150 mg/l standard for process water, while the standard for cooling water depends on the selection of materials for cooling installations. Seawater can be used for cooling if installations are purpose-built.

The chloride standard for irrigation water for agriculture depends primarily on the crops being grown. For instance, different standards are used for growing fruit and for growing potatoes. While there are no clear standards for irrigation water in the Netherlands, the Cultural Technical Handbook (1988), for example, defines a standard of 300 mg/l for fruit cultivation and 600 mg/l for potatoes.

Apart from the 'official' chloride standards, user perception also plays a key role in deciding whether to use water of a particular quality. This is determined by knowledge and experience, as well as by the available means and by the necessity of using water. For instance, farmers in the Flevopolders (Oostelijk Flevoland and Zuidelijk Flevoland) use water with a higher chloride content for irrigating bulbs than farmers in the western part of the country would accept.

7 Water quality

Drinking water companies, horticulturalists, the leisure industry, fishermen, everyone, in fact, and nature as well, benefit from good quality water.
The user determines what constitutes ‘good’: each designated use sets its own criteria. As a consequence, quality almost always plays a role in the distribution of water. Freshwater is used in deep polders to flush out seepage water that is high in chloride and nutrient content. Water supplies are required to combat drought. But in nature reserves, even if they are already too dry, water is usually only welcome if its quality is close to the water quality in that area.
Polder water that comes from the main system carries nutrients along and, in many cases, other chemical substances as well. This poses extra quality-related problems, especially for the stagnant waters in the main system such as Lake IJsselmeer/Lake Markermeer, Krammer/Volkerak and a number of canals. Also in the low-lying parts of the Netherlands, where the need for water intake alternates with the need for discharge and the pressure of seepage water is rising, quality complications pile up.

What is good water quality?

In general, freshwater can be regarded to be of better quality if it contains fewer nutrients, toxins or salt. Visually, it is important that it is transparent, while high oxygen content adds to the quality. Finally, it is also important that water quality has no adverse effects on water organisms and plants. Differences in quality are influenced by a series of factors: the water composition changes depending on its origin and on the land use, soil type and groundwater flow resulting in seepage or infiltration, in the area where the water originates from. Finally, water quality is closely linked to the quantity of water: contamination is less noticeable when highly diluted.

What causes poor water quality?

Nutrients and toxins reach surface waters along a number of ways. A primary source is leaching and run-off from agricultural areas, but effluents from wastewater treatment plants, let alone untreated discharges of wastewater, also contain high levels of phosphate and nitrate. Furthermore, rivers can carry pollutants and nutrients and even atmospheric pollution will be deposited on land and water.

Nutrients enter surface water even faster if drainage is intensive. For that matter, leaching of nitrogen does not only affect surface water but groundwater as well. High nitrate concentrations can cause problems if the groundwater is used for the production of drinking water.

In all of this, a distinction needs to be made between stagnant and running waters. Lakes, canals and ditches are generally more sensitive to eutrophication than rivers and streams. Nutrient concentration in stagnant waters is largely determined by external pollution, such as atmospheric deposition, supply via streams, pumping stations, rivers and wastewater discharges. In rivers and in closed estuaries such as Lake IJsselmeer and Haringvliet that are primarily supplied by large rivers, the concentration is also determined by what those rivers supply from across our borders. In the North Sea, the concentration is also determined by the influx of nutrients and, in particular, by the level of nitrates in the rivers. The key source of releases for streams on high sandy ground is leaching and run-off from

J.L. Hoogland pumping station at Stavoren. This is also an inlet point for the regional water system.

agricultural land. The pattern of rainfall has a certain influence as this depends on groundwater levels and on the extent to which the soil is saturated with water. In addition, it is also important in which season the pollution occurs.
Chemical substances can have an adverse effect on water organisms and plants in surface waters, such as reduced growth or fewer offspring, resulting in a reduced number of organisms. Some organisms even disappear completely. Birds and mammals risk being affected by consuming water organisms such as algae and water fleas that are contaminated by toxins.

Water quality in the Netherlands has improved significantly in recent decades and likewise effects of contamination have decreased. Nevertheless, new and largely unknown groups of substances keep appearing, effects of which may be even more significant. Examples include antibiotics, medicines and substances that disrupt the hormonal balance. These substances originate from effluents of wastewater treatment plants, as well as from manure that eventually makes its way from arable land into surface water.

The concentration of contaminated substances in the North Sea dropped significantly in the 1980s and 90s, but it appears that this decline has now halted.

What problems are linked to poor water quality?

Eutrophication

Eutrophication primarily occurs in areas that have to deal with a manure surplus. Yet eutrophication can also occur in areas with little or no agriculture, if these areas are flushed with non-area specific water originating from another area that is rich in nutrients. This can be water that is used to maintain water levels, or water that is pumped through to supplement water shortage somewhere else. Also, the entire coastal region is affected by eutrophication. In some places this reveals itself in algal blooms.

Toxicity

The concentrations of well known substances such as heavy metals, PCBs, PAHs declined in recent decades, but this decline has now come to a halt. Pesticides remain a problem, especially in regional waters. Yet the effects are not generally caused by substances alone. Hydromorphological conditions also play a role. This calls for an integrated approach in the management of water systems.
Specific risks occur at peak loads during unintentional releases. Such releases occur regularly in the Meuse, affecting sensitive species or causing them to disappear altogether.
The contaminants that flow into the North Sea can lead to disruption of the hormonal balance or to bio-accumulation in organisms, thus affecting the food chain. Prompt detection and therefore monitoring of these types of substances – new substances appear on a regular basis – and of their effects on organisms and the ecosystem is necessary. These problems should be tackled by following a river basin approach and at international level.

Who is affected by poor water quality?

All users, humans as well as plants and animals, are affected by poor water quality.
Many ecosystems depend on freshwater. Organisms are threatened or even destroyed by contaminated surface water. Eutrophication of surface water can lead to (blue) algal blooms or outbreaks of botulism. This also has consequences for bathing water.
As for drinking water, finding clean sources for human consumption is becoming more and more difficult and more and more expensive.

Control device for excess water on the right bank of the rivers Lower Rhine and IJssel.

8 Future developments

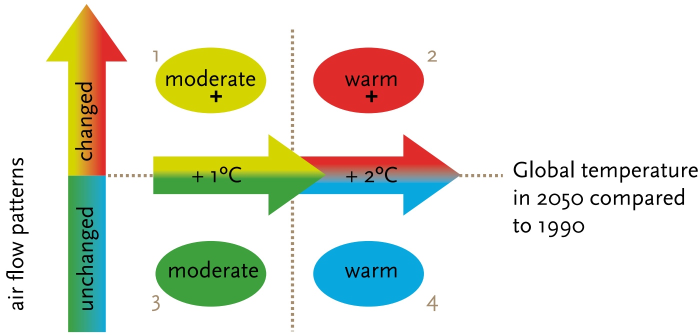
The Netherlands is getting wetter, dryer and saltier. The sea level is rising. While rainfall is getting heavier at times, it may also at other times hold off much longer. Soil subsidence continues, due to both geological influences and human activities. Land use is changing as well, the economic sectors are continuously changing and, societally speaking, new demands are made on water. All this can hardly indicate anything else than the necessity for a change in water management and water use.

Physical and societal changes

Climate

Since the early 20th century, average temperature has risen by approximately 0.74°C. It is highly probable that we also contribute to this rise: burning of fossil fuels, deforestation and certain industrial and agricultural activities lead to an increase in the concentration of greenhouse gases in the atmosphere. Model calculations indicate that the temperature could rise from between 1.1°C to 6.4°C between 1990 and 2100. Increases of more than 2°C will probably be accompanied by substantial changes, because the sea level will also rise significantly, there will be more periods of drought and heat and occasionally extreme precipitation will occur.

Since the climate scenarios of the programme Water Management in the 21st century were first published in 2000, several new global and regional climate models have been drawn up. Based on this recent knowledge, the Royal Netherlands' Meteorological Institute (KNMI) formulated four scenarios in 2006. These scenarios assume a maximum temperature increase of 2°C by 2050.



Four climate scenarios by KNMI (2006).

The general picture resulting from all four scenarios is that global warming is proceeding. As a result, we will have more mild winters and warm summers. In addition, winters will become wetter on average and we can expect more extreme periods of heavy rainfall.
Especially in summer, there will be heavy downpours, while in contrast, the number of rainy summer days will decrease. If the air flow patterns above western Europe change (the 'plus' scenarios), winters will become significantly wetter and summers much dryer.
Little will change in terms of wind, which will remain as changeable as it is now. Moreover, all four scenarios have in common that sea level will continue to rise.

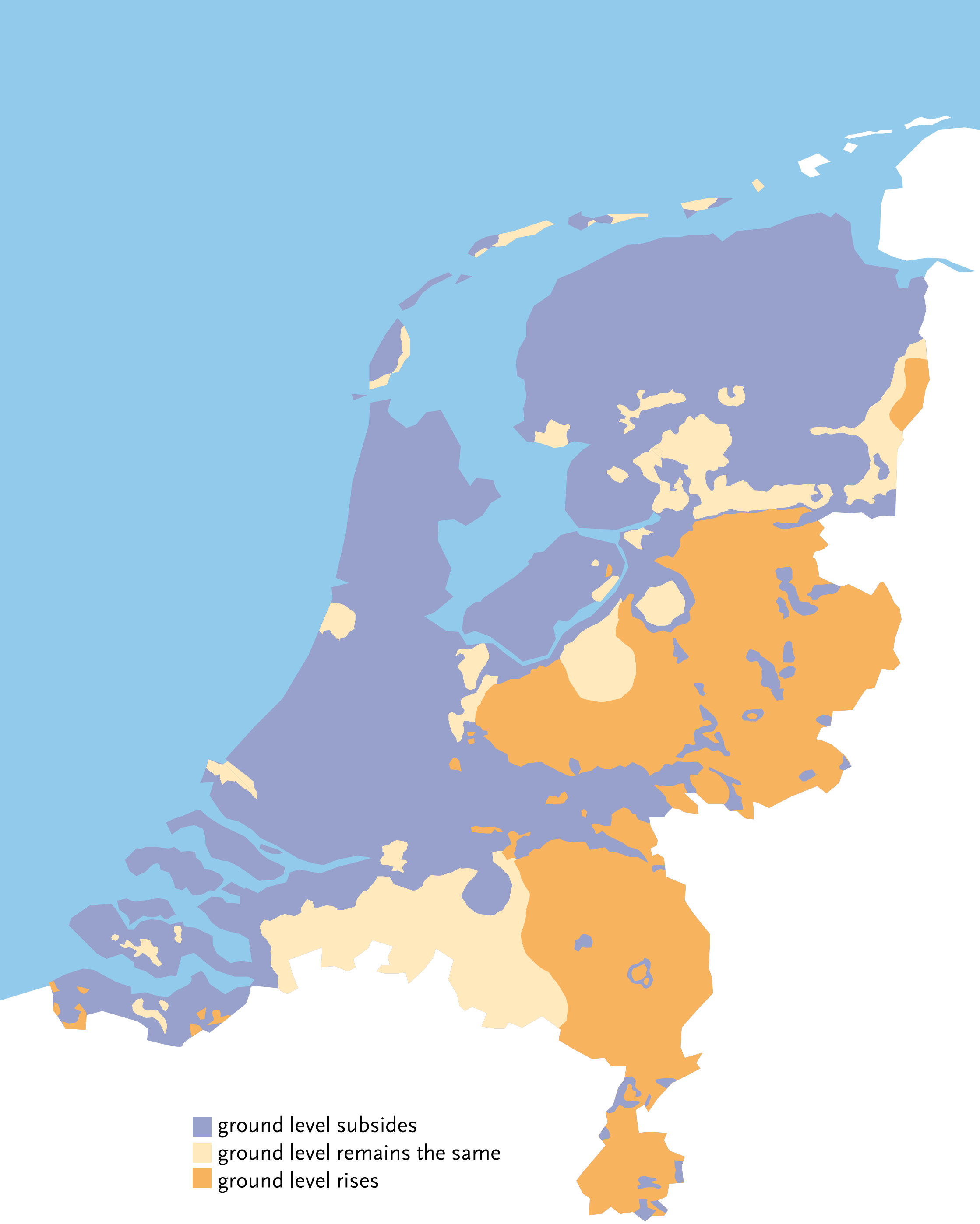
Soil subsidence and salinisation

In a large part of the low-lying areas in the Netherlands, soil subsidence is expected as a consequence of soil settlement and oxidation of peat. The largest subsidence is expected in Groningen due to extraction of natural gas and in Flevoland due to settling. On the other hand, a small increase in ground level is expected in the south eastern part of the country due to tectonic tilting (see figure on page 68). The quantity of subterranean salt will increase due to the following three causes: a time-lag effect of past reclamation projects, soil subsidence and sea level rise. As a result, seepage water pressure will increase and seepage water that rises from the ground will become more saline. A considerable increase is expected in the coastal zones of Zeeland, Friesland and Groningen in particular, yet some polders in the provinces of Noord-Holland, Zuid-Holland and Flevoland will be affected as well. Only in a limited number of locations salt concentrations will decline due to increased surplus rainfall, which will counteract the time-lag effect.

Economic and spatial developments

In coming decades, residential and commercial developments will continue to expand their claims to public space in low-lying areas. As transportation of freight over long distances is cheaper by shipping, the expansion of the internal waterways will continue.

Water recreation has become a significant factor both socially and economically and will just increase in scale and intensity. The demand for electricity will continue to increase as well. This means that more power stations will be built, sometimes in places where this conflicts with water related interests.



The expected subsidence and rise of ground level up to 2050.

Consequences of climate change for water management

KNMI scenarios forecast that the minimum temperature increase will be 1°C. In a worst-case scenario, the summers will become considerably dryer as well, which will have an impact on river discharges, moisture deficit and salinisation.

River discharges

All scenarios envisage that the average discharge of the Rhine will increase in winter (up to +12 percent and decrease in summer (up to –23 percent). The same applies for the Meuse, with a maximum increase of 5 percent in winter and a maximum decrease of 20 percent in summer.

Moisture deficit and drought

If there is no structural change in the air flow patterns above Western Europe, the average summer precipitation will increase by 3 to 6 percent. However, if easterly winds prevail, rainfall could easily decrease by 10 to 19 percent. Aside from this, the chance of extreme drought is greater because at high temperatures evaporation will exceed whatever extra rain may fall.

Salinisation

The combination of sea level rise and lower river discharges in summer will inevitably lead to increased salinisation. The saltwater tongue will penetrate further inland and the number of days that freshwater inlet points cannot be used will increase. At the same time, the amount of water that can be taken from our main water system in order to combat internal salinisation in the regional water systems will decrease, while the need increases.

Flooding and waterlogging

The Netherlands will experience more frequent periods of extreme precipitation, which will be longer in winter and shorter but more intense in summer. Extreme precipitation can lead to flooding and waterlogging. In contrast to drought, this often occurs locally or regionally because rainfall can vary significantly from place to place.
Along the Amsterdam-Rijnkanaal/Noordzeekanaal, the Twenthekanalen and the Veerse Meer, the potential of these water bodies being the cause for flooding is negligible. While the chance is also slight along the Hollandsche IJssel, if a dike will breach, this will affect a significant area. The upper

Sluice gates in the Haringvliet Dam. Together with the sluice complex in the Afsluitdijk and the one at IJmuiden, and with the weir at Driel, these sluice gates are key to the regulation of the discharge and distribution of freshwater.

course of the Hollandsche IJssel, the Meppelerdiep, the Zuid-Willemsvaart, the Wilhelminakanaal and the Lake Volkerak-Zoommeer are at a greater risk of being the cause of flooding with possibly substantial damage.
If we don't maximise retention and storage in regional systems, but instead drain extra rainfall by increasing discharge capacity, then the upper course of the Hollandsche IJssel, the Twenthekanalen and the Betuwepand of the Amsterdam-Rijnkanaal might not be ready in 2015 to deal with expected water discharges for the period up to 2050.

Safety

If the climate develops according to the scenarios, the normative conditions for the Rhine (16,000 m^3/s) and the Meuse (3,800 m^3/s) have actually been exceeded already, at least according to the 2008 study entitled Climate Change Resilience of Water Land the Netherlands. Yet, the chance that the dikes along the rivers in the country's eastern and central areas will burst is very small, particularly if by 2015 all the measures planned in the context of the Space for the River programme are implemented. A key assumption, however, is that in times of very high discharge volumes, the discharge distribution over the Waal, the Lek and the IJssel will be changed in such a way that the Lek is spared. The study also showed that if climate change develops according to the more drastic scenarios, there is a reasonable chance that the surcharge standard for the Rhine of 18,000 m^3/s will be exceeded somewhere between 2040 and 2045.

9 Towards 'climate-proof' water management

The changes ahead of us prompt the question whether our water system will still function effectively in the future. Different studies have shown that the key point of attention for water management up to 2050 is the supply of freshwater to the southwestern part of the Netherlands. According to two of the four KNMI climate scenarios, the periods of water shortages and low river discharges increase significantly, which raises the demand for water, while the supply decreases, partially due to the salinisation of the mouths of the rivers Rhine and Meuse.
Are these shortages so severe that they warrant a reconsideration of water management or water distribution? And apart from the predicted water shortages, are there other reasons for reconsideration?
What does alternative water management or water distribution entail? Adaptation of water distribution is only one of the many measures that could be used to solve the problems related to water shortages.

Solutions to water shortages and salinisation could be found either in supply or in demand. In both cases, changes can lead to a freshwater supply that is more resilient to climate change, but these changes can also have consequences for water quality, occurrence of excess of water and safety and therefore they must be considered in a coherent way.

The search for a more 'climate-proof' design of our water management system will be continued in countless plans and projects over the coming years. These studies and projects will be based on several key policy and management documents.
In developing these plans, it is important that every party involved uses the same vocabulary. Hopefully, this booklet will help to achieve that.

Bridge over Lake Ketelmeer.

Water Vision

In 2007, the government published its vision on water policy, entitled 'Reclaiming the Netherlands from the Future'. In the Water Vision, the cabinet states its intention to expand its ambitions in the field of national water policy and to strive for sustainable water management. This laid down the basis for the establishment of the second Delta Committee, whose task it was to issue recommendations on water policy for the coming century and even beyond. The Water Vision specifies five spearheads for which the cabinet would like to intensive its policies. One is resilience to climate change. Climate change plays a key role in the supply and discharge of water. Extreme situations will become more extreme and more frequent. In the Water Vision, the State Secretary argues that it can no longer be taken for granted that each area in the Netherlands will be continually provided with fresh water. The Water Vision is a prelude to the first National Water Plan in which these spearheads will be developed.

Delta Programme

In September 2008, before the publication of the first National Water Plan, the second Delta Committee issued its report 'Working with Water'. The committee issued twelve recommendations intended to face the threat of an excess of sea and river water and to safeguard freshwater supply in the long term. These recommendations are elaborated in a Delta Programme and will lead to decisions concerning safety and water distribution.

National Water Plan

The National Water Plan is the official government water policy plan. A key point of departure is 'sustainable water management'. The underlying principle is to 'go with the flow of natural processes where possible, offer resistance where necessary and seize opportunities to foster prosperity and well-being'. In order to achieve this, water will have to gain greater significance in spatial development. While the National Water Plan upholds much of the policy from the previous National Policy Documents on Water Management, a new element is that with respect to spatial aspects this plan is also a framework vision based on the Spatial Planning Act. Moreover, this national plan looks much further ahead in order to arrive at a 'climate-proof' approach. The National Water Plan will come into effect at the end of 2009.

Management and Development Plan for National Waterways

This plan describes how Rijkswaterstaat will manage the national waterways between 2010 and 2015. It combines the measures necessary to achieve the goals stipulated in the Water Framework Directive with those required for Water Management in the 21st century and Natura 2000. An important point of departure is the integrated approach towards the management of our water system.

One of the topics involved is the search for a balance between the existing agreements on water distribution (freshwater, salinisation) and the prospective agreements suggested by the second Delta Committee.

10 The Water Act and its legal instruments

The Water Act

The Act of 29 January 2009 containing provisions for the management and use of water systems, i.e. Water Act, has integrated eight previous sectorial water acts of the Netherlands. The Water Act highlights integrated water management based on the 'water system approach' addressing all relationships within water systems. For example, the relationship between the quality and quantity of water, between surface water and groundwater, but also the relationship between water, land use and water users. Integrated water management is also characterised by its relationship with other policy areas such as nature, environment and spatial planning. The Water Act is framework legislation that is being implemented on the basis of secondary legislation i.e. by governmental decree (the Water Decree) and ministerial regulation (the Water Regulation).

National Water Plan and regional plans

Integrated water policy and management is being reviewed in a six year planning cycle and therefore simplifies the implementation of EU water directives such as the Water Framework Directive, the Directive on the Assessment and Management of Flood Risks and the Marine Strategy Framework Directive. For the purpose of integrated water management the National Water Plan is enacted by the Minister of Infrastructure and

Environment, together with the Minister of Economic Affairs, Agriculture, and Innovation. The Minister for Infrastructure and Environment is responsible for the Water Management and Development Plan for the Main Waterways (rivers, canals, lakes and the North Sea). Regional water plans and regional water management plans are the responsibility of provinces and water boards.

New requirements for water systems

The Water Act provides the basis for the requirements to which water systems can be subjected. The standards for primary flood defence structures are laid down in the act itself. Other standards for public waterways are incorporated in the Water Decree or Water Regulation. Regional waterways are governed by the standards laid down in provincial regulations and plans. In this way the Water Act lays down the basis to set standards for water systems with a view to preventing unacceptable flooding. By doing so, it retains the practice of taking formal decisions on water levels or target water levels.

Because of land use, a water level is closely linked with spatial planning. In the event of water shortages the Water Act enables taking one function precedence over the other ('priority of rights').

The Water Act also provides standards for the storage or drainage capacity of regional water systems. A regional water system should be constructed in such a way that it can store or drain sufficient water in the event of an excess of water.

Obligations of water authorities

Water authorities are also obliged to meet a number of important water quality requirements. The quality of surface water is subject to chemical and ecological quality objectives. Groundwater quality is governed by chemical quality objectives only. For water quality objectives, the Water Act refers to a list of substances and objectives provided by the Environmental Management Act and the EU Groundwater Directive. The Objectives Decree, which takes effect in 2009, is decisive for water authorities.

Water agreements and administrative arrangements

Water authorities can conclude water agreements with other authorities on water management. These agreements are not subject to any formal requirements and may concern any water management topic.

The Act also provides for administrative arrangements between a water authority and a municipality. The procedural requirements of the latter possibility are more simplified.

Ledgers

The water authorities should draw up ledgers on waterways. This is a register, which states the requirements to be met by a waterway with respect to its orientation, shape, dimensions and construction. The ledger should clearly indicate the management borders of waterways and their protection zone.

Project plans

A water authority can construct a civil-engineering structure or modify it by means of a project plan, which should provide a description of the structure and the way in which the construction or modification will be implemented. Major civil-engineering structures are subject to a project procedure, in any case for primary flood defence structures. The project procedure may also apply to urgent projects of supra-regional importance, the application of which is laid down by provincial regulations. Project plans subject to a project procedure require the approval of the Provincial Executive. The province is responsible for a coordinated approach.

Obligation to consent

Rightful citizens and businesses should tolerate certain water management activities such as carrying out maintenance of waterways.
The violation of rights, such as property rights, is called an obligation to consent. New is the landowner's obligation to consent the temporary storage of water in a storage area. The ledger of the water authority and the zoning plan of the municipality determine whether or not such an area qualifies as a storage area.

General rules and water permit

One of the important points of departure of the Water Act is that as many activities as possible are governed by general regulations.
This clarifies in advances what is permitted and what not. However, it is not possible to lay down all details in general regulations.For human activities in water systems the Water Act has introduced the integrated water permit, replacing six permits from previous water legislation. These include a wide range of activities such as discharges of polluting substances into surface

water, the extraction of groundwater or the construction of a dike. A 'one stop shop' approach and ICT facilities will support efficient working procedures for the processing of applications and the issuing of permits.

Organisation of water management

The Water Act acknowledges only two water authorities, the State as authority for the main waterways and the water boards as the authorities for the regional waterways. The latter are also responsible for wastewater treatment. Provinces and municipalities do not act as water management authorities, though they do have certain tasks in water management.
For the time being, the provinces remain the competent authority for three categories of groundwater abstraction and infiltration: public drinking water extraction, underground storage of energy and industrial extractions of more than 150,000 m^3 per annum. The municipalities have the task to provide for the collection and drainage of rainwater and groundwater.
The Water Act also provides for mutual supervisory relationships of the government bodies involved. Provinces supervise regional water authorities and municipalities and, if necessary, they may issue instructions or guidance. A province or the state can act on behalf of a water authority by means of resolutions or proceedings.
In situations where the interests are supra-regional or if international obligations are at stake, the Ministry of Infrastructure and Environment can apply supervisory instruments.

Financial provisions

The Water Act contains provisions on levies such as charges, legal fees, subsidies, compensation and the recovery of costs, integrating and clustering provisions of several previous acts. It provides the basis for the pollution charge and groundwater charge. The pollution charge has to be paid for direct discharges into surface waters, subject to the 'polluters pay principle'. Provinces remain entitled to claim charges for groundwater extraction. Water authorities will be able to pay for expenses incurred with their groundwater-related responsibilities from the revenues of the water system charge as laid down in the Water Boards Act. Municipalities pay for their waterrelated responsibilities from the municipal water charge, which is laid down in the Municipalities Act.

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More information
Helpdesk Water, www.helpdeskwater.nl

Editorial team
Geo Arnold, Henk Bos, Roel Doef, Reinier Goud, Neeltje Kielen, Francien van Luijn, Rijkswaterstaat, Centre for Water Management

Text
BCP, Amsterdam

Design
VormVijf, The Hague

Illustrations and maps
Bureau Op Stand, The Hague

Photography
Henri Cormont/inZicht-foto

Printing
ANDO, Den Haag

Contact
Geo Arnold, Rijkswaterstaat, Centre for Water Management

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For more information visit
www.rijkswaterstaat.nl
Telephone +31 (0)800 - 8002
(toll free number, in the Netherlands only)

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