Water in the Netherlands

managing checks and balances

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The voice of the water

Thinking of Holland
I see broad rivers
languidly winding
through endless fen,
lines of incredibly
tenuous poplars
like giant plumes
on the polder's rim;
and sun in tremendous
open expanses,
the farmsteads scattered
across the plain:
coppices, hamlets,
squat towers and churches
and elms composing
a rich domain.
Low leans the sky
and slowly the sun
in mist of mother
of pearl grows blurred,
and far and wide
the voice of the water,
of endless disaster,
is feared and heard.

H. Marsman 1936

Translated by James Brockway
From: A Sampling of Dutch Literature
Dutch Radio World Service 1962

Netherlands Hydrological Society (NHV)

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Water in the Netherlands,
managing checks and balances

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Colophon

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The Rine branch Waal during high water. Photo: Frans Klijn, WL|delft hydraulics

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Preface

The poem of Hendrik Marsman on the title page not only depicts the serene Dutch landscape but also expresses the struggle for life in the Netherlands. This country is the result of human interventions in the natural conditions over centuries. As an illustration: without dikes, the sea and rivers would regularly flood 65% of the land. In dry summers, however, parts of the country are short of fresh water. Living with floods and droughts requires a ceaseless checking of flood control and water management systems as well as balancing of all water-related interests.

The internationally renowned Dutch polder model refers to the centuries-old decision-making process which defines the water level after establishing the current situation and balancing all concerning interests. Checks and balances in the subsiding Netherlands with rising sea and river levels have defined its present geographic shape, institutional structure and legislation. The oldest, democratically rooted organization in the Netherlands' balancing interests, the water board, is more than 700 years old. This institution is still serving the local and regional flood defence and water management. Some 500 years ago the democratic supervision on water issues by provinces was started. The national responsibility for water is rather young. The Rijkswaterstaat, the present national agency of the Ministry of Transport, Public Works and Water Management, began its activities in 1798.

In the course of time, the Rijkswaterstaat has focused on the improvement of the state-managed rivers, promotion of the navigation system by construction of canals and harbours, and improving water discharge in wet periods as well as water supply in dry periods in the different Dutch regions. Since the 1960s pollution is an important issue not only for the Rijkswaterstaat but also for all interested parties. The fight against pollution required and still requires mutually co-ordinated efforts at every governmental level and in all socio-economic sectors. Enlarging the discharge and storage capacity of the state managed rivers, creating and reserving storage for water in urban areas, and preserving and improving nature management are the current issues. These topics are the challenges in the national water arena. Moreover, according to law, every citizen can participate in the decision-making process about water-related issues.

The key to understanding the geography and institutions of the Netherlands and the Dutch behaviour can be found in the country's flood defence and water management.

In the scope of international activities, I have observed a recurrent interest in the specific features of the role of water in the Netherlands. In particular, foreigners co-operating with Netherlands experts and scientists in the field of water-related problems ask for more specific information about these man-made lowlands. Therefore I welcome the 2004 revised edition of "Water in the Netherlands" because this booklet gives a good overview of human interventions in natural conditions over time and their impact on the Netherlands society. It also provides information about the challenges for water management in the future. The concept of integrated water management launched in 1985 focuses on the mutual coherence between the quantity and quality of groundwater and surface water at local, national and international levels. It also concentrates on co-ordinating physical planning, environmental quality and management of nature areas. The concept of integrated water management was laid down in the legislation.

In 1986/1987, similar ideas on integrated water management, as formulated by the Netherlands, stimulated all riparian Rhine States to adopt a Rhine Action Plan, comprising a further reduction of pollution and the rehabilitation of the ecosystem of this river. Another important step towards integrated transboundary river basin management was taken in the nineties of the former century. The 1993 and 1995 floods of the Rhine and Meuse forced the riparian states to increase their co-operation on flood protection issues. Meanwhile, common principles and strategies have been formulated for a basin-wide approach to mitigating the flood problem.

Excessive rainfall in 1998 and 2000 caused flooding resulting in particular inconvenience in urban areas. It became necessary to reformulate the requirements of the regional and local water systems. This led to the triplet retain-store-discharge as the leading principle for these systems. In its document “Water policy in the 21st Century”, the Government also focuses on raising the awareness of citizens and encouraging their contribution in relation to water threats and problems.

In December 2000 the EU Water Framework Directive came into force. Efforts are underway at every governing level in the Netherlands to achieve the objectives of the Directive in time. The first results about the water basin approach have been published. The Netherlands’ Government strives to harmonize the Dutch efforts with those of our neighbours in the basins of the Rhine, Meuse, Scheldt and Ems.

Mrs. Melanie Schultz van Haegen
The Vice Minister of Transport, Public Works
and Water Management

Acknowledgements

In 1986 the Committee on Hydrological Research of the Netherlands Organization for Applied Scientific Research TNO (CHO-TNO) published the book “Water in the Netherlands” to meet the increasing demand, especially from people in other countries, for more information about the Dutch water management. The rapid sales resulted in a revised edition being published in 1989. The Netherlands Hydrological Society and the Netherlands Committee of the International Association of Hydrological Sciences completely revised the book in 1998.

My gratitude to those who enabled the present edition to be published also extends to the authors of the earlier publications: Messrs C. van den Akker, H.J. Colenbrander, W. Cramer, G. van Ee, R.A. Feddes, J.C. Hooghart, P. Huisman, P. Kusse, C.R. Meinardi, H. Salz, E. Schultz, C.J.E. Schuurmans, J.H.A.M. Steenvoorden, A. Volker (†), J. Wessel and F.C. Zuidema. Their contributions were partly used for this revision.

Many thanks go to Mr. Pieter Huisman of the Delft University of Technology, the main author of the 1998 publication. He has updated this edition to include recent developments.

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G. van Ee
President of the Netherlands Hydrological Society (NHV)

Contents

1 Synopsis

The Kingdom of the Netherlands, Holland, the Low Countries: three names for the same country? No, not exactly. The Netherlands is the correct name of the Kingdom bordering the North Sea in western Europe. Many people, both abroad and in the country itself, also call it Holland. The reason is that in the time of the Republic of the Seven United Provinces (AD 1572 - 1795) Holland was the predominant and most prosperous province of that republic. Before 1572 the 17 provinces covering the present kingdoms of Belgium and the Netherlands were a political unity, sometimes named the Low Countries.
Because of the rise of the ocean from prehistoric times up to its present level, the inhabitants of the low-lying areas in the western and northern parts of the country had to compete with the water. The present country is largely the result of this struggle, showing the balance of successes and failures. Life in the Netherlands is closely linked to water. Its history is full of stories not only about floods and dike bursts, but also of successful land reclamation.
In this century two storm surges changed the shape of the Netherlands. The storm surge of 1916 gave the final push to the closure of the inland Zuyderzee and the reclamation of large polder areas. In February 1953 a tremendous storm surge struck the south-western part of the Netherlands. Many dikes were breached, thousands of hectares were inundated and over 1,800 people drowned. This led to the world famous Delta works. Figure 1.1 shows one of the dike bursts in 1953.
The danger comes not only from the sea, but also from rivers, as proved in 1926 and 1995. In 1926 high discharges of the rivers Rhine and Meuse breached some river dikes, inundating large areas. Heavy rainfall during several weeks produced high discharges in 1995, threatening the river dikes. It forced the authorities to evacuate more than 250,000 people within 36 hours. Fortunately the dikes held.

This publication describes the events that occurred over many centuries and the Dutch experience in conquering water over that time. It also pays attention to other issues, such as water management, water quality and hydrological research.
It starts with a description of the geography, climate and hydrology of the Netherlands (Chapters 2 and 3). Next, Chapters 4, 5 and 6 give a historical overview of the development of the man-made environment in the Low Lands near the sea. Extensive attention is also paid to water-related interests, which increased during the last decennia, and to their mostly negative impact on the quality of the water systems. In this respect the required rehabilitation efforts are described. The growing importance of water as an international issue is illustrated in Chapter 7. The seriousness of disastrous events with respect to pollution of the Rhine has led to government initiatives in the Rhine States.

Figure 1.1 Dike burst in 1953

Chapter 8 reports on the long process of co-ordinating and integrating water management, including the recent progress in the international context, as a condition for the sustainable development of water systems. This approach is based on the philosophy that three elements always define the concrete situation of a water management system, namely, the natural features of waters, the water-related interests and functions, and the administrative system and legal framework.
Chapter 9 deals with the institutional and legal aspects from former times up to the present.
The European Union is playing an increasing role also in day-to-day water management practice. Chapter 10 presents the development of the EU water policy and pays attention to the implementation in the coming decades of the recently adopted EU Water Framework Directive .
Over the centuries many Dutchmen have dedicated their efforts to water engineering works and lowland development abroad. Chapter 11 presents an overview of these activities.
Finally, Chapters 12 and 13 illustrate the crucial role of science and education in water affairs, nationally as well as internationally. Among other trends in the Netherlands, hydrological research is described.

This publication will be of interest to a wide variety of people abroad, such as hydrologists, water management engineers, administrators and laymen working on water-related issues.

2 Geography

This chapter deals with the situation of the Netherlands in north-west Europe. It pays attention to the geological structure and the soils. Land use is also an important issue in this geographical description.

2.1 Situation and elevation

The Netherlands, having a land area of approximately 34,000 km^2, is situated along the North Sea in north-west Europe (Figure 2.1). The total territory, including inland lakes, estuaries and territorial sea, amounts to 41,160 km^2. The Netherlands comprises the deltas and former flood plains of the rivers Rhine, Meuse and Scheldt (Figure 2.2).

The western and northern parts have an elevation varying between slightly above and about 6 m below mean sea level (m.s.l.) and have little relief except for the coastal dunes. The lowest point, east of Rotterdam, is 6.7 m below m.s.l. About 25% of the land area lies below mean sea level. In the absence of dunes and dikes more than 65% of the country would be flooded at high sea and high river levels (Figure 2.3). In general the Netherlands slope from south-east to north-west. The highest point (322 m above m.s.l.) is found in the hilly region of the south-east where the national boundaries of the Netherlands, Belgium and the Federal Republic of Germany meet. The central part of the country north of Arnhem is slightly hilly with a maximum altitude just over 100 m above m.s.l.

2.2 Geology and soils

Throughout much of the country Tertiary and Mesozoic deposits are situated at great depth. The only outcrops occur at shallow depths in the south-eastern and eastern areas. The marine clay layers of Tertiary age are found at a depth of about 400 m and act as an impermeable base to the groundwater aquifer system. Nearly everywhere the Tertiary and Mesozoic formations are covered by Pleistocene and Holocene deposits. This is illustrated in Chapter 3 (Figure 3.6), where a geological profile is presented.

Figure 2.1 The Netherlands, part of Europe

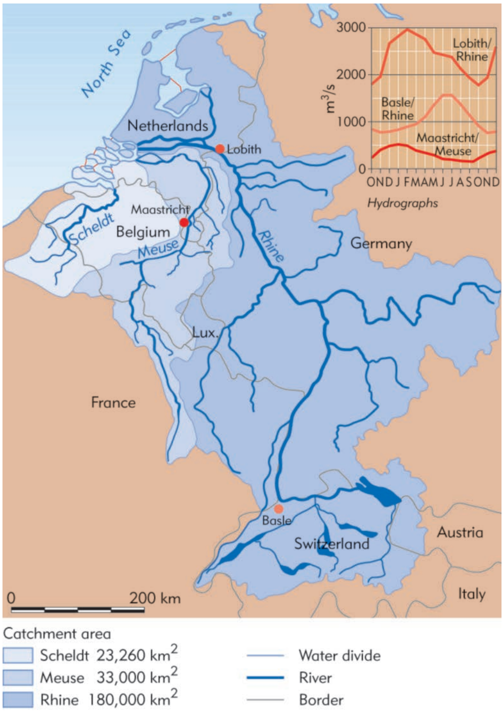


Figure 2.2 Catchment areas of the rivers Rhine, Meuse and Scheldt

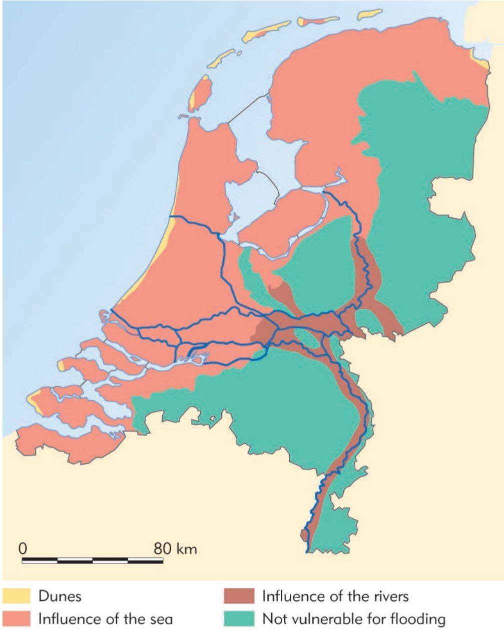


Figure 2.3 The vulnerability of the Netherlands for flooding

At the surface in the south-western, western, northern and central river districts, mainly loamy and clayey material of marine and fluviale origin dominates, together with some peat soils (partly covered with marine and fluviatile sediments) and fine sands (see also Figure 3.3). In time the drawdown of the groundwater table by drainage works has caused shrinkage and oxidation of the clay-peat soil by several metres in the western, northern and river areas. This makes the Netherlands vulnerable to storm surges and river floods. The soils in the eastern and southern parts of the Netherlands consist mainly of fine loamy sand (cover sand), medium and coarse sand (often gravel). In the south, silt and silt loam (loess) occur.

2.3 Land use

As shown in Table 2.1 nearly 70% of the total land area consist of cultivated land, of which almost two thirds are pastures and the remainder is used as arable land and for horticulture. Since 1950 the area of cultivated land has decreased. Woodland and uncultivated land together account for no more than 14% and urban and industrial areas for 17% of the total land area.
Arable farming is mainly found on the fertile, well-drained marine clay soils in the northern and south-western parts of the country and in the recently reclaimed polders. The most important crops are cereals, potatoes, sugar beet and corn. Livestock farming is usually located on clay and peat soils where dairy farming predominates. Mixed farming is traditionally practised on the sandy soils in the east and south of the Netherlands. Many of these farms specialize in pig and poultry farming (factory farming).

Table 2.1 Land use in the Netherlands in 1996 (Central Bureau of Statistics 2003)

	Land area (km^2)	%
Cultivated land	23,508	69.4
Woodland	3,233	9.5
Uncultivated land (heath, dunes, etc.)	1,379	4.1
Built-up areas (incl. roads, etc.)	5,793	17.0
Total land area	**33,873**	**100.0**

Horticulture is practised in many areas. Most well-known are the bulb fields behind the dunes around Leiden and Haarlem, although nowadays bulbs are grown in many other regions too.

The greenhouse area, located between Rotterdam and The Hague, is quite famous and produces a wide range of vegetables and flowers. The Aalsmeer region, south of Amsterdam, is famous for its flowers. Fruit-growing is concentrated in the south-west, the south-east and in the areas between the large rivers and the new polders around Lake IJssel.

Demography
(Central Bureau of Statistics 2003)

The population of the Netherlands amounts to 16.1 million (2002) against a mere 5.1 million at the turn of the century. Over the past decade the annual natural increase averaged 4 per 1,000. The present population density is on average 472 people per km^2. Fifty percent of the people live in the very densely populated western part of the country, the so-called Randstad.
In January 2002 the total working population amounted to 7.4 million, of which 4% were unemployed. The number of people working in the various sectors of the economy has changed drastically since 1900. In that year 31% worked in the agricultural sector, 34% in industry and 36% in the trade and service sectors. In 2002 the figures were 2%, 25% and 73%, respectively.

The national income of the Netherlands amounted in 2002 to more than €432 billion. The distribution of this amount among the various sectors is given in Table 2.2. The average national income per capita amounts to €26,800.

The economy of the Netherlands has a long standing and pronounced international orientation. For centuries the interest has lain in foreign trade and the transfer of knowledge to industry. It has to be stated that the discovery and exploitation of natural gas have been particularly important for the Dutch economy. Until 1970 the trade balance was negative. However, this was transformed by the large export of natural gas from 1970 onwards. In 2002 the total value of imported goods amounted to €218,330 million, whereas the value of exported products amounted to €241,339 million. This resulted in a surplus of €23,009 million.

Table 2.2 Breakdown of the national income (market prices) over the various sectors in 2002 (National Bureau of Statistics 2003)

	Sector	€10^9	%
1	Agriculture, forestry, fishing	10.1	2.3
2	Mining	10.6	2.5
3	Industry	59.8	13.9
4	Public business	7.2	1.7
5	Building industry	24.3	5.6
6	Foreign trade, tourism	61.0	14.1
7	Transport, communication	29.4	6.9
8	Services	108.4	25.1
9	Government, defence, education	47.9	11.0
10	Health, recreation	51.1	11.8
11	Saldi taxes, interests, depreciation, foreign income	–21.8	–5.0
	National income	**431.6**	**100.0**

3 Climate and hydrology

This chapter gives the characteristics of the climate, surface water and groundwater in the Netherlands. The transboundary rivers Rhine and Meuse play an important role in the hydrology of this country.

3.1 General characteristics

The Netherlands is located in the temperate zone, but due to strong maritime influences its climate is much milder than average conditions at the 52°N latitude. The annual average temperature in the centre of the country is between 9.0 and 10.4°C, while the annual average temperature at the 52°N latitude is close to 4°C. Apart from this large-scale maritime, or rather oceanic effect, there is also a small-scale effect caused by bordering the North Sea. This results in marked gradients in most climatological characteristics within the first tens of kilometres from the coast. In a sense the climate of this transition area may be called the coastal climate, as distinct from the inland climate, where gradients are generally small. In Table 3.1 some climatological characteristics of the coastal and inland climate of the Netherlands are compared. Data are based on observations during the years 1971 - 2000.

Table 3.1 Some climatological characteristics for the meteorological stations De Kooy and Twente Airbase, based on observations for the period 1971 - 2000

	De Kooy (coastal station)	**Twente Airbase** (inland station)
Mean temperature (°C)		
- January	3.2	2.1
- July	16.6	17.0
Mean daily temperature amplitude (°C)		
- January	4.4	5.0
- July	6.4	10.2
Mean relative humidity (%)		
- January	88	89
- July	82	78
Mean annual duration of sunshine (hr)	1,648	1,443
Mean annual wind speed at 10 m over flat open terrain (m/s)	6.0	3.5
Mean precipitation (mm)		
- annual	742	758
- driest month	35	42
- wettest month	92	79

As expected, the coastal area is milder in winter and cooler in summer, in comparison to the inland area. This means that the yearly amplitude of temperature in the coastal areas is smaller than in the inland area. The same applies to the daily temperature amplitude. The differences between the coastal and inland climate

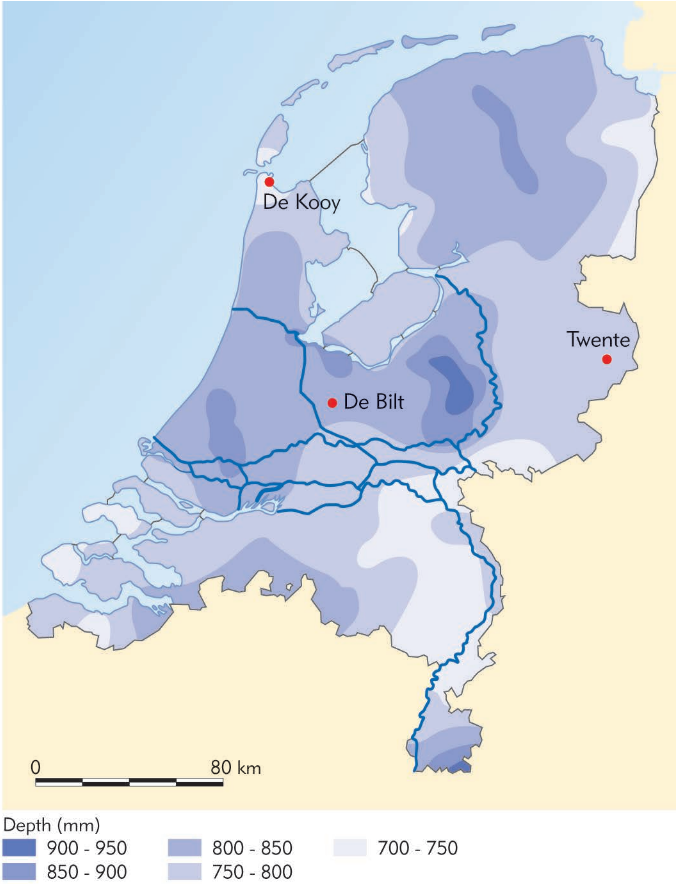


Figure 3.1 Mean annual precipitation in the Netherlands

are most pronounced in wind velocity and duration of sunshine. The more sunny climate of the coastal areas is of course attractive, but as one can see in Table 3.1, it is only at the cost of a much higher wind speed. Relative humidity is nearly the same in both areas.

3.2 Precipitation

According to the data given in Table 3.1, the coastal climate is drier on an annual basis, than the inland climate. However, such a conclusion is not generally valid. First of all, precipitation amounts are highly variable, even at time scales of 30 years. This means that a difference of some tens of millimetres in the annual mean amounts might well be oppositely directed in another 30-year period. In fact we have no indication of a systematic difference in precipitation amounts between the coastal and inland areas. As Figure 3.1 shows, the pattern of mean annual precipitation is somewhat more complex. Unfortunately, the figure is limited to the area within the borders of the Netherlands, which makes the delineation of certain features more difficult. In general the wettest areas coincide with the most hilly regions of the east-central and far south of the country. It may be concluded that these maxima are due to the orographic enhancement of precipitation. Other local maxima of precipitation are less easy to interpret. In some cases in the western part of the country, the large cities of Rotterdam and Amsterdam might be the cause. The areal average annual mean precipitation in the Netherlands is 795 mm and nowhere in the country do values deviate from this by more than 10 - 15%.

While the areal variation in precipitation amounts is small, the seasonal variation is more pronounced (Figure 3.2). Early spring is the driest season in all parts of the country. The wettest months are in the summer and late autumn, but again a clear distinction has to be made between the coast and the more inland part of the country. The heaviest showers occur in the inland in summer when surface warming is greatest. In the coastal areas the maximum is clearly shifted to the months October and November, due to showers developing over the relatively warm water of the North Sea.

As far as the temporal variation in precipitation is concerned the following characteristics may also be of importance. Interannual variability is quite large with the lowest annual amounts as low as about 400 mm and the highest nearly 1,200 mm. Daily and hourly amounts are usually mentioned according to their return periods. The 24-hour values that are exceeded on average once a year and once every 100 years are 34 and 73 mm, respectively. For hourly values and the same return periods these figures are 14 and 39 mm.

Finally it may be mentioned that about 70% of all precipitation in the Netherlands falls with wind directions between south and north-west. Some 10% falls in the form of snow.

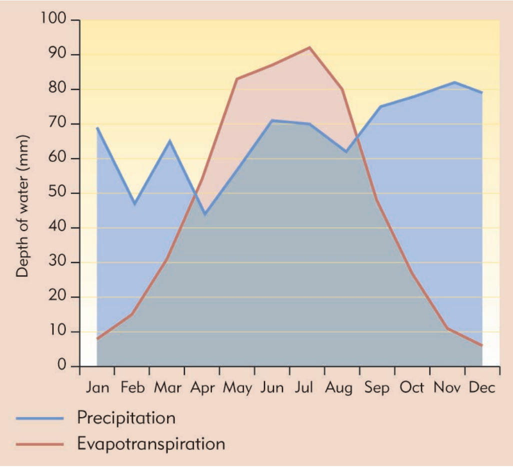


Figure 3.2 Mean monthly precipitation and the reference crop evapotranspiration in De Bilt

3.3 Evapotranspiration

Moisture conditions are determined not only by the amount of precipitation, but also by evaporation. Evaporation is governed by a number of meteorological factors, such as solar radiation, temperature, humidity and wind speed. The coastal areas with more solar radiation and higher wind speeds have higher evaporation rates than inland areas, even though in summer temperatures are usually lower. Evaporation is difficult to measure and estimates of actual evaporation are based on theoretical formulas concerning potential evaporation or rather evapotranspiration, since loss of water to the atmosphere is composed of evaporation from water surfaces or other wet surfaces and transpiration from vegetal covers (grass, arable crops, trees). According to the surface considered, evaporation or evapotranspiration may vary considerably. For example, open water in the Netherlands may evaporate as much as 700 mm per year, while annual losses from grass covered areas are several hundreds of mm less. Evapotranspiration from other crops is often smaller and paved surfaces have been found to evaporate only in the order of one or two hundred mm per year.

The mean annual evapotranspiration for the whole of the Netherlands is of the order of 560 mm, with values of 600 mm in coastal areas and 500 mm inland. As shown in Figure 3.2, the seasonal variation of evapotranspiration is very large, due to its dependence on solar radiation and temperature. The values in Figure 3.2 are based on the estimation of the so-called reference crop evapotranspiration, E_r.

The seasonal cycles of precipitation and evapotranspiration give rise to a water surplus in winter and a moisture deficit in summer. At least this has been the case in most years. On average, in the period between October and March, a surplus of about 300 mm is built up; the maximum deficit which accumulates on average in the months April to September is of the order of 100 - 150 mm. In individual years conditions may be worse, however. In exceptionally dry years the maximum summer deficit may be as large as 300 mm.

3.4 Dry weather

The Netherlands is often called a rainy country, probably because of the large number of days with (some) rain. Indeed, everywhere in the country and in all months of the year the number of dry days is equal to or less than the number of days with rain. The average of 795 mm precipitation is small in comparison to the much larger amounts in mountainous areas or the tropics. Also the duration of rain at 6 - 7% of the time is certainly not significant. The point is that rainy days as well as dry ones usually occur in groups.

Statistically, at all stations in the Netherlands, periods of 10 consecutive days of dry weather occur every year. Every 5 - 6 years dry periods of at least three weeks occur. Such periods of dry weather are convenient for all types of activities and only seldom cause a drought; these occur less than once in every ten years.

3.5 Natural variability and climate change

Apart from the effects of urbanization on climate other more large-scale changes due to human activities are possible and are, in fact, expected. Here we refer to global warming as a result of the increasing greenhouse effect. We cannot exclude that the climate data for the period 1971 - 2000, used here, have already been affected by this process. On the other hand, we will never be able to prove that such is the case, due to the natural variability of the climate. To give an example: when comparing the precipitation amounts at the De Bilt station in the centre of the country with comparable figures for the 30-year period 1931 - 1960 one can conclude that the climate has become wetter by some 40 mm. However, in view of the very large interannual variability of precipitation (standard deviation of about 150 mm) even 30-year averages in an unchanged climate are expected to vary considerably (standard deviation of nearly 30 mm). So a difference of 40 mm between 30-year averages is not unlikely and far too small to be considered as an indication of systematic climate change.

3.6 Landscape, soil and drainage

The general features of land and water in the Netherlands are characterized by the shaping of soil and landscape in geologically recent times. Sedimentation during the Pleistocene resulted in a vast and predominantly flat fluvial plain with mainly sandy soils, gently dipping to the north-west. Depending on the transport capacity of the subsurface, a stream pattern developed in the course of time, which is still draining the excess water in large parts of the southern and eastern regions.
The presence of ice sheets during glacial periods strongly influenced the landscape of the northern half of the country. Deep valleys were scoured, either by melt water, or by the ice itself. Many of these valleys can be recognized in the present stream patterns. The sandy material removed by the ice was pushed into ridges; the low hills resulting are at present important groundwater recharge areas. Because of a coarse textured soil and deep groundwater levels, these hills are less suited for agriculture.
They have mostly been planted with forest, and are now nature reserves and recreational areas. The glacial valleys were subsequently often filled with poorly permeable sediments, yet relatively low and wet areas remain where peat layers could develop. Sea levels rose by several tens of metres in the Holocene age,

which led to the deposition of clayey sediments on top of the Pleistocene sand in a broad coastal zone. Marshy areas originated more inland because of the rising groundwater levels, those areas being at the origin of large raised bogs with peaty soils.

The three major zones in the Netherlands, characterized by their top soil (Figure 3.3), are:
- elevated sandy areas, geomorphologically formed during the Pleistocene;
- areas of the most recent coastal accretions, largely covered by clayey soils;
- a relatively low transition zone with peaty soils.

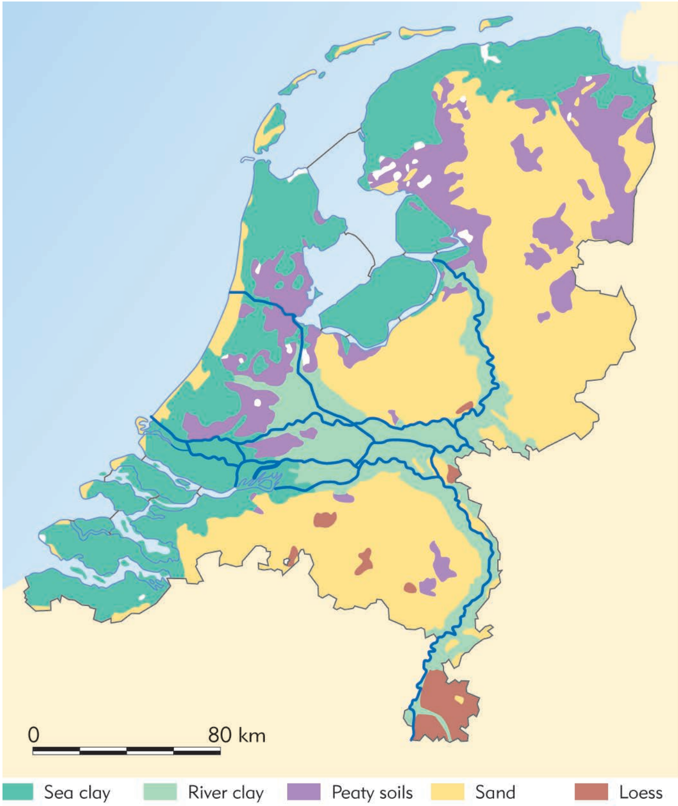


Figure 3.3 The major soil types of the Netherlands

The detailed drainage system in the lowlands of the Netherlands is almost entirely artificial and based on the discharge of excess water by pumping. Most of the surface peat layers have been excavated to supply fuel. Large lakes were created by this peat mining in the coastal regions. Many lakes were later reclaimed and made into polders, having a clayey soil (see Chapter 4). The excavated raised bogs in the higher regions were directly turned into agricultural land, drained by a system of ditches and canals. The soils of the latter land consist mainly of sand, but still with a large organic component.

The sandy regions were used for extensive agriculture, leading to a degradation of the soils, such that vast heathlands and bare soils with shifting sands developed. The situation changed after the introduction of fertilizers some 100 years ago. Heathlands were turned into pastures and only the most infertile soils were planted with trees. Land reclamation in the sandy regions continued up to the middle of the 20th century, including extension and deepening of the natural stream systems to drain the lowlands. The development still continues with the installation of tile drainage systems.

3.7 Surface water

Surface water plays an important role in the discharge of excess water, although in the relatively elevated regions with sandy soils this role is different from that in the coastal zones. Almost everywhere in the low polder areas water levels are artificially

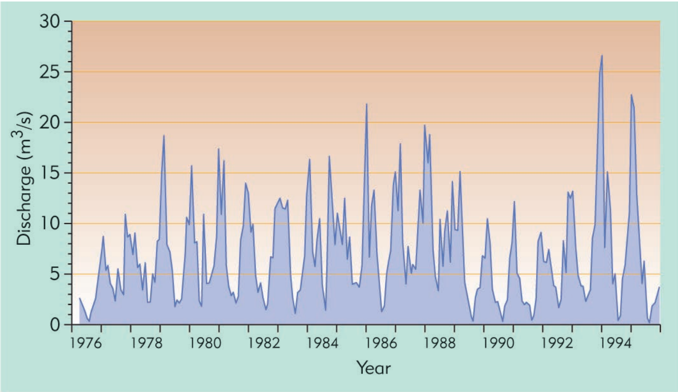


Figure 3.4 Mean monthly discharge of the River Aa

controlled by a forced discharge, but on higher grounds the drainage of water is mostly by gravity.
The smaller watercourses in the sandy regions will even fall dry in normal summer periods, whereas most ditches in the polder areas remain permanently filled. A varying but mostly small portion of the precipitation excess flows directly to the streams of the sandy regions; the majority of it infiltrates into the soil and joins the groundwater. A part of this groundwater flows quickly to the drainage system, the remainder recharges the aquifers and reaches the draining streams only after a period of months or years. Due to the precipitation excess in winter periods and the water deficit in normal summer months, the mean winter runoff is in general 2 to 3 times greater than that in summer periods. As an example Figure 3.4 shows the variation in discharge over the period 1976 - 1995 for the river Aa in the southern part of the country. The summer lows and winter peaks are quite pronounced but they vary from year to year due to the differences in precipitation.
Almost no excess precipitation on the clayey soils of the coastal zone will percolate towards the groundwater in the aquifer system. Yet, an opposite flow of seepage water will reach the surface water of the deep polders in the western and central parts of the Netherlands to a maximum of 1 - 2 mm per day. This seepage water originates from groundwater which is recharged by a regional flow from the sandy areas or by infiltration from higher lying river beds or other surface water.
The pumping stations, and formerly the windmills, of the polders have to pump the excess water of the winter periods, as well as a possible seepage flow having more permanent features.

Table 3.2 The highest, mean and lowest observed discharges of the Rhine (1901 - 2003) and Meuse (1911 - 2003)

River	Upstream catchment area (km^2)	Discharges at the Dutch border (m^3/s)		
		highest	mean	lowest
Rhine	180,000	12,500 (1926)	2,200	620
Meuse	33,000	3,100 (1993)	230	0

The rivers Rhine and Meuse are of great importance to the hydrology of the Netherlands. The characters of these two rivers are, however, quite different.

The Meuse is a typical rain-fed river, with relatively high peak flows in winter and generally low flows in summer, whereas the Rhine has a mixed character being partly fed by rain and partly by snowmelt from the Swiss Alps. This produces two significant seasonal flow peaks: one in the winter and a much lower one in the summer originating from snowmelt. The ranges of observed discharges of these two rivers are shown in Table 3.2.

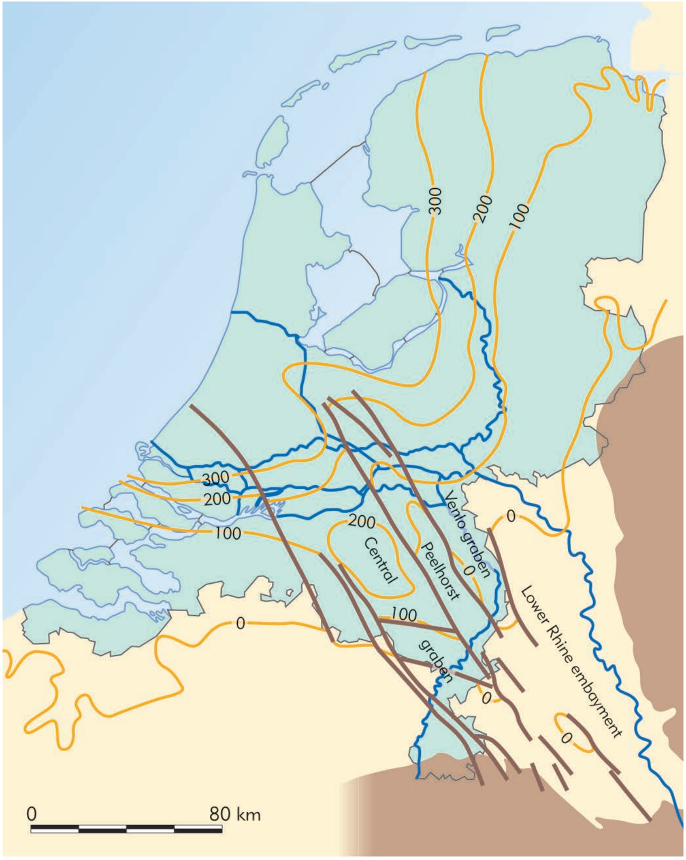
A water balance of all water passing through the country in an average year, as well as in the very dry year 1976 of the reference period 1971 - 2000, is shown in Table 3.3. The largest terms in the balance are by far the inflow and outflow of the River Rhine. In former times, the river water only passed through the country, being a nuisance during high level periods. But even in the recent years 1993 and 1995, the River Meuse inundated large areas and Rhine water reached dangerous levels, causing considerable economic damage. On the other hand, the river water is used for different purposes at present. Water is abstracted from both rivers at a rate of some 16,000 million m^3 per year for irrigation and the abatement of salt-water intrusion in the polder areas and for domestic and industrial uses. Projects aimed at bringing Rhine and Meuse water to the higher lying sandy regions suffering from water deficits have been realized.

Table 3.3 The water balance of the Neterlands' fresh-water mainland (36,750 km^2) for an average year (period 1971 - 2000) and the very dry year 1976

	Average year		Dry year 1976	
	mm	10^6 m^3	mm	10^6 m^3
In				
precipitation	795	29,200	535	19,700
Rhine (at the border)	1,915	70,400	1,130	41,500
Meuse (at the border)	200	7,400	95	3,500
other river inflows	90	3,300	40	1,500
Total	3,000	110,300	1,800	66,200
Out				
evapotranspiration	565	20,700	528	19,400
different uses	60	2,300	163	6,000
outflows	2,375	87,300	1,109	40,800
Total	3,000	110,300	1,800	66,200

3.8 Groundwater

The groundwater hydrology is controlled by the presence and the lithology of unconsolidated sediments, deposited in a subsiding basin. The axis of the basin dips to the north-west (Figure 3.5), resulting in the largest thicknesses of the Pleistocene and Holocene formations in the north-western part of the country. Thick aquifer systems are present in the north-western part. Aquifers are less important at the margins of the basin. Tertiary and even older sediments are near land surface at the eastern border, there being no exploitable aquifers at all in



100 Depth of top of Quaternary sediments (m below m.s.l.)
Fault active during Pleistocene
Pre-Tertiary near the surface

Figure 3.5 Depth of the top of Quarternary sediments

some areas. Lower Pleistocene aquifers along the southern border only reach a shallow depth. Where Quaternary deposits thin out, Upper Tertiary sand layers may form exploitable aquifers. However, except for the Upper Tertiary layers in the southern part of the country, the older strata are not exploited for public water supply. In recent years, the hydrogeology of the deeper soil layers has been investigated to assess its potential for the disposal of hazardous waste and for other human activities. Also, the deeper strata of the subsurface contain groundwater, but the permeability of deeper layers is normally low and the groundwater is brackish. The South Limburg region occupies a special position, in that shallow aquifers of Cretaceous limestone are present, which are covered by aeolian losses of the Pleistocene formation.

The Pleistocene consisted of a succession of cold and warm periods. The climatic conditions, along with important sea-level changes and tectonic movement, gave rise to an alternation of coarse and fine sediments (Figure 3.6). Thick layers of coarse sand form good aquifers. Finer sediments were deposited during interglacial periods, subdividing the aquifer system over large areas.

In the last cold period, the Weichselian stage, most parts of the country were covered by aeolian cover sands and loesses, which may now act as semi-confining layers. Also the boulder clay, deposited underneath the ice sheets of glacial periods, forms a semi-confining layer. Tectonic activity influenced the geological situation of the southern part of the country. Fault zones affected the presence and magnitude of aquifers and confining layers in the subsurface. After the Middle Pleistocene period, the rising Peel horst hindered a further deposition by the major rivers in western North Brabant, implying that the shallow layers are largely of a Lower and Middle Pleistocene period, often covered with relatively thin layers of younger deposits of a local origin.

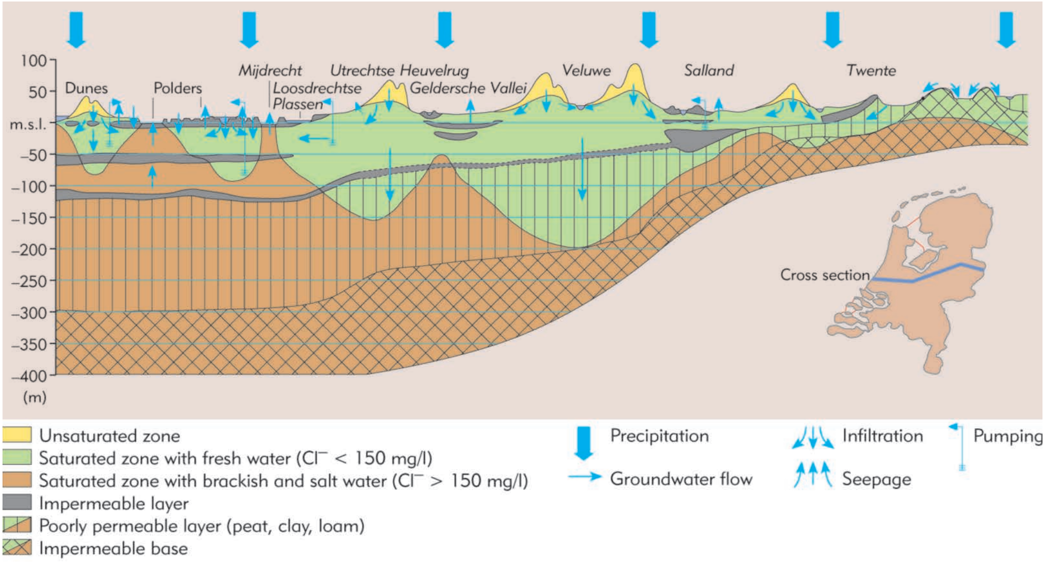


Figure 3.6 West to east hydrogeological cross section of the centre of the Netherlands

The Holocene sediments consist predominantly of clay and peat layers, deposited in a lagoonal and deltaic environment, due to the post-glacial sea-level rise. They are present in a broad coastal zone and can reach a thickness of more than 20 m near the coast (Figure 3.6).
A dune ridge has originated at the coast with an aquifer system underneath containing a fresh-water lens. The shape of the lens is determined by the width of the dune zone and the rate of groundwater recharge. Land-inward, the Holocene layers thin out; they are almost absent in the eastern and southern parts of the country.

The whole subsurface consisting of Quaternary sediments acts as one inter-connected aquifer system, although intercalated clay layers within the Pleistocene sand layers may constitute semi-confining layers over large areas. These clay layers can exert a considerable hydraulic resistance, but they will never be fully impermeable. Transmissivity values resulted from the interpretation of a large number of pumping tests executed in all parts of the country. Transmissivities of more than 10,000 m^2 per day were determined at the deepest part of the Quaternary basin in the province of North Holland. Transmissivities are lower at the margins of the basin. Near the eastern border, values are of the order of some hundreds of m^2 per day. The shallow aquifers along the southern border have transmissivities in the order of 1,000 m^2 per day. The aquifers in the sandy regions are recharged by the local precipitation excess.

In areas covered by Holocene deposits, the same Pleistocene aquifer system is present in the subsurface, but confined by shallow clay and peat layers. The groundwater recharge in the coastal regions consists of a lateral inflow of groundwater arriving from the higher sandy areas, often in combination with a local recharge by water infiltrating from actual river beds or from former river and gully beds where the soil

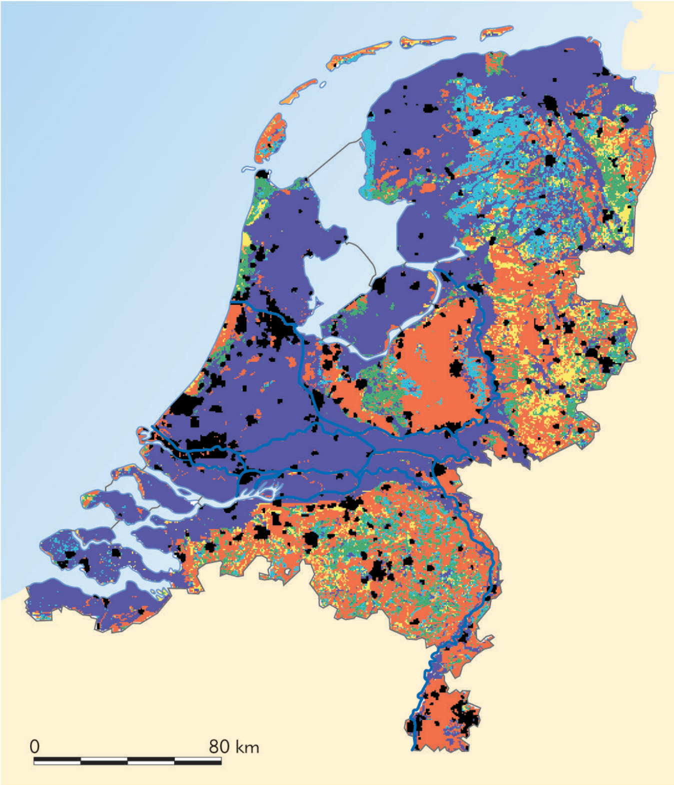


Figure 3.7 Surficial runoff

consists of sandy stream deposits. The fresh groundwater underneath the coastal dunes rests on a body of brackish groundwater. The brackish groundwater is not fully stagnant; it will generally move land-inward, but mostly at a lower flow rate than the fresh groundwater above it.

3.9 Groundwater recharge and flow directions

The recharge of groundwater in the Netherlands is complicated because it depends on the local topography. Infiltration of rainfall is the predominant form of recharge in the sandy areas. Important recharge areas are the ice-pushed hills, the Drenthe Plateau and the Peel region.
A part of the rainfall excess in the sandy regions is discharged by surface components, as overland flow, interflow and tile drainage. Factors affecting the flow rates of surface discharge (Figures 3.3 and 3.7) are the occurrence of shallow, less permeable layers, such as the boulder clay in Drenthe and loam deposits in the southern regions and also a shallow depth of the groundwater table, overcome locally by the installation of tile drains. The fast runoff of part of the excess precipitation results in a smaller amount of water being available for groundwater recharge of aquifers (Figure 3.8).

The recharge in the sandy regions is increased locally by sprinkling from surface water. Abstraction by wells may lead to a decrease in surface discharge and, hence, an increase in groundwater recharge.

The aquifer system in those coastal regions covered with clay or peat layers receives a relatively very small or even no recharge from local precipitation. Practically the full excess precipitation is discharged by surface flow to nearby open water courses, except for the sandy dunes. Parts of the coastal dunes have become important sites for artificial recharge by surface water transported from the rivers Rhine and Meuse to the dunes and infiltrating from ponds or canals.
The groundwater flow pattern can be shown by isohypses, representing lines of equal heads. Regional isohypses valid for the Netherlands indicate the large-scale

directions of the horizontal groundwater flows (Figure 3.9). Discharge areas can take the form of a river zone, where the shallow groundwater will have an upward direction and seep into open water courses. The deeper groundwater may continue to flow in the direction of draining water courses farther away and even into the coastal zone. Some of the polder areas in the western and central Netherlands discharge incoming groundwater flows, which originated in sandy areas far away from the polder. However, much of the groundwater in those polders is recharged by surface water, infiltrating at nearby river beds or coming from other surface waters. Prominent examples of areas receiving large amounts of seepage water are those in Figure 3.9, where the groundwater levels are 4 m below m.s.l. The deep polders are the focal points of regional groundwater flows.

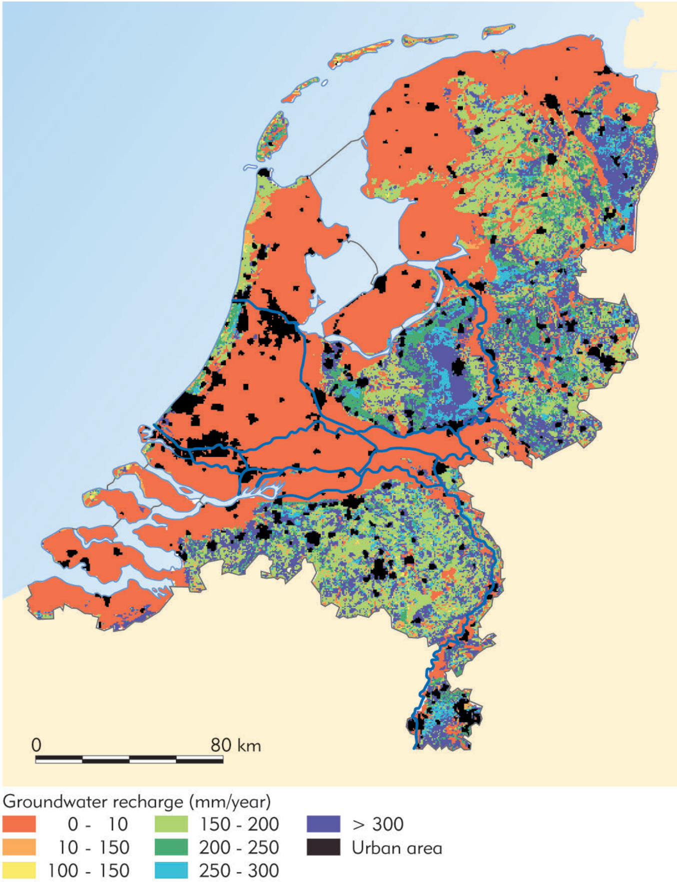


Figure 3.8 Groundwater recharge

3.10 Groundwater composition and the presence of saline and brackish groundwater

In the Netherlands the chloride content is an important natural component when considering groundwater composition. In recent years components such as nitrate and phosphate increased in the fresh groundwater reserves due to human activities. Consequently attention is nowadays paid to those chemical components as well.

The salt brought in by the various floodings of the sea during the Holocene period can still be recognized in the shallow soil, but the chloride concentration in the groundwater is relatively low, if compared to the chloride levels of sea water.
The salt content in the shallow subsurface was redistributed by the creation of high and low polders in the coastal region, resulting in the intensification of groundwater flow and changes in flow patterns. Shallow groundwater in the coastal zone is often brackish, but the groundwater in the sandy regions will generally be fresh.
So, in general, the chloride content of the groundwater in the Netherlands increases with depth. Hence, below a certain level all groundwater is brackish, or when penetrating deeper, saline.

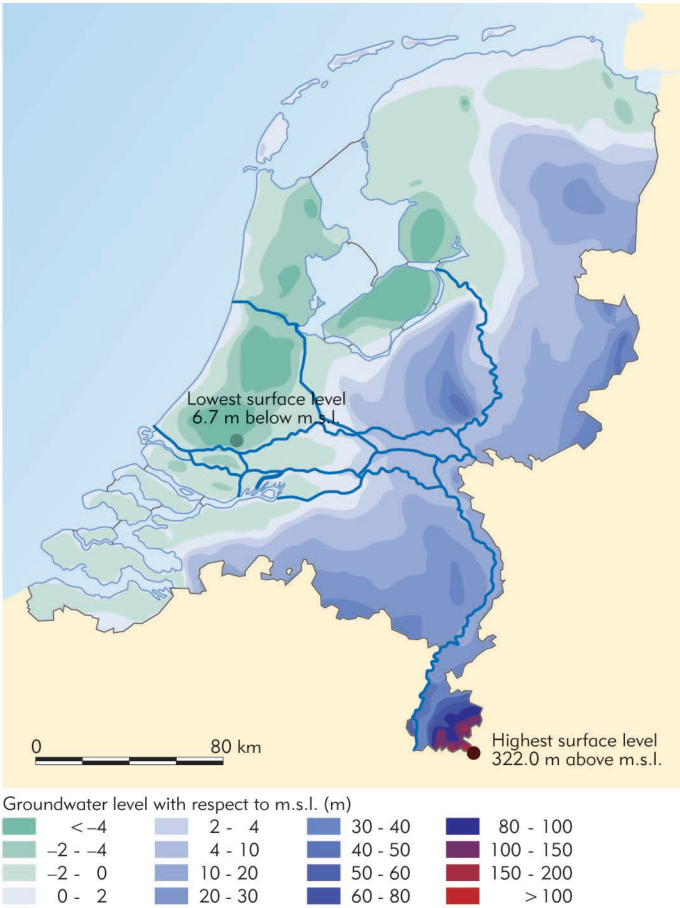


Figure 3.9 Groundwater levels

The depth of the transition from fresh to brackish and saline varies. In the western part of the Netherlands fresh groundwater forms only a thin layer over the underlying brackish zone. Towards the east the thickness of the fresh-water layer increases and hence the amount of available fresh groundwater increases. The interface between fresh and brackish groundwater is represented in Figure 3.10. The chloride content in the groundwater originates from the great number of marine deposits. Chloride distribution in the deeper aquifers is still influenced by lateral dispersion and groundwater flow. As a result of relatively recent (Holocene) marine transgressions and regressions in some specific locations, brackish water occurs in aquifers overlying fresh water. This phenomenon is called inversion.

3.11 Nature and water

A considerable proportion of the indigenous plant life in the Netherlands is characteristic of moist to wet conditions. Indeed, about 35% of the indigenous plant species are groundwater dependent, so-called phreatophytes, which grow in sites where they obtain their water supply directly from the saturated zone orthrough the unsaturated zone. In addition, more than half of the vegetation types occuring at the level of alliances are exclusively or largely phreatophytic. These vegetation types and plant species are susceptible to water management measures that significantly alter the quantitative and qualitative groundwater regime of their habitat.

Moreover, there is a high variability in the origin of soils, soil moisture and the availability of groundwater and surface water. These properties affect the natural conditions in the various areas.
Recognition of the value of ecological qualities for human welfare has increased awareness of the consequences of intensive land use on the natural environment. It is realized that water management plays an important role in this context.
As a result of the many cases revealing the severe impacts of water management

on wild animal and plant life in the period 1975 - 1985, the Government was urged to encourage eco-hydrology, a less traditional field of hydrological research. Ecohydrology is the study of the interaction between hydrology and natural vegetation, with the soil as an important interface.

Having unravelled the general mechanisms of ecohydrological systems it can be stated that local water management measures may have remote impacts on nature areas through regional hydrological systems linking land units within catchment areas. It has also become evident that the sensitivity of vegetation to changes in the hydrological regime is related firstly to the impairment of chemical buffering capacities, then to increases in the soil nitrogen supply and lastly to changes in availability of soil moisture.

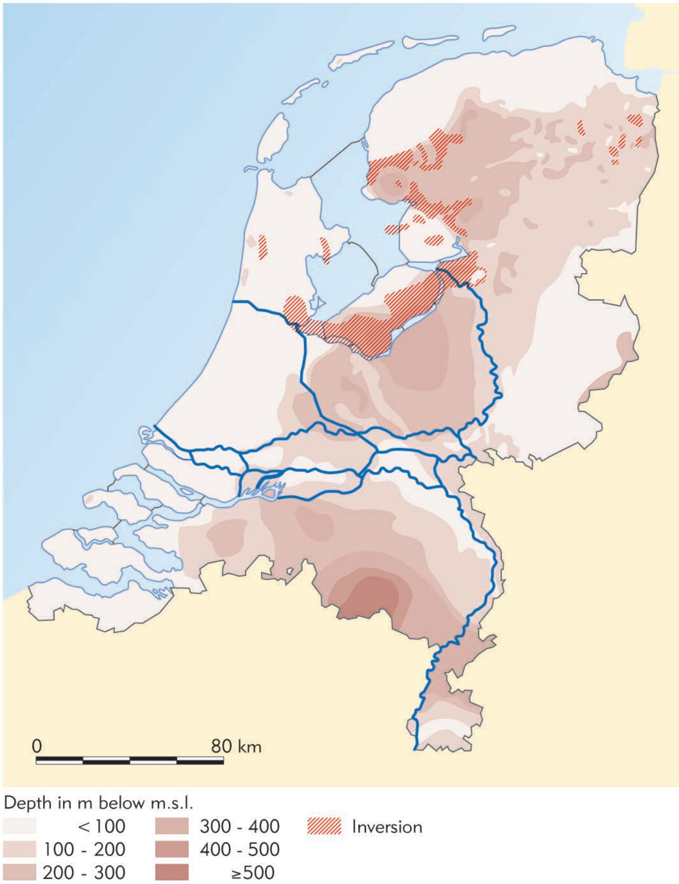


Figure 3.10 Depth of the fresh/brackish interface in groundwater, brackish means > 150 mg Cl^-/l

4 Genesis of the man-made environment

This chapter describes the essentials of human intervention in the Netherlands. Continuous lowering of the groundwater table in the peat and clay areas caused, and still causes, irreversible subsidence. Intervention to protect subsiding areas against flooding and (in the coastal regions) salination has grown in scale and impact over the course of time. Man-made developments have also defined the institutional and administrative structure of the country.

4.1 Natural circumstances

Over the course of time the position of the Dutch shoreline has varied with the rate of sea-level rise and the rate of sedimentation. During the glacial era the coastline of the North Sea was approximately 200 km further north-west than its present position. In the warmer Holocene era, the sea level rose and the North Sea flooded the western and southern part of the Netherlands. Sand ridges (called old dunes) were formed parallel to the present coastline. In about 1000 AD 'young dunes' developed on the west side. Although the latter eventually dominated the old dunes, the sea occasionally invaded the land, cut streams and formed lakes in the eroding peat area that had developed behind the dunes.

Lake Flevo in the heart of the country, originally a fresh-water body, was transformed into an inland sea. Figure 4.1 shows this inland sea, better known as the Zuyderzee, at different epochs of history.

The first settlers in these 'low lands', some 5,000 years ago, found themselves in a poorly drained flat delta or flood plain intersected by creeks, tidal inlets, and small and large rivers. Their dwelling places were on the high ridges or artificially raised hills along these water courses. Life was not comfortable, as the Roman Plinius described: "There the ocean throws itself, two times a day, daily and nightly, in a tremendous stream over a wide country, so one doubts if the ground belongs to the land or to the sea. There lives a miserable people at the highest known levels of the tide and here they have built their huts living like sailors when the water covers their environment and as if shipwrecked when the water has gone."

4.2 Irreversible subsidence caused by permanent drainage

In these areas people lived by hunting and fishing. Archeological finds show that small dikes and flumes were built at the beginning of our era to create conditions appropriate for agricultural activities on a very local scale.

Developments after the Roman times are unknown due to a lack of written and archeological information. A marked increase in the population of Western Europe took place about 1000 AD. To increase rye and wheat production the land was systematically cultivated. In the marshy land consisting of peat and clay, at that time lying 2 or 3 m above m.s.l., field drains and ditches were dug to lower the groundwater table and make agriculture possible (step 1 in Figure 4.2). The drop in the groundwater level subsided the peat and clay layers. Moreover the peat oxidized. The subsidence forced the people to deepen the drains and ditches further and to dig canals to lower the groundwater table in order to keep the land suitable for agriculture. This of course led to further subsidence of the surface. The permanent need to lower the groundwater table provoked an irreversible subsidence process.

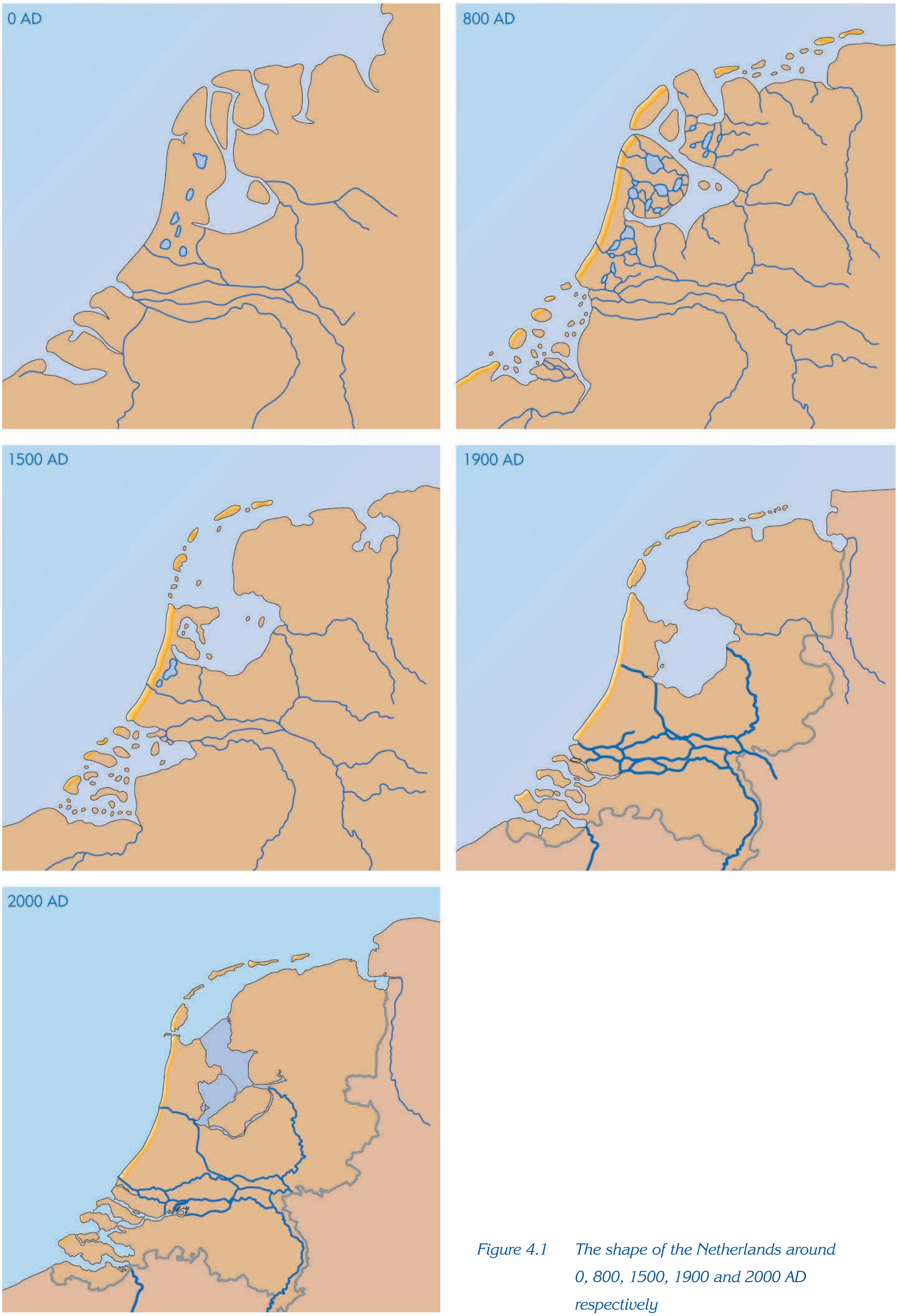


Figure 4.1 *The shape of the Netherlands around 0, 800, 1500, 1900 and 2000 AD respectively*

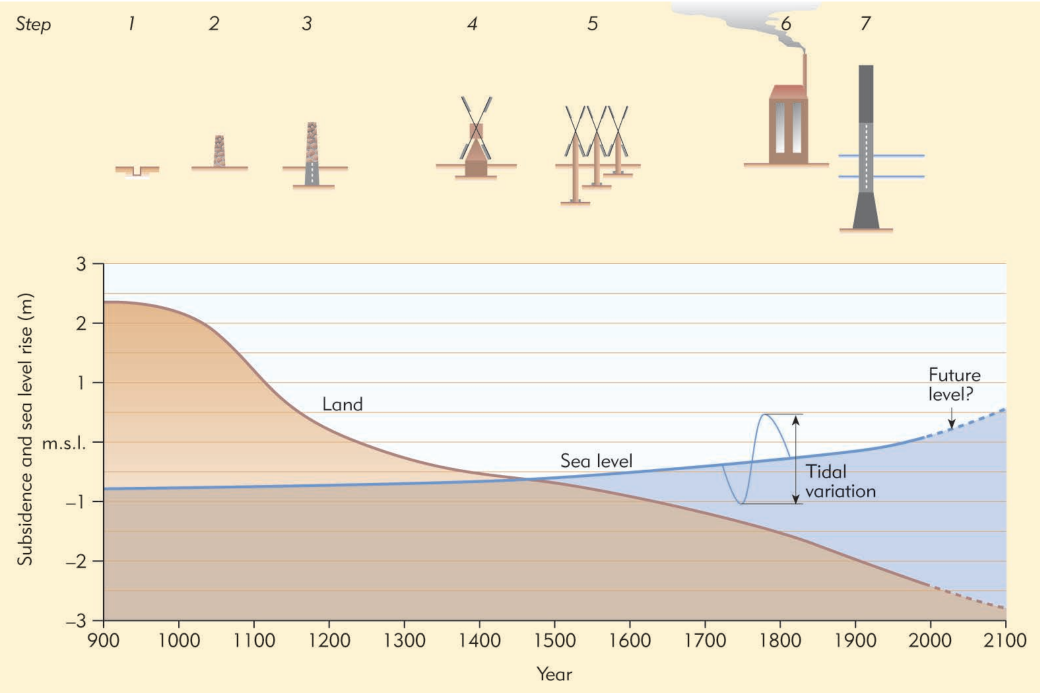


Figure 4.2 Stepwise response to the increasing subsidence of land and sea-level rise over time

By about 1100 AD the subsidence had increased to such an extent that large areas bordering the sea were flooded during high tide. Besides the man-made subsidence, the natural sea-level rise also affected the drainage problem.
Their combined impact resulted in an increase in the scale of mitigating intervention over the course of time. The measures, such as digging ditches, construction of dikes and dams, creating polders with artificial drainage, reclamation of former water areas, large-scale drainage by intermediate storage and closure of estuaries and the inland sea, are presented in Figure 4.2. This figure is the key to understanding the basics of the consecutive intervention in the natural (water) systems in support of the growing socio-economic interests and the development of the institutional structure of the Netherlands.

4.3 Dikes and dams to prevent flooding

Dikes were built to protect the land against the threatening sea water (step 2 in Figure 4.2). They protected the embanked areas against high water levels from outside. In north-west Europe precipitation exceeds evaporation. To avoid high water levels inside the embanked areas, excess water was released through outlets at low water levels outside the dikes.
In the 13th century local embankments were connected by dams closing the natural water courses intersecting the peat and clay regions. Many names of towns and cities are reminders of these events, e.g. the cities of Amsterdam and Rotterdam were developed around the dams and sluices in the tidal inlets of the Amstel and Rotte rivers about 700 years ago (step 3 in Figure 4.2).

Figure 4.3 A series of windmills for draining a deep polder

4.4 Embankments, polders and windmills

The considerable subsidence and the sea-level rise could not have been stopped. The surface behind the dikes and dams dropped below mean sea level; gravity discharge of the superfluous water from the embanked regions was hampered and became impossible. Behind the dikes and closure dams the embankment of small areas was started. From these small inner areas, called polders, the excess water was artificially removed and brought to the former natural water courses (step 4 in Figure 4.2). It was released from these water courses by sluices into closure dams at low water. The former inlets and creeks were and are still being used as intermediate storage areas (called 'boezem') during high water levels. This stepwise drainage system is very typical in the Netherlands.

The first artificial drainage tools were hand- and horse-driven mills; their capacity was very limited. Fortunately windmills became available for artificial drainage on a larger scale in the 13th century (Figure 4.3). The invention of turning the sails of the mills into the varying wind directions has been vital for the survival and development of the Netherlands.

4.5 Reclamation of large water areas

In the 16th century the drainage techniques reached such a high standard that it became possible to reclaim shallow lakes. The practice was to dig a canal around the lake or pond, constructing the enclosing dikes on both sides along the canal with the removed ground. Windmills drained the polder. Sometimes it was necessary to place a series of windmills in order to overcome the difference in level (up to

6 m) between the former tidal inlet and the new polder (step 5 in Figure 4.2 and Figure 4.3).
Since the 14th century the sea-states Holland and Zeeland have become centres of trade, industry and traffic. The sea and the navigable rivers played an important role. Thanks to this situation more capital became available. In the 16th and 17th centuries the Amsterdam merchants earned a lot of money and looked for investment projects. At the beginning of the 17th century the money was invested into the enlargement of the agricultural area, as there was a high demand for agricultural products due to the strong growth of Amsterdam and other towns in Holland. This was partly due to many refugees who found a new homeland in the Netherlands. In the course of time large areas have been reclaimed, in total 600,000 ha (Figure 4.4).

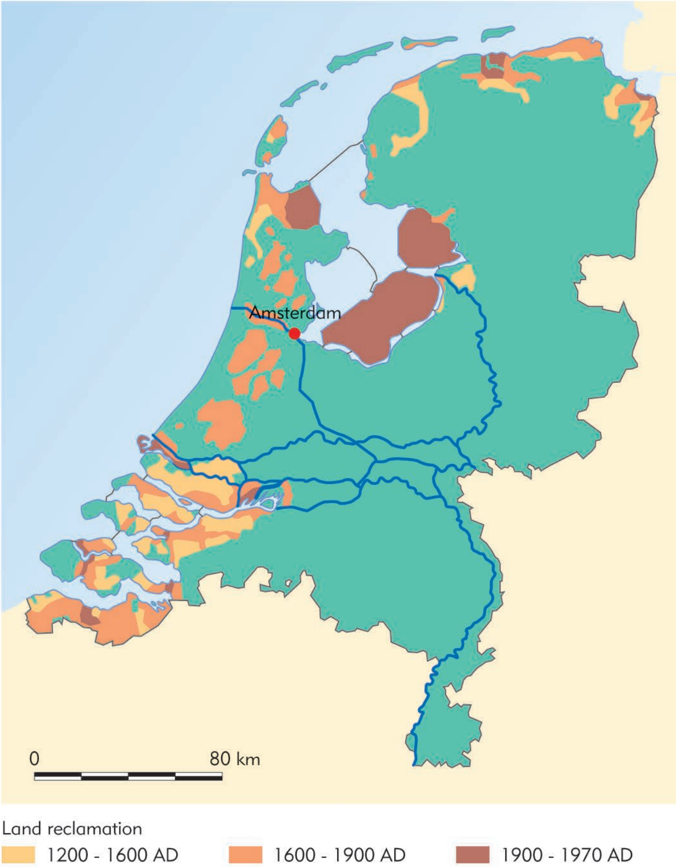


Figure 4.4 Land reclamation in the Netherlands

Industrialization, started in the 19th century, created new possibilities. Instead of many windmills draining large polders, steam-driven pumping stations became available. The artificial release of water from the boezem became possible too (step 6 in Figure 4.2.).

4.6 Increasing vulnerability to floods and saline water

The history of the Netherlands in the last ten centuries is particularly characterized by flood disasters, reparative works and reclamation.
The continuing subsidence of the surface in the polders and the rise in sea level have resulted in about 25% of the Netherlands now being situated below mean sea level (up to 6.7 m). Without dikes and dunes 65% of the land would be flooded daily (Figure 2.3). This situation makes the Netherlands vulnerable to storm surges and river floods.
Dikes may collapse during high storm surge levels or extreme river discharges and large areas could become inundated. In many countries the water drains away without manual assistance when the surge or flood is over, because the land lies above the sea and river levels. If dikes or dunes in the western part of the Netherlands were to collapse, large areas would be flooded and would remain

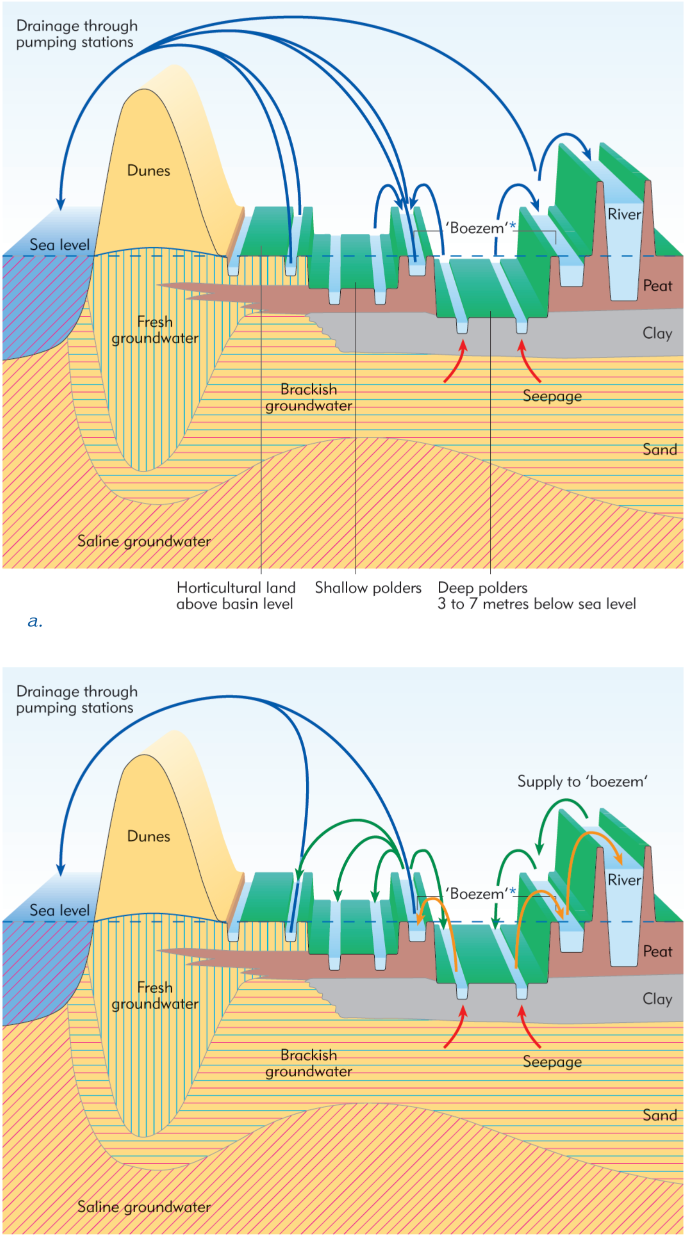
under water until the dikes could be repaired and the water artificially removed. But there is also another aspect of the vulnerability of living below mean sea level. This is represented in Figure 4.5. Due to the difference in water levels outside and inside a polder, an upward seepage flow in the polder will occur. The velocity of the flow depends on the differences in piezometric levels and the resistance the flow meets in the confining layers. The groundwater is brackish because the deposits are of marine origin. To avoid salination of the soil and to create good conditions for agriculture and horticulture, the saline seepage water is flushed to the sea by surplus precipitation and by using river water in dry periods. It is mainly the Rhine water that serves this purpose. That is the reason why the Netherlands reaction to increasing chloride content or pollution of the Rhine is so sensitive. Chapter 7 gives more details.

4.7 Water boards, the oldest democratic institutions in the Netherlands

The inhabitants of this country took the initiative to cultivate and protect the land against high water levels. They were responsible for the construction and maintenance of dikes, flumes and ditches. As a dike's strength depends on its weakest point, the inspection of its condition could not be entrusted to an individual landowner but had to be submitted to a general judgement. Therefore the inspection was carried out by the local community.
The rules applied were very strict. If a landowner was not able to fulfil his duty to maintain his section of the dike, he expressed this fact by putting his spade into the dike. The community forced him to leave his property forever. In order to close the gap in the flood defence, seven neighbouring farmers would come together and select a new farmer who was capable of maintaining the dike according to the rules formulated by the local community.
In the 13th century local embankments were connected by damming off the natural water courses intersecting the peat areas. The drainage area behind the dam now enclosed many local communities. It soon became very clear that maintenance of sluices and dams could not be realized by individual landowners and the inspection could not be exercised by local communities. Regional meetings were organized to discuss the common problems and interests. The local communities involved began to elect representatives to these meetings. The conventions about personal and financial involvement in the formation of the water control and maintenance activities of the communities concerned led to the still existing institutions, namely the water boards. The rulers of the different parts of the Rhine-Meuse delta stimulated this process and recognized the water boards as the competent water authorities. The water boards received charters from these rulers detailing their competencies. The water boards exercised the inspection of dikes, dams and sluices. For these activities a levy had and still has to be paid. The levy is proportional to the extent of 'interest' the possession of land expressed in hectares. Participation and the voting system for this authority are based upon the levy paid. The basic rule of the water boards is interest-payment-say.
The oldest existing written charter was given by the Count of Holland in 1255. The name of this water board is 'Rijnland' situated around the former main tidal branch of the Rhine. As the water boards were based on voluntary participation principles these organizations can be considered as the oldest democratic organizations in the Netherlands.

According to the Constitution of the Netherlands, the water boards are still the competent authorities for local and regional flood protection and water management issues. The institutional and administrative structure is defined by law. The provincial authorities formulate the tasks of every water board within their territory by establishing the ‘reglement’, the statutes of the water board. The law defines that water boards are administered by the assembly, the executive board and the chairman.
The assembly makes the important decisions on matters such as budget, taxation, orders and regulations. The executive board, composed of a small number of members of those entitled to attend the assembly, is responsible for day-to-day administration and implements the decisions of the assembly. The chairman chairs both the assembly and the executive board and has certain powers of his own.

The growth of the population and urbanization in the 20th century increased the number of interested participants in local and regional flood protection and water management. According to the ‘interest-payment-participation’ rule house owners and residents are members of the water board.



* ‘Boezem’ = Intermediate storage

Figure 4.5 *a. Drainage of polders in wet periods;*
b. Supply, flushing and drainage of polders in dry periods

In the 1970s the water boards were also charged with water quality issues. The ‘polluter-pays’ principle, led to taxes having to be paid by polluters. According to the device ‘no taxation without representation’ the polluting categories (households and firms) have representatives on the water boards. For more specific information, see Chapter 9.

4.8 Intervention in the Rhine-Meuse system

The Romans undertook the first large-scale intervention in the Rhine-Meuse system. Drusus Nero Claudius connected the Rhine with the IJssel and General Corbulo the Meuse with the (Old) Rhine. The systematic intervention in the areas along the branches of the Rhine and Meuse started in approximately 1100 AD, about a century later than in the coastal areas. People originally living on high ridges and river banks, began to adapt the lower lying areas between the delta branches for agricultural production. The drainage of the land caused subsidence of the clay layers. To protect the area against flooding, the inhabitants began to construct inner embankments perpendicular to the higher ridges. Later they began building dikes. As in the areas along the North Sea, the irreversible process of subsidence continuously lowered the land.

In the 16th and 17th centuries, the irregular course of the summer river bed and unregulated intervention in the winter bed considerably hampered the safe discharge of water and ice to the sea resulting in dike breaks and inundations. In particular the situation at the bifurcations of the Rhine and its delta branches and at the confluence of the Meuse with the Waal caused problems. It took almost two centuries for the first large-scale improvements to be made because the institutional situation was so complicated.

From 1579 to 1795 the Netherlands was a confederation of seven sovereign states. In 1707, after time-consuming negotiations, four states decided on an overall approach. The river works for improving the unequal water distribution over the bifurcation points of the Rhine were started in 1707 (Figure 4.6). After 1795, when the Netherlands became a unitary state, the national water authority, the Rijkswaterstaat, realized many hydraulic works to improve conditions for the discharge of water and ice, and for navigation.
The Rhine branch Waal and the Meuse were given new, shorter routes to the sea by the creation of the Nieuwe Merwede (1875) and Bergse Maas (1904), respectively. Improvement of the discharge capacity of the Lower Meuse in the period 1930 - 1940 prevented large areas from flooding, creating better conditions for the socio-economically poorly developed regions around 's-Hertogenbosch (Figure 4.6).

4.9 Closing-off and reclamation of the Zuyderzee

Figure 4.7a shows the Netherlands at the beginning of the 20th century. In the central embayment, called Zuyderzee, storm surges caused many inundations. The flood disaster of 1916 was the last impulse for carrying out the long-cherished plan to close off and partly reclaim the Zuyderzee. There were four main reasons to realize this plan: flood protection, the fight against salination, water supply in dry periods and land reclamation to increase food production.

The closure dam with large discharge sluices was completed in 1932 creating Lake IJssel (Figures 4.7b and 4.8). The IJssel, the northern flowing branch of the Rhine, supplies the lake. The lake was gradually transformed into a fresh-water reservoir by receiving the IJssel input, supplying the northern parts of the Netherlands with fresh water during dry periods and discharging the surplus through sluices into the sea. The sluices were designed based on the situation prevailing at the beginning of the

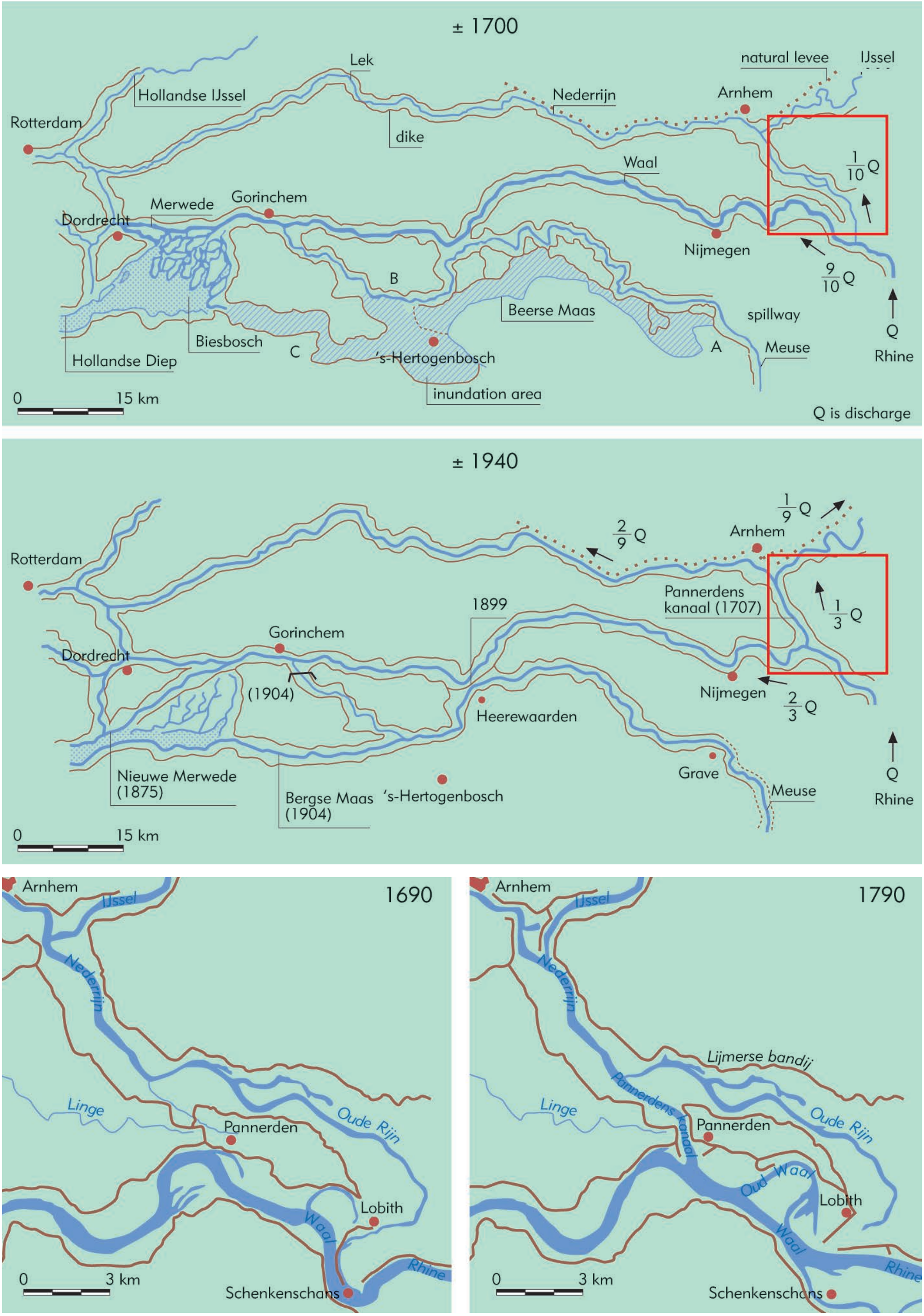
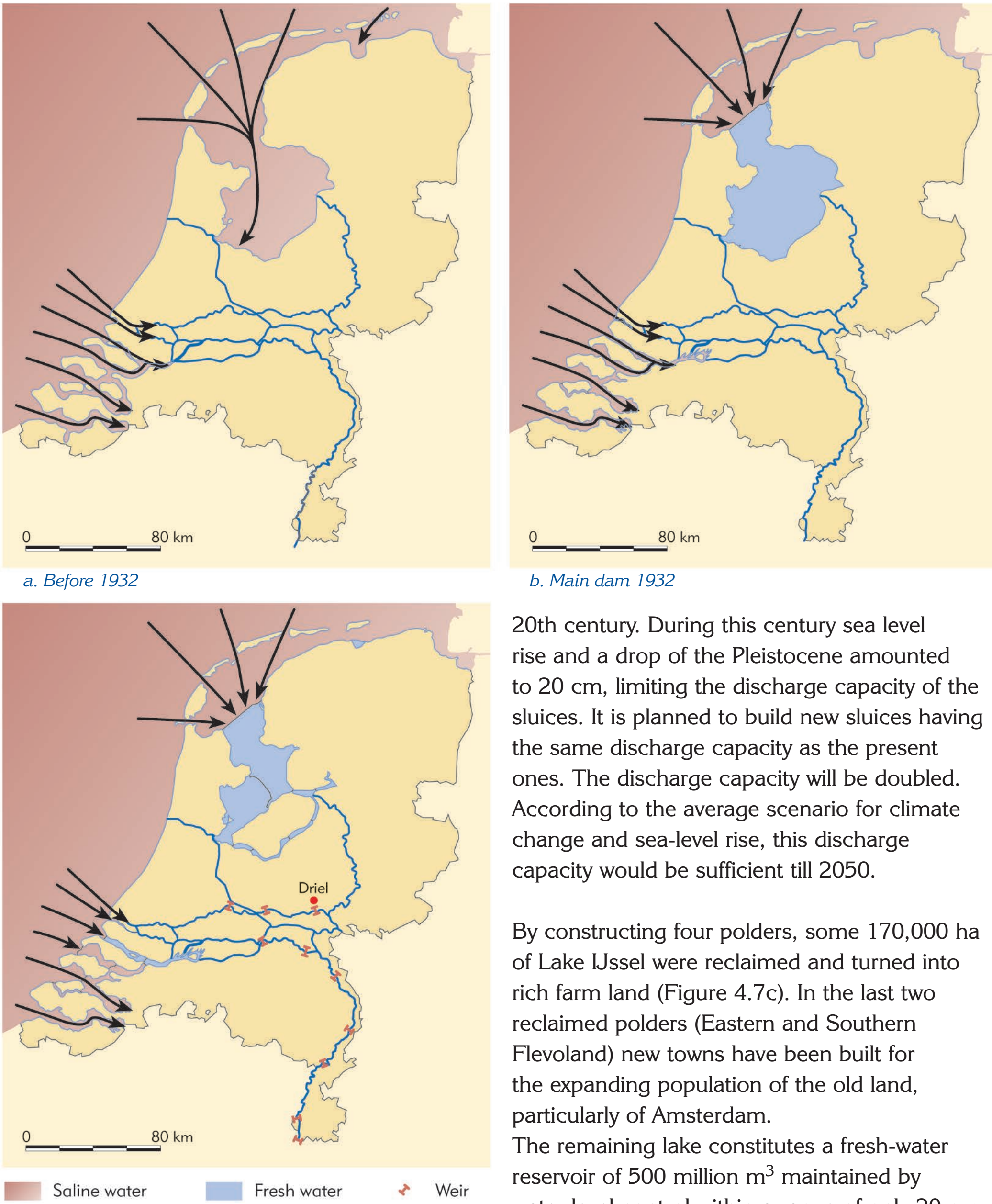


Figure 4.6 Changes in the Rhine bifurcations and river courses



a. Before 1932

b. Main dam 1932

c. 1970

Figure 4.7 Protection against storm surges and salinization in the 20th century

20th century. During this century sea level rise and a drop of the Pleistocene amounted to 20 cm, limiting the discharge capacity of the sluices. It is planned to build new sluices having the same discharge capacity as the present ones. The discharge capacity will be doubled. According to the average scenario for climate change and sea-level rise, this discharge capacity would be sufficient till 2050.

By constructing four polders, some 170,000 ha of Lake IJssel were reclaimed and turned into rich farm land (Figure 4.7c). In the last two reclaimed polders (Eastern and Southern Flevoland) new towns have been built for the expanding population of the old land, particularly of Amsterdam.
The remaining lake constitutes a fresh-water reservoir of 500 million m^3 maintained by water-level control within a range of only 20 cm. Besides supplying the northern and north-western parts of the Netherlands, the lake also receives excess water from these areas.

4.10 The Delta Project

The south-western estuarine area of the country consists of islands, surrounded by deep tempestuous estuaries, into which the Scheldt, the Meuse and 90% of the Rhine discharge. The storm surge of February 1953 breached the dikes in

900 places, large areas became inundated and many people and livestock drowned. It gave the final impulse to the Delta Project with the aim of damming the estuaries in the south-west to provide protection against storm surges and to fight the salination by the sea. The Rotterdam Waterway and the Western Scheldt were excluded from the scheme because of their importance as entrances to the ports of Rotterdam and Antwerp. Safety along these water courses would be achieved by substantial reinforcement of the dikes.

Figure 4.8 The 32 km long main dam (Afsluitdijk). Left: Wadden Sea (salt water), right: Lake IJssel (fresh water)

The original Delta Plan has been adapted at two major points: the Eastern Scheldt barrier and the Veerse Gat Dam. The Eastern Scheldt was to be closed by one of the largest dams ever built in the Netherlands. In 1975 environmental considerations led to the decision to build a storm surge barrier, that leaves the tidal movement largely unmodified, but can be closed during storms and high tides (Figure 4.9). Due to the rapid development of the port of Rotterdam, it proved necessary in 1987 to build a storm surge barrier in the Rotterdam Waterway (Figure 4.10). In contrast to the situation in the 1950s, the deepest harbours of Rotterdam were given a separate obstacle-free entrance to the sea in 1975.

Figure 4.9 The Eastern Scheldt barrier, compromise between protection and environmental interests

The main features of the final Delta Project are represented in Figure 4.11. Six primary elements oppose storm surges: the Rotterdam Waterway Barrier, the Hartel Barrier, the Haringvliet Dam, the Brouwers Dam, the Eastern Scheldt Barrier and the Veerse Gat Dam. The Eastern Scheldt Barrier is the most expensive work, having cost the equivalent of €2,000 million in 1986. The cost increased by 30% compared with the 1976 estimate. Secondary dams were necessary to allow construction of the primary dams. The Volkerak Dam divides the northern and the southern delta basins. The northern basin is important for national water management.
Secondary dams in the southern basin are the Grevelingen Dam, built primarily for the temporary function of moderating tidal currents during the construction phase of the project, and the Philips Dam which, together with the Oyster Dam, helps create the fresh-water basin 'Zoommeer' in the otherwise salty southern system. The Zoommeer serves agricultural interests and increases the safety of shipping

Figure 4.10 The first test closure of the storm surge barrier in the Rotterdam Waterway, May 1997

Characteristics of water courses due to the Delta works

RW	Rotterdam Waterway:	tide, brackish
ND	Northern Deltabasin:	few tide, fresh
LG	Lake Grevelingen:	stagnant, salt
ES	Eastern Scheldt:	reduced tide, salt
ZM	Zoommeer:	stagnant, fresh
VL	Veerse Lake:	stagnant, brackish
WS	Western Scheldt:	tide, salt

Dike
Dam
Sluice
Barrier

Chronology of the major Delta projects

1	Hollandse IJssel barrier with lock	1958
2	Zandkreek dam with lock	1960
3	Veerse dam	1961
4	Grevelingen dam, sluice and lock	1965
5	Volkerak dam, sluices and locks	1970
6	Haringvliet dam, sluices and lock	1970
7	Brouwers dam with sluices	1972
8	Eastern Scheldt dam, barriers and lock	1986
9	Oysterdam with lock	1986
10	Philipsdam with lock	1987
11	Hartel barrier with lock	1996
12	Rotterdam Waterway barrier	1997

Figure 4.11 The Delta Project (south-west Netherlands)

along the Antwerp-Rhine navigation route. As required by navigation and water management, the dam has been provided with locks and sluices.
The fresh water of the northern delta basin is supplied by the Rhine and Meuse.
The Haringvliet Dam is equipped with drainage sluices that keep salt water out at high tide and discharge surplus fresh water into the sea. At normal and low flows the sluices control the water level in the basin by directing part or all of the river flow to the Rotterdam Waterway. This limits the salt-water intrusion and improves the fresh-water balance in the northern delta basin. However, the sharp transition between the fresh-water and salt-water environments also has negative impacts on the ecology in the northern delta basin. That is why measures to allow limited salt-water intrusion are being considered today.

4.11 The main infrastructure

Due to the improvement of the fresh-water situation in the south-west of the country, it became possible to assure a larger supply of water to the northern and north-western parts of the country in dry periods. The diversion of water from the west to the north, to Lake IJssel, has been realized by the canalization of the lower Rhine. The weir built furthest upstream, at Driel (Figure 4.12), is the major valve through which the main water management system can be controlled in dry and normal periods. Other elements of the main system are the sluices in the Amsterdam-Rhine Canal/North Sea Canal, the Haringvliet, the Closure Dam (Afsluitdijk) (Figure 4.8) and the pumping station at IJmuiden. Regional and local water management works allow control of the flow of the Rhine and Meuse water to many locations in the Netherlands (Figure 4.13).

Figure 4.12 The weir in the lower Rhine at Driel, the major control valve for Dutch water management

Rhine
Meuse

Figure 4.13 Distribution of the Rhine and Meuse water in the Netherlands

In the 1960s the increasing demand for fresh water by households, industry, agriculture and navigation, and for flushing to prevent salt-water intrusion, indicated the need for a coherent policy. The planning instrument entered the water scene. In the first policy document on water (1968) the Government formulated the principles and measures at a national level to achieve efficient, long-term water management. However, the approaches for water quantity and water quality followed different tracks in the period 1970 - 1985. Reduction of pollution at source dominated the water quality approach (see Chapter 6). Water supply for all interests in every corner of the Netherlands prevailed in the water quantity approach. The second policy document on water (1985) defined the water distribution over the Netherlands during dry periods taking into account environmental aspects. The third policy document (1989) fully integrated both approaches. The fourth policy document (1997) reinforced, deepened and enlarged the integrated approach.

4.12 Adaptation of the local and regional water infrastructure since 1998

Excessive rainfall in 1998 and 2000 confronted large areas in the Netherlands with flooding in urban areas. Streets, cellars and ground floors became inundated. Although the situation did not threaten society, as did the 1916 and 1953 storm surges and the 1926 and 1995 river floods, it caused much inconvenience for residents, businesses and traffic. Citizens and, in their turn, governments were upset. How this could happen in modern times?
In the course of time, public opinion had changed. Fifty years ago citizens took their own measures to prevent or mitigate damage by water inconvenience.
Today many citizens do not take precautions, but blame the governments when a disaster occurs.
On the other hand, governments had systematically ignored the warnings of water scientists and water boards about the consequences of urbanization. Urbanization makes surfaces impermeable. To avoid inundation, space to store water, or enlargement of the discharge capacity of the water system are required.
Without adaptation of the local and regional water systems, inundation was destined to occur sooner or later. Municipal authorities often decided to enlarge their urban areas without making provisions to compensate for the loss of storage capacity or to reserve storage to increase the discharge capacity of a watercourse.
The supervising provincial authorities, competent for decision making on water, space, environment and nature generally, approved the municipal decisions.
The municipal and provincial authorities often sidelined the arguments of scientists and water boards. The national government did not formally notice opposition against the ruling policy.

In 2001, the Government and Parliament recognized that the space for water had been becoming gradually limited over time, particularly during the 20th century. They adopted the water management policy for the 21st century entitled “A Different Approach to Water”. This policy confirmed the space-making policy for rivers (see section 8.6) adopted nationally in 1995. This document also instructed the provincial, municipal and water board authorities to reserve and create space to retain, store and discharge water in present and future situations in this order.
To enforce this policy, the ‘water test’ was prescribed by law. According to the water test the municipality, as responsible authority for final spatial reserves, has to submit its proposals fo spatial reserves to the water board. The water board can reject the municipal planning permission; if the municipality ignores the water board’s recommendations, the water board can appeal to higher authorities.

Since the 1950s the Government has made many efforts toward mitigating flooding and other waterproblems. In 2001, the Government and Parliament observed a lack of understanding and acknowledgement among individuals and social interest groups with regard to water problems. People are often unaware of any looming threats and show little understanding for measures being taken by the authorities. Therefore, the policy document also stressed the responsibility of individuals to contribute to the prevention of water damage and inconvenience.

5 Water-related interests

The Netherlands is a sinking country bordering the rising sea. Watercourses intersecting the country are vulnerable to pollution. That is why flood protection and the preservation of sound water systems predominate all other interests. The Dutch Constitution charges the competent authorities "to ensure the habitability of the country and to preserve and improve the environment". These predominant interests define the conditions for living in this country. When flood protection and sound water systems are not ensured, the promotion of any other interest makes no sense. The other water-related interests, such as drinking and industrial water supply, navigation, water for agriculture, recreation, nature and power generation, depend highly on the multifunctionality of the land and water systems. Preservation of these systems is the main goal of the Netherlands water policy. In the following sections the different water-related interests are explained.

5.1 Flood protection

The previous chapter explained the continuous struggle against storm surges and river floods over time. Before the disaster of 1953, flood protection was primarily the responsibility of the water boards. The provincial government and parliament supervised flood protection requirements and defined the dimensions of the dikes around the low-lying areas and polders. The national Government could only intervene when dikes were neglected. It is responsible for the safe discharge of water, ice and sediment from the large rivers to the North Sea. After the disaster of 1953, the national Government and Parliament found that the definition of acceptable risks against flooding had become a national issue.

Based on the size of the population and the economic conditions in the 1950s, the Government and Parliament decided that the dikes and dams in the densely populated Holland have to resist a storm surge occuring once in 10,000 years

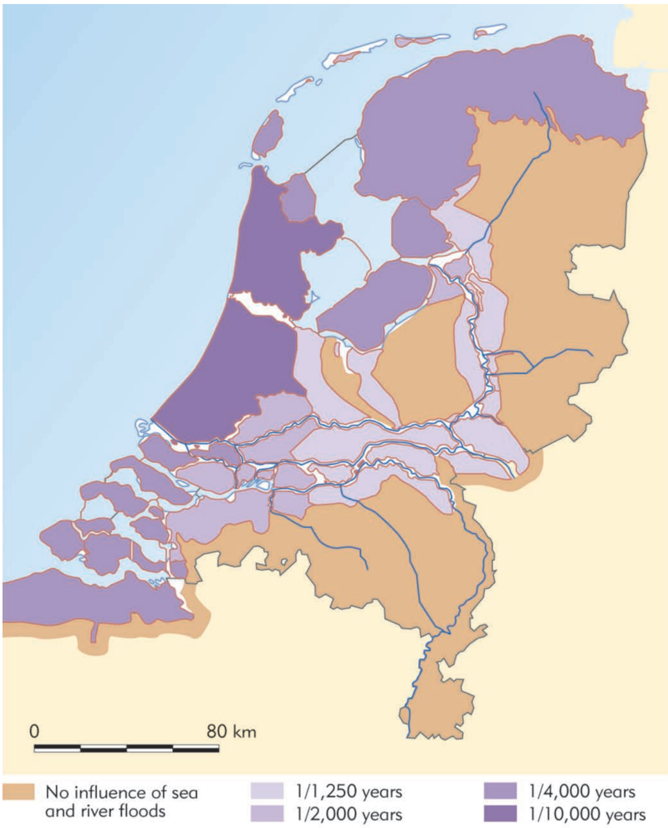


Figure 5.1 Safety standards for the different dike areas

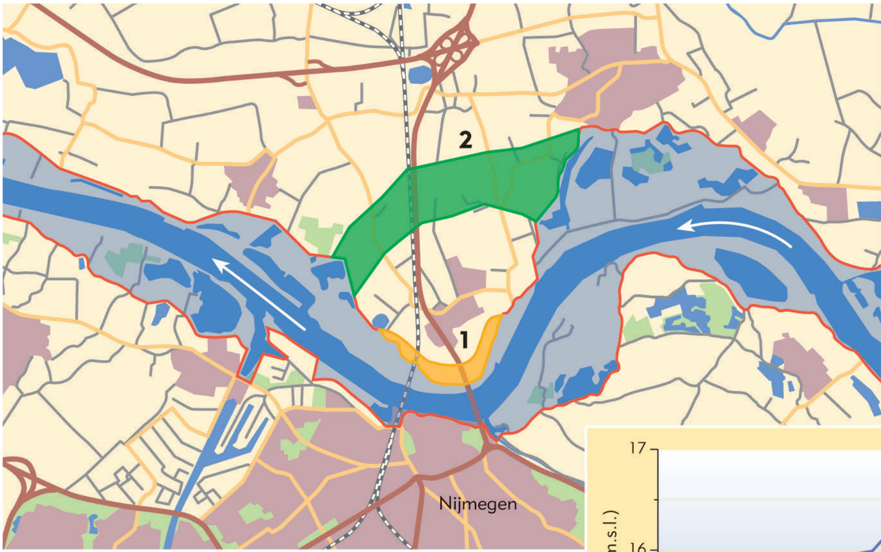
Figure 5.2 River flood of 1995

on average. They accept(ed) inundations by storm surges exceeding this safety standard. For the northern and south-western parts of the Netherlands and some Wadden Sea islands, dikes and dunes have to meet the safety standards of 1/4,000 and 1/2,000 years. The Deltaworks are designed according to these standards.

Frightened by the storm surge disaster of 1953, the authorities and population in the regions along the rivers Rhine and Meuse concluded that the protection against river floods was insufficient. They asked the Government to present guidelines and to provide funds to strengthen the river dikes. The Government set a standard of one flood in 1,250 years for areas vulnerable to river floods (Figure 5.1). The Deltaworks were given priority over protection against river floods. Storm surges are more dangerous than river floods in the Netherlands: surges threaten the lowest, very densely populated and economically most important parts of the country. The sudden occurrence of storm surges leaves only a few hours to alert authorities and to warn the population. Evacuation of the population is impossible. The warning time for river floods can be counted in days and allows for the evacuation of the population as demonstrated in early 1995.

The threat posed by storm surges is salt water; salt water destroys vegetation and makes the land unsuitable for agriculture for years. River floods do not have that impact. Repairing broken dikes at sea is more difficult than along rivers because of tidal currents which can cause deep channels in the gap in a dike.
After the completion of the Deltaworks, the strengthening of the river dikes began at full speed in the 1980s.
As the last big river flood dated back to 1926, there was strong opposition from environmentalists who were against the strengthening programme. The strengthening of river dikes resulted in loss of nature areas, landscape and sites of cultural value.

New research results recommending higher dikes increased the resistance of the environmentalists. In 1993 the Government and Parliament agreed upon a new approach, sparing the landscape, nature areas and places of cultural value. The river floods of 1995 (Figure 5.2) increased the pressure to realize the works by 2000 by the application of new techniques, acceleration of administrative procedures and the provision of sufficient funds by the Government. In 1995, out of the 1,800 km of river dikes, two thirds met the required safety standards and one third needed to be strengthened. Today, the river dikes meet the requirements of the 1993 recommendations.



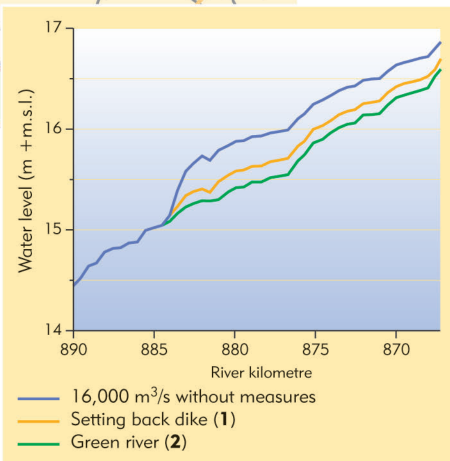


Figure 5.3 *Situation at Nijmegen*

However, Government and Parliament realized that the current policy of allowing any discharge-limiting activity in the river bed area, even if it was being compensated for, was too restricted in that it did not anticipate higher discharges that might occur due to climate change. The new policy allows only river-bound activities (i.e. in the winter river bed) by water-related interests (e.g. construction of bridges, weirs and boat yards). Licenses for such activities still include regulations on the compensation necessary for lost discharge capacity. Further, Government and Parliament have adopted a policy for creating storage areas and measures reducing high water levels. Figure 5.3 shows two alternative measures lowering the future water level by inland relocation of the winter dike of the Rhine branch Waal at Nijmegen.

The protection against storm surges concentrates on man-made structures, but the longest protection facility along the North Sea coast are the dunes (Figure 5.4). During the centuries large parts of the dunes were taken by the sea as a result of sea-level rise and local currents. Where the dunes disappeared they were replaced by dikes. In the framework of the Delta Project, the competent authorities strengthened weak dunes by artificial sand supply or by construction of bank protection works. To counter the slow erosion process along the sandy coast, the Government decided in 1990 to preserve the coast in its position of that year. Artificial beach replenishment ensures the preservation of the coast (Figure 5.5). The preservation of the North Sea coast completes the protection concept in the Netherlands.

It is not only a question of defining and maintaining the flood protection standards. Adequate protection and limitation of damage highly depend on actual information

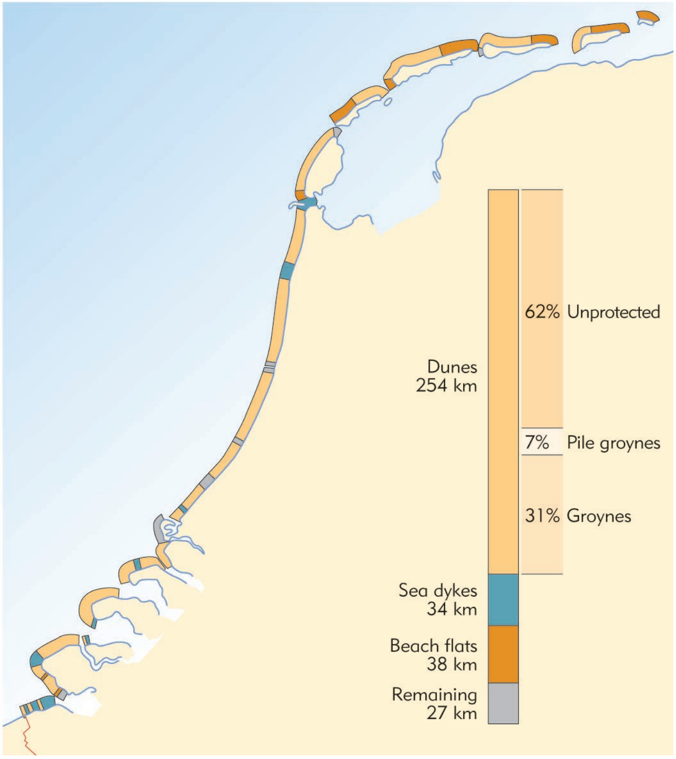


Figure 5.4 Protection along the North Sea coast

Figure 5.5 Artificial beach replenishment

and warnings. The emergency services for coasts and rivers inform the water boards and the public about expected water levels (Figure 5.6).

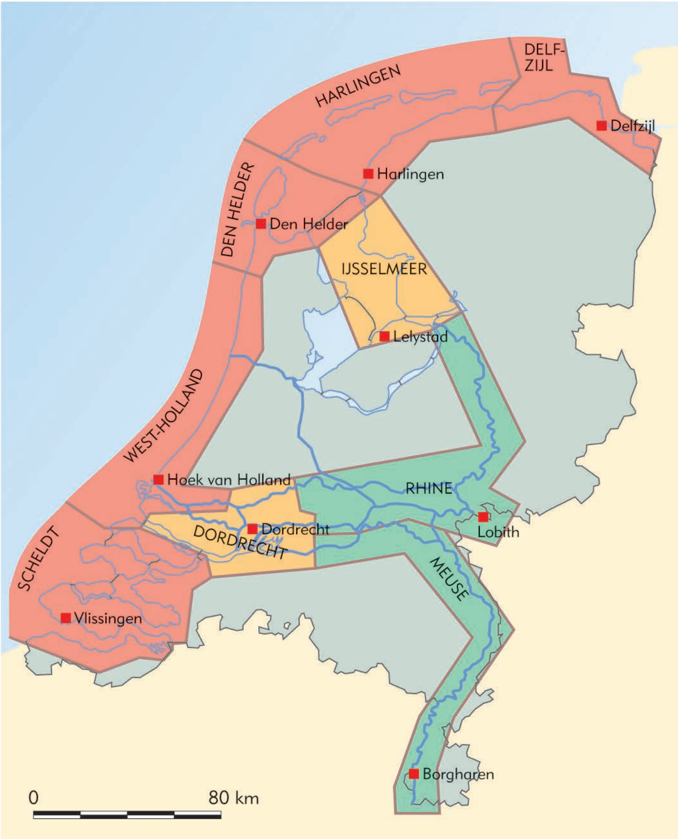
5.2 Preservation of aquatic ecosystems

It is necessary to protect ecosystems against intervention such as large-scale withdrawals of water or excessive discharge of harmful substances in order to preserve the multifunctionality of the water systems. Harmful intervention causes disfunction or poisoning of the water systems, as proved in 1971, when the Rhine was heavily polluted and poisoned by accidents. Thus, without sustainable, sound aquatic ecosystems, the promotion of human and nature oriented interests is limited or impossible. To preserve the aquatic environment and promote other water-related interests, the Government formulated general quality standards for inland surface waters. In the Netherlands all surface waters have to meet these standards. For every substance the standard has two levels based on risk assessment: the maximum admissible level (above this level the risk is unacceptable) and the target level (below this level the risk is negligible). Moreover the surface waters may not smell or look visibly polluted. The general quality provides conditions to support biotic communities such as some fish species, birds, and mammals which consume water animals.

Additional standards are applied for certain uses by man such as recreation, bathing, use for arable farming and cattle-breeding, angling, fishery, and disposal or re-utilization of dredged material.

5.3 Drinking and industrial water supply

Private and public water supply, the latter started from the 1850s onward, were and are predominantly based on groundwater. The water companies prefer groundwater because of its constant quality (the aquifer is protected against incidents by covering layers) and purification is simpler than for surface waters.
Initially, public water supply encountered problems only in the coastal areas where the supply of fresh groundwater was limited. Fresh-water lenses below the dune ridge were heavily exploited until 1940; since then, an ever increasing proportion of the dunes was converted into important sites of artificial recharge with river water. The effects of pumping, and thereby lowering the groundwater table, on agricultural production, natural vegetation and land subsidence have to be taken into account in exploiting well fields (see Chapter 6). This has led to the need for careful planning of all groundwater abstractions, controlled by a delicate balance between the economics of groundwater use and the environmental effects.



■ Sector station

	North Sea					Transition zones		Rivers	
Sector	SCHELDT	WEST-HOLLAND	DEN HELDER	HAR-LINGEN	DELF-ZIJL	DOR-DRECHT	IJSSEL-MEER	RHINE	MEUSE
Sector station	Vlissingen	Hoek van Holland	Den Helder	Har-lingen	Delf-zijl	Dor-drecht	Lely-stad	Lobith	Borg-haren
Limited alarm	3.30	2.20	1.90	2.70	3.00	1.80	VAR.	16.00	45.50
Full alarm	3.70	2.80	2.60	3.30	3.80	2.50	VAR.	16.50	46.00

Levels in m above m.s.l.

Figure 5.6 The early flood warning system

In the western part of the country the deeper groundwater is brackish or salty. Here, drinking water and water for industrial uses is mainly abstracted from the Rhine and Meuse rivers. Large reservoirs were created in the former tidal area of the Brabantse Biesbosch to supply the Rotterdam area with drinking water. When the water quality of the Meuse is good the water is pumped into the reservoirs

Figure 5.7 Reservoirs for drinking water in the Biesbosch

(Figure 5.7). The Hague also uses Meuse water, but Amsterdam withdraws water from the Rhine. The water for The Hague and Amsterdam is pretreated before it is stored in the dunes. The dunes filter the treated water improving its quality.

Water production by the water supply companies amounted to 1,168 million m^3 in 2002. About 709 million m^3 are used by households (121 litre/day/capita) 225 million m^3 by small businesses, 177 million m^3 by industry and 67 million m^3 for other purposes. Since 1992 the use of drinking water decreased by 4.4% as a result of water saving due to smarter design of showers, toilets, washing machines, etc. The water companies have observed a shift in usage from groundwater to surface water because of the 'verdroging' (see section 6.5 for definition). The proportion of groundwater in the water production decreased from 67% in 1992 to 57% in 2002.

Industries have their own source of water apart from the water supply companies. Industries mostly use fresh surface water, extracted from rivers etc. In 1990 the total amount of extracted surface water was approximately $1{,}200 \times 10^6$ m^3 (excluding the extraction of surface water for power plants). More than 95% of this water is used for cooling purposes. Important branches of industry influencing this matter are the food, paper, chemical and steel industries.
Generally speaking, one could say that the availability of fresh surface water does not constitute a problem in the Netherlands. Hence there is no pressure to develop policies aimed at limiting the use of this water.

Besides surface water, groundwater is also extracted by industry. In 1990 this amounted to approximately 200×10^6 m^3. A little more than half of this quantity is used for cooling purposes (mostly once-through cooling). This use of groundwater substantially decreased recently as a result of the implementation of strict water demand management by the provincial authorities and the introduction of the ecotax on groundwater. The responsibilities of provincial authorities concerning groundwater management are laid down in the Groundwater Act. According to this act the provinces are responsible for granting extraction licences (not only for industry, but also for the water supply companies and agriculture). The reason that provinces have implemented a strict licencing policy is that excessive abstraction, in combination with groundwater table management, has resulted locally in fresh-water deficits and the deterioration of conditions in nature conservation areas.

National and provincial policies aim at a further decrease in the extraction of groundwater for industrial purposes. Substitutes, such as the use of partially purified surface water, are being investigated.

5.4 Agriculture

The production of agricultural crops can be hampered by both abundance and lack of water. To maximize their income farmers strive for a situation in which the right amount of water of the right quality is available at the right moment. This means, for example, that the water level in spring, the start of the growing season, should not be too high to create a good bearing capacity for heavy machinery and to allow rapid warming up of the soil. In the Netherlands the growing season is characterized by precipitation shortage (see section 3.3). Therefore in summer time the water level in the ditches is set to increase infiltration into the fields or to have water available for irrigation. The desired high water level during the growing season can be maintained only if sufficient water is available from external sources such as the rivers Rhine and Meuse. The desired water level is different for arable crops, grassland and horticulture. The water boards play an essential role in meeting the demands from the agricultural sector. In the coastal zone, the Holocene part of the country, surface water quality is threatened by brackish and saline seepage. In summer time flushing with water from the River Rhine is essential to prevent the reduction in crop production by salination. Most glasshouses cultivating vegetables and flowers are found in this region. Sometimes this sector has very high water quality demands, which in many cases are met by private water reservoirs with an additional supply from public drinking water sources. In the southern and eastern parts of the Netherlands, the diluvial part that is lying above sea level, surface water quality is usually not a problem. In this area groundwater is an important additional water source for agriculture, but its quality may be a limiting factor for some crops due to too high iron or manganese contents.
The decrease of wetlands by ‘verdroging’ (see section 6.5) and the increase of nutrients has led to nature conservation measures being introduced. These measures limit the agricultural production in many regions. The input of river water in periods of water shortage is no longer obvious. The use of groundwater for irrigation is being restricted in some provinces.

5.5 Electricity production

The generation of electricity from fossil fuel produces heat. Since the start of this form of production, the heat has been cooled by water. The power stations withdraw large quantities of fresh and salt surface water to cool their installations. The only requirement is the low water temperature. The emission of used cooling water can affect water quality by the rise in temperature and by the additives used for preventing corrosion of the cooling systems.

To limit the rise in temperature, the ministers of the Rhine states decided in 1972 that future power stations have to be equipped with cooling towers, which release the heat into the atmosphere. Another method limiting the rise in temperature is to apply the waste heat in industry and for city heating. The demand for cooling water by electricity generation amounts to 10 million m^3 yearly. The energy demand and the available cooling capacity has concentrated most of the power stations in the

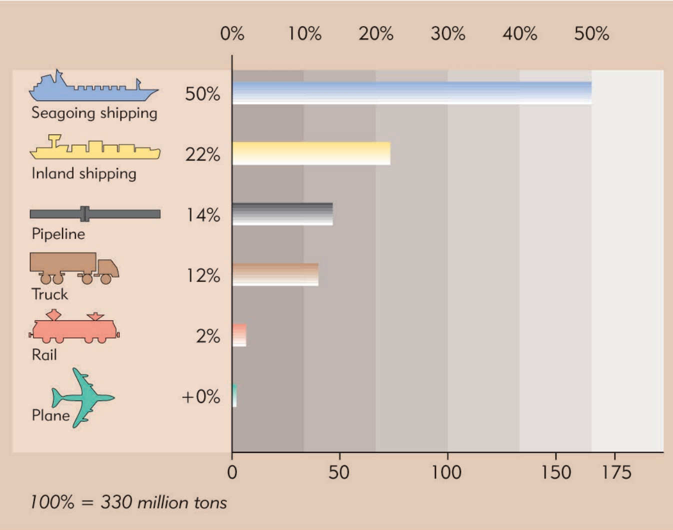


Figure 5.8 Transboundary transport in 2001

Figure 5.9 Push barges

western part of the country. During periods of high temperature and low river flows, power generation has to be reduced to meet the emission standards. Therefore, future developments for power generation are planned at coastal waters.

5.6 Navigation

The Netherlands is blessed with excellent waterways. The country has a 3,500 km long network of rivers and canals to transport goods by barges. According to the Central Bureau of Statistics inland navigation carried 109 million tonnes, 19% of the total inland transport, in 2001. The Netherlands is the natural entrance to a large part of Europe because it is situated at the mouth of the rivers Rhine, Meuse and Scheldt. Figure 5.8 shows that 50% (850 million tonnes) of the transboundary transport was carried by sea going vessels in 2001 and 22% by inland water navigation.
The Dutch flag is carried by 4500 vessels, nearly 50% of the inland fleet in Western Europe. The dimensions of the ships vary from small vessels of 300 tonnes up to push barges of 17,000 tonnes (Figure 5.9).
The water management system must take care of the depth of navigation channels, the current and the time required to pass the locks. The depth and current in rivers depend highly on the actual discharge, but are also influenced by water withdrawals for other purposes and by the loss of water at weirs and locks.
The authorities use modern communication techniques to inform ships about the services at bridges, locks, weirs, congestion, accidents, etc. to minimize waiting times. The information system also contains the names of the ships, their dimensions and cargo data. These are the preconditions for adequate assistance in case of accidents.

5.7 Water and recreation

The Netherlands is known for the large amount of surface waters and their great diversity. It is therefore not surprising that, in a densily populated country like the Netherlands, recent policy efforts have been aimed at combining the functions of surface waters (e.g. water supply, transport, nature) with recreation and tourism. For recreation the Government has tried to create a linked waterway for pleasure crafts along two main routes. One extends from the Lauwersmeer in the north-east to the delta area in the south-west. The other runs from east to west through the river area. Traditionally the strength of water recreation has been the availability of the huge inland water network, the overall presence of natural scenery, the small scale of the waterway network and the combination of this network with culturally and historically interesting cities.

The total number of recreation anglers above the age of 15 years amounts to 1.5 million, which is almost 10% of the total population. Total spending in the fishery sector amounts to roughly €300 million, which is the equivalent of some 2000 man-years of employment. Roughly 340,000 ha of surface water is in use for recreational fishery, of which 55% have an open connection with the sea. The total amount of fry put yearly into fishing waters is roughly 75,000 tonnes, but the importance of fry input is decreasing as a result of improved fish population management. The total number of boats is estimated to be 25,000. Based upon a broad definition of water recreation as an economic sector (inclusive of all kinds of supply firms and retailing) the total turnover is about €1,200 million (1998). About 15,000 people are employed in this sector. The tourism and recreation potential of several water recreation regions in the Netherlands will be used to improve the market position on the tourism market. The prospects for further development are favourable. The average growth of tourist income in the water recreation areas in the period 1990 - 1998 was estimated to be 6%.

5.8 Fishery

In former days inland fishery was an important sector; today it is a minor sector with a turnover of €30 million. The construction of weirs, sluices and reservoirs has created obstacles for migratory fish. The salmon fishery in the Rhine has mainly disappeared due to these obstacles (see also Figures 7.1 and 7.2). The changes in water quality and overfishing reduced biodiversity in the rivers. Consumption of eel and perch from the sedimentation areas of the Rhine and Meuse was discouraged in the 1970s because of the high concentrations of heavy metals and organic compounds in the fish.
To improve the situation, the European Union formulated water quality directives for salmonides and cyprinidae. But other aspects such as variations in current, level and salinity are also important. That is the reason that many rehabilitation plans for large and small surface waters take these aspects into account. The provision of weirs and reservoirs with adequate fish passages (Figure 5.10) attempts to improve the situation for migratory fish.
In contrast to the inland situation, fishery in the salty surface waters is important. The turnover amounted to more than €570 million in 2001. Water quality is an important condition for fish as was found in 1989 when high mortality of fish occurred in some parts of the North Sea due to the algae bloom.

Figure 5.10 Fish passage

Besides water pollution there is the danger of overfishing. That is the reason why the European Union took steps to assure fish stocks in the long term by the introduction of quotas. It may be that closed areas and other catch techniques can contribute to sustainable use and biodiversity. Research is necessary to answer this question.

5.9 Water for wildlife and landscape

Wildlife and landscape are related to water. Nature conservation in the Netherlands is of international importance because of the country's deltaic character and the presence of a large number of wetlands. However, due to the intensive use of soil and water, environmental values diminished significantly during the past 50 years. Large numbers of plant and animal species are becoming rare. The species that depend on nutrient-poor soils and wet conditions are becoming rarer, whereas the number of those that thrive in well-drained land and fertile conditions increases.

The interrelationship between the abiotic structure of the environment and man-made landscape has been weakened. As a result, characteristic landscapes are disappearing. Since the late 1980s much effort is being put into the conservation and rehabilitation of both terrestrial and aquatic ecosystems. Planning is an important instrument for landscape and nature conservation. The efforts are focused on what is called the National Ecological Network. Priority is given to developing elements with a specific ecological or scenic value, while safeguarding phenomena of more general value. The Government spends €500 million a year on rehabilitation projects. This effort is illustrated by the Baakse Beek Watershed (see box).

Rehabilitation of the Baakse Beek watershed

The Baakse Beek watershed landscape is characterized by a small-scale variation in meadows and fields, hedges, small woods, heaths, rivulets, farms, small towns and estates. Agricultural land use is based on high inputs of fertilizers, animal feed and insecticides. The capacity of the drainage system has been increased enormously for agricultural purposes. The combination of these agricultural and water management practices and the small-scale landscape pattern is responsible for eutrophication and drop of the groundwater level in areas with natural landscape elements. The lowering of water tables since 1950 has been increased by artificial wells for drinking water supply. Water quality, however, is endangered by agricultural practices. Most rivulets and artificial ponds in the estates dry up during summer. These changes have such an impact that variation in landscape declines. Basically these problems are caused by insufficient attunement of the interests of nature, agriculture and drinking water supply.

A better attunement of these interests has been found in both the introduction of new techniques and the spatial rearrangement of land use. An example of a new drinking water supply technique is the use of drainage (surface) water from small watersheds designated solely for nature conservation. Large reservoirs are needed in order to solve the problem of low discharges during summer. For the rearrangement of land use three spatial strategies have been formulated.
In order to evaluate these landscape planning strategies, three scenarios for the Baakse Beek Watershed have been designed and evaluated by state-of-the-art hydrological models. The results indicate that the small nature area watersheds for drinking water supply require the same area of land as the actual protection zones around drinking water wells. Within the nature area watersheds natural ecosystems will not suffer from eutrophication and low groundwater tables, as all agricultural land use is forbidden or no longer a pollution risk due to more rigid environmental constraints than those outside these areas. Water tables within the nature-watersheds will have to rise in order to restore ecosystems and to increase water storage capacity and base flow of rivulets.
The main profit of this strategy is the mutual support of nature conservation and drinking water supply in solving these problems.

The Dutch tradition of landscape planning is based on the consideration that landscape dynamics is a complex process. Its visual manifestation is influenced by changes in almost all land utilization types and water management. Landscape planning therefore needs an integral approach and, in this respect, all interests should be incorporated in such a way that the landscape structure is enhanced or reconstructed. As mentioned before the water system is a major structure in the Dutch landscape. During the last decade this water system approach in landscape planning was developed further.

5.10 Water in urban areas

As in many other countries a rapid urbanization process has been going on in the Netherlands during the last two decades. Pastures and cropland disappear as a consequence of the shift in land use to urban functions and infrastructure. In the lower parts of the country new residential quarters and industrial sites mostly

require that a sandy layer of more than one metre is transferred to the peat or clay soil. New canals and subsurface drainage systems are being built to drain the surplus water.
In that environment new living conditions for human beings as well as for flora and fauna have to be shaped. Open water may fulfil more functions than in the past.
It can be stated that not only in these newly built areas, but also elsewhere, for example in old city centres, the role of water has been changed during the last decennia. Besides the water supply for domestic and industrial use and the traditional functions of drainage, storage and transport, new functions have been established. These are related to the requirements of urban quality of life, such as the recreational, ecological and landscape-ecological functions.
In the field of housing and physical planning the high value and attractiveness of open water have been discovered. Today, urban design pays more attention to open water in residential quarters and business centres, and especially to the recreational potential and ecological quality of water areas.
Such demands require a more integrated approach to water management with special care for the interaction between the water systems in the urban areas and the adjacent rural areas.
Also special attention is needed (and given) to the ecologically sound conditions of surface waters, groundwater levels and water quality in urban areas.
Recently several research projects have been directed towards the relations between sewerage systems, surface water, groundwater, and to the ecological conditions of water systems.

6 Pollution, impact on and improvement of water systems

Large amounts of wastewater discharged into the water systems have an undesired impact on water quality and aquatic life. Since the last decennia efforts are being undertaken to improve the water quality by reducing pollution. Hydraulic installations serving human interests have undesired side effects on the terrestrial and aquatic environment, too. The different administrative levels try to cope with these side effects by mitigating measures. This chapter describes the impacts and the efforts to improve the water systems in the Netherlands.

6.1 Wastewater and its treatment

For centuries surface waters removed the wastewater produced by the population. The size of the population was limited and so was the pollution. The self-purification capacity was sufficient to maintain good water quality. This situation began to change in the second half of the 19th century. The growing population and industrial activities produced large quantities of wastewater which was discharged untreated into the surface waters.

During the last four decennia the pollution of the surface waters by oxygen consuming substances drew much attention. In many surface waters the oxygen balance was in disorder. Poisoning of fish and bad smells (odour) created problems in local and regional water systems. The polluted Rhine and Meuse were of little use in flushing the regional and local waters because the other regions in the basins had to cope with the same problems. The authorities developed sanitation plans. Favoured by the regulations and finance system of the Pollution of Surface Waters Act (1970), the pollution was reduced. The increasing efforts to reduce the pollution by households and industries can be seen in Table 6.1.

Table 6.1 Pollution by oxygen-consuming substances and sanitation of surface waters in the Netherlands (in million inhabitant equivalents)

	1969	1975	1980	1985	1990	1995
Households	12.5	13.3	14.3	14.5	14.9	15.4
Industries	33.0	19.7	13.7	9.8	9.7	10.2
Total	**45.5**	**33.0**	**28.0**	**24.3**	**24.6**	**25.6**
Elimination in wastewater treatment plants	5.5	8.7	12.6	14.5	17.0	18.6
Discharge into the surface waters	40.0	24.3	15.4	9.8	7.7	7.0

The figures of the last inventory of 1998 slightly differ from the 1995 data. It can be concluded that pollution with oxygen-consuming substances is a problem, which nowadays is under control.

Table 6.2 Decrease of chlorinated hydrocarbon pollution from industry

	1975	1980	1985	1990	1995	2005
Organochloride (EOCl) in tonnes/year	1,000	5,300	60	50	40	5

Under the power of the above mentioned act industrial pollution by dangerous substances began to decrease with the introduction of new production methods, recycling and new purification techniques. Table 6.2 and Figure 6.1 represent the industrial discharge of chlorinated hydrocarbons and heavy metals in time. The agreements of the Rhine and North Sea states to strengthen the clean-up efforts have contributed considerably to this development.

6.2 Pollution from diffuse sources

The pollution of groundwater and surface water from diffuse sources is a point of major concern. This can be observed in Figure 6.1; the industrial discharge of heavy metals has been reduced by a factor of 40. Pollution from non-point sources merely reduced by a factor 4 in the same period. Diffuse sources are responsible for the failure to achieve some objectives that were formulated for the Rhine and North Sea. The substances concerned are nitrogen, some heavy metals, polycyclic hydrocarbons and insecticides. It is difficult for the water authorities to get a direct grip on the diffuse sources. Changes in the behaviour of consumers and producers as well as intervention by other authorities can contribute to the reduction of diffuse pollution. This can be illustrated by the eutrophication problem in the North Sea.

The most important sources of nitrogen and phosphate are agriculture, households and industry, both in the Netherlands and abroad. Eutrophication can lead to excessive growth of algae, some of them toxic. The dying off in the autumn often causes shortage of oxygen in stagnant waters and in the North Sea. Both phenomena can result in the death of fish and other animals. The Rhine and North Sea states agreed upon reduction objectives of 50% for phosphate and 70% for nitrogen in the period 1985 - 1995. The objective for phosphate will be achieved. The replacement of phosphate in detergents, mainly forced by consumers was particularly important. Within some months they were buying only non-phosphate containing detergents. The removal of phosphate in wastewater treatment plants also contributed to the 50% reduction. The objective of nitrogen reduction will not be achieved. Wastewater treatment plants remove nitrogen produced by households and industries. However, reduction in the agrarian sector is difficult.

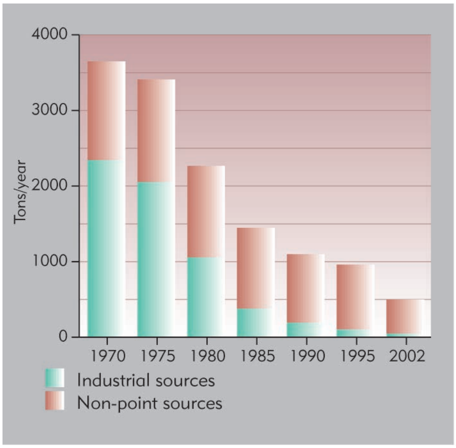


Figure 6.1 Discharge of heavy metals by different sources in the Netherlands

6.3 Groundwater pollution

In this century the explosion in socio-economic and technical developments has led to a serious assault on the quality of soil and groundwater. Today, all over the world, a variety of problems is encountered: physical, chemical and biological degradation of soils, soil erosion, overdrawn aquifers, salt-water intrusion and groundwater contamination.

Many activities hold a potential threat for soil and groundwater pollution. Hence, it is not surprising that cases of pollution have been reported for quite some time. At first, these were seemingly only local pollution, caused by point sources such as waste disposals, and accidental spills of chemicals, and were of minor importance for the state of the subsurface environment at regional or national scales. However, in the 1970s it gradually became clear that soil and groundwater were being treated rather carelessly, not only in the Netherlands, but also in many other countries. Numerous human activities appeared to have significant and large-scale effects on soil and groundwater quality, in spite of the natural protection provided by the physical, chemical and biological properties of soil and groundwater.

The discovery of some serious cases of soil pollution in urban areas at the end of the 1970s, led to nationwide inventories of suspect sites of soil and groundwater pollution. The result is a long list of approximately 100,000 sites.
Since 1983 a large operation has been in progress to clean up these polluted sites, with a yearly governmental budget of about €125 million and another €120 million coming from polluters, owners and users of specific sites. The objective is to clean up all urgent cases before the year 2010.

Another serious impact on soil and groundwater results from the intensification of agriculture. The use of fertilizers, pesticides, sewage sludge and animal waste produces a substantial and widespread deterioration of soil and groundwater quality. Several groundwater pumping stations in agricultural areas are threatened by high levels of nitrate, heavy metals and organic micropollutants. It is expected that in the near future a quarter of the extracted groundwater will be in need of extra treatment. Atmospheric deposition (e.g. acid, heavy metals and organic micropollutants) caused by industry, traffic and agriculture is another diffuse threat to the quality of soil and groundwater.

6.4 Polluted sediments, a mortgage on use

The water sediment is polluted. The degree of pollution differs from place to place and varies from slight to severe. The risks for the environment are mainly due to the absorption into the biological food chain and the spreading of polluted sediment into vulnerable regions, such as the lower reaches of the Rhine and the North Sea. The water and port authorities dredge up quantities of 25 - 30 million m^3 in situ annually. About 5 - 10 million m^3 of nautical dredging spoil is so polluted that relocating it threatens the environment. Treatment and storage in depots is necessary. To safeguard the North Sea against polluted sediments from the Port of Rotterdam a large storage depot was created in 1985 (see Figure 7.5).
To solve urgent regional problems, authorities created small depots for polluted sediments. In 1997 two large-scale depots for inland water sediments became available to store polluted sediments from both state- and regionally-managed waters. Research for treatment and reutilization techniques are underway to reduce the quantities to be stored.

6.5 Unbalanced hydraulic design and excessive use

The regulation of brooks, canalization of rivers, reclamation of land, closing estuaries, etc. have had undesired side effects. The annually recurring phenomenon of fish such as salmon, sea trout etc. migrating up-river, has disappeared from the Netherlands as a result of hydraulic works and the abrupt changes from salt to fresh water.

Spawning grounds have become inaccessible, shore plants and organisms have disappeared. Hard constructions along the river banks disfigure the landscape and make the banks unsuitable for terrestrial animals and recreation. It is not only a problem in the Netherlands. Unbalanced hydraulic design occurs basin-wide as described in Chapter 7.

Other intervention has lowered the water levels and groundwater tables. Agriculture and urbanization require accelerated drainage in wet periods. Improvement of field drainage and the regulation of water courses have had the required effect on high water levels. However, the drained quantity fails in dry periods. Drinking and industrial water supply extract groundwater in considerable quantities. In dry periods agriculture also extracts (ground)water to cope with the increasing evaporation by the selected and intensified crops. In rural areas an average drop in the groundwater level of 35 cm could be established since the 1950s; in areas with permanent extraction the drop is more than one metre. The lower groundwater tables have adversely affected the moisture content, mineralization, seepage and the influence of precipitation. Nature areas, forests and the landscape became dried out. This chain of causes and impacts is defined as 'verdroging'.
In Figure 6.2 the nature areas affected by 'verdroging' are illustrated. In these areas the terrestrial and aquatic species which depend on water have (almost) disappeared.

Figure 6.2 Inventory of 'verdroging' in 1996

6.6 Impacts on regional water systems

In the past decades high priority was given in rural water management to the creation of good conditions for agricultural production. Many measures

were taken to improve the water management of agricultural soils. The construction of deeper and wider canals and ditches lowered surface water levels, especially in winter and spring. In addition pipe drainage was installed to drain the land in wet periods and allow subsurface infiltration in dry periods. These efforts enabled the farmers to work in the fields in early spring and to sow crops at an early stage of the growing season. In dry periods water, mainly from the Rhine and Meuse, was transported to agricultural areas. This water is rich in nutrients causing eutrophication in stagnant water courses. Moreover, cheap mineral fertilizers and pesticides increased agricultural production, worsening the water quality.
The increasing water demand of the population also led to larger groundwater abstractions especially in the higher diluvial parts. In these regions the shortage of water for agriculture was met by groundwater extraction too. Unfortunately there was little coordination between the different authorities, resulting in unwanted side effects such as 'verdroging' and a waste of money. For example, in one region measures were taken to improve the agricultural drainage, while at the same time groundwater abstraction for public water supply was permitted. Together, both activities caused undesired drops of the groundwater level. The combined effect resulted in conditions too dry for agriculture and caused ecological damage.
In the past little knowledge was available to quantify the effects of these measures and impacts on other interests.

6.7 Rehabilitation efforts

The rehabilitation of the water systems started with discussions about the impacts of the storm surge barrier in the Eastern Scheldt in the early 1970s. If the barrier had been built as planned, the mussel and oyster catches and the marine environment would have completely disappeared. The barrier would have created a fresh-water reservoir supplied by polluted Rhine and Meuse water with all its negative impacts. There was strong opposition which succeeded in convincing the Government to look for other solutions. Three alternatives were considered. Finally the Government and Parliament decided on the alternative of an open Eastern Scheldt, closed only during high storm surges. Thus rehabilitation started with the preservation of the existing environment.
In the early 1980s it became necessary to rehabilitate the water systems; some small-scale projects were realized. The rehabilitation plan of the International Rhine Commission created the overall framework for large-scale projects. These projects are of national interest and therefore financed by the Government. In order to support the efforts of the provinces, municipalities and water boards the Government also decided to co-finance small rehabilitation projects for improving the situation at local and regional levels. Since the late 1980s many rehabilitation projects have been realized and the efforts are still in progress. The projects concerned combating eutrophication and 'verdroging' by isolation and regeneration measures, biomanipulation to restore the ecological equilibrium in lakes, introduction and repair of fish corridors and environment-friendly shores, zoning, etc.

A number of ecohydrological studies, carried out in the 1980s, improved the knowledge of the function of ecosystems in relation to water management. Nowadays, ecohydrological knowledge is involved in nearly all policy plans dealing with water management, nature management and environmental protection.

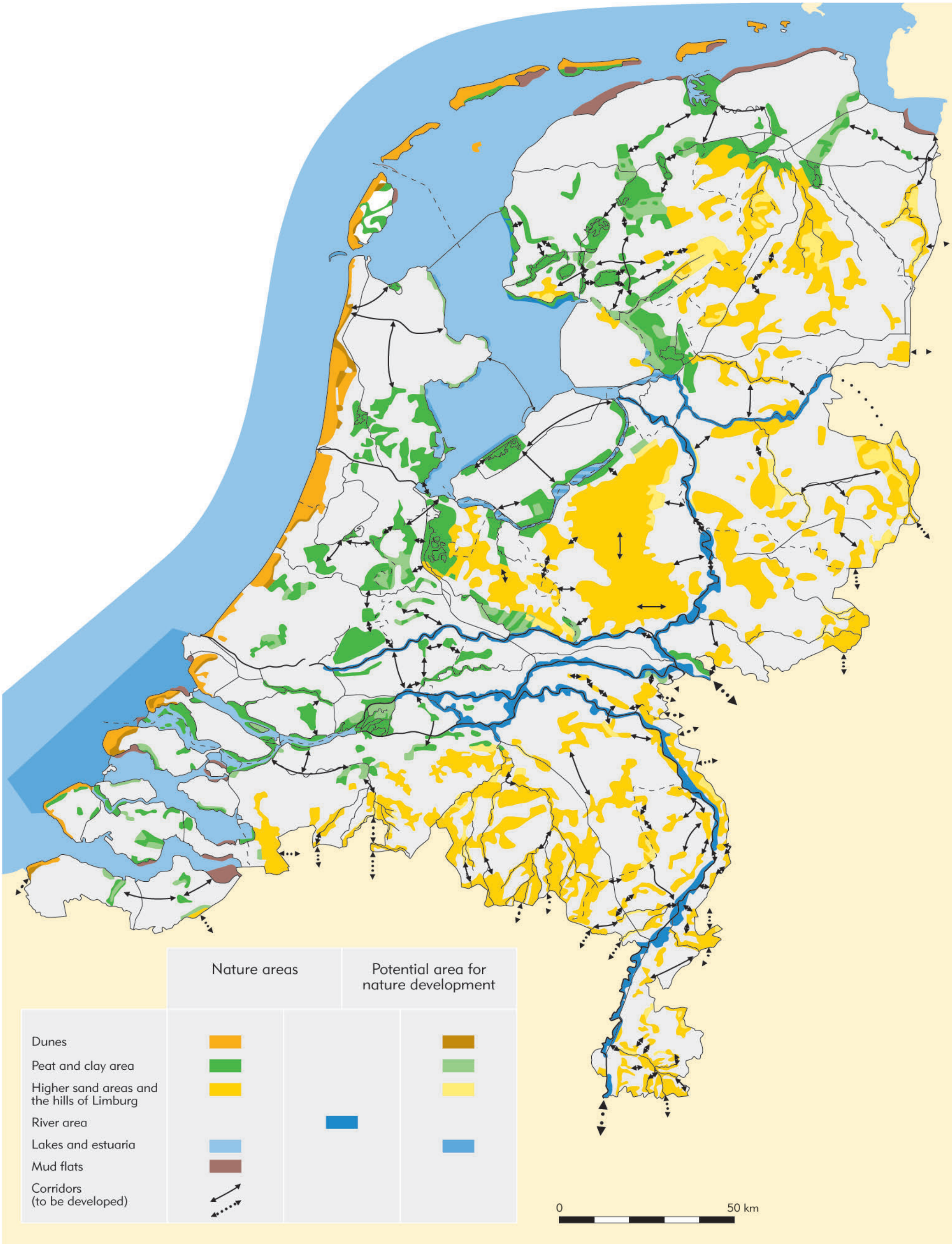


Figure 6.3 Ecological Main Structure of the Netherlands

Both local, regional and national scales are covered. Until recently most studies, using either sophisticated models or more knowledge-based approaches, were carried out to evaluate the impact of prospective measures of water management for policy plans. Since 1990 national nature policy plans changed from a defensive to a more offensive policy after policy makers became aware of the serious 'verdroging' (Figure 6.2) and acidification of nature reserves. This was the foundation of the Ecological Main Structure of the Netherlands, which is founded on ecohydrological patterns in the landscape and is part of a strategy to create new chances for nature (Figure 6.3). Ecohydrological and environmental scenario studies are carried out on a national scale using national databases, to decide on optimum hydrological and environmental conditions for the sustainability of ecosystems.

Regional authorities stimulated studies in physical planning, where both knowledge-based and model-based ecohydrological approaches are involved in decision making. Numerous local nature restoration projects have been launched and ecohydrological systems analysis has become a basic requirement in the planning of measures to restore a sound water management for nature area development. Monitoring networks have to be generated and standardized in the near future to evaluate the effectiveness of measures to reset and restore ecosystems.

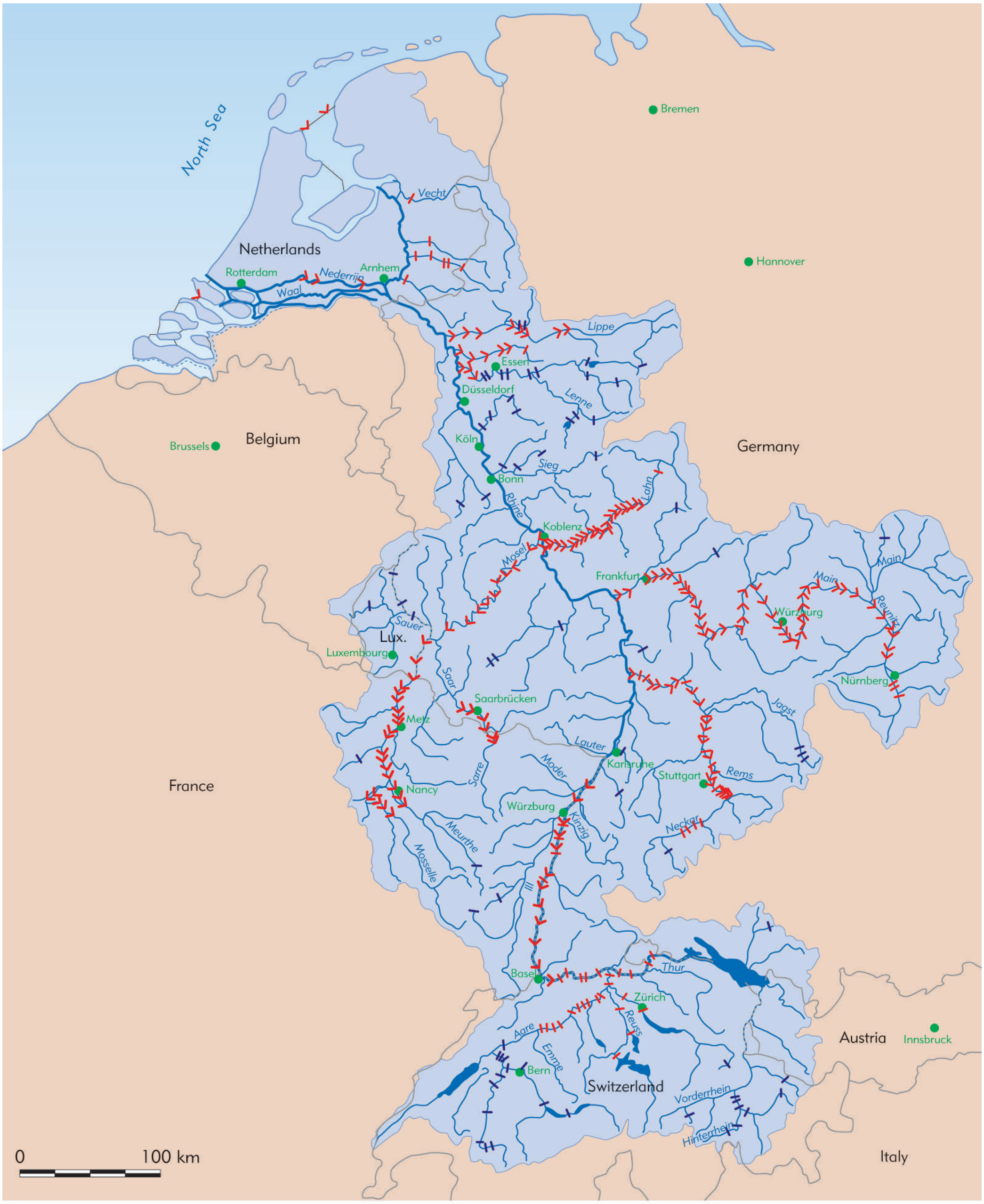
7 Water, an international issue

International cooperation in transboundary river problems often starts with issues of common interest, e.g. the promotion of navigation. The promotion of opposing interests, such as the fight against pollution in transboundary river basins and seas, is more difficult. The pollution problems in north-west Europe have shown that international cooperation on this subject is a time-consuming process. It took several decades to reach a mutual understanding on specific problems in the countries of the Rhine basin and the North Sea area as well as to take measures to reduce pollution. The first ministerial conferences, in 1972 on the pollution of the Rhine, and in 1984 of the North Sea, marked the transition from mutual understanding to taking concrete measures.

7.1 One-sided promotion of interests harms the ecosystem

As a result of its hydrological characteristics, the Rhine has become an important navigation link in north-west Europe. International co-operation on navigation, which started in 1815 with the creation of the Central Commission for the Rhine Navigation, was promoted in every country and contributed considerably to trade and industry in this part of Europe. The river authorities of the Rhine States succeeded in eliminating obstacles which hindered navigation. Improvement works affected other interests. For example the concentration of river discharges into one channel in the section Basle-Karlsruhe caused a lowering of the river bed by 2 - 7 m. Consequently the groundwater table dropped by several metres. This seriously affected the landscape and agricultural use. Vegetation died off and spawning grounds were lost. At the end of the 19th century hydropower was introduced and plans were developed to serve both hydropower and navigation interests. Today more than 450 dams, weirs, sluices and locks in the Rhine and its tributaries serve these interests. However, they prevent migratory fish from reaching their spawning grounds. Moreover, these hydraulic structures produce higher water levels which change the velocity and sedimentation processes. In the Netherlands the Closure dam and Delta dams also created barriers for migratory fish. Figure 7.1 gives an impression of the physical obstacles for migratory organisms in the Rhine basin.

Figure 7.2 shows the impact of these interventions for the salmon supply to Dutch and German fish markets. This amounted to some 100,000 salmon a year, before 1900. After 1915 there was a sharp reduction. In 1940 salmon had almost disappeared from the Rhine. Only few salmon could reach their spawning grounds because of the weirs and dams. This happened in spite of the Salmon Agreement of 1885, by which the riparian Rhine States agreed to preserve the salmon stock and to protect the spawning grounds along the Rhine and its tributaries. But navigation and hydropower got higher priority than fishery interests. Spawning areas became inaccessible or disappeared in higher water levels. After an inventory, made in 1913, it was shown that only some larger spawning areas along the High Rhine above Basle and along the River Moselle were left. When the works of the Grand Canal d'Alsace were realized and the canalization of the Moselle began, these spawning grounds also disappeared. The few quantities of salmon surviving in small spawning areas were finally wiped out by pollution.



Weir with lock Weir Reservoir dam

Figure 7.1 Obstacles in the Rhine basin

7.2 Chloride, trigger for the Netherlands to tackle the Rhine pollution

Chapter 4 describes the vulnerability of the polders to floods and salt-water intrusion because many polders are situated below meansea level. The saline seepage which collects in ditches and canals has to be flushed away by the surplus of precipitation and by using river water, which mainly originates from the Rhine, in dry periods.

The Rhine water used to be very suitable for this purpose because of its natural low salt content. Before 1900 it had a chloride content of 10 - 20 mg/l. The industrial revolution in the Rhine basin resulted in a strong increase in the salt content originated by industries and mines in the countries upstream of the Netherlands (Figure 7.3). In 1932 the Netherlands Government undertook the first diplomatic steps to stop the increasing chloride content and other activities polluting the Rhine water. However, this effort was in vain.

7.3 The international fight against pollution, a laborious process

After the Second World War there was a marked increase in industrial activities. Large quantities of untreated wastewater heavily polluted the Rhine. In 1946 the Netherlands again tried to start international negotiations on the pollution problem. It took until 1950 before the Rhine states: the Federal Republic of Germany, France, Luxembourg, the Netherlands and Switzerland, created the International Commission for the protection of the Rhine against pollution (IRC). The creation was based on an exchange of diplomatic notes. The IRC received its legal basis from the treaty of Berne in 1963. Since 1953 the IRC thoroughly investigated the type and the quantity of pollution. With that aim the IRC developed common measurement and analysis methods. Later these efforts also served the water-related activities in other international fora.
However, the negotiations in the IRC did not lead to concrete arrangements to combat pollution. The quantities of organic and inorganic pollutants discharged into the waterways still increased. Dangerous substances, nutrients and heat

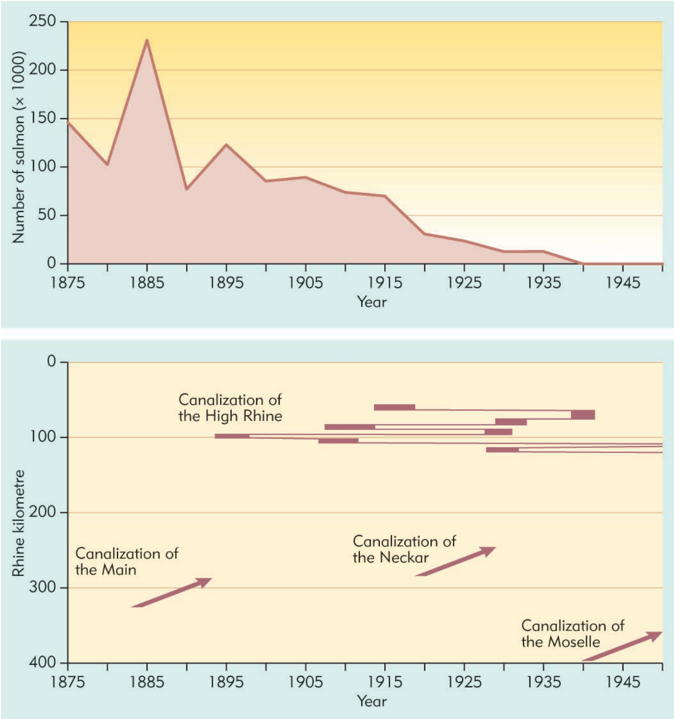


Figure 7.2 Decrease in salmon caught due to increase in navigation and hydropower structures

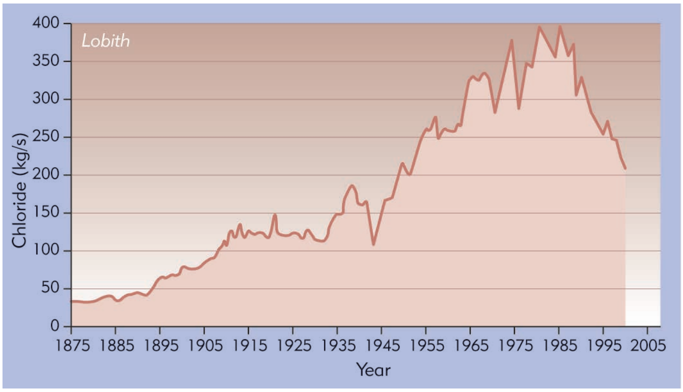


Figure 7.3 The chloride load of the Rhine at Lobith on the Dutch-German border

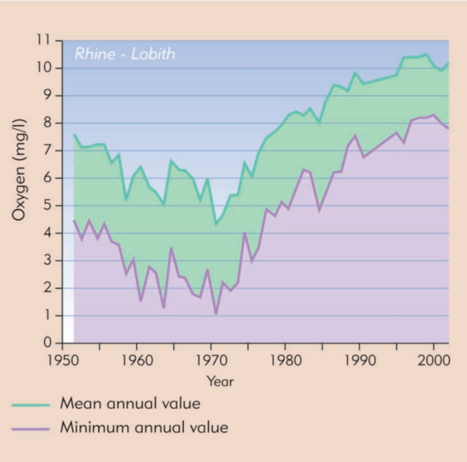


Figure 7.4 Oxygen content of the Rhine at Lobith on the Dutch-German border

were also released without purification or other provisions. The water quality of the Rhine was continuously deteriorating. Figure 7.4 illustrates this by means of the oxygen content. The impact of the pollution reached its worst levels in the autumn of 1971. At that time the Rhine water lacked oxygen in the downstream river sections and accidents had poisoned the river with chemical substances. Oilspills from ships and industry left a black ribbon on river banks and dikes around the mean river level. Carbol dominated the odour of the river. The Rhine was considerably damaged; aquatic life had disappeared. The press and the public began to designate the Rhine as the open sewer of Europe.

7.4 Public opinion forced governments to act

Shocked by the dying Rhine in 1971 and under pressure of public opinion, the ministers of the Rhine Commission States met for the first time in The Hague in 1972. They charged the IRC with elaborate conventions containing the main objectives for the fight against chemical pollution and pollution due to chlorides. They also asked the IRC to draw up a long-term working programme for the reduction of all polluting sources (time target 1985). In 1976 the ministers adopted the conventions and the working programme providing concrete arrangements to combat pollution. Taking into account the competencies, the European Union became a member of the IRC.

Table 7.1 Improvement of the water quality of the Rhine (pollution measured on the German-Dutch border in 1972, 1985 and 2000)

	1972	1985	2000	Reduction 2000 w.r.t. 1972	Natural load/ content
Mercury	99 t	5 t	1.6 t	98%	0.7 t/y
Cadmium	167 t	9 t	5.2 t	97%	1 t/y
Chromium	3,627 t	378 t	101 t	97%	40 t/y
Lead	2,000 t	441 t	243 t	88%	75 t/y
Copper	2,018 t	473 t	334 t	85%	70 t/y
Nickel	-	356 t	199 t	-	-
Zinc	13,800 t	2,995 t	1,250 t	99%	250 t/y
TOC	29 kg/s	13 kg/s	11 kg/s	63%	-
Oxygen	4.4 mg/l	8.0 mg/l	10.0 mg/l	56%	10 mg/l
Phosphate	1.3 kg/s	1.0 kg/s	0.4 kg/s	70%	0.2 kg/s
Nitrogen NH_4	1.0 kg/s	1.4 kg/s	0.2 kg/s	88%	0.2 kg/s

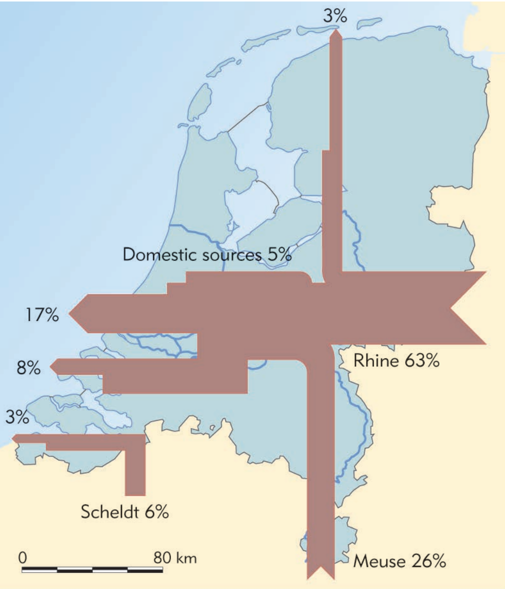
In 1976 the IRC believed that the emission standards mentioned in the chemical convention could have established the bulk of the point-sources within a few years.

Figure 7.5 Slufter, storage reservoir for heavily polluted sediment

However, the work proved to be more complicated and consumed more time than expected. Many substances were involved and eco-toxicological data were available for only a few compounds. The convention prescribed the use of the best technical and best applicable means to reduce the pollution, but the best means of today are outdated tomorrow. The required approval of the proposed measures by the EU produced time-consuming negotiations at Brussels.
In spite of these difficulties sanitation measures for wastewater from industries and municipalities were realized. After 1971 the pollutant loads decreased and the water quality of the Rhine improved (Figure 7.4 and Table 7.1); aquatic life returned. The improvement of the Rhine stimulated the riparian states to continue their efforts.

7.5 Contaminated water and sediment threatens north-west of Europe

In the stagnant waters of the Netherlands sand and silt settle down. For centuries sand and silt have been dredged and used to raise the land and as natural fertilizers because of their nutrient content. Dredged material was a desired product. To ensure sufficient navigation depth to the Port of Rotterdam, large quantities of dredged sediment from the Rotterdam Waterway were dumped into the North Sea without a quality licence. This is no longer the case. In the late 1970s, in the new housing and agricultural areas where dredged material was being used, it became clear that dangerous substances had heavily contaminated the soil. The authorities advised the population about the health risks of consuming vegetables from their own gardens. That is why nobody wants the dredged material that has been removed from channels and harbours. The sediments of the polluted river beds are an unwanted heritage. But what can be done?
As the first step to avoid irreversible effects on the marine environment, the Government decided to stop the dumping of polluted sediment into the North Sea. The polluted sediment must be stored under controlled conditions. For that reason a reservoir was built near the coast (Figure 7.5). The cost is high and the storage



Source	Quantities		Destination	Quantities	
Rhine	6,000 t/y	63%	Sedimentation	2,600 t/y	27%
Meuse	2,400 t/y	26%	Deposited on land	3,900 t/y	41%
Scheldt	600 t/y	6%	Deposited in sea	3,100 t/y	32%
Domestic sources	500 t/y	5%			
Total	9,600 t/y	100%	Total	9,600 t/y	100%

Figure 7.6 Pollution of the Netherlands by seven heavy metals in 1984 - 1985

capacity limited till 2005. In that year the quality of dredged sediment has to meet the standards which will allow dumping in the sea or using it on land without repercussions for the environment.

The Netherlands brought this problem to the international fora at the beginning of the 1980s, and pointed out that most of this material was imported from abroad, as illustrated by Figure 7.6. The Dutch pleaded for further measures to be taken to reduce this pollution. These demands implied that not only did the water have to be cleaned but efforts should be oriented to the quality of the sediments.
As this would be a costly matter, the Netherlands did not succeed initially in convincing other states and organizations about the threat posed by the polluted sediments.
The Netherlands pressed for consideration of the pollution issues not only on a river basin scale, but also at the level of the recipient marine environment. The (recipient) North Sea has its own characteristics influencing the pollution pattern and its impact. Figure 7.7 shows the water and sediment movements in the North Sea.

Due to the tidal influence, there is a south-north current along the Dutch coast, transferring polluting fine particles from the Scheldt, Meuse and Rhine to the German Bight. The tidal current from the east of England also carries polluted material to that area. Of course, the Weser and Elbe rivers also contribute to the water quality problems, e.g. oxygen deficit, fish diseases and high mortality of seals. As for the Rhine in the 1970s, the most involved country took the lead. The Federal Republic of Germany took the initiative for the First Ministerial Conference on the protection of the North Sea in 1984. Later, more consultations were held at ministerial level resulting in a slow but continuous reduction of the pollution in the North Sea.

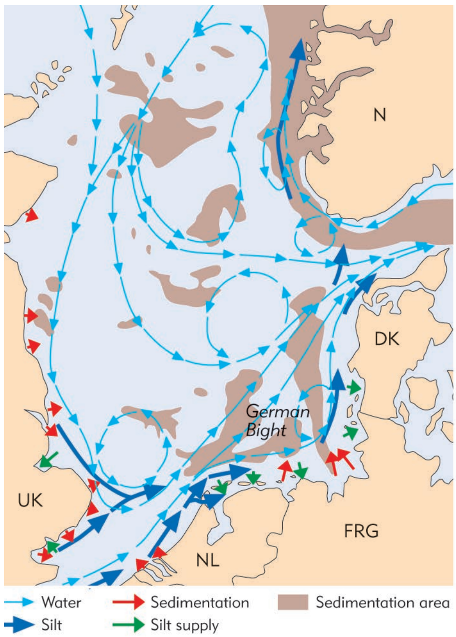


Figure 7.7 Water and sediment movements in the North Sea

8 Integrated water management, essential for sustainable development

This chapter deals with the attempts to analyse systematically the water management problems and to formulate comprehensive policies. The concept of integrated water management was the result of these efforts. This concept had a great influence on the working methods and organization of the water management authorities. The never-ending process of harmonization of the often opposing interests is being realized by means of planning as a legal instrument. The process is not limited to the water sector. Spatial, environmental, natural, agricultural and economic issues are also involved. Integrated water management took on an international dimension through the Rhine and North Sea action plans. These plans created a coherent framework for national, regional and local activities to reduce pollution and rehabilitate water systems. The 1995 peak discharges in the Rhine and Meuse rivers gave an additional impulse towards integrated water management in transboundary river basins.

8.1 Attempts at harmonization and integration

Against the background of a strongly increasing population in the 1960s, the Government concentrated its efforts on fresh water to meet future needs. In the first Water Policy Document (1968) the Government formulated a coherent vision about the necessary activities. The infrastructure to meet the future demands on drinking water and water for agriculture were considered to be important issues. The document also considered items such as drainage, salination caused by the North Sea, and the Rhine pollution. For water quality problems the document refers to the reduction of oxygen-consuming and other substances by the Bill on Pollution of Surface Waters (in force since 1970) and to the negotiations with the riparian Rhine states on this subject. In this period the water management problems were tackled in fourmain areas: the quantity of surface water and groundwater, and the quality of surface water and groundwater.

The increasing water demand and the deteriorating water quality of surface waters made the water supply issue complicated for the interested bodies. Hydrologists of national institutes and provincial water authorities pleaded for an integrated approach to the problems. The study Water Management in the province of Gelderland and the study Policy Analysis of Water Management for the Netherlands (PAWN) tried to relate water demand by different sectors in order to find an optimum solution. The application of the systems approach broadened the insight into the interactions between the quantitative and qualitative aspects of groundwater as well as the coherence with physical planning, nature and environment. The document "Living with Water" by the Minister of Transport, Public Works and Water Management (1985) pleaded for a comprehensive approach to water-related problems in their relevant natural, social and administrative environments. Provincial and regional water authorities responded positively to this concept of integrated water management as did the interest groups and nature conservation organizations.

8.2 Impact of integration on organizations

In the 1950s the flood protection and water quantity management tasks were split between 2,500 water boards. These authorities were weak in management power and had small technical support staffs. The 1953 storm surge disaster prompted the reorganization of local and regional water management. The concentration

Figure 8.1 The water boards in the Netherlands in 2004

of water boards was necessary. In 1970 the water boards were also charged with water quality management of local and regional waters.
These tasks required larger water boards with greater financial and managerial strength. Only a few existing water boards could manage the new tasks.

This was the reason for the creation of the new water boards dealing only with water quality. It led to a dispersion of tasks and competences. Since the mid-1970s a second wave of integration and reorganization of water boards was started. Today 66 water boards take care of flood protection, and quantitative and qualitative water management at local and regional levels. Figure 8.1 shows the territories managed by the water boards as at 1 January 2004.

In the 1970s the provincial authorities were organized along the lines of departments for water management, environment, spatial planning, etc. Today the water management and environment departments are integrated into one department for water and environment. In some provinces the integration has been enlarged to include spatial planning.

8.3 Water-related issues in spatial, nature and environmental policy

The Netherlands is the most densely populated country in Europe. From 1970 to 2002 the density grew from 384 to 472 inhabitants/km^2. The pressure on land use is high and mutually competing. Urban areas and roads are expected to increase from 8 to 16% in the period 1970 - 2005. At the same time land use for agriculture will decrease from 70% in 1970 to 60% in 2005. The demand for agricultural area is diminishing by 300 km^2 per year in the 1990s. On the other hand there is an increasing demand for nature areas, water and landscape of high quality and great diversity. The policy document of the Government on nature (1989) defined the ecological structure and requirements. These ideas are worked out in national spatial schemes. The preservation and improvement of spatial quality present a challenge for the authorities. Laws define policy planning and decision making with respect to harmonization and creation of new projects.

The fourth document on spatial policy and its addendum (1989 and 1993) explain the spatial water-related strategy decided upon and specify the quality demands. The Government aims to improve spatial quality by means of three objectives: strengthening of the cohesion between water supply, recreation, tourism, nature and landscape; reinforcement of the interrelation between large water courses; and giving special attention to nature development. This national policy means a change is required in the approach to rural areas. The mainly agricultural development in these areas can be replaced by other regional policies. The regional spatial policy may vary from the preservation of the present conditions to the marginalization of agriculture and the stimulation of nature development. As problems and opportunities differ from region to region, the provincial, regional and local authorities have to formulate tailor-made spatial policies.

The spatial quality along the Rhine and Meuse branches (Figure 8.2) and the south-north axis that connects the Delta region with the Lake IJssel region has to be improved. The harmonization of nature development and navigation conditions

Figure 8.2 Improvement of spatial quality along the Rhine and Meuse branches and the south-north axis

must be accompanied by water quality measures which are necessary to meet recreational, nature and landscape requirements. The Government and provinces have to work out the water-related requirements in their schemes for spatial structure and in the strategic documents on water. These plans should contain specific assignments for operational water management.

Another important item is the harmonization of the policy areas of environment and water. Environmental policy considers the mutual coherence of three environmental sectors: water, soil and air. Harmonization is a neccessary activity to avoid pollution reduction in one sector increasing the pollution in another.
The elaboration of quality standards for water, soil and air and policy formulation to tackle specific polluting activities therefore take place in the framework of environmental planning. The Government defines the national environmental policy providing the objectives and conditions for the provincial strategic environmental plans.

The Policy Document on Environment also contains operational assignments for the state managed infrastructure. The provincial document on the environment defines the strategic issues to protect the environment and to reduce pollution.
It charges the local and regional authorities with meeting the objectives in the scheduled period.

8.4 Present water management

In the Netherlands water management is the responsibility of public authorities and not of private individuals or institutions. These authorities have to co-ordinate the possibilities of the water system to the demands of the socio-economic system. Figure 8.3 relates the steering function of the governing-administrative structure to the water-related demands of the socio-economic interests and the potential of the (natural) water system to meet these demands. This system consists of groundwater and surface water, water quantity and quality and its environment such as river bed, banks and technical infrastructure. The socio-economic system defines the requirements of the interests concerned. The Netherlands' society created an institutional and administrative framework to manage the water resources system in an efficient way. The role of the public authorities stems from the basic objective that water resources – as public property – should be managed in such a way that the optimal social benefit results. The demands of the various users and interested parties are often competing and/or conflicting. To meet all the demands is impossible and therefore choices have to be made. It is the task of the management bodies to make the choices and then execute them.

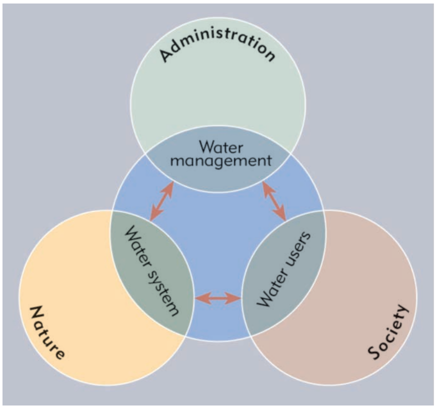


Figure 8.3 Harmonization of water-related functions with the water system by the administration

Chapter 9 describes the institutional structure for regulating the water resources management at three governing levels. The central Government formulates the main lines for the strategic policy about water issues at the national level. The central Government is also responsible for the operational management of the state-managed waters and some major flood protection works. Within the framework of the national policy, the provincial Government defines the strategic policy for the non-state managed waters and the regional framework for flood protection. The provinces also take care of the operational management of groundwater extraction and, in some cases, of water courses serving navigation. The water boards and the municipalities are responsible for the operational management and actual enforcement of the policy issues. The tasks of the municipalities concern wastewater collection by the sewerage system, and drainage in urban areas. The water boards are responsible for the overall drainage in urban and rural areas, water quantity and quality including wastewater treatment, as well as flood protection.

8.5 Fire in Basle, occasion for integration in the Rhine basin

In 1986, the storage facilities of a chemical factory in Basle, Switzerland caught fire. The fire-fighting water became heavily contaminated by insecticides. The poisoned water was released into the Rhine. The poison wave spreading down the river killed all organisms. The disaster led to several meetings of the Rhine states at ministerial level in the same year.

In addition to discussing the measures to be taken to prevent such accidents, the ministers adopted new long term objectives for the Rhine:
- higher species such as migratory fish should return to the Rhine by the year 2000. Salmon, as the best known species, is to be used as an indicator;
- future use of Rhine water for public water supply must be possible with simple production methods;
- the pollution of sediments has to be reduced to such a low level that sediment can be applied on the land or dumped into the sea without harmful consequences for aquatic organisms.

In the Rhine Action Plan (RAP) the International Commission for the protection of the Rhine (IRC) presented proposals to fulfil these objectives. The adoption

of the RAP by ministers in 1987 implied an integrated commitment of the riparian Rhine states to the further reduction of pollution and to the rehabilitation of the ecosystem of the Rhine.
Instead of continuing the detailed elaboration of emission standards prescribed by the chemical convention, the ministers adopted the IRC proposal to reduce pollution by selected substances by 50% during the period 1985 - 1995. This decision allowed the riparian states to define the most effective way of reaching this goal in their territory. It implied that not only the point sources but also the diffuse sources from households, agriculture and traffic etc. could be tackled. This approach was worthwhile. In recent years the detergents containing phosphate have disappeared and wooden products containing polycyclic aromatic carbons have been considerably reduced in the Netherlands.
The states bordering the North Sea adopted the IRC approach in 1990. Some IRC proposals were amended, referring to the ecological impacts of some substances on the North Sea. The objective of 50% reduction was raised to 70% for mercury, cadmium, lead and dioxin.

An integrated approach is necessary in order to meet the objective for the presence of migratory fish such as salmon etc. in the Rhine. The IRC developed such an approach by its masterplan “Salmon 2000”, published in 1991. This plan considers two issues:

- the rehabilitation of the main stream and tributaries as the backbone of the ecosystem for migratory fish;
- the protection, preservation and restructuring of ecologically important Rhine reaches.

Priority must be given to rehabilitation of the spawning grounds to meet the first issue. In this scope the IRC investigations indicated that 250 ha along the Rhine and some tributaries can be restored as nurseries for the migratory fish. But the spawning areas have to be accessible. For that reason the present dams and weirs must be equipped with proper provisions for allowing the fish to surmount these obstacles. Weirs in the Rhine are being provided with fish passages to allow the migration and spawning. The water-release regime of the sluices in Lake IJssel and the Delta Plan barriers has been adapted to meet the migration demands.

Administrative-legal provisions are required to meet the second issue. Particularly the reaches Constance/Basle, Karlsruhe/Mayence and Duisburg/Nimegue/Arnhem should be assigned as wetlands subjected to the regulations of the Ramsar Convention. These reaches are the stepping stones for the rehabilitation of the ecosystem of the Rhine. The masterplan envisages an extension of the stepping stones (Figure 8.4). All applications for land use along the Rhine and its valleys must be subjected to an environmental audit to prevent further degradation of the ecosystem.

Did the efforts pay off? The migratory fish salmon and sea trout are important indicators for the ecological rehabilitation of the Rhine. Since 1999 more salmon have been caught in the Rhine tributaries then before as Figure 8.5 illustrates: there are salmon again in the Rhine. It is an encouraging situation. But, it is too early to say “the salmon has returned”.

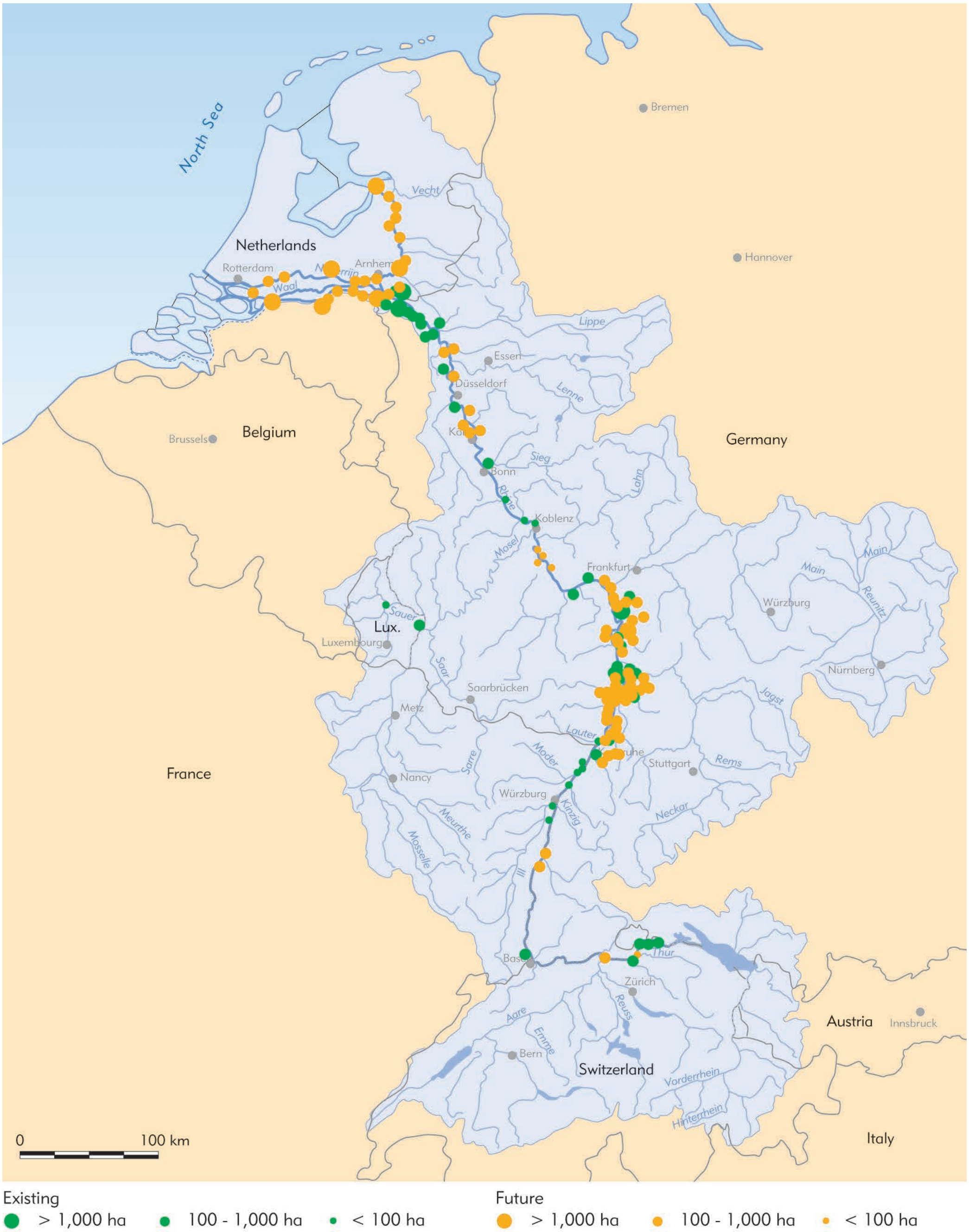


Figure 8.4 Stepping stones of the masterplan to rehabilitate the Rhine ecosystem

8.6 Updating of the Rhine agreements

In 1994 the Rhine ministers evaluated the legal framework, former and actual activities of the IRC. They found that the Berne Agreement of 1963 had to be updated because of the new tasks, such as the ecological rehabilitation and flood

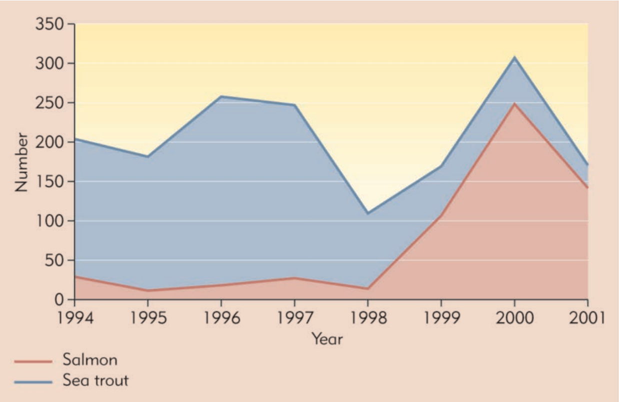


Figure 8.5 Salmon and sea trout caught in the Rhine tributaries

protection, which exceeded the original mandate. The ministers charged the IRC to draft a new agreement in view of the new tasks, knowledge and experience gained during 45 years of transboundary co-operation.
The new agreement has to take into account the regulations of the Helsinki Agreement. The major guiding principle is sustainable development in the Rhine basin.
The ministers found that the new agreement will address the exchange of information and views with non-governmental organizations, because it improves the quality of the decision making and the acceptance of proposed measures. The Rhine ministers signed the updated agreement in Berne on 12 April 1999. It came into force on 1 January 2003. As an illustration of the broader mandate of the ICPR, the words “against pollution” were dropped from its name.

The RAP and the Salmon programme expired in 2000. The Rhine ministers and the representatives of the EU evaluated the results in January 2001. They found that, in general, point source pollution (of residential or industrial origin) is under control. The majority of substances no longer pose a problem in the Rhine.
The reduction from diffuse sources, however, was less successful. The proportion of diffuse nutrients and heavy metal inputs in the total load has increased.
The efforts to reduce emissions from diffuse sources will remain.
The targets of the first phase of the Flood Action Plan (FAP) have largely been achieved. More attention must be paid to the reduction of damage risks in flood plains and flood-prone areas. The FAP comprises measures costing about €12 billion to be implemented by 2020. The ministers and the EU have asked the ICPR to prioritize the identified measures in view of the possible climate change.
The FAP will also contribute to the further improvement of the ecology of the Rhine.
This also largely corresponds to the requirements of the EU Water Framework Directive adopted in 2000 (see Chapter 10).

8.7 International co-operation in the Meuse and Scheldt basins

In the previous section much attention was paid to the Rhine issues. However, the Meuse and the Scheldt also play an important role in the Netherlands’ water management. In particular, the use of the Meuse for the production of drinking and industrial water for Rotterdam and The Hague has to be stressed.
After many years of deliberations, the Netherlands, France and the Belgian regions of Flanders, Brussels and Wallone signed respective treaties in 1994.
The flood problems in the Rhine and Meuse (January/February 1995) brought a further step: the ministers of the riparian states declared in Arles, France that measures have to be taken to reduce the future risks imposed by high water levels in the rivers Rhine and Meuse.

They asked for special attention to be paid to land use, water management and spatial planning. Land use defines the impacts of agriculture, forestry, nature management, urbanization and recreation on runoff. Water management can influence buffer zones, dikes and embankments, and flow management in the flood plain. Basin-wide spatial planning is necessary to implement the proposed measures.

To expedite matters, the ministers decided to make maximum use of existing structures and research institutes. From this starting point they charged the IRC with developing a flood prevention plan similar to that applied in the RAP for the reduction of pollution and rehabilitation of the ecosystem. For the Meuse and Scheldt the action plans should follow the steps of the IRC.
The developments in the last decade illustrate the truth of the title of this section. The adaptive capacity of the institutions (both national and international) is a prerequisite for sustainable water management.

8.8 Planning, an important instrument for water resource management

The harmonization between the natural characteristics of the water system and the water-related interests requires a structural and actual weighting mechanism. The objectives of the interested parties are partly complementary and partly conflicting. The trade-offs between each of them are not always clear. This fact demands careful selection of management objectives and allocation of resource measures in time.
Policy making and the Netherlands tradition of participation in it does not make a decision of today become a fact of tomorrow. That is why planning is an important instrument for arranging commitments at the different governing levels, as well as in the short and long terms. Planning and subsequent decisions are based on the process concerning recognition of problems, formulation of alternative options for solving the problems, presentation of the impact of the actual situation and the alternative options, as well as the selection of strategies by the competent authorities.
Although planning is applied on a voluntary basis in flood protection and water management issues, Government and Parliament found that the coordination of planning between the participating authorities has to be enforced by law. The Water Management Act (1989) formulates the framework, objectives and contents of the management plans. It also defines the updating of the plans every four to eight years.
The central Government and the provincial authorities make the strategic plans. These plans are restricted to major areas which limit the operational plans. The chosen strategies and the expected financial, economic and spatial results are shown in these plans. The water resources management plans also describe their interaction with the spatial planning and the environmental policy plans. This is important because water resources form a part of public responsibility. Figure 8.6 represents the relationship of water resource planning with spatial and environmental policy planning. It looks like a top-down exercise, but it also works bottom-up. The plans have to be revised regularly.

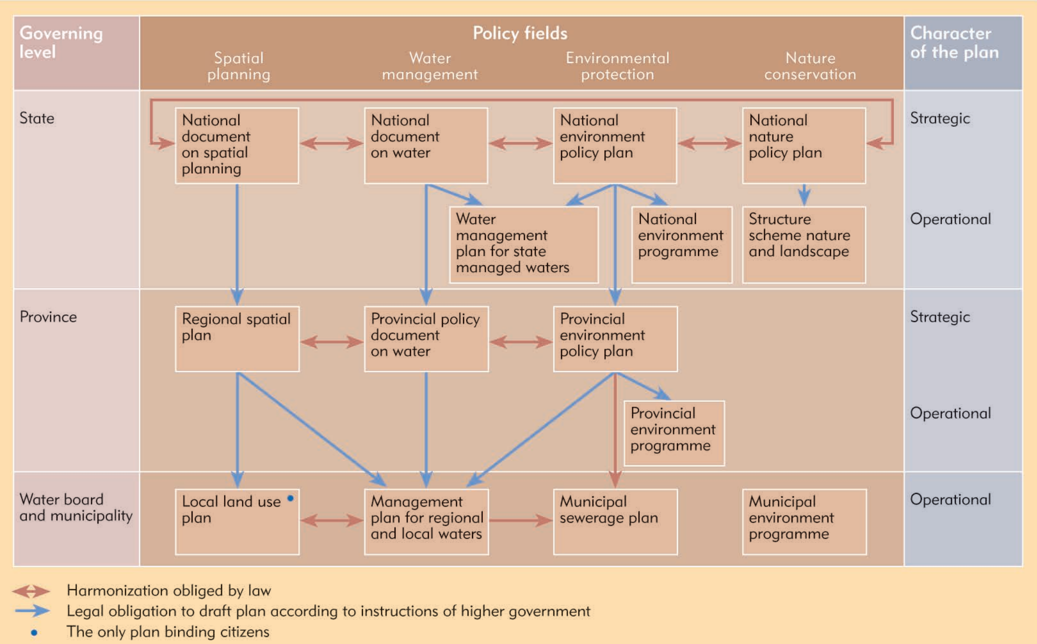


Figure 8.6 The water-related planning structure in the Netherlands

The revision starts with an evaluation of the operational management plans in the framework of the current strategic policy. The results of this bottom-up exercise mainly define the issues for revising the policy.

8.9 System analysis, the tool in the planning process

Planning anticipates and supports the decision making of a particular strategy.
In an integrated and complex water resources system, it is essential to know the impacts of particular decisions and selected strategies. The state and the provinces use a system approach for water resources management. A system approach carefully identifies the important issues and alternative measures with regard to flood protection, water demand and supply. The system approach assesses and evaluates the impacts of the formulated strategies in a way that is meaningful to the decision maker. To investigate the often complicated structure of the water management problems, the many components to be considered and the complex relations between the different parts of the water management system, the analysts make extensive use of mathematical modelling and analytical techniques.
In order to carry out its planning and management task the Rijkswaterstaat commissioned Delft Hydraulics and the Rand Corporation (USA) to develop the so-called PAWN-instrument (Policy Analysis of Water Management for the Netherlands). This ranks the various user categories of the water management policies and shows the limitations and impacts of the considered solutions for all parties concerned. PAWN was used to provide information for the national Policy Documents on Water in 1985, 1989 and 1997.

8.10 Regional water resources planning and management

The structure of the strategic and operational plans by provinces and water boards enables sound water resources planning to take place at a regional level. In the regional water management and development projects, the above mentioned water system approach is generally applied. Many of the water projects are prepared and carried out within the framework of land development projects.
The Third National Policy Document on Water Management (1989) aims at an integrated approach. In the past six years this policy has been implemented in provincial regulations and in plans of the water boards.
To promote the introduction of integrated water management of the water boards in practice, the Third National Policy Document contained regulations to stimulate projects for improving water related interests, which also have a positive impact on other policy fields. The so-called REGIWA projects aim to realize REGional Integrated WAter management in practice; later such stimulation took place under the acronyms GEBEVE and SGB. Thus these projects aim to reduce the eutrophication of local and regional surface waters, reduce 'verdroging' and improve the conditions for nature-friendly river banks. These measures have positive impacts on wildlife and the environment and create new possibilities for spatial planning. The concept of integrated water management intends to find a new balance between (private) economic interests and the requirements of society for the environment and wildlife. The responsibility for the strategic decisions about the desired policy and projects lies with the national and provincial authorities.
The implementation of the new policy by realization of projects is in the hands of the water boards. Before taking decisions on strategic issues, the possible benefits and drawbacks of the relevant functions must be quantified. At the moment one of the difficult issues is the 'rewetting' of dried nature areas by raising water levels and introducing higher seepage rates in areas where other interests are also important. The rewetting of nature areas can particularly affect agriculture. In other cases nutrients and the application of insecticides can cause damage in nature areas. Therefore methods are being (further) developed to quantify the benefit for nature area development. Sometimes a change of land use can be a wise (but expensive) solution.

8.11 Cost and financing of flood protection and water management

Other countries often ask about the cost of the flood protection and water management in the Netherlands and how these are financed. This section describes the principles of financing water control activities and presents the figures for 1998.

The Netherlands government sets the following priorities in the field of financing:
- costs should be paid by those concerned or by those who are responsible for them;
- if the costs of water authorities cannot be allocated individually, they are distributed among the community of those concerned/responsible by levies;
- if both methods prove not to be feasible, financing can be provided from the general budget of the central Government (the state budget).

The first priority means that the costs of a new project undertaken to meet the licensing regulations have to be paid by the enterprise. Similarly, if a water authority implements specific requirements for an individual undertaking, the bill is presented to the enterprise.

According to the second priority, the cost of the dikes and the regional and local quantitative water management measures, exercised by the water boards, is financed by the 'user pays' principle, which is that the extent of a user's interest in a project defines the amount of their taxation and representation.According to the third priority, the activities of the State and the provinces to prepare and co-ordinate the water control activities with other public interests are financed from the state budget. Further, the costs for the main flood protection dams and storm surge barriers, as well as for operational quantitative water management activities at the central level, are financed from the central Government budget.

Tables 8.1 and 8.2 represent the cost and financing of the public water management activities such as flood protection, quantitative and qualitative water management including wastewater treatment and wastewater collection by the sewerage system.

Table 8.1 Public water management costs in 1998 in million €

Task	Institutional level				Total	€ per capita
	State[1]	Province	Water board	Municipality		
Flood protection	236	98	115	-	449 15%	28.7
Water quantity management	125 [2]	38	436	50	649 20%	41.5
Water quality management	277 [2]	40	962	796	2,075 65%	132.6
Total	**638**	**176**	**1,513**	**846**	**3,173**	**202.8**

1 These data concern the efforts of the Ministry of Transport, Public works and Water management and contain a substantial overhead cost. The data also include the modest financial contribution of other ministries. The overhead of these ministries is unknown.

2 The operational water management and navigation tasks of the Rijkswaterstaat are considerably interlinked. Since 1998 the Rijkswaterstaat does not distinguish financially between these tasks. The presented figures have been based on the relations in the past.

Table 8.2 Finance of public water management in 1998 in million €

Paying principle	Institutional level				Total	€ per capita
	State	Province	Water board	Municipality		
General budget	605	136	-	213	954 30%	61.0
Water board tax	-	-	547	-	547 18%	35.0
Groundwater tax	-	11	-	-	11	0.7
Pollution levy	33	30	907	-	1,060 33%	67.7
Sewerage tax	-	-	-	633	633 20%	40.5
Balance goods, services and interest	-	-	–31		–31 –1%	–2.0
Total	**638**	**177**	**1,513**	**846**	**3,173**	**202.9**

These data show that the water quality management costs considerably exceed those of flood protection and water quantity management. From the 1998 water management cost; 15% is spent on flood protection, 20% on water quantity management and 65% on water quality issues. The cost of these activities is financed by 18% by the water boards' profit principle, 33% according to the polluter-pays-principle to the water board and 20% by the municipality sewerage tax. At local and regional scales the cost recovery of water services is 100%. Some 30% of the total cost are financed from the general budget. This concerns the national and provincial activities, which cannot be ascribed to water boards and municipalities.

Investigations into the costs and financing in 1994, 1996 and 1998 showed that every year the total cost increases, but follows the development of the national income. During the above-mentioned years, the total cost remains 1% of the national income. As a result of the reshuffling of tasks between provinces, municipalities and water boards, there is only a slight shift in the total cost moving from the provinces and municipalities to the water boards.

It should be noted that both tables only contain cost and financing by public authorities. The figures exclude the cost and finance of specific supplies such as drinking water, and water for agriculture and industry.

Drinking water supply is not a matter for the public water authorities, although provinces and municipalities own the water companies. To complete this contribution, an impression about the price for drinking water in the Netherlands is necessary. Data of the Netherlands Waterworks Association (VEWIN) showed that the price varied between €0.73 and €1.92 with an average of €1.28 per m^3 in 1998. The variation is due to the application of groundwater or surface water as raw material and the eco-tax on groundwater extraction. To make the tax-system more eco-friendly, extraction of ground water was charged with €0.17 per m^3. On average, households consumed 725 m^3, 126 litre per capita per day. This results in an average figure for 1998 of €58.3 per capita.

9 Institutional and legal aspects

The legitimacy of water-related intervention was and still is an important issue in the Netherlands. This chapter summarizes the institutional structure and the present competencies of the authorities charged with water issues. It also provides brief information about the water-related laws in force.

9.1 Water administration and its background

The Netherlands is a decentralized unitary state with three main hierarchical administrative levels of water management: national, provincial and regional (Figure 9.1). At each level there are bodies with specific responsibilities: legislative and executive. A multitude of different departments or agencies is responsible for the various sectors of public policy, each deriving its authority from legislation.
Water has played a dominant role in the course of Dutch history. In the 12th century local communities began to construct dikes to prevent flooding and control the water levels behind the dikes. Following the construction of dams in the tidal water courses in the 13th century, the local communities began to elect representatives to the regional meetings where the common water management affairs were discussed. These meetings formed the basis for the water boards. The election system was (and still is) based on the rule: interest-payment-say. The extent of interest defines the levy to be paid to meet the costs of water control as well as the participation in the representative body. Until today the water boards still exist as specific administrative units for local and regional water management.
In the 20th century the level of participation has been increased to include house owners, tenant farmers and residents because these categories were interested in flood protection and regional management too. Since the water boards take care of the water quality based on the 'polluter pays' principle, representatives of households, industries and companies participate in the administrative and executive bodies of the water boards.
In 1798 a national agency, the Rijkswaterstaat, was created in order to administer all water-related affairs at a national level.
In the 19th century provincial water authorities were established and charged with the supervision of the water boards and water-related issues of the municipalities.

9.2 Institutional structure

National level

The Netherlands is a constitutional monarchy with a parliamentary system. The central Government, the executive, consists of the Monarch and the Ministers and is called the Crown. However, since the Monarch is inviolable, the ministers have full responsibility and supreme control. The ministers together form the so-called Council of Ministers (the Cabinet), chaired

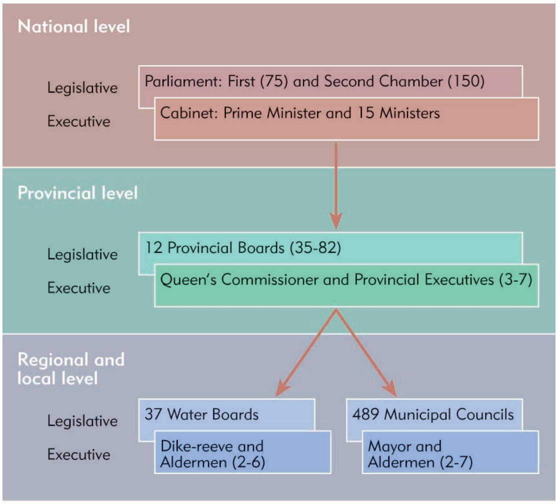


Figure 9.1 The institutional structure of the Netherlands

Figure 9.2 State managed waters and infrastructure

by the Prime Minister, which deliberates and decides on general Government policies. The Dutch parliament consists of the First Chamber and the Second Chamber of 75 and 150 members respectively. The Second Chamber, the House of Representatives, controls and approves the actual decisions of the Government. The First Chamber, the Senate, elected by provincial representatives, is the house of reflection and has the power to approve or reject a bill. The Second Chamber provides the right of amendment. Legislative power is with the Government and Parliament together. An act may transfer the authority to issue decrees and regulations to other governing bodies, such as the Crown, Ministers, provincial authorities, municipalities and water boards. The administrative rules given by the Crown (in practice the relevant Minister), called Orders in Council (Amvb) are quite common in the policy field of water and the environment. They prevail over provincial orders. Provincial orders prevail over orders of municipalities and water boards. The Council of State is the most important advisory body to the Crown with regard to legislation.
The judiciary power includes the Council of State (Raad van State) and the Supreme Court (Hoge Raad). The Supreme Court and its subordinate courts are primarily responsible for the proper execution of the civil and criminal law. The Chamber for Administrative Justice of the Council of State is the highest judicial level responsible for administrative affairs.

In water management three ministries have important tasks. The Ministry of Transport, Public Works and Water Management is responsible for flood protection and water management. The Water Directorate of this ministry, created in 2002, prepares national policy on flood protection and water management. The directorate 'Rijkswaterstaat' of this ministry, which has been in existence since 1798, supervises the implementation of water policy by the provinces and water boards. This directorate also has the operational responsibility for the state managed waters and water retaining structures of national importance. Figure 9.2 represents the state managed infrastructure.

The Ministry of Housing, Spatial Planning and the Environment is responsible for general environmental policy; setting of water quality standards and emission standards; laws concerning air, soil and groundwater protection, waste, noise, harmful substances, radiation, Environmental Impact Statements and external safety; drinking water and sewerage; and spatial planning (land use).
The Ministry of Agriculture, Nature Management and Food Quality is responsible for general policy on agriculture, nature management, food quality, fisheries, rural areas and outdoor recreation; and legislative policy concerning nature conservation with regard to species and areas.

Provincial level

The organization and tasks of the 12 provinces are ruled by the Province Act.
The administrative bodies at provincial level are:
- the Provincial Council: the elected body of 45 - 85 members (depending on the number of inhabitants);
- the Provincial Executive: appointed by the Provincial Council;
- the Provincial Governor: chairman of the council and the executive board, nominated by the Provincial Council and appointed by the national Government.

The water management at provincial level was formerly performed by the provincial water management department. In the 1990s these departments have merged with the provincial environmental departments.
With the exception of the state managed infrastructure, the twelve provinces define and supervise the responsibilities and activities related to flood protection and water management.
Since the Pollution of Surface Waters Act came into force in 1970, the provinces no longer have virtual autonomy in specifying the tasks and competencies in water management; the State now plays a leading role in the assignment of tasks and competencies in qualitative surface water management. The same system was continued in the Groundwater Act, the Water Management Act, the Soil Protection Act and the Flood Protection Act. The Water Board Act defines that local and regional flood protection and water management is exercised by the water boards.
Each province co-ordinates the policies of the various sectors involved, such as water management, environment, nature conservation, housing, physical planning, transport, economics and welfare. The provinces can formulate policies of their own but must adhere to the directives issued by the national Government. They must ensure that the national and provincial policies are implemented by the municipalities and water boards.
The provinces have created the Interprovincial Platform, in which organization common views and statements of the provinces are formulated.

Regional and local level

Water boards

The water boards became the competent regional water authorities in the 13th century. Since the 13th century water boards administered the dikes, local embankments and polders. In time thousands of water boards existed. After the storm surge disaster in 1953 the number of water boards decreased (see Table 9.1).

The scaling-up process can be illustrated by the province of Groningen. The map of Figure 9.3 represents the 74 water boards in 1978 and the two interprovincial water boards in 2004. The present 37 water boards are organized according to the Water Boards Act. The water board organization comprises:
- the General Assembly, elected by specific groups such as land owners, owners of real estate, wastewater dischargers, residents;
- the Executive, appointed by the General Assembly;
- the Chief Executive, chairs both bodies and is nominated by the General Assembly and appointed by the minister of Transport, Public Works and Water Management.

Table 9.1 Number of water boards

Year	1946	1969	1978	1990	1998	2004
Number of water boards	2,500	1,000	400	129	66	37

Whereas the central Government, and the governing bodies of the provinces and municipalities are so-called ‘general democracies’, the water boards are ‘functional’ governmental bodies. The election of general democracies is based on the principle ‘one man, one vote’. A functional democracy such as the water board is based on the rule ‘interest-payment-say’. The distribution of seats in the water board among landowners, residents and wastewater dischargers is defined by this rule. As the situation differs in each region, the composition of the water boards varies. The provincial authorities define and supervise the tasks of the water boards under approval of the national Government. The water boards are responsible for flood protection, and water quantity and quality management in their territory, in some cases together with the management of waterways, bridges and roads. As many provincial borders do not coincide with the hydrological/hydraulic borders of the water boards, interprovincial water boards were created.
The water boards are united in the Union of Water Boards. In the Union common views about flood control, water management and water-related issues are prepared.

Municipalities

The tasks and organization of the 489 municipalities are governed by the Municipal Act. Municipal organization comprises:
- the Municipal Council: an elected body of 7 - 45 councillors;
- the Municipal Executive: a number of Aldermen appointed by the Municipal Council.

The Mayor is chairman of both councils, is nominated by the Municipal Council and appointed by the Crown.
The water management task at municipal level is limited to the management of sewerage systems performed by the local public works department.
The municipalities promote their common views through the Netherlands Association of Municipalities.

Drinking water companies

Drinking water supply is taken care of by 17 drinking water supply companies. Although they have a privatized structure, the shares are owned by public authorities (provinces and municipalities). The drinking water companies are united in the Netherlands Waterworks Association (VEWIN).

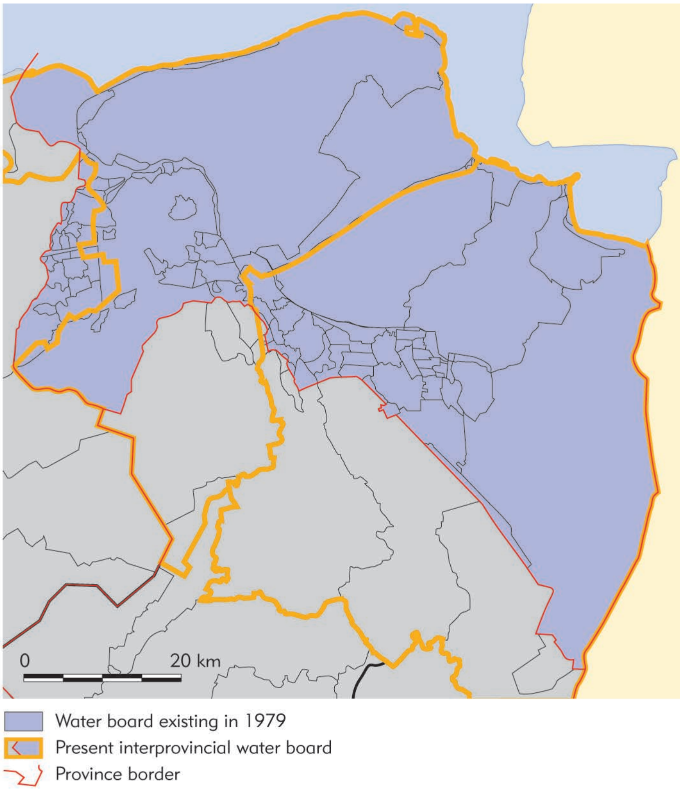


Figure 9.3 *The integration of water boards in the province of Groningen: the 78 water boards existing in 1979 are incorporated in three interprovincial water boards*

9.3 Water legislation

There is a wide variety of water legislation. Apart from the fundamental directives in the Constitution, the water laws can be divided into five categories. The first one deals with the water management organizations, the second with aspects of (integrated water) policy, and the third with the management of the water-related infrastructure. The fourth, specific category is drinking water, and the fifth category pays attention to acts relating to other relevant water issues.

Constitutional directives

Article 21 of the Constitution of 1983 provides, that "Public concern focuses on the living conditions of the country and the protection and improvement of the environment". The explanation of this directive highlights the importance of flood protection and related water management, but requires that this be balanced with the interests of the environment as a whole (including, for example: nature, landscape, history, land use and water quality). Chapter 7 of the Constitution charges the formal legislator to draw up the duties and authority of province, municipality and water board. Article 133 defines that an act sets out the rules for the creation and termination of water boards by provincial by-law, and prescribes both the legislative and executive authority of the water board and the provincial and national supervision of the water board. Provincial by-law defines territory, structure and composition of the water board.

Legislation on water management organizations

Water Administration Act (1900)

This act details the remit of the Rijkswaterstaat and sets out its powers to enter dwellings, and its obligations to protect, maintain and improve flood defences including provisions relating to water management on the national, provincial and local water board levels. Further provisions describe the emergency rules and powers of the Rijkswaterstaat, provincial and local water boards in the event of potential or actual flooding disasters.

Water Boards Act (1992)

This act defines the creation, termination and composition of the general assembly of the water boards by the provinces. The act gives powers to issue by-laws and provide financing. The responsibilities and authority of the water boards are directed towards the functions allotted to them by the provinces.

Acts concerning integrated water resources management policy

Water Management Act (1989)

The Water Management Act defines the planning structure for water management by the Government agencies at different levels and gives rules for the quantitative management of surface waters. It provides the following policy instruments: planning; permissions; registration of abstractions and discharges; water covenants; level decisions; and charges.
The planning structure of this act is of major importance because it presents an integration of national and provincial plans based on the Pollution of Surface Waters Act, the Groundwater Act and the Water Management Act itself. It also includes statutory cross-references with spatial planning and environmental planning.

Groundwater Act (1981)

The Groundwater Act covers all abstractions by means of pumping works.
The provincial government is responsible for the instruments provided by the act. These are: abstraction permissions; abstraction registration; duty to report; and levies. All abstractions of more than 10 m^3/hour require permission.
This act concerns groundwater quantity only, although qualitative aspects are incorporated where the recharge of aquifers is concerned. Other quality aspects are dealt with in the Soil Protection Act.

Pollution of Surface Waters Act (1970)

The main objective of this act is the pollution control of all surface waters for which it provides a framework for a two-track policy: the reduction of emissions and the improvement of water quality (emission approach). The instruments of the act are: the issue of discharge permissions; the setting of standards; and the use of levies.

Pollution of Seawater Act (1975)

This act aims to prevent the pollution of seawater as a result of dumping from both ships and aircraft. The Pollution of Seawater Act prohibits the dumping of waste or polluting substances. Exemptions may, however, be granted with regard to certain substances.

Legislation for the management of the water infrastructure

Flood Protection Act (1997)

This act aims to maintain the flood protection standards achieved by the Delta Plan and the reinforcement of the dikes and dunes. It contains a 'finger on the pulse' mechanism, by which each flood defence authority must report on the condition of its defences every five years. The reports are progressively summarized by the provincial and central Government and sent to Parliament.
The Flood Protection Act also contains procedures for the approval of reinforcement plans, for emergency plans and for the combating of coastal erosion.

Delta Act (1958)

This act formulates the principles for the protection of the Netherlands against storm surges by the closing of estuaries and the reinforcement of dikes and dunes. The Delta Act will lose its significance in the near future as almost all works of the Delta Plan have now been completed.

Delta Act – Major Rivers (1995)

The river floods of 1993 and 1995 precipitated this act, which enabled the strengthening of some 150 km of very weak dikes along major rivers in 1995 and 1996, along with the construction of a number of embankments. The Delta Act replaced the previous time-consuming procedures described in a total of 19 laws with one single decision and one opportunity for appeal. As a result of this emergency act, the weak dikes were rapidly strengthened.

Reclamation Act (1904)

This act requires that a permit be granted by the Ministry of Transport, Public Works and Water Management for the reclamation of land from the sea, estuaries and rivers.

State Managed Infrastructure Act (1996)

All activities which are outside the normal use of state managed infrastructure are subject to licensing: e.g. cables, wires and pipes in navigation canals, rivers and dikes. This act incorporates the former River Act of 1908.

Legislation for drinking water

Legislation with regard to drinking water supply can be found in several acts and regulations because different aspects are concerned: the source, quality and protection of the raw material as well as production and distribution. Drinking water has two main sources: groundwater and surface water. Relevant acts are: the Groundwater Act, the Soil Protection Act and the Water Management Act. These last acts create the conditions for water resources development and protection.

Drinking Water Supply Act (1958)

This act is directly concerned with the provision of water and its quality and regulates the supervision of the water producing and distributing companies in the interests of public health. It contains regulations on supply conditions, quality standards, organization and planning.

Legislation related to other water issues

For the performance of the water authorities, related water legislation is also of the utmost importance. Here the legislation in the field of spatial planning and environmental and nature protection is mentioned.

Soil Protection Act (1987)

This act contains a general duty to prevent and, if necessary, to clean up soil and groundwater pollution. It provides the structural basis and the necessary administrative instruments for the implementation of the soil and groundwater protection policy. It should be noted that, anticipating this act, a Soil Clean-up Interim Act already became operative in 1983 for the regulation of soil clean-up operations. The latter was incorporated in the Soil Protection Act in 1994.
The Soil Protection Act distinguishes two levels of protection: a general level and a specific level. Both protection levels differ from each other only in the level of acceptable risk for soil pollution caused by certain activities.
The general protection level is formed by regulatory measures set by the national Government. These rules concern the regulation of activities that may lead to pollution or impairment of soil and groundwater, and the formulation of soil quality standards.

To illustrate the system of the orders in Council, the administrative rules given by the Crown, the orders based on this law are given below:

- application and spreading of manure on soil (1987)
- discharge of liquids into soil and groundwater (1990)
- application and spreading of sewerage sludge and organic household waste (compost) on soil (1991)
- dumping of solid waste materials (1993)
- storage of petrochemical products in underground tanks (1993)
- artificial recharge of aquifers (1993)
- leaching standards for building materials produced from recycled waste (1995).

In addition to the general protection levels, a specific protection level must be implemented in soil protection and groundwater protection areas used for water supply. In these areas potentially harmful activities are either not admissible or additional preventive measures are necessary. The acceptable risk level of pollution is lower in these areas. At present, the groundwater protection areas cover about 1,400 km^2, i.e. approximately 4% of the Netherlands.
Since 1994 the regulations concerning soil and groundwater protection areas are part of the Environmental Protection Act

Spatial Planning Act (1965)

The Netherlands has a well established system of spatial planning on three levels of administration, based on the Town and Country Planning Act of 1965, as amended in 1983. The municipalities make the most binding and country-wide plans in which the potential uses of all areas are indicated. The provinces adopt regional plans and the national Government issues a policy document on spatial planning at a national level almost every ten years.
This act is applicable to sectors requiring land, such as transport, harbours, nature, airports, etc.

Environmental Protection Act (1993)

The first Dutch legislation concerning the environment was the 1875 Nuisance Act. Businesses or private individuals need licences for activities hindering the actual use of space, water and soil. The licences prescribe conditions to be respected. Since 1970, several environmental acts have been introduced dealing with water, air, soil, waste products, etc.

The basis for integrated environmental legislation was laid by the 1979 General Environmental Provisions Act, which in turn formed the basis of the Environmental Protection Act which came into operation in 1993. This act provides the legal framework for the environmental plans and programmes of central Government, the provinces and the municipalities and lays down the regulatory procedures for planning and permissions. This Act also regulates the environmental aspects of a great number of industrial activities. Since 1997 the Environmental Protection Act contains an obligation for the municipalities to prepare sewerage plans.

Nature Conservation Act (1967)

This act was renewed in 1998. The present Nature Conservation Act details the national Policy Plan for Nature regarding nature conservation and the relevant sectoral structure scheme for spatial planning purposes. The intention of this act is to provide additional protection to ecologically important areas by designating them as natural monuments. Large areas of the Wadden Sea and areas along the Rhine, Meuse and Scheldt rivers have been given this status.

Mineral Extraction Act (1965)

This act deals with the extraction of the raw materials used for many construction activities. Large areas and volumes of water usually remain following the extraction of such materials. Rehabilitation of such areas raises a number of important issues for water managers, from the planning phase onwards.

10 European water policy

To avoid unequal competion in the fight against water pollution, the European Union was obliged to issue Directives. The rather detailed rules on this subject contain emission standards or waterquality objectives or both. For many reasons, it became necessary to reconsider the EU water policy in the 1990s. The coherent, river basin oriented Water Framework Directive came into force in December 2000. EU-member states are now making efforts to implement the regulations by 2027.

10.1 EU participation in environmental issues a necessity

The European Union (EU) started its involvement in transboundary water politics in 1972 as the European Economic Community (EEC) to avoid unequal competition, particulary between the EEC countries in the Rhine basin. Directives were issued to deal with these problems. These rather detailed rules aim to limit the emission of specific substances, to formulate water quality standards within specific parameters, and to monitor and evaluate quality measurements. The directives can be classified into three categories: source-oriented, dealing with the input of pollutants into water; impact-oriented, protecting specific types of water use; and directives combining both orientations.

The most important source-oriented instrument is the Directive on Pollution Caused by Dangerous Substances Discharged into the Aquatic Environment of the Community, known under number 76/464. The regulations of this Directive have the same structure and wording as the Convention to protect the Rhine against chemical pollution. Based on this Directive, the EU agreed on seven 'daughter directives' containing emission limits, water quality objectives and monitoring requirements. Four impact-oriented Directives have outlined quality standards for specific uses: the Directive on the use of surface water to produce drinking water (1975) defines three levels of quality objectives corresponding to treatment processes – if the surface water does not meet the objectives, drinking water production is prohibited; the Bathing Water Directive of 1976 obliges EU member states to observe certain quality standards in places frequented by large numbers of bathers – observations have to be reported; and the Directives on Fish Water and Shellfish Water (1978 and 1979 respectively) contain quality standards which have to be respected for waters designated by EU member states as appropriate for salmonides, cyprinides or shellfish. Originally, Directive 76/464 contained regulations for groundwater. These regulations ceased to apply as the Groundwater Directive came into force in 1980. This Directive aims to protect the groundwater against discharges and pollution by substances on the black and grey lists.

The Directive on Urban Wastewater Treatment (1991) obliges all urban conlomerations to be connected to a sewer system, to purify wastewater according to secondary treatment. In vulnerable situations, i.e. when the recipient water is used for drinking water, treatment of phosphates and/or nitrates should beincluded. The second source-oriented instrument deals with nitrates from agricultural sources. It obliges EU member states to establish codes for good agricultural management up to a maximum nitrate level of 170 kg per hectare.

In practice the EU legislation has shown a lack of consistency in the Directives. The interrelation between the source- and impact-oriented ones is not always clear. Similarly, this is the case with Directive 76/464 and the Urban Wastewater Directive. The directives were often difficult to apply and to enforce. The source-oriented Directives also lacked flexibility. It took much time before emission limits were adopted by the Council of Ministers. The periodical assessment and actualization of the black and grey lists were not foreseen. The diffuse sources were ignored. The importance of these sources grew when the pollution by point sources was decreased by sanitation. Some quality standards of the impact-oriented directives were outdated at the date of their enforcement. Nevertheless the Directives have contributed considerably to the reduction of pollution in the EU member states.

10.2 The EU on the move to the Water Framework Directive

Since the end of the 1980s new orientations in the EU water policy have taken place at a time when many international water agreements have undergone fundamental revisions. New river treaties were concluded, many of them focusing on a river basin approach. They coincided with new orientations of the general EU policy such as subsidiarity and transparancy.

In 1993 the European Commission submitted a proposal for a Directive on integrated pollution prevention and control. In June 1994, the Commission presented the proposal for a Directive on the ecological quality of water. Some directives were updated. However, neither the Council of Ministers nor the European Parliament were sastisfied. They invited the Commission to present a coherent strategic document on water policy. This should start with the ecological water quality proposal and be based on principles for sustainable water management: the principles of precautionary measures, preventive action, priority for rectifying environmental damage at source, progressive reduction of the use of dangerous substances, and of ‘the polluter pays’. Where possible the river basin should be taken as a basic unit for the coordination of planning and management. Special attention should be given to achieving a high level of environmental protection, to regional diversity, to subsidiarity and to the functioning of the common market.

In December 1996 the Commission submitted the proposal of a Water Framework Directive. The proposal was welcomed by the EU member states. In June 1997 the Council of Environmental Ministers reached a political agreement on the outline of the proposal. After many deliberations the Commission and the European Parliament agreed the Water Framework Directive in July 2000. The Directive came into force on 22 December 2000.

The Water Framework Directive formulates as main objectives and principles:

1. Protecting and raising the quality of aquatic ecosystems and their environment;
2. Sustainable use of water resources;
3. Improvement of the aquatic environment by reducing pollution; and
4. Mitigating the impact of floods and droughts.

The Directive contains dates on which the objectives have to be achieved.

The EU also reconfirmed the relationship between the source- and impact-oriented approaches on the adjacent policy fields of soil and air. Co-operation between EU member states on emission standards and quality objectives for water, soil and air was limited for some substances. The EU aims to harmonize the water policy with the other relevant environmental components. Perhaps Air and Soil Framework Directives can be expected in the long term.

10.3 Implementation of the EU Water Framework Directive (WFD)

To establish the feasibility of the objectives for surface waters, groundwater and protected areas, it is necessary to:

- define the present condition of these elements;
- gain insight into the present manmade impacts on water;
- obtain an overview of the necessary measures;
- make an economic analysis of the costs and effectiveness of the measures and
- introduce price incentives for sustainable water use.

Figure 10.1 represents the time schedule to achieve these objectives.

The WFD prescribes that a river basin management plan has to be established for every international river basin including the territorial sea. Such a basin is defined as an international river basin district. Every EU member state is now implementing the WFD. The Netherlands and their up-stream neighbours agreed to create four international basin districts, namely the Rhine, Meuse, Scheldt and Ems, for which a harmonized water management plan has to be drafted in 2009. Figure 10.2 gives the boundaries of the river basin districts with their sub-basins in the Netherlands.

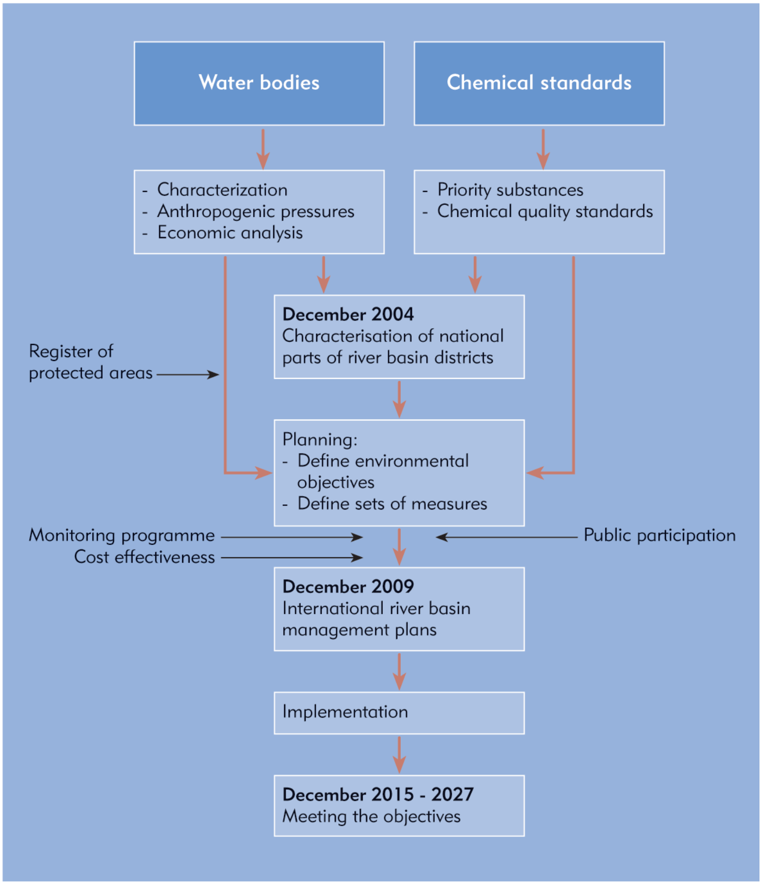


Figure 10.1 Schedule of activities since 1 January 2003 to meet the environment objectives

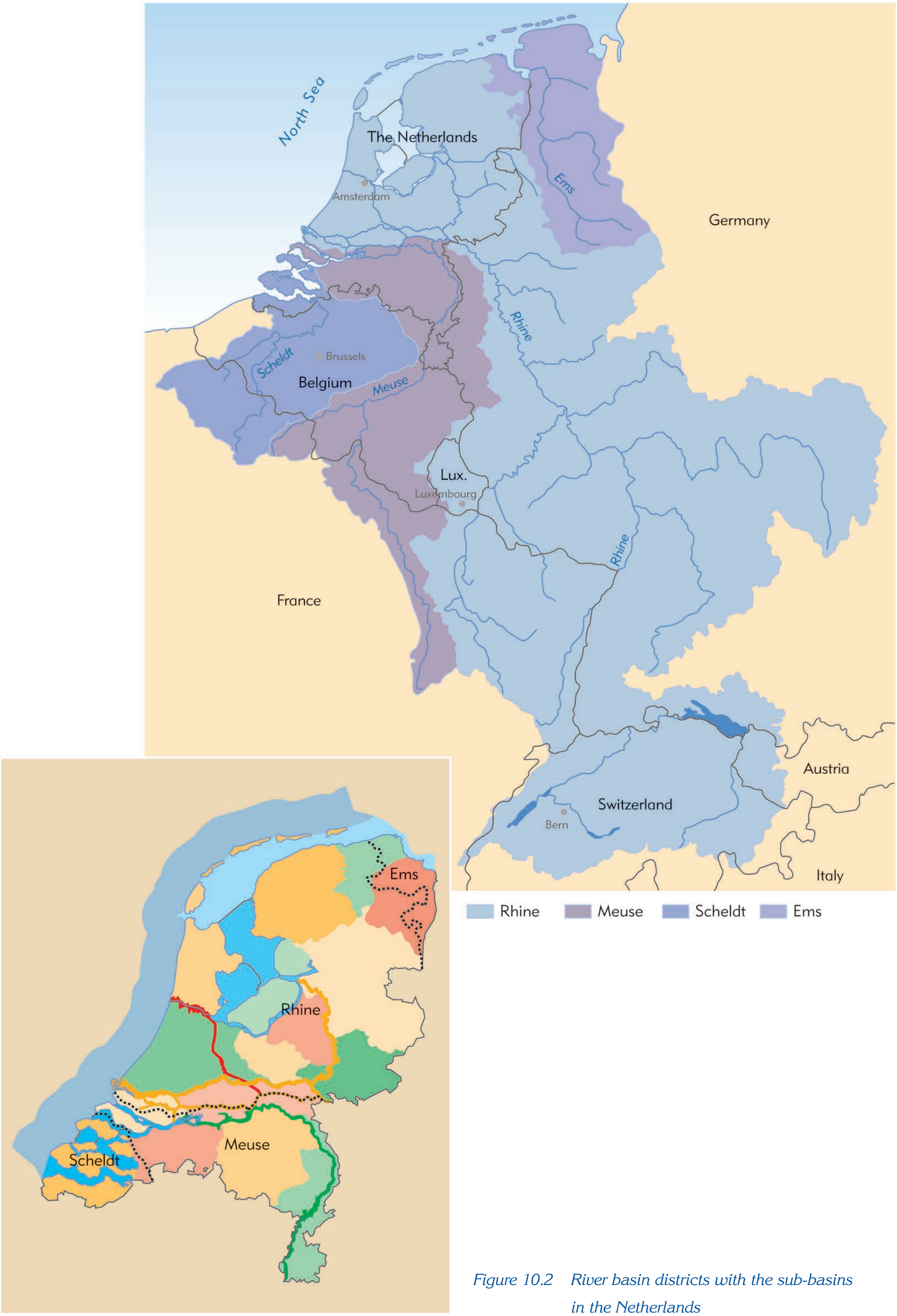


Figure 10.2 River basin districts with the sub-basins in the Netherlands

As a first step to be considered in the basin management plan, the characteristics of the river basin districts have to be submitted to the EU. The following elements are required:

1. Characterization of river basin district.
2. Summary of significant anthropogenic pressures and their impact on the condition of surface water and groundwater.
3. Maps with designated protected areas and the legislation from which the designation of these areas ensues.
4. Maps with monitoring networks and results of monitoring programmes, including the condition of surface water and groundwater, as well as protected areas.
5. Incorporation of environmental objectives for surface water and groundwater and for protected areas.
6. An economic analysis of the use of water.
7. A summary of the programme of measures, including the manner in which the (environmental) objectives are proposed to be met.
8. A register of all more detailed programmes and management plans relating to sub-basins.
9. Summaries of measures to be taken to inform and consult the public, the results, and any change of plan arising therefrom.
10. A list of competent authorities.
11. Details relating to information and public participation as well as about measures to be taken and monitoring data.

The elements 1, 2, 3 and 6 have to be sent to the European Commission in December 2004.

11 Activities abroad: ten centuries in a nutshell

For many centuries a large number of low-lying areas all over the world have been reclaimed, drained and developed by, or with the help of, Dutchmen. The historical overview in this chapter on the challenges, problems, failures and successes of land reclamation shows the involvement, creativeness and perseverance of the Dutch hydraulic engineers and many other vocational emigrants.
Today's activities reflect the great experiences of former generations. However, they simultaneously show an enlargement of the scope of e.g. the development of masterplans and the introduction of environmental impact studies as part of water and lowland development.
With gratitude the publications on this subject by J. van Veen[1] and G.P. van de Ven (ed.)[2] is referred to.

11.1 Vocational emigration and specialisms

Vocational emigration is a feature of many nations. It is defined as the emigration, temporary or permanent, of people having the same occupation with a view to practising their calling abroad. They may belong to different levels of the hierarchical organization of the vocation or profession. Emigration in the context of this publication comprises both short and long stays abroad for consulting services or construction works and permanent emigration with settlement in the new country. The reasons for emigration are varied: overpopulation, better job opportunities and living conditions in the new country, political or religious oppression, colonial expansion, longing for the unknown, and, more recently, contribution to the development co-operation or implementation of projects on a commercial basis.

As shown in previous chapters, man has transformed waterlogged and even submerged lowlands in the Netherlands into both arable lands and urban and industrial areas where surface water and groundwater levels can be controlled. This situation is not unique. Indeed, there are low-lying coastal areas all over the world which are densely populated and highly productive thanks to judicious systems of flood protection and water management. The development of some of these areas could benefit from the know-how and experience acquired in the Netherlands where reclamation started some ten centuries ago and, due to the special conditions, assumed a significance for the country as nowhere else. It is no wonder that professional emigration in the field of water and land development in the Netherlands also started early and is still continuing today.

11.2 Beginning of a large-scale emigration

It seems that the reputation of the Dutch in the field of land reclamation had established itself shortly after the beginning of works of this type in the Netherlands, which was even before Norman times (9th - 10th centuries AD). Ditches to drain the land were made before dike building began. The saga relates how a certain

1 Dredge, drain, reclaim. The art of a nation. Martinus Nijhoff Publishers, The Hague, 1962
2 Man-made Lowlands. History of water management and land reclamation in the Netherlands. Matrijs Publishers, Utrecht, 1994

Walfridus and his son, who had been great men in draining parts of the low Wapelinga, were slain by the Normans while praying. About 950 AD the Norman invasions relented and only then could land reclamation and land drainage start properly.
Already at the beginning of the 12th century, use was made of the water management knowledge of Dutchmen, especially in North Germany. It concerned the expertise to reclaim land through systematic drainage. Dutchmen had acquired this expertise with the reclamation of peat areas. The reclaimers came from the surroundings of Leiden.

The expertise consisted not only of technical knowledge, but also of the administrative organization of the free village communities. The communities with their self-rule, including water management, were capable not only of reclaiming an area by draining it, but also of maintaining the infrastructure of the water ways. In this respect, the administrative instruments of issuing by-laws and carrying out inspection were of major importance.

The first mention of the involvement of the Dutch in reclamation dates from the year 1113. The ruler-bishop of Bremen then concluded a treaty with a few Dutchmen concerning the reclamation of an area in the valley of the River Weser. This treaty is virtually identical to the ‘cope’ agreements the Count of Holland had with the reclaimers of his wilderness. The size of the homesteads and the rights and duties of the new village community were laid down. Just as in Holland, the settlers enjoyed personal freedom and they were the rightful landholders.

During the 12th century the Dutch also reclaimed large areas along the river Elbe. They were in demand as settlers, because they had the technical expertise to drain areas. The settler villages are not found along the coast, but further inland. Further upstream along the Elbe, too, there have been many reclamations following the Dutch example. Here, the Dutchmen reclaimed not only the lands in the vicinity of this river, but also more inland situated areas, such as the soggy area between Salzwedel and Stendal.

There are indications that in the 12th and 13th centuries the Dutch also reclaimed land on a large scale and according to the same methods in central East England. In the vast peat areas around The Wash, some of which still have Holland in their names, a multitude of unmistakable clues point to that direction in parcellization structures, names of fields and in historical sources.

The activities continued into the next centuries. The Dutchmen mainly moved to regions which were then in East Prussia, now the Polish territory for the greater part, and Poland. Here too, they reclaimed marshy grounds by means of ditches and canals, sluices and, later, windmills. The most important reclamations were in the mouth of the Nogat, a branch of the River Weichsel (Vistula). In the delta of the Nogat and further upstream on the Weichsel about a dozen settlements were founded by the Dutch or the Flemish in the course of the 15th and 16th centuries. More southward – in Thuringia, Saxony and Silesia – they also settled on the wet grounds along the rivers.

It can be assumed that, initially, the reclaimers settled in these regions mainly for economic reasons. In the course of the 16th century, however, there was a change as the Dutch colonists then mainly came from Baptist circles, also called anabaptists or Mennonites, according to their leader Menno Simons. This religious group was persecuted and many fled to Prussia, Poland and later to Russia. Apart from these, there were Roman Catholics who emigrated because of the changed religious climate in the Netherlands.
In the course of the 17th and 18th centuries, the Dutchmen founded many more settlements, for instance in the German Pommerania (now Poland). The agricultural reclamations are characterized by a very systematic parcellization into rectangular strips of land separated by ditches, as was customary in the Dutch peat areas, too. All this shows that these reclamations did not end around 1600, but continued beyond that century.

11.3 Appearance of the individual expert

In Western Europe the 14th and l5th centuries were periods of agricultural depression. The effects differed from country to country. In the low-lying coastal areas of the Netherlands, losses of land occurred as a result of storm surges at sea.

These losses were not or could not have been immediately recovered. Since there is no evidence for a more frequent occurrence of storm surges in these two centuries than before, the only explanation of this issue is that the economic incentives for a recovery were lacking and, indeed, low prices of cereals and high wages were characteristic for this period. The agricultural depression must have had a negative effect on the professional emigration in the field of land reclamation.

The situation changed completely around 1550 and favourable conditions prevailed until the last decades of the 17th century. The period 1550 to 1650 was an era with an unprecedented increase in population and an increase in currency amount.
The first repercussion was a rise in prices of food, in the first instance, of cereals. New forms of energy such as aeolian power (windmills) and animal tractive power (horses) acted as technological stimuli. In a number of European countries strong central governments were established, ending the feudal wars. These favourable conditions led to the reclamation of new arable lands, not only in the Netherlands, but also in Germany, France, England and Italy. The lands were often located in the vicinity of large cities and the reclamation works were undertaken by merchants.

Naturally, conditions were also favourable for emigration from the Netherlands but here, after 1550, a new participation came to the fore in the person of an individual expert who would have been called to give advice on certain matters and who, in most cases, returned to his country of origin after completing his assignment.
He was the predecessor of the modern consulting engineer but operated individually and on an ad hoc basis. The Dutch experts who went abroad in the period 1580 - 1660 to work on lowland reclamation can be considered the first ‘hydraulic engineers’ of the Netherlands: Allerts, Bradley, Van Ens, Van den Houten, Leeghwater, Meijer, Van der Pellen, Rolwagen, Vermuyden, De Wit, etc.

They worked in practically the whole of Europe. Van Veen states about their performance:
"When we read the books about their achievements we cannot help admiring their energy and courage. Even with modern means some of the works they attempted would be outstanding. Yet, most of these intrepid men died in misery. None of them grew rich. The good they achieved was for future generations, not for themselves. They were the heralds of the new and first mechanical era."

The most well-known expert from this period is Jan Adriaensz Leeghwater (1575 - 1650). He was an authority on draining lakes and marshes by pumping. The water wheels, by that time mainly paddle wheels, were driven by windmills which were installed from the beginning of the 15th century. Leeghwater called himself in the first place a windmill builder. He applied them for draining large lakes to the north of Amsterdam (see Figure 4.4) such as the Beemster (1612), Purmer (1622), Wormer (1625) and Schermer (1631).
Where the lift of the water was too high for a single windmill (i.e. more than 2 m), two or three windmills were installed in a series (see Figure 4.3), lifting the water step by step. Although most of his work was done in the Netherlands, he found time to do consulting work in the Baltic region, Denmark, England, France and Germany.
Dutch activities in Germany were mainly concentrated on Schleswig-Holstein. The duke of this area stimulated immigration of Dutchmen in the hope that they would contribute to the development of his country by their expertise and capital. Under the leadership of Jan Claeszoon Rolwagen, six polders with a total area of about 2,000 ha were reclaimed. Finally it should be mentioned that the system of dry peat cutting and the subsequent rise of the peat colonies was exported to Germany.
In 1630 the first settlement, Papenburg in East-Friesland, was founded, where peat cutting was carried out 'the Dutch way', i.e. via a system of main canals and side canals. Dutch investors, engineers and surveyors played an important role in the construction. Later they were also involved in peat cutting activities, but gradually the local population took over.

The life of Humphrey Bradley, a native of Bergen op Zoom, is not well-known. His original name may have been Braat but perhaps he anglicized it after a short stay in England, where he made reclamation proposals for the Fenlands.
In France King Henry IV was searching for ways to help his war-stricken country. Land reclamation was to play an important role. Humphrey Bradley was appointed 'maître des digues du royaume' by the king in 1599. Bradley's idea was to reclaim the French marshes with foreign capital. In the Netherlands such private enterprise was quite usual, albeit that it was the Dutch people themselves who supplied the venture capital. Bradley surrounded himself with fellow countrymen who had capital at their disposal. Just as in the Netherlands, the investors were granted a number of privileges, such as exemption from land taxes for a period of 20 years. In 1607 the 'Association pour le dessèchement des marais et lacs de France' was established, headed by Bradley.
In the framework of the 'Association' a great number of projects has been executed, initiated by people from the north and the south of the Netherlands.

In England, two major peat reclamation schemes were executed by Cornelis Vermuyden. He left for England in 1621. After having carried out some minor projects he was commissioned in 1626 by King Charles I to make Hatfield Chase, an area of 30,000 ha situated southwest of Hull, suitable for agricultural purposes. Vermuyden improved the drainage by digging a number of canals. He made a distinction between the drainage of Hatfield Chase itself and the water coming down from the surrounding higher areas, and constructed separate drainage systems. The king was deeply impressed by the achievement and knighted Vermuyden in 1629. In 1630 Vermuyden was appointed Head of the Great Level, a peat district of well over 120,000 ha, north of Cambridge, which is the southern part of the Fen District and was to be called Bedford Level later. Until 1655 Vermuyden worked there. Just as in Hatfield Chase, Vermuyden had separate canals dug for the discharge of water from the neighbouring areas and water from its own territory. The major work was the construction of the main drainage canal, the Bedford River. Drainage of the peat caused subsidence which could amount to four metres and therefore people later switched over to drainage by windmills and pumping stations. To achieve adequate drainage, Vermuyden had proposed to dig an additional discharge canal, but for financial reasons the proposal was not realized in the 17th century, which caused a lot of waterlogging. Only between 1954 and 1964 was such a cannel dug, almost entirely along the track Vermuyden had proposed in 1638. On this occasion he was recognized as a designer of genius and one of the greatest Dutch hydraulic experts.

In Italy the Dutch engineers were less successful. Gilles van der Houten was the first to be called into the service of the Holy See in 1623 by Pope Urban VIII, from whom he received the title ‘Dic maestro’.
Together with his friend and successor Nicolas Cornelis de Wit, he studied the reclamation of the Pontine marshes which had been reclaimed by the Etruscans some twenty-five centuries previously. The works fell into disuse after the third century BC and were not restored during the Roman Empire. De Wit did not succeed. After him Nicolaas van der Pellen came, but he also had to give up the work in 1659.
Then Cornelis Meijer appeared on the scene. His ideas were embodied in an illuminating essay ‘Del modo di seccare le Paludi Pontine’, but only his son could make a modest start with the actual works. These were destroyed by the local inhabitants in 1707 and it was not before the thirties of the 20th century that the Pontine marshes were definitely reclaimed.
In the 18th century Jan Pieter van Suchtelen (1751 - 1836) was active in Russia. When he was 31 years old he left for Russia where he rose to the position of general and superior engineer officer. His most impressive hydraulic plan was the construction of the Catharina Canal, started in 1786 and completed in 1822.

In the 18th century the Dutch were also active in Spain, namely in the construction of the Canal Imperial from Tudela to Saragossa. In the 1870s Krayenhoff gave technical advice on how best to construct this canal. Significant was the fact that this canal was partly financed with capital via the Dutch banker Hope. The Spanish government accepted responsibility for the project. This illustrates the shift in Dutch society at that time: whereas the merchants/entrepreneurs were very active in investing in venture enterprises in the 17th century, in the 18th century they were more cautious.

It is apparent from the above that the Dutch ‘hydraulic engineers’ were welcome guests abroad in the 17th and 18th centuries. They had the expertise which was lacking elsewhere. That several of the projects they started failed was partly due to inadequate attention to the interests of the local population, partly because technical knowledge was still not perfect and partly because the works, once constructed, were not properly maintained. This does not alter the fact that the great interest abroad in Dutch hydraulic engineers shows that in this period the Netherlands played a leading role in this field.

The depression of the period 1650 to 1750 explains the sharp decrease in the number of Dutch experts abroad shortly after 1650. Typical symptoms were: the fall in cereal prices, relatively high real wages, little activity in the field of reclamation, conversion of arable land into grassland, extension of cattle breeding, etc. The situation changed again around 1750 when an unforeseen population growth was manifested. Whereas the large-scale emigration and the settlement of ‘Hollandries’ continued, the change did not increase the activities of Dutch experts abroad. This may be partly due to the fact that, in the meantime, the countries in Western Europe had acquired their own expertise in the field of land reclamation and partly to a lack of initiatives and incitements. The Napoleonic era and the ensuing political issues would soon form another drawback. Actually it was not before 1850 that a real revival of the migration of experts started. By that time the world had changed completely.

11.4 Netherlands experts on the Asian scene

The decades around 1850 mark the transition of a predominantly agricultural to a predominantly industrial society in Western Europe. Hydraulic and agricultural engineering sciences expanded from land reclamation and drainage to damming rivers, constructing ports and water management on large and small scales. Institutions for higher technical education were established. In Indonesia, the former Netherlands East Indies, the government decided to carry out large-scale irrigation projects – the so-called ‘technical’ irrigation. This led to a demand for a staff of qualified engineers to carry out the work. Technical education in the Netherlands had to be geared to these new needs.
For this reason an ‘exotic’ element was introduced in the hydraulic and agricultural education of engineers, which has remained very fruitful to this day.

Thanks to the quality of the projects that were carried out in the Netherlands East Indies, the Dutch engineers acquired a good reputation in a new field.
Thus, Homan van der Heide, associated with the irrigation service in the Netherlands East Indies, was invited to come to Siam – the present Thailand – to give advice on the water management of the Central Plain. The main construction, proposed by him, a dam on the apex of the delta of the Chao Phraya River to control the division of the high waters, was built 50 years later on the same spot and according to the design he had proposed.
He also proposed the establishment of the Royal Thai Irrigation Department, of which, after having completed his mission, he became the first Director-General.

Another example of broadening the scope of activities of the Dutch engineers is the lengthy stay (4 to 10 years) from 1872 onward of a group of engineers and

Figure 11.1 Enclosing Dam, Kojima Bay, Japan

skilled labourers in Japan, shortly after the reinstatement of the Meiji dynasty.
The engineers Van Doorn, De Rijke, Lindo, Rouwenhorst Mulder, Escher and Thissen worked in the fields of port construction, river improvement, the construction of irrigation canals and coastal land reclamation. In Japan coastal land reclamation was an age-old method to expand the acreage of cultivable land. Until the reinstatement of the Meiji dynasty, Japan had developed its own technology, independent of the developments in Western Europe. Rouwenhorst Mulder (1848 - 1901) studied the coastal land reclamations in the Kojima Bay near Okayama, where in the 17th - 19th centuries, alluvial land at the coast had been reclaimed from the sea. He proposed to complete the reclamation by making three polders. He did not propose to build an enclosing dam with a fresh-water reservoir. This element was added much later, in the early 1950s (Figure 11.1).

The services of the Dutch engineers proved to be important for the development of hydraulic engineering in Japan and the Japanese were very grateful. They erected a statue for Van Doorn, who had designed the irrigation works in the prefecture of Fuhushima.

His statue looks out on Inawashiro Lake, which he used for water supply by means of a tunnel. The bronze statue was saved during the Second World War, when farmers hid it in the ground. In remembrance of the works by Escher and De Rijke, to improve the discharge capacity of the River Kiso (near Nagoya), a small temple was built at the mouth of this river.

Some of the engineers mentioned earlier were also active in China (De Rijke and Escher), especially in the field of river control. They were succeeded by engineers such as Nijhoff, Boudrez, Van der Veen and Visser, who all had to face the huge problems of the Yellow River. Another name that should be mentioned is Van den Heuvel, who set up the hydraulic laboratory in Nanjing, still the leading institute of the People's Republic of China.

11.5 Modern times

The drastic changes in the economic and social circumstances all over the world following the Second World War had consequences for the vocational emigration of Dutch experts in the field of water management and land reclamation. The geographical field of activities was no longer restricted to Asia, but spread to Africa, South and Central America and southern Europe. Hundreds of senior and

junior experts, including many who had worked in the former Netherlands East Indies, were given the opportunity to apply their know-how and to gain expertise. They stayed abroad for periods varying from a few weeks to several years.
The rapid development of a number of industrialized countries and the need to offer help to an even larger number of less developed countries, caused a boom of technical activities abroad. United Nations organizations, such as the FAO, UNESCO and WMO, and other international organizations, such as the World Bank and the Asian Development Bank, were looking for experts to staff their land and water projects.
In the framework of the development co-operation the Ministry of Foreign Affairs started to support many projects in countries such as Bangladesh, Colombia, Egypt, India, Indonesia, Kenya, Nigeria, Pakistan and Yemen.
Dutch consulting firms entered increasingly the international market. In competing with foreign firms, these firms had limited experience in multidisciplinary projects.

Tellegen, a consulting engineer himself, persuaded a number of Dutch consulting firms to cooperate in Nedeco – Netherlands Engineering Consultants, which was to be a coordinating body. This organization could recruit experts, not only from the participating consulting firms, but, thanks to the support of the central government, also from the official services and universities. In this way use could be made of the entire intellectual potential of the country and experts could be selected according to the specific character of the project. This formula turned out to be a very successful one and although the participating consulting firms acquired expertise that could measure up to foreign firms, the organization still exists and has gained an international reputation. Nowadays the larger consulting firms have developed various associations with local consulting firms in relevant countries. Partly they were forced to do this due to the requirements of the local governments, partly they did it for economic reasons as various tasks in the framework of a project can, of course, be implemented by local staff. For individual projects all kinds of ad hoc agreements are made during the tendering process, either with local consulting firms, or with other enterprises that are active on the international market.
As a more recent development, manufacturers of all kinds of hydraulic equipment and dredging contractors entered the international market. Until the beginning of this century, there was only a limited export of such products or services. This may be partly due to the larger projects in the Netherlands, like the Zuiderzee Project, the Delta Project in the south-west of the Netherlands, large-scale dredging activities in the mouth of the River Rhine, and the operation and maintenance activities in the small and large water courses and polder areas. The companies obtained special skills and developed specialized equipment, that could be exported. Partly these skills and equipment were also developed during overseas projects. Most if not all of these services have to be offered in processes of international tendering. Regarding equipment mention can be made of pumps, lifting devices and pumping stations, subsurface drainage machinery, maintenance equipment for open water courses, dredging equipment, geotextiles, canal lining and all kind of weirs and culverts. The contractors are mainly operating in the larger harbour construction and dredging projects; some of them, however, are also involved in the construction of land reclamation projects.

Figure 11.2 Hachiro Gata drainage sluices

Figure 11.3 Seashore reclamation in the Republic of Korea

Before giving a brief review of modern land and water development projects in which Dutch experts have been, or are involved, one project in Japan will be highlighted, because of its distinct 'Dutch aspects' and the traditional relations. It is the reclamation and cultivation of a lagoon, Hachiro Gata, in the northwest of Honshu with a size of about 23 000 ha (Figure 10.2).
The then prime minister of Japan, H.E. Shigeru Yoshida, who had visited the works in the bay of Kojima, mentioned before, and had been shown Rouwenhorst Mulder's designs, insisted on calling in Dutch experts once more (1954). Consequently, in the years 1956 and 1957, a joint project was carried out by Japanese engineers of the Ministry of Agriculture and Forestry and a group of Dutch engineers, Jansen and Volker of the Rijkswaterstaat.
Essential elements are the fresh-water reservoir for additional irrigation and a wide collecting and transport canal along the east coast for the discharge of water and for the prevention of drops in the groundwater level in the neighbouring areas. The surface level in the central polder is more than 4 m below m.s.l. (mean sea level) and so the area must be drained with pumping stations.
The project was completed successfully and, in keeping with Japanese tradition, a monument and a memorial stone were erected to commemorate the contribution of the Dutch engineers.

Although full responsibility for a certain overseas land and water development project is not so likely anymore, while most projects are executed under the responsibility of the local government, maybe with financial support of a bilateral, or multilateral donor, various Netherlands companies have played, or play an important role in such projects. To include all projects would result in a very long list. Therefore, only some of the more interesting ones are mentioned.

Figure 11.4 Oil production and subsidence in Venezuela

Coastal reclamation projects:

- seashore reclamation in the Republic of Korea;
  coastal protection and reclamation of about 300,000 ha, mainly for rice production, but in the newer projects also for urban and industrial development (Figure 10.3);
- tidal lowland development projects in Indonesia;
  reclamation and development of about 1 million ha tidal lowland for small-scale agriculture;
- coastal urban or industrial reclamation projects in Indonesia, Malaysia and Thailand;
- landfill for the new airport of Hong Kong.

Development of masterplans

For river catchments, or certain urban or rural areas, masterplans on the integrated development of water management have been made.
Some examples are:

- the deltas of various rivers, like the Danube in Romania, the Mekong River in Thailand, the Yangtze River in China;
- regions, mainly focusing on irrigation development, such as water resources development planning per district in Kenya, and per catchment in the Republic of Yemen;
- polder areas, like the Bolivar Coast polders in Venezuela. Coastal protection and polder development in an area 120 000 ha along the east coast of Lake Maracaibo, where the major part of Venezuela's oil production comes from. Due to the extraction of oil the total subsidence in the area may be up to 10 m (Figure 10.4);
- cities, such as Bangkok and Jakarta.

Drinking water supply and sanitation projects:

Various drinking water supply and sanitation projects in both rural and urban areas. Also in the framework of these projects, studies are executed related to water resources development, social and environmental implications.

Environmental impact studies:

In the framework of almost all the land reclamation projects, nowadays an environmental impact analysis is required by the bilateral or multilateral donors. Many of such studies are made by Netherlands consulting firms and institutes.

Irrigation and drainage projects:

Involvement in these projects mainly refers to consultancy work and hydraulic studies. However, all kinds of equipment that is applied in such projects is also exported. Mention can be made of pumps and pumping stations, weirs, culverts, and all kinds of control equipment. Larger projects with Netherlands involvement are:
- large-scale subsurface drainage projects in Egypt, Iraq and Pakistan;
- large-scale irrigation projects in Egypt, India, Indonesia and Pakistan.

Dredging projects:

Netherlands dredging contractors are leading the international dredging market and are involved in various large-scale dredging projects in harbours, rivers, tidal inlets, canals, reservoirs, etc. In addition, Netherlands manufacturers have developed all kinds of special dredging equipment, both for large-scale dredging under difficult conditions, and for small-scale specialized dredging.

As in the Netherlands, almost all over the world pollution of surface water and groundwater resources is a problem of increasing importance. Various programmes have been developed and implemented to control future pollution and to clean polluted land and water areas. These experiences add a complete new field of science to land and water development, including aspects of wastewater treatment, specialized dredging methods, design and construction of disposal sites for polluted soil or sludge, and reuse of polluted material.

The Netherlands Water Partnership

Today all these developments can be applied on a worldwide scale via the ‘Global Water Partnership’. The Global Water Partnership aims to realize the principles for water and environment, as endorsed at the conferences in Dublin and Rio de Janeiro, by building a network for sustainable water resources management.
For an effective contribution of the Netherlands to that network, representatives of the government, the business community, knowledge institutions and civil society organizations founded the Netherlands Water Partnership (NWP). The mission of the NWP is to stimulate Dutch contributions and promote Dutch interests in the international water community. The NWP aims to span the bridge between the stimulation of export of Dutch know-how and sustainable development and better international water policy. This aim is translated by strengthening the co-operation between the NWP-partners and the representation of the Netherlands in international fora so that the Dutch capacity can be used optimally.

12 Education and research organizations

In the past the transfer of knowledge and skills in the fields of flood protection and water management took place in practice. Elder, experienced engineers trained the younger generation. In 1842 the Government started the education for civil engineering in Delft, concentrated on all water issues. Later, other institutions began to educate in and study specific water aspects.

12.1 Education

The education of professional hydrologists has existed in the Netherlands for more than 50 years. Until the 1960s the subject of hydrology was included mainly in courses on hydraulic engineering and water management to sustain land and water use by drainage and irrigation, to reclaim land, to supply water for drinking water production and to make use of hydropower.
In the framework of the European education policy of simplifying educational qualifications, ensuring the qualification standards and improving the mobility of students and academic staff, the Netherlands introduced the bachelor/master system in 2000. Subjects such as hydrology of surface water and groundwater, water management, and sanitary and hydraulic engineering are being taught as individual subjects comprising general introductions and some lectures on main topics in the bachelor phase. Students can choose hydrology and related topics during the last one or two years of their education as the main fulfilment of the requirements for a master's degree. Their main programmes are civil engineering (Delft University of Technology), agriculture (University of Wageningen) and geology (Free University of Amsterdam). In all three cases most elements of hydrology are studied, but there is a certain emphasis on groundwater and surface water hydrology at Delft, on agrohydrology at Wageningen and on hydrogeology at Amsterdam. Certain hydrological aspects can also be studied at other universities e.g. Utrecht and Groningen (Departments of Physical Geography) and Twente (Department of Process Dynamics and Environmental Control).

The advantage of this approach is that hydrology and water management can be placed in the perspective of practical applications in large fields of economic development and environmental quality. At bachelor degree level, hydrology and water (resources) management is part of the lecture programme of many courses in civil engineering and agriculture. A disadvantage of this study system of hydrology as a specialization within a major branch is that the students cannot study hydrology full-time.
The Dutch universities co-operate with many universities in the countries of the European Union in the framework of the Socrates Programme (staff and student exchange) and the European Thematic Network of Education and Training for Water. The EU programme Phare/Tempus provides co-operation with universities of Central and Eastern Europe.

In the Netherlands various courses are being provided for foreign experts. There are international postgraduate courses lasting eleven months focusing on, among others, hydrology, hydraulic engineering and land and water development. Qualified participants may follow Master of Science and PhD programmes.

The courses are organized by the International Institute for Infrastructural, Hydraulic and Environmental Engineering (IHE) in Delft; since 2001 the UNESCO-IHE Institute for Water Education. UNESCO-IHE envisages a world in which people manage their water and environmental resources in a sustainable manner, and in which all sectors of society, particularly the poor, can enjoy the benefits of basic services.
Besides these, there are several postgraduate courses at Wageningen University, the International Institute for Land Reclamation and Improvement (ILRI) in Wageningen and the International Institute for Geo-Information and and Earth Observation (ITC) in Enschede. ILRI aims to disseminate knowledge improving and facilitating sustainable management of land and water in developing countries. The ITC mission is capacity building and institutional development on survey, specifically in countries that are economically and/or technologically less developed.
As a contribution to capacity building programmes of multilateral and bilateral donors, more and more projects are implemented, where institutes or universities in developing countries are supported with the development of curricula of courses at various levels and with the set up of research programmes.
Also in the framework of research and implementation projects, training components become more and more an integrated part of the projects.

The increasing population on this globe concentrates in river and coastal zone areas. More interests than ever before place specific requirements on water resources. Technological developments can provide tools to measure, calculate and manage the water systems. Today mathematical models can assess the various impacts on the supply possibilities of the water systems concerned. Transfer of knowledge and experience was and is an important issue in this country. Therefore, the Water branch of the Delft Interdisciplinary Research Centres, DIOC-Water, studies the behaviour of natural or manmade water systems along three themes:
- surface water systems: rivers, lakes, estuaries, coasts, lagoons, shelf seas;
- dirigible water systems: collecting systems such as river basins and sewer networks, and distributing systems, such as polders and irrigation works; and
- groundwater systems.

12.2 Research organizations

In the Netherlands a great number of institutes, university departments, services and other organizations are active in the field of hydrology and water management research. Due to the great diversity of organizations, co-ordination of the research activities is considered essential.

Initially the TNO Committee on Hydrological Research (CHO-TNO) brought together the main research organizations and water management authorities at national, provincial and regional levels. In the period 1946 - 1993 CHO-TNO fostered co-ordination and co-operation in the field of hydrology and water management considerably and facilitated the transfer of research results and exchange of information.
Many reports containing results of hydrological research were published in the series Proceedings and Information of the CHO-TNO.
CHO-TNO's role of promoting co-ordination and co-operation has been gradually taken over by research institutions involved in the same research programmes

and projects. Further, exchange of information occurs incidentally and is mostly focused on timely items from the viewpoint of science, management and/or policy. In this respect a number of scientific and technical associations with an individual membership, such as the Netherlands Hydrological Society, play an increasing role. In Annex 1 a selection of the institutions and associations is presented. Since some decades two national Research Councils have been dealing with the demands and opportunities of research in the medium and long terms, concerning, among other things, rural areas and the environment, thus including water issues. At present, the National Council for Agricultural Research (NRLO) is carrying out foresight studies to explore social, scientific and technological changes over the next fifteen to twenty years which may affect developments in agribusiness, rural areas and fisheries. Possible new dilemmas, challenges and opportunities are explored. The Advisory Council for Research on Nature and Environment (RMNO) is focusing on matters concerning the environment, nature research, and sustainable development once every four years, leading to a Long Term Perspective on strategic research.

For more than twenty years, the water boards, provinces and the Ministry of Transport, Public Works and Water Management have channelled research of joint interest through the Foundation for Applied Water Research (acronym in Dutch STOWA). The general objective of STOWA is to carry out applied research for the benefit of all water management authorities in the Netherlands. It tries to achieve this goal by investigations in the fields of groundwater and surface water, collection, transport and treatment of wastewater, and flood defence. STOWA offers central services, collects and distributes information and knowledge in these fields.

Recently Delft Cluster was created in the framework of the Interdepartmental Commission for the Economic Structure (ICES). ICES aims to develop an integrated scientific programme to support infrastructural developments in the Netherlands and abroad. Delft Cluster is a scientific co-operation of a number of Dutch institutes, notably Delft University of Technology, WL|delft hydraulics, Geo-Delft, TNO (Applied Geosciences), IHE and KIWA (research arm of the drinking water companies). These institutes obtained considerable financial support from the Government in the framework of ICES. The topics of Delft Cluster are seamlessly related to the themes of the DIOC-Water and concern:
1. Subsoil and constructions
2. Flooding risks
3. Sustainable development of coastal areas
4. Urban infrastructure
5. Soil management
6. Integrated water management
7. Knowledge base management.

Alterra is the research institute for the green living environment. It investigates flora and fauna in relation to water, soil, man and society using geo-information and remote sensing, and landscape and spatial planning. Alterra is part of the Wageningen University and Research Centre concern. The university focuses on processes in soil, water, air and ecosystems that involve nutrients, environmental pollutants and greenhouse gases, as well as the conservation of water, soil and genetic resources.

13 Trends in research

During the last ten years there has been an evident shift in Netherlands hydrological and water-related research. This chapter describes the important trends over a longer period and pays special attention to the recent changes.

13.1 Netherlands situation

In the Netherlands the topographical situation and the intensive use of land and water are major factors determining the nature and extent of Dutch hydrological research. Naturally most important has been the continuous struggle against the sea and rivers, the reclamation of land, the drainage of areas with high groundwater levels and the demands for adequate water supply. These challenges have resulted in developing a comprehensive expertise of Netherlands engineers in the fields of hydraulic engineering and hydrology. As in some other countries, the systematic study of hydrology in the Netherlands started in the second half of the nineteenth century. Earlier, only occasional studies of specific aspects of the hydrological cycle had been undertaken. The flat Netherlands countryside with its very high groundwater tables and extensive aquifers has stimulated research in groundwater problems. In contrast, the study of our surface waters has been concentrated mainly in the hydraulics of water and sediment movement in open channels. Much research has been associated with large-scale engineering works such as the canalization of the Rhine, the reclamation of the former Zuiderzee (now Lake IJssel) and the Delta Works. Dutch engineers gained an international reputation for their high standard of hydraulic engineering and also the physical and mathematical modelling of tidal and inland waterway systems. At present foreign experts like to learn about the Dutch day-to-day and asset management experiences. This expertise is available e.g. through the Netherlands Partnership for Water.

Up to the mid-1980s, most hydrological research fell into one of three main categories: water supply, agriculture and environmental quality. Now and in the years to come, many questions within these categories still have to be solved and are subject to research. The same applies to urban hydrology, a rather new branch of the hydrological sciences. These four categories will be briefly discussed in this chapter.

Hydrology faces new and challenging problems. Due to the increase in the world population and strong industrial expansion, the need for water will grow. The relationship between hydrology and environmental quality, will be stronger in the future. It will be increasingly difficult to fulfil the demands for water of good quality and, at the same time, the problems of sanitation and disposal of (solid) waste will demand continual attention. With respect to this, studies on sustainable development of water and the environment and the relationship between the environment and physical planning are of utmost interest: hydrologists have important contributions to make to these studies.
They will face new challenges in their field of expertise. They will have to contribute to studies concerning new subjects such as the recycling of wastewater and new water saving techniques. The ongoing studies on the hydrological consequences of climate changes will be increasingly important. The effects of the hydrological cycle on regional and global scales will be subjects of research.

Due to the expansion of modern society, living conditions will change. However, the people of the Netherlands have been convinced more and more that it is crucial to maintain the natural environment as much as possible. Therefore water management tools also have to be focused on minimizing the damaging environmental effects. The accurate description and analysis of the hydrological system and processes and the development of new models will remain important tools for recognizing new problems in time and contributing to their solution. With respect to this there is the need for continuing attention to monitor the hydrological cycle. The ongoing improvement of measuring devices and methods is necessary and the use of Geographical Information Systems is essential.
In 1985 the Ministry of Transport, Public Works and Water Management published a memorandum, named "Living with Water", which can be considered as presenting a fundamental change in the ideas on water policy and water management.
The memorandum introduces a new approach to the role and functions of the national water systems as part of the physical environment, and to the need to integrate water management measures depending on various interests. In 1989 the strategy for integrated water management, based on the water system approach, was presented in the Third Policy Document on Water. In order to make this strategy operational, new outlines for water-related research were formulated, with a broader scope than before, in the field of hydrology and hydraulics as well as ecology, soil science, economics, technology and legislation. The Fourth Policy Document on Water published in 1997 and the Water Management Policy in the 21st Century adopted in 2001 confirmed, strengthened and expanded this approach.

From the ecological point of view, there is a need to deepen the knowledge on ecological relationships in (regional) surface fresh waters, for the use of integrated water management, nature development and nature management. In this respect the following trends for the Netherlands fresh-water research should be mentioned: ecological description of the actual and target situation of the surface waters, development of methods to monitor and evaluate changes in water quantity and quality, development of methods and models that relate management measures to ecological changes.

It looks strange that in a wet country such as the Netherlands, its population is facing the problematic situation that in the long term, the availability of sufficient water of good quality may not be ensured to meet the demands of drinking water supply, nature reserves, agriculture and horticulture. A further harmonization of national and regional water management is needed. This situation has led to various scenarios with options for different conflicting (spatial) interests and their hydrological consequences. Such research is still in progress, as are studies to increase the knowledge on soil moisture processes, desired groundwater levels and quality, and water demands of agriculture, nature reserves and forests. Reference is also made to current development of modelling tools for sustainable water management. Furthermore supporting studies on regional water management plans are necessary. Policy makers and managers of water resources show increasing interest in using these results. Such activities may reflect on agriculture, which may benefit from the groundwater levels in nature reserves.

Another trend, which needs attention, is the increasing importance of the international dimension in hydrological and water-related research. This development is the result of various activities, such as river basin hydrology (Commission for Hydrology in the Rhine-basin, CHR), international programmes on global or regional hydrological problems (the International Hydrological Programme – IHP of UNESCO, the Hydrology and Water Resources Programme of WMO, the International Geosphere-Biosphere Programme of ICSU, and the Environment Programme of EU); international strategies in physical planning, water policy, environmental or nature policy (European Ecological Network – EECONET), a coherent network of sustainable ecosystems, e.g. the wetlands, that are of international importance; and bilateral co-operation between universities and institutes.
For the coming years the following items will have high priority: sustainable water systems, water quantity and quality at river basin level, flood protection, water policy and management of cities, groundwater at risk, water scarcity, climate change and its hydrological consequences, ecohydrology, and hydraulic engineering projects.

13.2 Hydrological research and water supply

The first Netherlands public water supply company was set up in Amsterdam in 1853. It derived its water from the North Sea dunes by extraction of groundwater. Little was known at that time about groundwater hydrology and it was in the early 1850s that the first systematic investigation of groundwater flow in the Netherlands was performed. From that date geohydrological research and investigations kept pace with the development of groundwater resources. Throughout the years the potential for groundwater withdrawal has been studied extensively at local and regional scales. For many decades the classical approach was followed: geohydrological mapping, water balance studies and pumping tests. In later years simulation models were introduced and proved to be very useful extensions of the scientific tools available for the hydrologist. The development of these models began in 1940 with the introduction of physical analogue models, followed in 1970 by more powerful mathematical models. Special interest continues in the salt-water intrusion from the sea and the swelling of brackish groundwater bodies. From the investigations in the 1850s to the present day, research has been carried out in the dune areas, not only into the salt water - fresh water transient zone, but especially into the movements of this zone due to natural circumstances and human activities. Research in this field has focused on improving the mathematical modelling of groundwater flow which incorporates changes in the density of water. The salt-water intrusion caused by groundwater abstraction has been the first limiting factor in the exploitation of fresh groundwater bodies in the Netherlands. In the 1930s it was decided that mining of the fresh groundwater in the dunes should be carried out. This led in 1940 to the introduction of artificial recharge with surface water. In the following years this method proved to be successful from the point of view of water supply. From about 1970, however, it became evident from field observations that large-scale artificial recharge operations could have a serious impact on the natural vegetation and fauna of the dunes due to changes in the groundwater regime and the groundwater quality. This has led to a comprehensive research programme to evaluate the feasibility of artificial recharge by means of wells instead of canals or lakes. It is expected that such a method, if properly implemented, will have less environmental impact. Although over most of the Netherlands the geohydrological

situation is favourable for groundwater extraction on a large scale, in practice there are substantial limitations caused by the undesirable environmental impacts. In particular, the negative effects on agriculture and the natural environment became evident in several areas. Therefore hydrological research was intensified on the relationship between groundwater, soil moisture and evapotranspiration. This has resulted in a set of methods to calculate the effect on crop yield, ranging from simple graphical relations to very complex and sophisticated numerical models. Progress has been made with respect to determining the impact on the natural environment at the level of species or ecosystems.
Another research topic is the relationship between groundwater withdrawal and surface water. This is important when dealing with the exploitation of groundwater near the banks of large polluted rivers, such as the Rhine. In these situations the configuration of wells is critical in providing adequate travel times of water between surface water recharge locations and groundwater abstraction points. A second area of interest is the impact of groundwater withdrawal on the surface water regime, where, in the case of small water courses, it is important to study the impact on the ecosystem and landscape.

In a densely populated and highly industrialized country such as the Netherlands there are many human activities which hold a (potential) threat for soil and groundwater pollution. Hydrologists are becoming increasingly involved in the search for solutions of this environmental problem. Specific research topics, directly related to water supply, include identifying protection zones around the well field based on flow patterns and the vulnerability of the groundwater system in these zones.
About one third of the yearly amount of drinking water distributed by the Netherlands water supply companies is withdrawn from surface water, particularly from branches of the rivers Rhine and Meuse. The need for related hydrological research, however, is small. Both river discharges and water quality are comprehensively monitored and evaluated in the framework of the Dutch water management system.

13.3 Hydrological research and agriculture

Before 1950, from a scientific point of view, there was only little progress in hydrological research related to agriculture, although there was always a keen, practically orientated interest in drainage problems of agricultural land.
From 1950 agricultural research has developed rapidly. The necessary impulse came from the need for large-scale improvements and intensification in agriculture to achieve higher crop yields. Research in this area covers a broad scientific spectrum, in which hydrology and soil physics play important roles. For many years the study of evapotranspiration or, more generally, the study of water flow in the soil-plant-atmosphere system has been a major subject in agricultural research.
As a starting point one may consider the water balance study of the Rottegatspolder (1947 - 1952). This was the first experimental hydrological basin in the Netherlands, although it was a typical Netherlands polder area and not a natural river basin.
After a period of lysimeter studies in the 1950s, theoretically-based physical mathematical concepts for water transport in the soil-plant-atmosphere system showed a new dimension to evapotranspiration research from 1960 onwards. These concepts were based partly on research abroad and partly on original work of Dutch hydrologists and meteorologists. The introduction of the personal

computer in the early 1970s was a major improvement in the operational value of theoretical concepts. Extensive monitoring of experimental basins also supplied data for calibration and verification of numerical models simulating soil moisture flow, evapotranspiration and crop growth, and for calculation of the water demand of crops.

This research has led to the development of a wide range of techniques and a high level of expertise. As a result of the socio-economic aspects of agriculture one may anticipate further research in this field in the near future. Reference must also be made to the use of remote sensing techniques in establishing the variation in soil physical and hydrological field conditions. Based on airborne reconnaissance it has been possible to draw an areal map of actual evapotranspiration, thus providing a new potential water management tool.
In the greater part of the Netherlands the groundwater level is near the surface and, consequently, influences the soil moisture conditions in the root zone. This explains the continuous research effort in the field of agricultural water management. Initially research was carried out almost exclusively for the improvement of land drainage to improve soil structure and allow heavy farm machinery in the field. From the late 1960s attention has focused on the conservation of water in dry periods by the control of surface water levels and on additional supplies of surface water. In the extreme dry year of 1976 it became clear that, in some areas, a substantial deficit could occur between the water demand of the crop and the actual available water in the root zone. Current research in this field is carried out within a framework of a system approach to water management problems at a regional scale.

Such problems arise from the conflicting interests of agriculture, drinking water supply and environmental protection (including natural conservation) and also from the economic feasibility of technical solutions. Specific problems include the impact of groundwater resources development on crop yield, the environmental impact of the (excessive) use of fertilizers and manure on water quality and the large-scale use of groundwater for irrigation of farmland. The solution to these problems will undoubtedly influence the research of Netherlands hydrologists for some time to come.

13.4 Hydrological research and environmental quality

Several environmental problems, identified in the 1960s and 1970s, are determining the hydrological research in the 1980s and 1990s. Some of these problems originated from changes in the hydrological regime as a result of human activities and have been described earlier. Another group of problems is related to the pollution of soil and water by waste disposal and some forms of land use. Large-scale drainage and groundwater exploitation have led to substantial changes in the groundwater regime in some areas and in the soil moisture conditions. This has consequences not only for the crop yield, but also for the natural environment. However, in contrast with the estimation of agricultural impact, research has not led to the development of operational methods for the quantitative assessment of the effects on natural vegetation, fauna and ecosystems. Much research will be needed in this complex area particularly in the development of quantitative relationships between changes in the hydrological regime and the effects on the environment. Another important research topic for Dutch hydrologists in the coming years will probably be the impact on hydrology and water management of an increasing carbon dioxide concentration in the atmosphere. This may lead to a change of climate but also to rapid rise of the sea level, a factor which causes much concern to the people living 'behind the dikes'. The climate change may also have repercussions for the precipitation patterns, with consequences for flood protection along the rivers and basic level water management. The pollution of surface waters is another environmental issue, which has contributed to a new dimension in hydrological research in the Netherlands. In the 1960s the unwanted environmental effects of the growing population and the industrial expansion in the basins of the Rhine and Meuse became evident. A major concern for the future of the public water supply and the aquatic ecosystems led to a comprehensive monitoring and research programme. Much effort was put into the development of water quality models, thereby building on the extensive knowledge of the hydraulics of Netherlands rivers, lakes and estuaries.

This research has resulted in a wide range of operational models and other methods used in water quality management. During the 1970s it became clear that groundwater quality was gradually deteriorating, not only as a result of local point sources, but also at a more regional scale from various diffuse sources. Groundwater in the Netherlands appeared to be more vulnerable than was previously thought. This awareness gave a strong impulse to hydrological research, and soil and groundwater quality problems will continue to direct research programmes in the coming years. At first research focused especially on pollution by point sources such as waste disposal and oil spillage. After the discovery of some severe cases of soil pollution in urban areas, hydrologists, together with soil scientists and chemists, became involved in clean-up operations developing a new field of expertise. Nowadays there is also a special interest in more diffuse sources of pollution, including the use of fertilizers, manure and pesticides in agriculture, and the effects of acidification. In this field the Dutch hydrologists have to work together with fellow scientists and engineers from other disciplines. Their particular contribution deals with the transport of nutrients and (toxic) pollutants in the saturated and unsaturated zones. In this respect new methods for field investigations have been developed, along with groundwater quality models. Furthermore continuous attention is given to spatial and temporal variability, and to the extrapolation of point-values into area-values. This concerns various pollutants, soil characteristics and hydrological conditions.

This research is not only related to the assessment of the nature and extent of pollution in the field, but is also connected with the prevention of pollution, including the development of methods for the safe disposal of hazardous waste. Recently – in 1993 and 1995 – the Netherlands was facing the problem of high floods in our main rivers, the Rhine and Meuse. This led to the evacuation in 1995 of 250,000 people in the endangered areas. A research challenge will be the determination and prediction of the discharges in the main rivers on a more physical base. It is a common challenge for the Rhine and Meuse countries.

13.5 Urban hydrology

Netherlands hydrologists, as well as hydraulics experts, have been involved for many decades in the water management of urban areas. The acquired knowledge and experience were successfully applied in the development of new towns, especially in the reclaimed polders in the former Zuiderzee. Nevertheless, urban hydrology in the Netherlands has been recognized only recently as a branch of hydrological sciences in its own right. Today's research topics include the relationship between precipitation and drainage, the environmental aspects of sewerage systems, the functions of open waters in urban areas and the control of surface water and groundwater levels. Most sewers in the Netherlands are of the combined type, although the number of separate sewerage systems is steadily increasing. Since water quality became an important issue, the acceptability of an overflow structure in a combined sewerage system has been assessed on the basis of its overflow frequency. If the frequency exceeds the standard, generally in-pipe storage is increased. For flat areas, typical for most parts of the Netherlands, this approach indeed reduces the overflow frequency. However, no attention has been paid to the receiving water. Large eutrophic water bodies can stand more polluted discharge than small oligotrophic waters. In practice most overflow structures discharge into small, semi-stagnant and stagnant waters, which are highly vulnerable. Considerable progress has been made to assess the effects of overflows, both in physical-chemical and ecological ways, to provide the basis for new standards. Research in rainfall-runoff modelling is necessary to optimize sewer design by including surface and sewer routing terms and precipitation losses due to infiltration in paved surfaces. Furthermore, research is in progress on sewer quality processes to establish a better understanding of the accumulation, mineralization and re-suspension of the sewer sludge, which take place due to the small gradients of the sewer pipes.

Besides the above mentioned items dealing mostly with a technological approach to urban hydrological problems, two recent developments deserve our attention. Firstly, integrated water management is being introduced within urban areas, with the aim of relating quantitative and qualitative aspects of surface water and groundwater to each other (internal coherence). Moreover, urban water policy and management are being related to questions concerning physical planning and the environment of adjacent rural areas (external coherence). Secondly, strategies are being developed for ecologically sound urban development ('Ecopolis-strategy'). Water is only one of the 'flows', besides energy, waste and traffic. Water also fulfils a crucial role within the urban landscape and the spatial policy of cities (built-up and open areas). Furthermore, citizens' involvement is needed in the management of their daily environment, including various aspects of water. In the coming years, research efforts will be directed to the operational side of these strategies by means of interdisciplinary studies.

Appendix

Useful addresses

Ministries

Ministry of Transport, Public Works and Water Management
Directorate-General Water
Directorate-General Public Works and Water Managment
PO Box 20906
2500 EX The Hague – NL
www.minvenw.nl

Ministry of Agriculture, Nature Management and Food Quality
PO Box 20401
2500 EK The Hague – NL
www.minlnv.nl

Ministry of Economic Affairs
PO Box 20101
2500 EC The Hague – NL
www.ez.nl

Ministry of Spatial Planning, Housing and the Environment
PO Box 20951
2500 EZ The Hague – NL
www.minvrom.nl

Ministry of Foreign Affairs
PO Box 20061
2500 EB The Hague – NL
www.minbuza.nl

Ministry of Education, Culture and Science
PO Box 16395
2500 BJ The Hague – NL
www.minocw.nl

Provinces

Association of Province Councils (IPO)
PO Box 16107
2509 BC The Hague – NL
www.ipo.nl

Water Boards

Union of Water Boards
PO Box 93218
2509 AE The Hague – NL
www.uvw.nl

Municipalities
Association of Netherlands Municipalities (VNG)
PO Box 30435
2500 GK The Hague – NL
www.vng.nl

Water related institutions
Rijkswaterstaat, Institute for Inland Water Management and
Waste Water Treatment (RIZA)
PO Box 17
8200 AA Lelystad – NL
www.riza.nl

Rijkswaterstaat, National Institute for Coastal and Marine Management (RIKZ)
PO Box 20907
2500 EX The Hague – NL
www.rikz.nl

Royal Netherlands Meteorological Institute (KNMI)
PO Box 201
3730 AE De Bilt – NL
www.knmi.nl

Foundation for Applied Water Research (STOWA)
PO Box 8090
3503 RB Utrecht – NL
www.stowa.nl

Netherlands Water Partnership
P.O. Box 3015
2601 DA Delft – NL
www.nwp.nl

National Institute of Public Health and the Environment (RIVM)
PO Box 1
3720 BA Bilthoven – NL
www.rivm.nl

Alterra, the Green Research Institute
PO Box 47
6700 AA Wageningen – NL
www.alterra.nl

Netherlands Institute of Applied Geoscience TNO – *National Geological Survey*
PO Box 80015
3508 TA Utecht – NL
www.nitg.tno.nl

GeoDelft
PO Box 69
2600 AB Delft – NL
www.geodelft.com

WL|delft hydraulics
PO Box 177
2600 MH Delft – NL
www.wldelft.nl

Netherlands Waterworks Association (VEWIN)
PO Box 1019
2280 CA Rijswijk – NL
www.vewin.nl

KIWA Water Research
PO Box 1072
3430 BB Nieuwegein – NL
www.kiwa.nl

Government Service for Land and Water Use
PO Box 20021
3502 LA Utrecht – NL
www.minlnv.nl/dlg

Universities / International Courses
Delft University of Technology
Faculty of Civil Engineering and Geosciences
PO Box 5048
2600 GA Delft – NL
www.tudelft.nl

Wageningen University
Water Resources Department
PO Box 9101
6700 HB Wageningen – NL
www.wur.nl

Free University of Amsterdam
Institute of Earth Sciences
De Boelelaan 1085–1087
1081 HV Amsterdam – NL
www.vu.nl

University of Utrecht
Faculty of Geosciences
PO Box 80000
3508 TA Utrecht – NL
www.geo.uu.nl

IRC International Water and Sanitation Centre
PO Box 2869
2601 CW Delft – NL
www.irc.nl

UNESCO-IHE
Institute for Water Education
PO Box 3015
2601 DA Delft – NL
www.ihe.nl

International Institute for Geo-Information and Earth Observation (ITC)
PO Box 6
7500 AA Enschede – NL
www.itc.nl

International Institute for Land Reclamation and Improvement (ILRI)
PO Box 47
6700 AA Wageningen – NL
www.ilri.nl

Consultants
Netherlands Engineering Consultants (NEDECO)
PO Box 90413
2509 LK The Hague – NL
www.nedeco.nl

Secretariats of Dutch Associations
Netherlands Hydrological Society (NHV)
c.o. Netherlands Institute of Applied Geoscience TNO – *National Geological Survey*
PO Box 80015
3508 TA Utrecht – NL
www.nitg.tno.nl

Royal Institution of Engineers in the Netherlands (KIVI)
Division for Water Management
PO Box 30424
2500 GK The Hague – NL
www.kivi.nl

National Secretariats of International Organizations

International Hydrological Programme (IHP) of UNESCO and
the Hydrology and Water Resources Programme of WMO
PO Box 201
3730 AE De Bilt – NL
Phone +31 30 220 69 11
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International Association of Hydrological Sciences (IAHS)
PO Box 80015
3508 TA Utrecht – NL
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International Association of Hydrogeologists (IAH)
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International Association for Hydraulic Research (IAHR)
PO Box 177
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Fax +31 15 285 85 82

International Commission on Irrigation and Drainage (ICID)
PO Box 20000
3502 LA Utrecht – NL
Phone +31 30 285 89 32
Fax +31 30 285 81 95

Literature

Books and reports on applied water research are available in the HYDROTHEEK in Wageningen (e-mail: *BLUW.HAAFF@PD.BIB.WAU.NL*). Information about ongoing research can be obtained by consulting the STOWABASE in Delft (e-mail: *STOWABASE@Library.TUDelft.nl*).

Sources of figures

Ministry of Transport, Public works and Water Management, Directorate-General Rijkswaterstaat:
1.1, 2.1, 2.2, 2.3, 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, 4.12, 4.13, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 6.1, 6.2, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 8.3, 8.5, 8.6, 9.1, 9.2, 9.3, 10.1 and 10.2.

Royal Netherlands Meteorological Institute:
3.1 and 3.2.

Ministry of Agriculture, Nature management and Food quality:
6.3.

Ministry of Spatial planning, Housing and the Environment:
8.2.

National Institute of Public Health and the Environment:
3.3, 3.5, 3.6, 3.7, 3.8 and 3.9.

Water Board De Aa:
3.4.

Union of Water Boards:
8.1.

Commission for the Hydrology of the Rhine basin:
7.1.

International Commission for the Protection of the Rhine:
8.4.

Netherlands Institute of Applied Geoscience TNO – *National Geological Survey*:
3.5, 3.6, 3.9 and 3.10.

G.P. van de Ven:
4.6.

A. Volker:
11.1 and 11.2.

E. Schultz:
11.3 and 11.4

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De Bilt	City or town of major importance for this publication		

Netherlands Hydrological Society