1 Strategies for storing water in a river basin, alternative solutions considered and criteria for assessing alternatives

Reservoirs in River Basin Development, Santbergen & Van Westen (eds)
© 1995 Balkema, Rotterdam. ISBN 90 5410 559 3

Time for a revival of the Rhine: A quest for a sustainable river basin

H. L. F. Saeijs
Ministry of Transport, Public Works and Water Management, Middelburg, Netherlands

C.-J. van Westen
Ministry of Transport, Public Works and Water Management, Road and Hydraulic Engineering Division, Delft, Netherlands

M. H. Winnubst
Communication and Information, Utrecht, Netherlands

ABSTRACT: Over the past 150 years human beings have made the Rhine what it is now: a river system showing widespread degradation. It has been canalized with dams to make navigation possible. The river bed has been confined between two dikes. It is frequently used as a sewer and has been stripped of its natural beauty. The diversity of organisms in the river is low, while locks and reservoirs form impassable barriers for fish and other organisms. The time is now ripe for a revival of the Rhine. Such a revival needs a strategy based on a policy analysis containing various scenarios, with the policy to be developed in more detail in action plans. This approach will guarantee that the concept of sustainable development takes hold in the Rhine catchment area. International cooperation is vital to this, because only by working together we can restore the Rhine to health.

1 INTRODUCTION

The Rhine was world news in the first two months of 1995, when its water level reached a height which occurs on average once a century.The average flow increased to almost 12000 m^3 (TAW, 1995; KNMI, 1995; Table 1). In the Netherlands, 200,000 people, 700,000 pigs, 700,000 cows and a million chickens had to be evacuated (Figure 1). It is fair to ask whether we are dealing with a freak occurrence here or a structural problem. In order to answer this question, we need to understand more about the background to the flooding.

Table 1 Peak flows of the Rhine from 1901 to 1995

Date	Flow (m^3/s)*	Water level (m above MSL**)
18-1-1920	11365	16.45
04-1-1926	13000	16.93
30-3-1988	10300	16.08
25-12-1993	11100	16.39
31-1-1995	11900	16.68

* average flow of the Rhine is 2200m^3/s
** MSL= mean sea level

We will begin with a sketch of the Rhine and some general information, a description of the river basin and the history of human intervention during the past 150 years. This leads on to a diagnosis of the main problems. We then outline a strategy, involving possible avenues towards finding a solution. The Dutch approach serves as an example here, although this cannot be seen in isolation from international developments in the management of the Rhine catchment area. The article concludes with recommendations based on the aim of achieving a sustainable river basin within the next 150 years.

Figure 1 Battle against flooding

2 A SKETCH OF THE RHINE

2.1 *The catchment area*

The Rhine is originally a natural watercourse, where the water makes its way along a bed formed by the river itself, flowing from the more mountainous parts of Western Europe to the lowlands. The water which flows off the surrounding land comes together in small watercourses, which in turn merge into streams, small rivers, larger rivers and finally the main stream of the Rhine. Together they form a river system which drains a particular section of the earth's surface, known as the river basin.

The Rhine is 72nd on the list of the world's principal rivers, with a length of 1320 km. It is the only river connecting the Alps with the North Sea. The main stream of the Rhine is now about 40 per cent shorter than it was originally. The river flows through glacial areas, with snow, ice and glaciers, and regions characterized by heavy precipitation. It has an average flow of 2200 m^3/s as measured at Lobith (The Netherlands), the lowest flow ever measured being 620

m^3/s and the highest 13000 m^3/s (see Table 1). This flow is relatively stable as a result of precipitation and the tremendous storage capacity of glaciers and snowmelt, lakes, groundwater and soil moisture. These water reserves are responsible for what is known as the basic flow. This is the component of the flow which is slow to change, forming the fluctuating lower limit. Changes in the water flow downstream can be attributed largely to the surface discharge, water that flows away at ground level and through the top layers of soil. This is known as the rapid runoff component.
Admittedly the basin of the Rhine with its 185,000 km^2 is smaller than other rivers such as the Danube and the Volga, but if one looks at the average amount of water it discharges, the Rhine is the largest of these rivers (Saeijs and Logemann, 1990). The amount of water from ice and other reserves, the soil conditions (groundwater reserves and flow) and the climate provide the Rhine with an abundance of water unrivalled by most other river systems in Europe.

2.2 *Geographical features*
The Rhine (Figure 2) can be subdivided into 6 regions:
The Alpine Rhine. The Rhine rises in the Alps. Its main sources are on the flanks of the Gotthard Massif: Lake Toma, the source of the Vorderrhein, and the Paradise Glacier, where the Hinterrhein rises. The water plunges down a drop of about 2000 m into Lake Constance. Gravel and large stones mark the channel. The Rhine Valley is narrow and inhospitable here; the countryside has few inhabitants and is used for extensive farming. Lake Constance forms a natural reservoir on the border between Switzerland and Germany. Measuring about 60 km long, 10 km wide and 25 m deep, the amount of water in the lake and its storage capacity are enormous.

The Hochrhein ("High Rhine"). Between Lake Constance and Basel the Rhine becomes a swiftly flowing river again. The Rhine Falls at Schaffhausen are a well-known spot. From here onwards the Rhine is navigable, although only for small boats, and the shipping is hampered by numerous locks. The Aare flows into the Rhine at Rheinfelden.

The Upper Rhine. Below Basel the Rhine flows across the plain of the Upper Rhine, which is bounded by the Vosges Mountains and the Black Forest. Here the Rhine forms the boundary between Germany and France. For a 450-km stretch the Rhine Valley is 30 to 50 km wide and the drop is less than 115 m. Both the Neckar and the Main flow into this valley. The lowlands of the Upper Rhine are used for intensive farming and stock-breeding, while the slopes of the Black Forest are exploited extensively for wine-growing. The Rhine passes various large industrial areas as it flows along.

The Middle Rhine. Between Bingen and Bonn the Rhine changes character. It winds through a region of moderately high mountains, the Hunsrück, the Taunus and the Eiffel. The Rhine Valley is only a few hundred metres wide here. The river bed consists mainly of gravel banks, beside which roads, railways and power cables run, filling practically the whole of the Valley. The only form of agriculture is wine-growing on the hillsides. On this stretch the Rhine is joined by major rivers such as the Moselle and the Lahn. The river itself serves as a shipping route.

The Lower Rhine. Between Bonn and the Dutch border, the Rhine becomes a wide, slow-moving river again. Little remains of the original

Figure 2 The basin of the Rhine with locks and dams

Pleistocene Kampen landscape. It has been replaced by an industrial landscape, made possible partly by the lignite and coal mines in the region. The main industrial centres are the Rhine and Wupper regions, which include Cologne and Leverkussen, and the Ruhr with Essen, Bochum and Dortmund, which are situated beside the basin of the Rhine, and Duisburg, which is further away from the Rhine. An area measuring no more than 400 km² contains over 7 million people in all.

The Rhine Delta (Figure 3). After the Rhine crosses the Dutch border at Millingen, the river splits into three: the Waal, the Lower Rhine/Lek and the IJssel. In this region the river has all the characteristics of a river delta. In the West of the Netherlands, the main branch, the Waal, splits up again forming a southern arm. This becomes in turn the Beneden Merwede, the Hollandsch Diep and the Haringvliet, before discharging into the North Sea. A northern arm flows via the Noord, the Nieuwe Maas and the New Waterway Canal. The Lek also flows into the Nieuwe Maas and the New Waterway. The IJssel flows north and discharges into the IJsselmeer. Between the German-Dutch border and the Central Netherlands, the landscape is rather open and small-scale. The land is used mainly for agriculture, which is also the case on both sides of the IJssel. The adjacent, partly covered clay soil was only exploited fairly recently. Agriculture is also practised on the flood plains. Finally the southern branch forms a wide inlet, now partly cut off from the sea, amid polders where there is large-scale agriculture; the northern branch passes Rotterdam, a major industrial and transhipment centre.

Despite all the differences between these subregions, the Rhine Valley or Rhine Delta is characterized by an extraordinary uniformity of plant growth. It can even be classified as a separate botanical/geographical zone. Different species of plants which are typical of inland areas in Europe are found along the whole of the Rhine, as far as the North Sea (Saeijs and Logemann, 1990).

2.3 *Human beings and the basin of the Rhine*

At the beginning of the 19th century, about six million people lived in the basin of the Rhine. Beside the High Rhine and the Upper Rhine, the population made a living mainly from agriculture and fishing. At that time the Rhine was well-known as the largest and most important salmon river in Europe. The negative effects of fishing on salmon stocks led to the drawing up of the Salmon Treaty in 1885. However, this did not have the desired result and salmon became increasingly scarce. Many of their resting places and spawning grounds had disappeared over the years as a result of changes in the river bed. The groundwater level fell and as a result former tributary arms silted up (IKSR, 1995). Agriculture remained an important source of income, but with the mining of lignite and coal, more and more people earned a living in the emerging industrial sector. In the 19th and 20th centuries, the population increased to 60 million. The basin of the Rhine now contains the most industrialized region in the whole world (Saeijs and Logemann, 1990). From its source in Switzerland to its mouth in the delta in the Netherlands, the Rhine is responsible for the flow of water and sediment, the discharge of waste water, the production of drinking water, and the flow of water to and from agriculture and industry, as well as having a transport function (Postma and Cals, 1994).

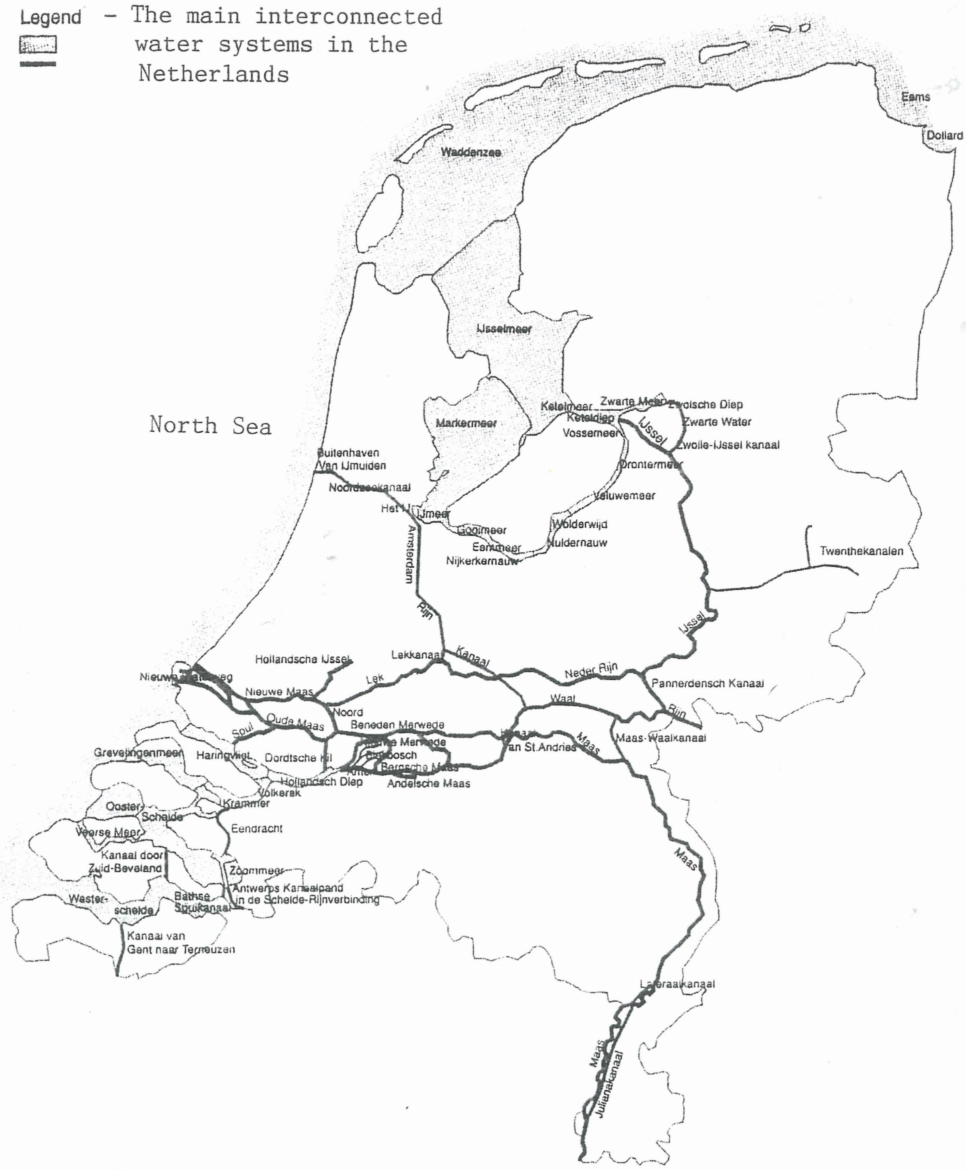

Figure 3 The state-administered waters in the Netherlands

Through the ages the river basin has been subject to many drastic instances of human intervention (Adriaanse et al, 1986, De Jong et al., 1988, Saeijs, 1988, Huisman, 1990). In the Lower Rhine, the tributary arms of the river were cut off and dikes and groynes were constructed. The Middle Rhine was only regulated later on, in the period between 1880 and 1900. In the Upper Rhine many projects were completed between 1817 and 1874. These were not without certain consequences. The changes resulted in the drying up of large swamps in the lowlands of Southern Germany. In low-lying areas north of Basel the Rhine used to meander through a zone 6 km wide over a 450-km stretch. Here the river was 'tamed' by cutting off the bends, while the main stream was embanked. In this way the Rhine was confined in a channel from Basel to Hessen and shortened by 25 per cent at a stroke (IKSR, 1995). The brain behind this change was Tulla, a hydraulic engineer. He was succeeded by more hydraulic engineers, who made the flow of the river even narrower, without taking into account the need to cope with high water. The river dug its way deeper and the water level dropped between 5 and 7 metres, and in some places as much as 9 metres. When the water flow was low, the water level of the river and the groundwater in the adjoining areas fell dramatically. The result was a sterile 'gutter', surrounded by an infertile, dried-out steppe. Between 1895 and 1966 eleven hydro-electric power stations were built to use the rushing water of the High Rhine for electricity. The Grand Canal d'Alsace, completed in 1948, was designed to provide a solution for shipping.

Other 20th century works of engineering included the Zuiderzee (De Jong and Roelofs, 1983), the Delta of the Southwest Netherlands (Saeijs 1982, 1986, 1988; Saeijs et al., 1978, 1983, 1988) and the regulation of almost the entire length of the Rhine and its branches (Anonymous, 1988), optimizing the water management for the purposes of industrial and agricultural production and urban areas. In 1992 came the completion of the shipping route connecting the basin of the Rhine with the Danube.

Figure 2 is an overview from 1990, showing the main river dams and locks for shipping, as well as the reservoirs to improve the distribution of the water. These engineering works are instrumental in improving the distribution of the water flow throughout the year, regulating the water level for the benefit of shipping.

The Rhine is the second largest river in terms of economic activity in the catchment area (Saeijs and Logemann, 1990; Figure 4). It is now the busiest waterway in the world, with long canals and engineering works regulating the water level. These canals connect the Rhine and its tributaries with the rivers of almost all the surrounding river basins. Up to now this has taken place without any consideration of the ecological impact of breaking through the natural wet infrastructure, the changes in the hydrology, and the interchange of water and organisms belonging to other river basins. According to Dynesius and Nilsson (1994) the Rhine belongs to the category of rivers where the pollution percentage is 'average'. This classification is based on research comparing the flow regulation and the fragmentation of the river basins concerned. De Boer (1995) shows that the Rhine and the Maas are the most polluted rivers in the area around the North-Atlantic Ocean. This has emerged from research into micropollutants in fish.

In the basin of the Rhine, large quantities of substances are extracted, imported, produced and processed, or discarded. These substances vary from harmless nutrients to highly toxic micropollutants, such as PCBs and dioxines, which have to be absorbed by the system in one way or another (Saeijs and Logemann, 1990). Since the fifties, the quality of the water in the Rhine has deteriorated significantly. Immeasurable quantities of waste materials are spread by the system, leading to disruption of the ecological balance.

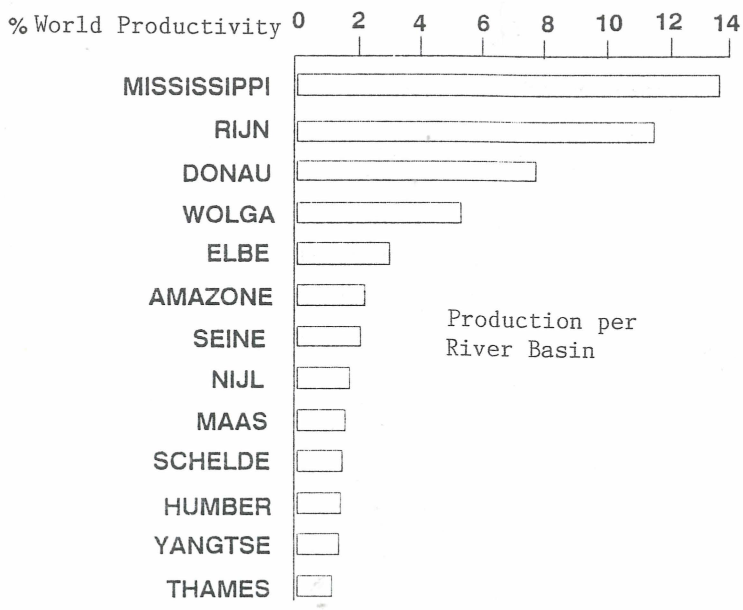

Figure 4 The ten economically most important river basins in the world

3 DEFINING THE PROBLEM: SECTORAL INTERESTS TAKE PRECEDENCE OVER THE WHOLE

As this short historical survey of human intervention suggests, the Rhine underwent many major changes in the 19th and 20th centuries, as a result of which it lost much of its fragile natural beauty. The question now is whether the wet infrastructure of the basin of the Rhine with its approximately 450 engineering works is 'finished'. Most scientists think it is (Filarski and Brolsma, 1989). Are they correct? The article does not make it clear what criteria this assertion is based on. In fact it probably only refers to shipping interests. We could answer the question above with another question: Why has there been such frequent and large-scale human intervention in the river system? The main arguments boil down to the need to increase safety, make the river more navigable and improve the availability of sufficient good- quality water, extract minerals and boost agricultural production.

If we take stock of the current situation, it appears that the attempt to meet the wishes of all the different parties concerned has led to various series of so-called improvements. Each party concerned was able to present its own arguments for a new series of improvements. It is fair to say that the arguments for making changes were usually of a sectoral nature and of local origin. There was - and still is - no sign of a well-founded, integrated consideration of **all** the results and consequences for **all** the interests in the whole of the catchment area. Potential changes in the use of the river are generally considered only from the point of view of safety or the interests of shipping, while the river is seen as the supplier of water as a human resource, the producer of 'white coal' or as a sewer for discharging waste materials. Changes which are extremely useful for one interest turn out to be extremely harmful for others.

In our view, this ad hoc approach means that the wet infrastructure is far from finished. However, further changes to the system are only justified if they are motivated by a comprehensive vision of sustainable development for the whole river basin of the Rhine (Saeijs and Logemann, 1990).

We therefore define the problem of the basin of the Rhine as follows: *Changes designed to serve sectoral interests have led to the river's degradation.* We will justify this assertion in the next section, Diagnosis. *There will be no change from degradation to revival until there is a framework for an integrated approach to the whole river basin. Such a framework should contain a number of coordinated policy objectives.* In the section Strategy we present a set of such policy objectives. This leads on to a description of how they would work in practice, illustrated by various examples.

4 DIAGNOSIS: THE DETERIORATING BASIN OF THE RHINE

The basin of the Rhine is now facing various structural problems, which are the result of human intervention. The main ones are:

Hydrological problems

The water storage capacity is showing structural decline throughout the basin of the Rhine. There are various reasons for this.

- More and more of the surface, for example urban and industrial areas and roads, is being drained as fast as possible using sewers and other drainage systems.
- Regulation of the groundwater level is taking place in agriculture.
- The groundwater level is falling in thousands of km^2 of surrounding land as a result of dewatering during lignite extraction.
- Deforestation is reducing the soil's water-retention capacity.

The hydrology of the whole system is being affected by this. This means that yet more improvements are necessary, such as the construction of reservoirs, to improve the water distribution. If the predicted climatological changes due to the 'greenhouse effect' actually materialize, these could also present a real long-term threat to the water reserves in the Alps. The glaciers have been in the process of melting for over a century now. If the predicted temperature rise of 1.5 to 4.5 degrees Celsius (Smit, 1989) as a result of the greenhouse effect come true, the glaciers in the Alps will shrink considerably and possibly disappear altogether (Saeijs and Logemann, 1990).

Problems of quality

The water and air are being polluted both from specific points and diffuse sources, as well as through accidents. The Low Countries are experiencing serious salinization problems, due partly to land reclamation and the creation of new polders. The problems are also caused partly by excess salt in the river water flowing in. In certain parts of the Rhine there is too much sediment in the water. Apart from the increasing erosion, the faster flow in a trained channel of the river and a lack of sedimentation areas along the way also play a role. This is all the more serious because many pollutants are inclined to cling to sludge, leading to the creation of polluted channel beds in sedimentation areas throughout the river basin (in flood plains, reservoirs, sand and gravel cavities, in the river's lower course and in the sea). Almost all the ports and industrial areas also have to contend with severely polluted channel beds, the causes of which are partly local. We should point out here that this process is counterbalanced upstream in a number of places by the 'sediment hunger' which prevails there as a result of human intervention in the past.

Atmospheric pollution, such as occurred with Chernobyl, falls mainly in places with large amounts of precipitation. Some places have more precipitation than others and the pollution is correspondingly higher or lower. Mountainous regions such as the Alps are especially vulnerable in this respect. The poison that falls with the precipitation accumulates in the water supplies there.

The availability of water

Water of suitable quality is not always available everywhere. The rapid increase in the demand for water and the fluctuations in water quality will only aggravate this problem.

Ecosystem problems

As a result of the poor water quality, the decrease in the surface area of the basin of the Rhine and the associated decline in variation in types of environment, fewer and fewer species of plants and animals can find a suitable habitat there (Postma and Cals, 1994; Figure 5). River ecosystems have been disrupted and river banks have deteriorated throughout the river basin. This has been caused by changes in the river's flow, hydrological problems and pollution. The groundwater is deficient in both quality and quantity in many places, with inevitable consequences for the ecosystem.

Summarizing

This analysis of the situation shows that the river basin is only just managing to carry on functioning. If future generations are also to benefit from the natural resources, there will need to be a number of dramatic changes, leading to the laborious process of revival and sustainable development of the Rhine.

- The hydrological problems in the basin of the Rhine deserve just as much attention as the problems of water quality.
- More attention needs to be paid to enlarging the water-retention capacity of the river basin and sustainability must be an integral part of any solution.
- The wet infrastructure of the river system has come into being in an ad hoc way, usually to meet local needs, without taking into account the consequences of these changes for the river basin as a whole. An integrated approach is necessary.
- Even today, changes to the river system are still not seen in connection with the consequences for the river basin as a whole.
- The existing wet infrastructure and the way in which it is managed do not provide sufficient guarantees for sustainable development, as formulated by the Brundtland Commission and developed at the UNCED Conference (UNCED, 1992).

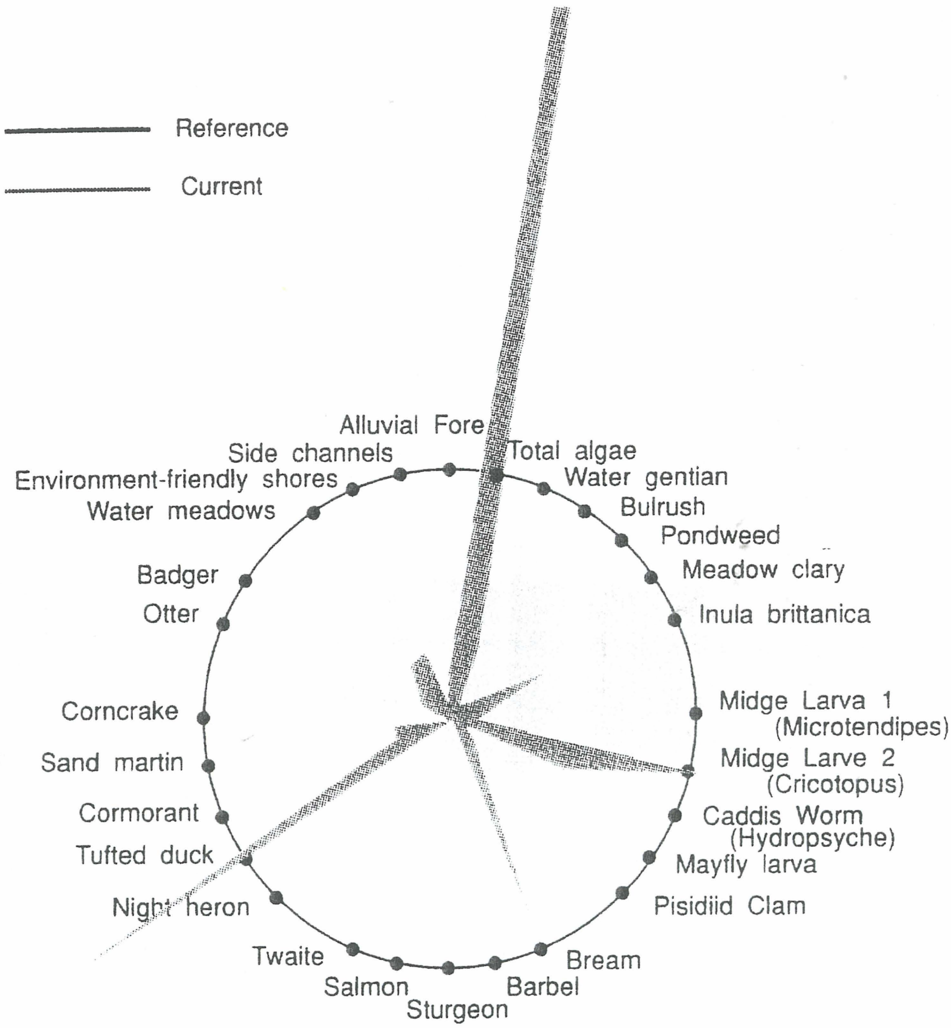

Figure 5 The so-called river amoeba, as measured in 1988. If the river system were functioning optimally, at least the species indicated in the circle (reference) should be present in such numbers as to completely fill the circle. Many species are currently no longer present and some species are found in excessive quantities (Ministry of Transport, Public Works and Water Management, 1989).

The problems of the Rhine have a useful side-effect, however: more and more people are realizing that the tremendous problems which exist in the river basin can only be solved through more far-reaching international cooperation and a coordinated approach to the problems in the whole of the river basin (Saeijs and Logemann, 1990).

5 STRATEGY

It will be clear from the above that the Netherlands is not capable of dealing with the problems of the Rhine on its own. Human activity has produced major changes in the ecosystems of the basin of the Rhine. Much of the pollution in Europe ends up in the water sooner or later or clings to sludge. Both the water and the sludge end up in the Netherlands. This situation is aggravated by the fact that sedimentation areas upstream have disappeared. The flooding in the basin of the Rhine in the first two months of 1995 indicates that safety can be added to the list of major problems.

The conclusions of the Brundtland Commission are still valid: the environment and economic development are inextricably linked at both international and national level. Although economic growth is possible, this has to be based on sustainable development (World Commission on Environment and Development, 1987; Jordaan et. al., 1993). The revival of the Rhine is necessary. This requires a strategy based on an analysis of the problems and possible avenues towards finding solutions. This policy analysis needs to take various scenarios into account.

Here we present a strategy with several strands, based on a similar policy analysis in the Third Policy Document on Water Management (Ministry of Transport, Public Works and Water Management, 1989). The same approach has also been laid down in international policy to some extent (IKSR, 1987 and the Second Ministerial Conference on the North Sea).

This strategy contains the following elements:

- precautionary principle: risk prevention
- standstill principle: preserve whatever is good
- faster reduction of pollution:
  * an 80-90 per cent reduction (compared to 1985) in nutrients and heavy metals
  * more drastic reductions in organic micropollutants
  * adjustment of the standards
- hydraulic design
  * design of river banks for multiple purposes
  * maintenance, revival and development of the national ecological network of protected areas
  * revival of specific types of environment
- guiding principles for use
  * reduction of dehydration
  * making more efficient use of fresh water
- organization and measures
  * harmonization and integration of the measures used by countries along the Rhine for water management, spatial planning and legal procedures
- international
  * reducing the risk of disasters
  * the establishment of a River Basin Authority

6 MOVING TOWARDS SOLUTIONS

This strategy can be developed in problem areas for the basin of the Rhine:

(1) safety
(2) water quality
(3) hydrology
(4) revival of the ecosystem at national and international level

6.1 *Safety*

In the Declaration of Arles on 5 February 1995 the EU environment ministers stated that concrete measures must be taken in the field of spatial planning, land use and water management in order to increase safety (Ministry of Transport, Public Works and Water Management, 1995). At the same time, civil engineering solutions should be related to the functions of the water systems.

A good example of this is the implementation of the Delta Project in the Southwest Netherlands. The original intention was that the tidal inlets, the Haringvliet, the Grevelingen and the Eastern Scheldt, should be closed off from the sea by a dam; the new areas thus created would become freshwater lakes for agriculture, horticulture and drinking water. The Western Scheldt and the New Waterway Canal, major shipping links to the ports of Antwerp and Rotterdam, would not be closed off. Here the need for safety would be met by raising the dikes.

However, under pressure from environmental organizations and the fishing industry, the decision was made in the mid seventies not to close off the Eastern Scheldt with a solid dam but to construct a storm surge barrier, which is only closed when the water level in the North Sea is extremely high. At the same time an integrated policy plan for the Eastern Scheldt area was drawn up in order to protect environmental and fishing interests. Thus the changes in the plans as a result of public pressure led to the realization of a highly innovative civil engineering project in the shape of the storm surge barrier, while in terms of spatial planning, they were translated into an integrated policy plan (Van Westen and Colijn, 1994).

The decision concerning the Grevelingen was also different from the original proposals. After it was closed off from the North Sea by a solid dam, the decision was made that because of its great ecological value it should remain fairly salty and not become fresh water.

Finally the plans for the New Waterway Canal were also changed. Raising the dikes in the centre of cities such as Rotterdam and Dordrecht and the surrounding urban and industrialized areas would have created so many town planning problems that a different solution was needed. This involved the construction of a storm surge barrier in the Rotterdam-Europort (Figure 6) area, consisting of two steel sliding doors, each as long as the Eiffel Tower. Here too we find the integration of various policy areas leading to innovative solutions which can count on widespread public support.

6.2 *Water quality*

In 1950 the countries along the Rhine decided on international cooperation to combat the deterioration in water quality. This resulted in the establishment in 1963 of the IKSR, the International Commission for the Protection of the Rhine against pollution. This was charged with advising the countries along the Rhine

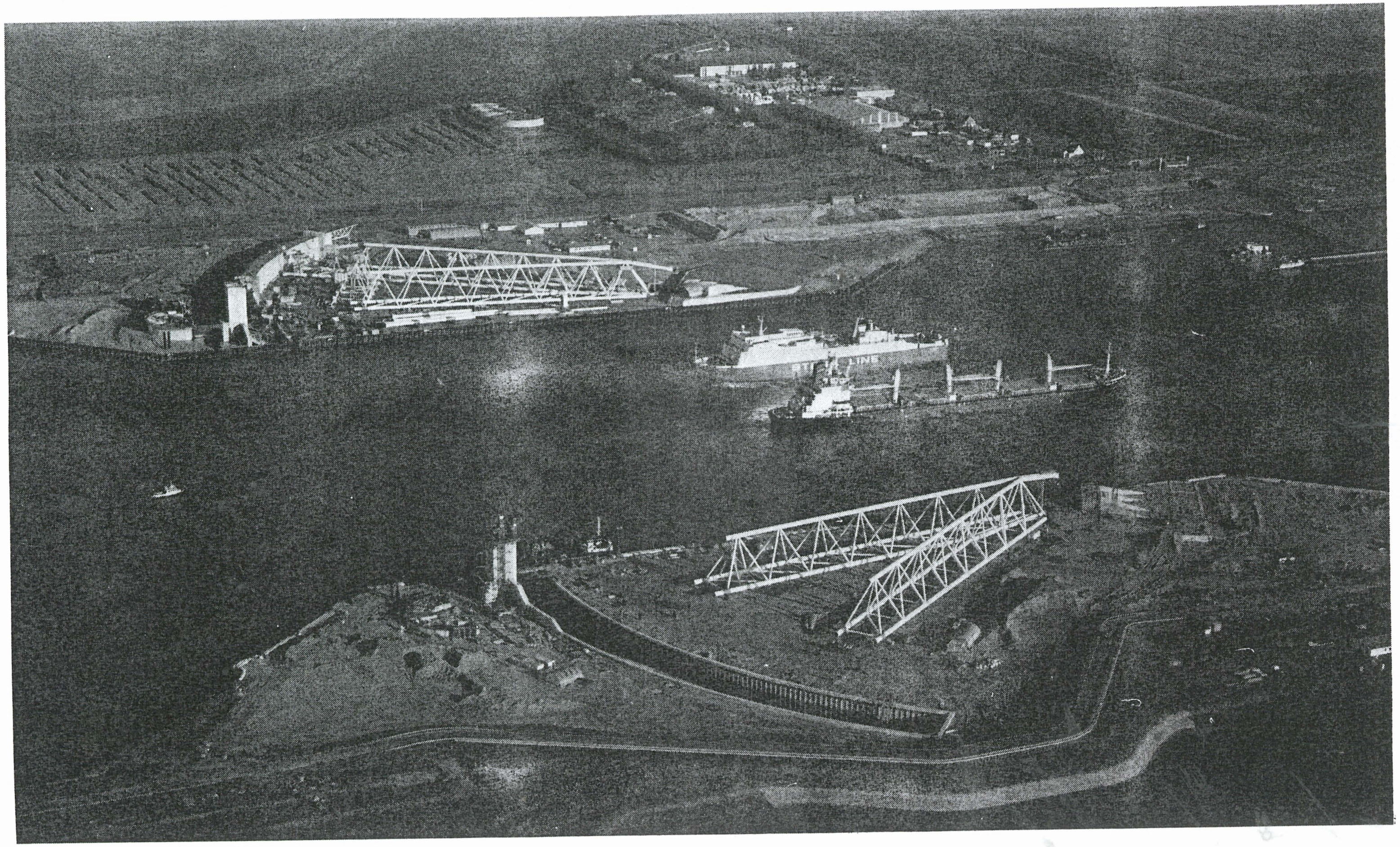

Figure 6 Storm surge barrier on the New Waterway Canal under construction

on measures to improve the water quality. Despite this, many disastrous discharges took place in the sixties. The need for more decisive action and agreements of a binding nature resulted in two treaties. In 1973 the Chemicals Treaty and the Chloride Treaty were concluded, containing statutory provisions for reducing emissions. In the same period the European Commission also joined the IKSR, in order to ensure that the Rhine Treaties and EC directives were consistent. The statutory nature of the Rhine Treaties meant that steps were actually taken to reduce pollution. On the other hand, the cooperation on the legal aspects caused tremendous delays, as well as difficulties in making new agreements.

In 1986, as a result of an accident at Sandoz, a company in Basel, almost 30,000 kg of toxic chemicals ended up in the Rhine. The effects on the ecosystem were disastrous. The entire stock of fish and insect larvae was destroyed within a radius of hundreds of kilometres from the site of the accident, while the river bed sediment over several kilometres was contaminated with mercury. This accident showed clearly how vulnerable the ecosystem of the Rhine is. A year after the accident, the ministers of the countries along the Rhine decided to carry out the Rhine Action Programme (RAP), containing international agreements on broad objectives. The plan of action says that by the year 2000 the following aims should be achieved:

- There should be a revival of the Rhine's ecosystem for higher species of animals which were found there in the past but have now disappeared, such as the salmon;
- The suitability of Rhine water for the preparation of drinking water should be guaranteed;
- Toxic substances, particularly in sediment, should be reduced significantly;
- The North Sea should be protected in accordance with the North Sea Action Programme.

Measures for achieving these objectives involve the reduction of pollution from discharges from specific points and diffuse sources and the prevention of disasters. For the first aim of the Rhine Action Programme, revival of the ecosystem, it is not sufficient just to improve the water quality; morphological and hydraulic changes in the river system are also necessary. The IKSR therefore launched an Ecological Master Plan in 1992. This contains two principal aims: revival of the main stream as the backbone of the ecosystem, particularly for migratory fish, and the protection, maintenance and revival of ecologically important areas along the Rhine. The plan has been given the name 'Salmon 2000' because the return of salmon to the Rhine is seen as a symbol of ecological revival. The realization of both the Action Programme and the Master Plan is left to the individual countries, which will use their own statutory means for the purpose. This approach has turned out to be very effective in practice (Postma and Cals, 1994). The first results have appeared. For example, the river's oxygen content has risen and the amounts of organic waste and some heavy metals have fallen (Ministry of Transport, Public Works and Water Management, 1993; IKSR, 1994; IKSR, 1995).

6.3 *Hydrology*

It is only in recent years that hydrological aspects have also been the focus of attention in international discussions. At the ministerial conference of countries along the Rhine on 8 December 1994, the first guidelines were drawn up for a new Rhine Treaty regulating the flow of water, among other matters. The ministers stated expressly that it was the intention to consider the river basin in its entirety. They also agreed to include the exchange of information on the discharge of water in the current activities. This involves such matters as the IKSR scientific task force, the Commission on the Hydrology of the Rhine (1978), which has been doing research for years into the hydrological aspects of the basin of the Rhine. In recent years the researchers have also been busy developing models for precipitation and for the duration of flood waves (Commission for Hydrology, 1993). However, the studies have not had any impact at the political or administrative level.

6.4 *Revival of the ecosystem at national and international level*

The Netherlands' water policy has undergone a complete change in the last few decades. In the sixties the country's water policy could best be characterized as 'for human use and abuse'. In the following decade, the emphasis was mainly on 'dealing with pollution'. After that, the philosophy of integrated water management gradually gained ground. Integrated water management means that a water system is managed as an integral structure, taking into account the life in the water and on the shores, as well as all the physical, chemical and biological processes which take place and all the relevant pressure groups involved with water management. An important element in integrated water management is the fact that water systems are central to the approach. A water system is a geographically defined area, a hydrological unit containing all the necessary elements for the proper functioning of the system. This includes the water (both ground and surface water), the subsoil, the banks or shores, as well as the surrounding land. Two examples at a regional scale are lakes and river mouths. On a larger scale, a water system can also be the catchment area of a river, a coastal lake or even an ocean. The water system is not the final, decisive factor in decision-making, implementation and management but is actually one of the preconditions for any changes which take place (Saeijs and Turkstra, 1994).

There is a great difference between the policy twenty or thirty years ago and now. Over the years a gradual shift has taken place from qualitative aims to quantitative, measurable objectives in the policy plans. Originally these policy plans were sectoral and drawn up by separate ministries, whereas now they are gradually being changed into plans of a more integrated nature, based on multidisciplinary collaboration. The broad objectives are being converted into concrete operation plans. Besides preparing such plans, practical expertise is being accumulated from small-scale pilot projects. This is greatly increasing our understanding of the possibilities of ecological recovery (Postma and Cals, 1994).

In the eighties various policy documents were published simultaneously in the Netherlands in various policy areas: the Fourth Policy Document on Physical Planning (1988), the National Environmental Policy Plan (1989), the Nature Policy Plan (1989) and the Third Policy Document on Water Management (1989). The Nature Policy Plan charted the connections between the main system of water management and the regional water management systems. The ecological relationship is one example of this. It is represented most clearly in the map of the main ecological structure. The map shows that the major rivers act as elongated connecting zones between various areas. These areas contain ecosystems which are important nationally and internationally and should be preserved on a sustainable basis, together with ecological development areas. The Third Policy Document on Water Management provides targets for the various functions of the major rivers. These can be summarized by the following concepts: 'transport arteries', 'salmon in the Rhine and Maas in the year 2000' and 'green belts in the landscape'. The document includes the

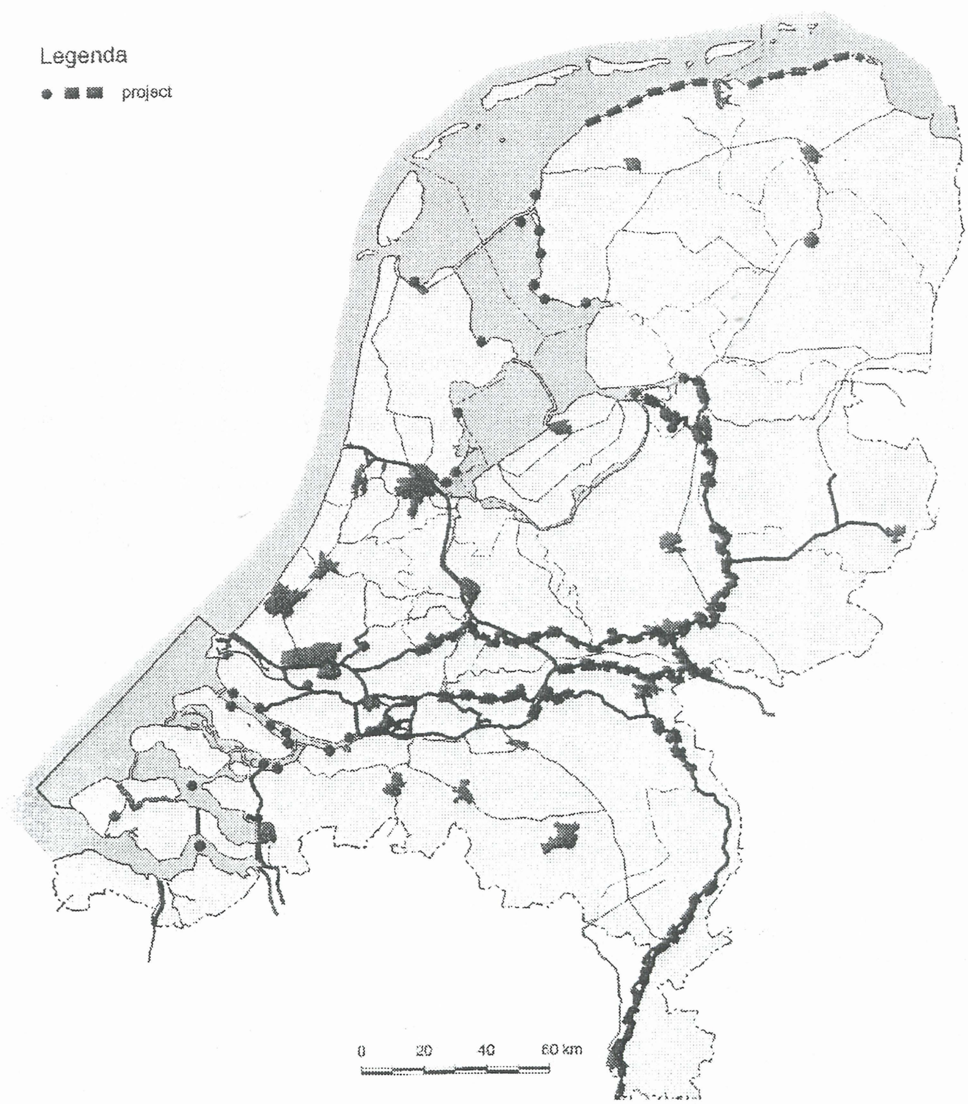

Figure 7 Many projects are being carried out along the banks of the major rivers to reintroduce species which had disappeared, thus bringing new life to the river.

implementation of the Rhine Action Programme as an interim objective for 1995 for the Rhine. The ultimate objective is that the Rhine, "including the flood plains, should be a major axis through the Netherlands for transport, animal migration and nature". The achievement of this goal will involve not only emission targets but also rural development measures. For the Rhine this means the construction of environmentally friendly banks, the implementation of pilot projects on the flood plains, the expansion of land use on the flood plains, the construction of passages for fish, and the maintenance and revival of places where fish can shelter, spawn and grow (Figures 7 and 8). The World Wide Fund for Nature in its 1992 report "Living Rivers" made an important contribution to the development of policy. This report shed new light on the life in the river itself, besides the wildlife on the dry and swampy flood plains. The implementation of the policy plans is in full swing. Experience with pilot projects has shown that 538 km of banks out of a total of 594 km along the branches of the Rhine are suitable for the construction of environmentally friendly banks. The plan is to construct 15 km a year, where possible combined with maintenance and improvement work for shipping. Since 1989, various trial projects for the development of the countryside have been completed along the branches of the Rhine. These projects include the Duursche Waarden, Blauwe Kamer (Blue Chamber) and the Plan Doorstroming (Flow-through Project), while others are in preparation. These projects vary in size from a few hectares to several thousand hectares. In the next few years more agricultural land will be purchased on the flood plains for development of the countryside. Research is being done at the Driel dam in the Lower Rhine to see whether it is possible to build a fish ladder in the form of a side channel, not only so that fish can pass the dam but also so that new wildlife can develop (Postma and Cals, 1994).

Figure 8 New nature along the banks of the Rhine

7 CONCLUSIONS

The Rhine and its tributaries are the lifeline of the river basin. Together they form the natural wet infrastructure. Any attack on this backbone of the river basin and ecosystem is an attack on the health and economy of the area. If we look at the main features of the basin of the Rhine, we see that the reasons for carrying out civil engineering work in the past were as follows:

- in the most elevated parts of the river basin, electricity generation was the main reason for building dams;
- in the central section, water management in the broadest sense was the reason for building dams and locks; and
- in the delta region, the need for safety was the reason for constructing seven large dams and raising hundreds of kilometres of dikes.

In the section Moving Towards a Solution, we showed how in the delta region it was actually public pressure that led to the creation and implementation of new techniques for achieving safety - techniques which are now being implemented near Rotterdam.

In the central section of the river basin, projects are now being carried out both to increase safety by widening and deepening the river bed and to promote ecological recovery by designing specific types of environment. Safety in the whole basin can be increased by constructing buffer basins in the highest sections of the catchment area.

We particularly want to emphasize the need to ensure that all these measures are not implemented in an ad hoc way or considered only on a national level. We are in favour of a New Master Plan for the revival of the Rhine. This should provide an integrated framework for examining the impact of local or national measures on the whole of the river basin.

8 RECOMMENDATIONS

1 In the past 150 years human beings have stripped the Rhine of much of its fragile natural beauty. In the next 150 years we should be able to bring about the revival of the river basin.

2 The river basin approach can only be achieved if there is cooperation between the countries along the Rhine on the level of both policy and implementation.

3 The water problems of the Rhine require a comprehensive approach, based on the integration of disciplines and policy fields.

4 The river basin as a whole is in need of a policy analysis, leading to measures with the following aims: raising efficiency, increasing the buffer supplies and reducing the risks (Vellinga and Bertels, 1994).

5 The characteristics of the ecosystem and an understanding of what is possible in the river basin and what is simply not feasible are just as important as the wishes of pressure groups.

6 A National Ecological Network of Protected Areas should be drawn up for the Rhine and implemented by multidisciplinary teams.

7 The integration of water management, the environment and physical planning, together with the attempt to win public support, can lead to innovative solutions, as is shown by the construction of the storm surge barriers on the Eastern Scheldt and the New Waterway Canal.

8 Public pressure groups should be involved in decision-making on the river basin, right from the start of each project. An essential condition for clear decision-making is that everyone involved should support the openness of the process and exchange correct information about the current situation.
9 Every river system requires the establishment of a River Basin Authority.
10 In 1997 the Fourth Policy Document on Water Management will appear. It will be a challenge to publish the First Policy Document on Water Management for the basin of the Rhine at the same time.

LITERATURE

Adriaanse, M., J. de Jong and H. v.d. Tuin, 1986. Historical and present day engineering aspects of lowland development. Directorate General for Public Works and Water Management, Department of Inland Waters, Lelystad.

Anonymous, 1988. Der Rhein unter der Einwirkung des Menschen, Ausbau, Schiff-fahrt, Wasserwirtschaft, (The Rhine and Human Intervention, Development, Shipping, Water Management), IHP Task Force. Pub. Commission for the Hydrology of the Rhine, Lelystad.

Boer, J. de, 1995. Analysis and Biomonitoring of Complex Mixtures of Persistent Halogenated Micro-Contaminants, Free University Amsterdam.

Commission for the Hydrology of the Rhine, 1978. Lelystad.

Commission for the Hydrology of the Rhine, Report no. I-11, 1993. KHR Task Force, Pub. Commission for the Hydrology of the Rhine, Lelystad.

Dynesius, M., and C. Nilsson, 1994. Fragmentation and Flow Regulation of River Systems in the Northern Third of the World. Science, 266: 753-762.

Filarski, R. and J.U. Brolsma, 1989. New opportunities for inland navigation. PIANC Bulletin. Vol. 63, nr 66.

Huisman, P., 1990. The Rhine, artery of Europe. Human interference in the delta and international cooperation in the basin of the Rhine. Conf. On The Lower Mississippi Delta, Memphis, 21-23 February 1990.

International Commission for the Protection of the Rhine against pollution (IKSR), 1987. Rhine Action Programme. Technical & Scientific Secretariat, Coblenz.

Internationale Commission for the Protection of the Rhine against pollution (IKSR), 1992. Ecological Master Plan for the Rhine. Salmon 2000. Technical & Scientific Secretariat, Coblenz.

International Commission for the Protection of the Rhine against pollution (IKSR), 1994. The Rhine; towards ecological revival. Technical & Scientific Secretariat, Coblenz.

International Commission for the Protection of the Rhine against pollution (IKSR), 1995. Salmon 2000. Technical & Scientific Secretariat, Coblenz.

Jong, J., de, and J.H. Roelofs, 1983. Ecology and the Zuiderzeeproject. Wat. Sci. Techn., 16: 51-77.

Jong, J. de, H. Smit, 1988. The Rhine: Two centuries of international river management. Proc. Int. Congr. Nature Management and Sustainable Development, Groningen, 6-9 December 1988. Ed. W.D. Verwey: 385-405.

Jordaan, J, E.J. Plate, E. Prins and J. Veltrop, 1993. Water in our common

future; a research agenda for sustainable development of water resources. Committee on Water Research (COWAR). Ed. Unesco, Paris.
KNMI(Royal Netherlands Meteorological Institute), Press release, 4 February 1995.
Ministry of Agriculture, Nature Management and Fisheries, 1990. The Nature Conservation Policy Plan. Pub. SDU, The Hague.
Ministry of Transport, Public Works and Water Management, 1989. Water for now and later. Third Policy Document on Water Management. Pub. SDU, The Hague.
Ministry of Transport, Public Works and Water Management, 1993. The Rhine. Directorate General for Transport, Public Works and Water Management, RIZA. Arnhem.
Ministry of Transport, Public Works and Water Management, 1995. Delta Plan for the Major Rivers. Pub. SDU, The Hague.
Ministry of Health, Spatial Planning and Environment, 1988. Fourth Policy Document on Physical Planning. Pub. SDU, The Hague.
Ministry of Health, Spatial Planning and Environment, 1989. National Environmental Policy Plan. Pub. SDU, The Hague.
North Sea Ministerial Conference, 1987. Ministerial Declaration.
Postma, R. and M.J.R. Cals, 1994. Ecological revival of the Rhine; current situation; workbook for course on Integrated Water Management given by the Flemish Environmental Association.
Saeijs, H.L.F., 1982. Changing estuaries; a review and new strategy for management and design in coastal engineering. Communications 32. Directorate General for Public Works and Water Management, The Hague.
Saeijs, H.L.F., 1986. Towards control of an estuary. Proc. 4th Int. Conf. On River Basin Management. Sao Paulo, Brazil, 13-15 August 1986. Pub. ANAIS: 169-188.
Saeijs, H.L.F., 1988. From treating of symptoms towards a controlled ecosystem management in the Dutch Delta. Lessons learned from 2000 years of living with water and ecotechnology in The Netherlands. Seminar 'The Dutch Delta', 17 November 1988, on occasion of the Australian Bicentennial, Sydney, Australia. The Institution of Engineers Australia. Pub. Directorate General for Public Works and Water Management, The Hague.
Saeijs, H.L.F. and B.A. Bannink, 1978. Environmental considerations in a coastal engineering project. Hydrobiol. Bull. 12: 3/4, 178-202.
Saeijs, H.L.F., E.K. Duursma and W.T. Davoren, 1983. Integration of ecology in coastal engineering. Wat. Sci. Techn. 16: 745-757.
Saeijs, H.L.F., W. Zevenboom and R.C.A. Coenen, 1988. De Noordzee ons gezamenlijk erfgoed (The North Sea - our common heritage). Spectrum Yearbook 1988. The world in 1987; facts and background. Pub. Spectrum: 335-338.
Saeijs, H.L.F. and D. Logemann, 1990. Life history of a river basin; towards sustainable development of the Rhine catchment area.
Saeijs, H.L.F. and E. Turkstra, 1994. Towards a Pan-European integrated river basin approach: plea for sustainable development of European river basins. European Water Pollution Control, 4, no. 3: 16-28.
Smith, D.K., 1989. Natural disaster reduction: How meteorological and

hydrological services can help. WMO, 722, World Meteorological Organisation. Geneva.

TAW (Technical Advisory Committee for the Water-Control Structures), 1995. Water tegen de dijk (Water at the dike). In press.

UNCED, 1992. The Global Partnership for Environment and Development; a Global Guide to Agenda 21. Geneva.

Vellinga, P. and J. Bertels, 1994. Hoog water in de 21ste eeuw (High water in the 21st century), The Water Control Board, 2: 57-63.

Van Westen, C.J. and C.J. Colijn, 1994. Policy Planning in the Oosterschelde Estuary. Hydrobiologia 282/283. Kluwer Academic Publishers, Dordrecht.

World Commission on Environment and Development, 1987. Our Common Future, Oxford University Press.

World Wide Fund for Nature, 1992. Levende Rivieren (Living Rivers).