Report Overseas Study Tour Rhine Basin 7 – 21 November 1999

Hydrology Project India

W. Boiten

Rapport 92

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Contents

1. *Introduction*

Wageningen University was requested on 25 august 1999 by the Hydrology Project India to take up the organization of the Study Tour Rhine Basin for 12 Indian Government officials in the framework of the Hydrology Project.

The main objective of the tour was to study, to observe and to discuss the organization and the management of hydrological data collection in the Rhine Basin in order to create awareness of new development, automation and overall management of data collection, processing and interaction with data users, covering the following aspects:

- how are Hydrological Information Systems organized in the Rhine Basin States, both the technical infrastructure (the hydrological network) and the human resources (training aspects)
- issues of water sharing and exchange of hydrological information between the various Rhine Basin states.

The Tour took place in the period 7-21 November 1999 with a group of 10 participants from India, in stead of 12 expected. During the Tour technical meetings and excursions have been hold in Switzerland, Germany and The Netherlands.

The report is composed as follows:

- List of participants chapter 2
- The Tour Programme chapter 3
- The Rhine Basin chapter 4
- Detailed programme per agency chapter 5
- General observations and recommendations chapter 6

The objectives of the Tour have been reached amply, thanks to the enthusiast co-operation of the various hosting organizations and the very pleasant sphere in the group of participants.
The Tour has been organized with the assistance of WL/Delft Hydraulics and guided by Mr. W. Boiten from Wageningen University, who also compiled this report.

2. *List of participants*

The following Indian officials participated in the Study Tour:

Mr. P.C. Mathur
Commissioner (WM), Ministry of Water Resources, Government of India

Mr. C.D. Khoche
Chief Engineer, Central Water Commission

Mr. R.B.L. Tiwari
Chief Engineer, Central Water Commission

Mr. Narasimha Rao
Executive Engineer, Andra Pradesh

Mr. P.A. Jethwa
Superintending Engineer, Gurajat

Mr. S.T. Thomas
Chief Engineer, Kerala

Mr. N.S. Bhadoria
Superintending Engineer, Madhya Pradesh

Mr. S.D. Kamble
Superintending Engineer, Maharashtra

Mr. S.S. Samanta
Chief Engineer, Orissa

Mr. B. Velayudhan Pillai
Superintending Engineer, Tamil Nadu

Annex I, photo page II-1 shows the group in front of the office of the Federal Institute of Hydrology (BfG) in Koblenz.

3. *The Tour Programme*

The fortnight's programme of the Study Tour has been as follows:

Sunday, 7 Nov. `99	12.15 hr.	Arrival Schiphol Airport Amsterdam
	13:00 – 17:00 hr	City tour Amsterdam, guided by Keytours
	19:30 – 23:30 hr.	Journey Amsterdam – Zürich – Bern
Monday, 8 Nov. `99	09:00 – 12:30 hr.	Swiss National Hydrological and Geological Survey, Bern (see detailed programme in section 5.1)
	14:00 – 16:00 hr.	Excursion cable-way flow gauging station, Bern-Schoenau in the River Aare (see photo page I-2)
Tuesday, 9 Nov. `99	13:30 – 16:00 hr.	Visit Hydropowerstation Ruppoldingen in the River Aare, guided by ATEL (see photo page I-3)
Wednesday, 10 Nov. `99	09:30 – 13:30 hr.	Journey Bern – Basel – Koblenz by train
	16:00 – 17:30 hr.	City walk Koblenz (see photo page I-4)
Thursday, 11 Nov. `99	10:00 – 12:00 hr.	Federal Institute of Hydrology (BfG), Koblenz (see detailed programme in section 5.2)
	12:00 – 16:30 hr.	Visit to the Koblenz Office for Waterways and Shipping and excursion weir complex Müden, River Moselle
Friday, 12 Nov. `99	10:00 – 12:00 hr.	Federal Institute of Hydrology (BfG), Koblenz (section 5.2)
	14:00 – 16:30 hr.	International Commission for the Protection of the Rhine (IKSR), Koblenz (see detailed programme in section 5.3)
Saturday, 13 Nov. `99	09:00 – 12:30 hr.	Journey Koblenz – Arnhem – Ede/ Wageningen by train
	13:30 – 17:30 hr.	Excursion Rotterdam Harbour
Sunday, 14 Nov. `99	10:00 – 17:00 hr.	Sight-seeing and shopping in The Hague

Monday, 15 Nov. '99	10:30 – 16:30 hr.	WL/Delft Hydraulics, Delft (see detailed programme in section 5.4)
Tuesday, 16 Nov. '99	10:00 – 12:30 hr.	Royal Netherlands Meteorological Institute (KNMI), De Bilt (see detailed programme in section 5.5 and photo page I-5)
	14:00 – 16:00 hr.	Excursion weir complex Amerongen in the River Rhine
	19:30 – 21:00 hr.	Excursion National Museum of historical agricultural equipment, Wageningen
Wednesday, 17 Nov. '99	10:00 – 12:00 hr.	Excursion Storm Surge Barrier at the mouth of the Nieuwe Waterweg, Hoek van Holland (see photo page I-6)
	14:00 – 16:30 hr.	Excursion The Biesbosch water storage scheme, Werkendam
Thursday, 18 Nov, '99	10:00 – 12:00 hr.	Excursion Survey Department, Ministry of Transport, Public Works and Water Management, Arnhem
	14:00 – 16:00 hr.	Excursion Northern Bank of the Nether Rhine (natural development, living rivers), Wageningen
	19:30 – 21:00 hr.	Excursion Poultry Museum, Barneveld
Friday, 19 Nov. '99	09:30 – 16:00 hr.	Institute for Inland Water Management and Waste Water Treatment (RIZA), Lobith and Lelystad (see detailed programme in section 5.6 and photo page I-7)
Saturday, 20 Nov. '99	09:00 – 17:00 hr.	Sight-seeing and shopping in Utrecht
Sunday, 21 Nov. '99	11:00 hr.	Departure Schiphol Airport, Amsterdam.

4. *The Rhine Basin*

The principal characteristics of the hydrological conditions in the Rhine Basin and the users' demands on the river's water have been summarized as follows in the CHR paper, nr. 1-11, 1993:

"*Natural conditions*

With an average discharge of 2,200 m^3/s at the bifurcation of the Bovenrijn in the Netherlands, the Rhine ranks high among the European rivers that transport most water. Its catchment area extends from south to north over some 900 km and its surface area amounts to 185,000 km^2. It extends from the High Alps, where its source brooks rise, through the low mountain ranges, where the largest tributaries the Main and Moselle join the main stream, to the lowland. This is where, through several branches, its discharge flows into the North Sea.
The subbasins have different hydrological characteristics showing certain opposing factors. This is why the discharge of the Rhine is less prone to fluctuations than that of other European rivers of comparable dimensions. The upper course, for example, has lower discharges in the cold season than in the warm season, because a large part of the winter precipitation is transferred to the summer in the form of snow. Towards the Lower Rhine, on the other hand, this relation is reversed, because in the low mountains and lowlands snow storage is negligible and summer precipitation largely evaporates.
Only in the Alpine Rhine does the river show a very irregular discharge regime. Further on, from the Lake of Constance with its levelling effect down to the estuary, the discharge is relatively steady. From time to time, however, marked low-water periods and considerable flood waves occur. They present the riparians of the Rhine with the arduous task of securing the more and more highly developed use of the bank landscapes and of the river itself by engineering works and regulations.

Requirements for watercourses and water use

Switzerland, Germany, France and the Netherlands are principal countries that have a share in the Rhine basin, while 5 other countries only cover a small part of the precipitation area. With 54% of the surface, Germany covers the largest part and the same applies to the number of inhabitants. In the whole Rhine basin the population has increased from about 10 million in 1800 to about 50 million today. This population growth has lately been coupled with an enormous rise in economic productivity which, however, has entailed an ever increasing stress on the landscape. At the cost of woods and wasteland, the area of agricultural land has been extended. Nowadays it yields five to ten times as much per hectare as two hundred years ago. Flood protection, drainage and irrigation measures have contributed to this increase.

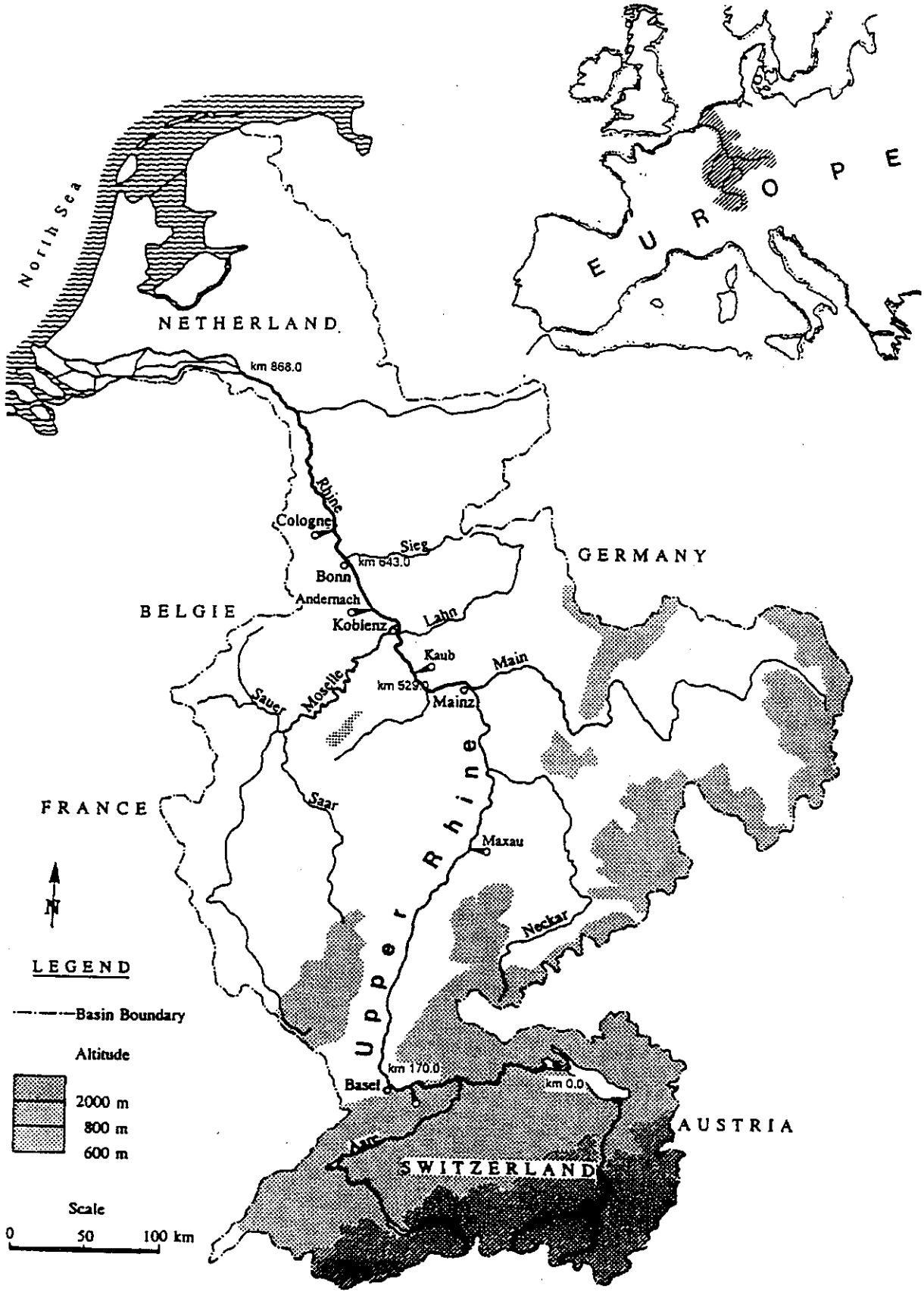

Figure 1: The basin of the River Rhine

Industry in the Rhine basin has not only expanded according to the presence of mineral resources, such as in the Ruhr area and along the upper course of the Moselle. Intensification has occurred in numerous places and involves almost all branches of modern economy, even including nuclear power stations. The costs of water supply and wastewater treatment have risen accordingly.
The Rhine as a waterway is used for the transportation of goods as well as passengers. It has been completed with connections to canalized rivers and canals. The High Rhine, Upper Rhine and numerous tributaries are used for waterpower supply. Lately the demand for water sports and recreational possibilities at the waterside has grown considerably, and these have become major considerations that have to be included in water management planning. Another important aspect to be considered is the augmentation and qualitative improvement of the fish stock.

Outlook

In response to the needs of both people and industry, the Rhine has been transformed from an uncontrolled, often destructive natural waterway to a vital artery of landscapes that are cultivated and developed by man. In spite of many alien intrusions, it has retained its character as a cultural asset. Numerous efforts have been made to regain as much as possible of the lost or damaged natural resources along its course.

Engineering operations will also have to be carried out in the future in order to keep what has been gained and develop it further. The dynamics of the water cycle never stand still, any more than do those of society. New water engineering and management projects have been announced. They involve, for example, artificial flood retention measures as part of a comprehensive control system. There will also be a problem on the left bank of the Lower Rhine when the huge hole left by brown cole open-cast mining west of the Erft has to be filled quickly with Rhine water once mining comes to an end. Further improvements to the quality of the Rhine water, will entail clean-up measures on the part of more than one country.

So far it has proved possible to increase the economic value of the Rhine and to maintain its cultural splendour. One may trust that this will remain so in the future. The countries through which it passes are acting jointly in co-operative bodies to meet this challenge."

Organizations

Various "Rhine-related" organizations are active in the Rhine Basin countries, both national governmental institutes for research in the fields of hydrology and watermanagement, and international commissions:

- Swiss National Hydrological and Geological Survey, *LHG*, Bern, Switzerland
- Federal Institute of Hydrology, *BfG*, Koblenz, Germany
  The BfG hosts the Secretariat of the German National Committees of UNESCO's International Hydrological Programme (IHP) and WMO's Operational Hydrology Programme (OHP) as well as the Global Runoff Data Centre (GRDC)
- Institute for Inland Watermanagement and Waste Water Treatment, *RIZA*, Lelystad, the Netherlands
- International Commission for Protection of the Rhine, *IKSR*, Koblenz (Ministerial platform of the Rhine Basin Governments and the European Community)
- International Commission for the Hydrology of the Rhine Basin, *CHR*, composed of the national committees of the Rhine Basin countries, in the framework of IHP and OHP. The CHR was founded in 1970. RIZA hosts the CHR secretariat.

5. *Detailed programmes per agency*

5.1 *Swiss National Hydrological and Geological Survey (SNHGS), Bern*

The SNHGS monitors Swiss waters and records the waterlevels, discharges, sediment transport, temperature and various physical and chemical properties of rivers and lakes in Switzerland. The measuring network is designed so that questions of users can be answered with the necessary accuracy.
The water level and streamflow forecasts of the SNHGS are based on three keystones:

- Hydrological and Meteorological measuring data. About 80 hydrometric stations of the SNHGS transmit information automatically by telephone to the forecasting centre of SNHGS in Bern. And 70 automatic weatherstations of the Swiss Meteorological Institute (SMI) relay their information every hour to the SNHGS centre
- Meteorological forecasts calculated with a weather prediction model of the SMI
- Scientifically elaborated procedure for hydrological forecasts, developed by the Federal Institute of Technology in Zürich.

The main users of hydrological data are government departments, universities, engineering offices and power stations.
The Swiss Hydrological Yearbook contains all the hydrological measurements since 1867. The Swiss National Hydrological and Geological Survey Bulletin includes articles on the subjects of water balance, flood discharge and sediment transport. Further results are published in the Hydrological Atlas of Switzerland.

The SNHGS organized the following programme on 8 November 1999:

- Introduction of the activities of the SNHGS, (dr. Bruno Schaedler)
- Introduction of the automatic monitoring system (mr. Ch. Koch)
- Runoff forecasting and alarm systems (dr. Bruno Schaedler)
- Communication between data-suppliers and users (dr. Bruno Schaedler)
- Visit of the calibration tank for current meters (mr. S. Graf)
- Visit Gauging station in the River Aare at Bern-Schoenau: water level, discharge measurements with a cable-way system, water quality and sediment transport (mr. B. Sigrist, and dr. Bruno Schaedler)

Photo page I-2 gives an impression of the visit to Bern-Schoenau

5.2 Federal Institute of Hydrology (BfG), Koblenz

The BfG is a principal authority of the Federal Republic of Germany, reporting to the Federal Ministry of Transport, Building and Housing, with headquarters in Koblenz and a branch office in Berlin. It is the scientific institute of the Federal Government for research in the fields of hydrology, water management and water protection and acts as a consultant for federal ministries and other authorities. The BfG also advises the Federal Waterways and Shipping Organization (WSV) in matters concerning the inland and coastal waterways, from the planning stage, development and construction, to operation and maintenance.

The BfG works principally in the following fields:

- Hydrological studies, waterbalance computations and forecast models
- Interaction between surface water and groundwater (quantity and quality)
- Analysis of dredged materials from waterways and assesment of disposal methodes
- Studies in rivermorphology
- Surveying and mapping of rivers and lakes
- Qualitative hydrology (chemistry and radiology)
- Ecology (environmental protection, ecological interactions, flora and fauna).

The BfG organized the following programme on 11 and 12 November 1999, forenoon:

- Organization and tasks of the Bundesanstalt für Gewässerkunde (dr. Lüllwitz)
- Characteristics of the floods in the River Rhine basin (mr. H. Engel)
- Forecasting methods within the River Rhine basin (mr. G. Steinebach and mr. K. Wilke)
- Visit of the Koblenz Office for Waterways and Shipping (mr. G. Werner)
- Visit of the lock Müden at River Moselle (mr. Heynert)
- Structure and activities of the IHP/OHP secretariat (mr. U. Schröder)
- Organization and tasks of the Global Runoff Data Centre (dr. W. Fröhlich)
  Since 1988 the BfG has operated the GRDC in coöperation with the World Meteorological Organization (WMO). Runoff data from the major river basins all over the world are collected and made available for users worldwide (yearbook).

Annex II-1 gives the presentation:
'Action plan on flood defence and control strategies for flood retention on the Upper Rhine', by H. Engel, German Federal Institute of Hydrology (BfG).

5.3 *International Commission for Protection of the Rhine (IKSR), Koblenz*

The IKSR is a cooperation between the Governments of:

- the Federal Republic of Germany
- the French Republic
- the Grand Duchy of Luxembourg
- the Kingdom of the Netherlands
- the Swiss Confederation

and

- the European Community

The IKSR desires to work towards the sustainable development of the Rhine ecosystem on the basis of a comprehensive approach, taking into consideration the natural wealth of the river, its banks and alluvial areas. The restoration of the Rhine is also necessary to conserve and improve the ecosystem of the North Sea.

The Commission shall prepare international programmes and studies of the Rhine ecosystem and make use of their results, in cooperation with scientific institutions.

On 22 January 1998 the 12th Conference of Rhine Ministers adopted the "Action Plan on Flood Defences" in Rotterdam, implying expenses of up to 12 Billion ECU. This Action Plan aimed at the improvement of precautionary flood protection and will be implemented within the next twenty years (see Annex II-1) For the first time there is international demand to give considerably more expanse to the Rhine in case of floodings. In the course of the last two centuries the Rhine lost more than 85% of its natural alluvial areas, as man used them for settlements or agriculture.

Present counter measures, such as the assignment of alluvial areas, their preservation and expansion and improved water storage in the entire catchment area, must simultaneously aim at an ecological improvement of the Rhine, its valley and its catchment area.

The IKSR organized the following programme on 12 November 1999 afternoon:

- The Rhine, use and conflicts (mr. K. Wieriks)
- International Cooperation to protect the Rhine: the IKSR (mr. K. Wieriks)

5.4 *WL/Delft Hydraulics, Delft*

WL/Delft Hydraulics is an independent consulting and research institute, founded in 1927. The institute is working within the Netherlands and abroad, providing advices and technical assistance on water-related issues. It is renowned for its experimental resources and its computer programmes:

- The experimental resources include a variety of flumes, waves-, current- and tidal basins, calibration facilities and testing circuits.
- A wide range of computer programmes have been developed and validated, with which many water systems can be simulated.

WL/Delft Hydraulics provides principally the following advisory services:

- Feasibility studies
- Impact assessments
- Fast finding missions and site-specific surveys
- Monitoring, processing and analysing field data
- Technical assistance
- Decision-support studies
- Performance evaluations

WL/Delft Hydraulics organized the following programme on 15 November 1999:

- Introduction of the activities of WL/Delft Hydraulics (mr. Jan Groen)
- Project on flood risks in North-East Belgium (mr. Jaap Kwadijk)
- The Rhine in the future (mr. Frans Klijn)
- Project FLORIJN on Flood Early Warning System in the Rhine (mr. Aart Vermetten)
- Miscellaneous projects in the Inland Water Systems Division (mr. Karel Heynert)
- Design discharges in the Netherlands (mr. Ron Passchier)
- Visit to the facilities of WL/Delft Hydraulics (mr. Ron Thieman)

During this visit Mr. P.C. Mathur form the Indian delegation gave a presentation on "Water and agriculture in India".

5.5 *Royal Netherlands Meteorological Institute (KNMI), de Bilt*

The KNMI is an agency of the Ministry of Transport and Public Works. It is the Dutch national centre for information on weather, climate and seismology. It concentrates on fullfilling the following public tasks and responsibilities:

- Weather forecasts and weather alerts
- Climate monitoring

- Collecting and providing meteorological data and the related infrastructure
- Model development
- Aviation meteorology
- Scientific research and public information

The KNMI has fifty observation stations in the Netherlands, some of which are located on platforms in the North Sea. They automatically measure temperature, atmospheric pressure, humidity, solar radiation, wind, precipitation, visibility and cloud cover. In addition, over three hundred volunteers throughout the country measure rain and snowfall. The KNMI also has a lightning detection system, radar systems and ground stations for receiving satellite images and instrumentation to measure ultraviolet radiation.
The KNMI periodically publishes reports, overviews, tables, charts and graphs with up-to-date information about weather and climate in the Netherlands, to serve both the national and the international communities.

The KNMI organized the following programme on 16 November 1999:

- Organization of KNMI (dr. A. Kattenberg)
- Models in weather forecasting (mr. A.T. Moene)
- Network design for climatology (mr. A.M.G. Klein Tank)
- Network maintenance with respect to raingauges (mrs. P.J. van Eif)
- Visit weather room and weather station (mrs. M. Boedhoe and mr. R. Jilderda)

Photo page I-5 gives an impression of the visit to the KNMI weather station, de Bilt.

5.6 *Institute for Inland Water Management and Waste Water Treatment (RIZA), Lelystad*

Water management in the Netherlands is mainly carried out at two levels:

- National Water Management is the responsibility of the Ministry of Transport, Public Works and Watermanagement carried out by Rijkswaterstaat and RIZA
- Regional Water Management is the task of about 60 Waterboards.

The Department of Public Works and Watermanagement (Rijkswaterstaat) is responsible for the major rivers in the Netherlands. The Institute for Inland Water Management and Waste Water Treatment (RIZA) is the fresh water research and advisory institute of the "Rijkswaterstaat".

The RIZA was set up in 1920. The head office is located in Lelystad. There are branch offices in Arnhem and Dordrecht and monitoring stations in Lobith (River Rhine) and Eysden (River Meuse). The RIZA has four main-departments:

- *Information and Measurement Technology*
  Collecting and storing data about inland waters in the Netherlands and processing these data into information for the users: shipping, waterboards, drinking water companies, consultants and policy-makers at the Ministry.
- *Water Systems Department*
  Research into biological, environmental, chemical and physical processes that take place in and around inland waters.
- *Water Pollution Control*
  Research into waste water treatment technology and clean production processes and advices when discharge permits are granted.
- *Wetland Development and Restoration*
  Ecohydrological soil- and ecological research.

The Department makes her expertise available for (development cooperation) projects in Europe as well as abroad.

The RIZA hosts the Secretariat of the International Commission for the Hydrology of the Rhine Basin (CHR).

The RIZA organized the following programme on 19 November 1999:

- Monitoring in the Netherlands (dr. Bart Parnet)
- Permanent water quality monitoring station Lobith (mr. Peter Brandt)
- Water pollution control (mr. Jaap Rus)
- Flood forecasting (mr. Mauk Burgdorffer)
- Visit Inland Waters Information Centre (mr. Klaas Wieringa)

Photo page I-7 shows the on-line monitoring station Lobith and its bio-alarm with fish.

The RIZA programme included also a presentation about international cooperation on hydrology in the Rhine basin, which has been canceled due to illnes of the speaker.
Annex II-2 gives this presentation: "The International Commission for the Hydrology of the Rhine Basin (CHR)" by mr. Marius Meulenberg, secretary of the CHR and working with RIZA Lelystad.

6. *General observations and recommendations*

- The Tour programme appeared to be a rather full programme, both concerning the "lecture days" and the field visits/excursions.

- All the participants attended the full programme. They made many annotations and took an active part in the discussions.

- In the future it would be advisable for the "lecture days" to supply the full written paper and a copy of overhead sheets of the presentations beforehand, in order to make the lectures more effective.

- It is expected that the participants in this Study Tour went home after two weeks in the River Rhine Basin, with a lot of professional inspiration.

Annex II-1

ACTION PLAN ON FLOOD DEFENCE AND CONTROL STRATEGIES FOR FLOOD RETENTION ON THE UPPER RHINE

H. ENGEL
German Federal Institute of Hydrology – BfG

1. General background

The 1980/90s experienced a series of major floods both on a global scale and in Central Europe. Following a 12-year period nearly without floods, a dual event occurred in 1983, with the two flood peaks merely about seven weeks apart. In March 1988, the riparian dwellers on the Middle Rhine had to cope with the highest discharge measured so far. This gave the first impetus for reviewing man's attitude towards the elementary event of flooding. Finally, in response to very extreme events in the northern Rhine basin (at Christmas 1993 and in January 1995) concrete steps were initiated both at national and international levels.

2. The Action Plan on Flood Defence of the International Commission for Protection of the Rhine (*IKSR*)

Following an initiative of the Environmental Ministers of the German Federal States, the "Guidelines for Forward-Looking Flood Protection" (1] were drafted and adopted already in May 1995.

In parallel, the Ministers of the Environment of France, Germany, Belgium, Luxemburg and the Netherlands declared on 4 February 1995 in Aries that they deemed necessary to reduce flood-related risks as rapidly as possible. It was not acceptable to them that situations as came up at that time put people's lives and property and the environment at such great risk. Prior to its adoption this declaration had been agreed upon with Switzerland.

In the same month still, the existing River Commissions on Rhine, Saar/Moselle and Meuse were ordered to establish action plans on flood defence. In response to this order the International Commission for the Protection of the Rhine (*IKSR*) commissioned the Project Group "Action Plan on Flood Defence" with this work for the River Rhine under consideration of its basin. Ecological improvements of the Rhine and its floodplains should be integrated and promoted by this effort too.

On the one hand, the Project Group harnessed the findings of other commissions and study groups and, on the other hand, made or commissioned its own surveys and investigations.

In March 1997,

- an inventory on flood defences on the River Rhine
- and a survey on warning systems and proposals for improving flood forecasting in the Rhine basin

had been completed.

In January 1998,

- the "Rhine Atlas - Ecology and Flood Protection" and
- the compilation "Ecologically valuable areas and first steps toward interconnected biotopes on the River Rhine"

were available.

2.1. OBJECTIVES OF THE ACTION PLAN ON FLOOD DEFENCE

The *IKSR* Action Plan on Flood Defence [2] was published in March 1998. The intended improvement of the protection of population and property against flooding and the integration of the aim of ecological improvement of the River Rhine and its floodplains presuppose integrated thinking and action at local, regional, national, and transnational levels. Here, contributions from such policy fields like water-resources management, regional planning, nature conservation, agriculture and forestry are indispensable.

The Working Group "Action Plan on Flood Defence" formulated five guiding principles in matters of preventive flood protection:

1. **Water is part of the whole** - everywhere water is an element of the balance of nature and of land uses and must be given due consideration in all policy fields.
2. **Store water** - water must be retained as long as possible in the whole catchment and along the River Rhine.
3. **Let the river expand** - we must return to the river enough room to expand, so that runoff is delayed without posing dangers.
4. **Be aware of the danger** - despite all efforts taken a certain risk will remain. We must team again to live with this risk.
5. **Integrated and concerted action** - integrated action in the spirit of solidarity throughout the catchment is a prerequisite for the success of the action plan.

On the basis of these conditions, the action plan postulates four essential action targets, which should be understood as political objectives.

- **Reduce damage risks** - no increase of damage risks until the year 2000, their reduction by 10 % until 2005, and by 25 % until 2020.
- **Reduce flood stages** - reduce extreme flood stages downstream of the impounded river reach by 30 cm until 2005 and by 70 cm until 2020.
- **Increase awareness of flood risks** – increase the awareness of flood risks by drafting risk maps for 50% of the floodplains and flood-prone areas until the year 2000 and for 100% of these areas by 2005.
- **Improve the system of flood forecasting** - short-term improvement of flood warning systems by international cooperation. Prolong the forecasting period by 50% until the year 2000 and by 100% until 2005.

The percentages given here refer to the base year 1995. The figures of flood-stage reductions are the result of an effectivity assessment of water retention in the Rhine basin [3]..

2.2 IMPLEMENTATION OF THE ACTION PLAN ON FLOOD DEFENCE AND ITS COSTS

Cost estimates for the necessary actions for the scheduled project life (until 2020) amount to ECU 12.300 million.

Of these, nearly ECU 2,000 million must be raised until the year 2000 and until 2005 another ECU 2,500 million.

Table I shows a breakdown of the costs in the various categories including their achievable flood-protection effects. It is obvious that water retention in the catchment area and along the River Rhine requires by far the highest financial inputs. If one compares the protection effects to be expected with the necessary costs in detail, one finds that technical flood retention facilities are already operational, while others are in the contract phase. These two parts together provide a retention volume of about 270 million m^3. Another 95 million m^3 are conceivable, reasonable, and desirable. High flood stages can be reduced through water retention by 60 to 70 cm on the Lower Rhine.

The implementation of the measures listed in the Action Plan calls for an international and interdisciplinary policy understanding which is not oriented at the local success of single activities. The appeal to implement consistently the activities of the Action Plan in their sphere of responsibility addresses all riparian states.

The Action Plan should not be understood as a tied-up bundle of activities, but as a target framework for which the contents are regularly newly defined by new experiences. A first balance on achievements will be drawn by the Governments in the year 2001. The yardstick will be the flood- and damage-reducing effect for a variety of floods from

frequent to rare events. The effectiveness of prepared and implemented measures of flood prevention and defence is verified by a collective of model floods which simulate the flood-flow behaviour in the catchment. The tools for this exercise are currently being developed in the context of the EU projects INTERREG IIc with active participation of the *BfG*. Experiences of more than three decades of mathematical runoff modelling and from the cooperation in the *IKSR* effectivity assessment [3] are thus contributed.

TABLE 1. Action Plan on Flood Defence on the River Rhine - Overview on activities 1998-2020, - Effects and costs

Activity categories	Flood protection effects	Other effects	Cost estimate [million Ecu]
Water retention in the Catchment	**About 10 cm reduction of flood levels**		**8400**
- Renaturation of rivers (11.000 km)	- Little close-range effects	- Restoration of aquatic and Terrestrial habitats	1.160
- Reactivation of inundation Areas (1.000 km^2)	- Local effects, little effects in the Rhine	- Groundwater recharge, Restoration of aquat. and terr. habitats	2.030
- Extensification of Agriculture (3.900 km^2)	- Little close-range effects	- Groundwater recharge, new habitats	1.705
- Promotion of nature, Afforestation (3.500 km^2)	- Little close-range effects	- Groundwater recharge, new habitats	680
- Desealing (2.500 km^2)	- Little close-range effects	- Relieving sewers and Treatment plants	1.890
- Tech. Flood retention (73 million m^3)	- Local effects, little effects in the Rhine	- New habitats	935
Water retention on River Rhine			**2.410**
- Reactivation of inundation Areas (160 km^2)	- Flood-level reduction 15-25 cm	- Groundwater recharge, Restoration of aquat. and terr. - New habitats	1.450
- Techn. flood retention (364 million m^3)	- Flood-level reduction 45-60 cm		960
Techn. flood defence			**1.418**
- Maintenance and strengthening of dykes, adaptation to the required degree of protection (1.115 km)	- Reduction of damage risks	- Increased safety for Downstream dwellers	
Precautionary activities in the planning area			**60**
- Flood-adapted land uses - Risk mapping	- No increase of damage risks - For 100% of inundation areas and flood-prone sites	- Prevention of soil erosion - Increasing flood awareness	
Flood forecasting			**12**
- Improved forecasting - Improved cooperation	- Prolonged forecasting time: 100% - Improved warning system	- Increased safety for riparian Dwellers	
Certain types of activities are justified not alone by their flood protection effects, but do also meet important targets in other policy fields			

3. Water retention on the Upper Rhine

The possibilities for improving the protection of riparian dwellers against floods listed by the *IKSR* include also the technical flood retention facilities on the Upper Rhine. Their construction must be seen as a direct consequence of the impoundment of the Upper Rhine by a series of weirs, what had reduced the safety against floods for the downstream reaches. 'The International Study Commission of Floods on the River Rhine (*HSK*), that was founded in 1968, was able to derive from detailed studies pertinent conclusions and to quantify the effects. In line with its task, the commission also formulated recommendations for "measures against the increased flood risk due to the training of the river".

This study took into consideration only such floods which remain below or are equal to the 200-year discharges, but would today overflow the protective dykes (that could safely hold 200-year discharges until 1955). Flow-accelerating effects were left out of account. **Figure 1** gives a schematic presentation of changed flow patterns due to the impoundment of the Upper Rhine and the planned effect of the compensation measures.

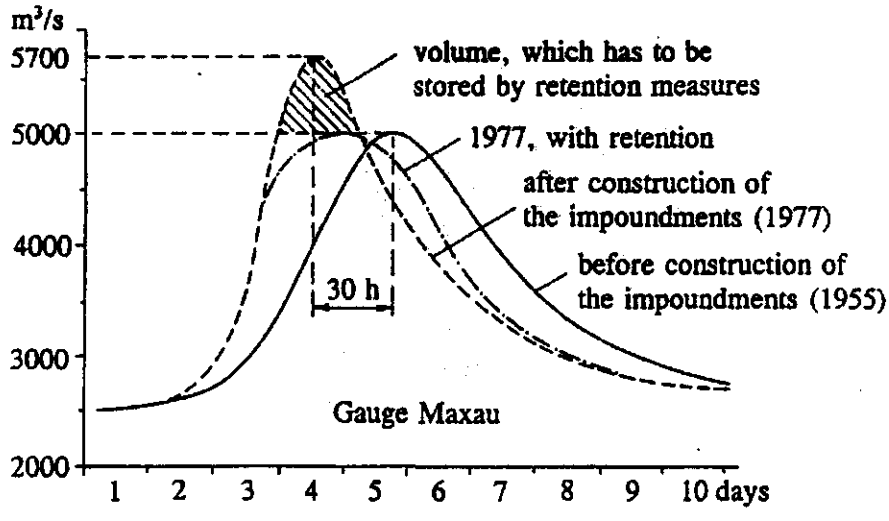

Figure 1. Changing flood hydrographs in the Rhine with focus on flood retention (schematic)

For attenuation of flood peaks, the *HSK* recommended three different approaches to water retention [4]:

- In the special operation modus of the Rhine hydropower stations from Kembs downstream to Strassburg, the water volumes that flow usually through the lateral canal or through the following canal loops are diverted into the natural bed of the river, what causes a time delay and - through retention in the riverbed - a reduction of discharge.

- Impoundment behind retention weirs in the Rhine riverbed allow to achieve nearly any desired reduction of discharge per time unit within the limits of the available discharge-dependent storage volume.
- Inundation of presently non-flooded polders reactivates old floodplain areas of the river. This inundation should be regulated by controllable inlet structures.

All three forms of retention are only practicable in the impounded reach. On the free-flowing reach of the Rhine this can be achieved only by lateral retention basins along the river.

In 1978, activities to yield a maximum retention volume of about 220 million m^3 were proposed. In 1982, a concept providing for retention of 226 million m^3 was adopted on contract basis (**Table 2**). Delays in its implementation and new ecological aspects in its assessment have led to changes in some activities, while others had to be abandoned altogether.

Flood protection activities, which have an ecological orientation, were reflected in new proposals. Ecological operation modes of retention capacities, however, require in comparison with the previous concept wider inundation areas or more retention volumes (**Table 2**) alone to restore the flood safety of the year 1955 (protection against the 200-year peaks at that time). Additional improvements can be achieved by technical possibilities downstream of the inflow of the River Neckar, namely by better utilisation of existing inundation areas for flood retention or by reactivation of former floodplain areas. Here, controllable polders are practicable as well as landward shifting of dykes and flooding of expanded alluvial areas in the former floodways on the back side of the dykes (Auenzüge).

3.1. CONTROL STRATEGIES

The control strategies for flood retention projects [5] must generally meet the following requirements:

- Reduce effectively damage-inflicting floods;
- Prevent ecological damage or improve the overall ecological situation on the River Rhine and in the polders;
- Regain the full retaining capacity possibly immediately after use (to accommodate possible following floods).

On the impounded river reach, additional demands are:

- Minimise the losses in energy generation of hydropower stations during flood retention;
- Prevent hindrances to navigation already in the period before the flood.

In order to make best use of the local conditions, for each implementation phase control options have to be defined which promise the optimum effectiveness of the existing retention potential.

TABLE 2. Retention facilities on the Upper Rhine

Nr.	Retention measure	Type of retention[2)]	Concept 1982 [million m^3]	Concept May 1996 [million m^3]
	France			
1	• *Special operation modus of Rhine hydropower stations* [1)]	Operational regulations	45	45
2	Erstein	Polder	6	7,8
3	• *Moder*	Polder	5	5,6
	Sum for France		**56**	**58,4**
	Baden-Württemberg			
4	South of Breisach GW-recharge weir	Weir or lowering of forelands	53	25,0
5	GW-recharge weir Breisach [1)]	Weir	10	9,3
6	Breisach/Burkheim	Polder	-	6,5
7	Wyhl/Weisweil	Polder	-	7,7
8	Elz inflow	Polder	-	5,3
9	Ichenhein-Meissenheim	Polder	-	5,8
10	• *Altenheim*	Polder	18	17,6
11	• *GW-recharge weir Kehl/Strassburg* [1)]	Weir	37	37,0
12	Freistett	Polder	-	9,0
13	Söllingen/Greffern	Polder	8	12,0
14	Bellenkopf/Rappenwört	Polder or landward shift of dykes	-	14,0
15	Elisabethenwört	Polder or landward shift of dykes	-	11,9
16	Rheinschanzinsel	Polder	-	6,2
	Sum for Baden-Württemberg		**126**	**167,3**
	Rhineland-Palatinate			
	No defined sites		30 + 14	
17	• *Daxlander Au*	Polder		5,1
18	Wörth/Jockgrim	Landward shift of dykes		8,8
19	Neupotz	Polder		8,6
20	Mechtersheim	Polder		7,4
21	Flotzgrün	Polder		5,0
22	Kollerinsel	Polder		6,1
23	Waldsee/Altrip/Neuhofen	Polder		8,1
24	Petersau/Bannen	Landward shift of dykes		1,4
25	Mittelbusch (Worms II)	Landward shift of dykes		2,3
26	Bodenheim/Laubenheim	Polder		6,0
27	Ingelheim	Polder		3,8
	Sum for Rhineland-Palatinate		**44**	**62,6**
	Sum total		**226**	**About 288**

- *Completed or operational (at the Groundwater-recharge weir Kehl/Strassburg at present only 12 million m^3 useable)*

1) Maximum values; the real volumes depend on stream flow in the Rhine

2) The effectivity of all measures in the free-flowing reach depends on stream flow.

At present about 110 million m^3 of technical retention capacity are provided for, of which around 75 million m^3 are operational:

- Special operation modus of hydropower station in the lateral canal and in the four canal loops downstream to Strassburg;
- The polder of Moder built on French territory;
- The polders of Altenheim and Daxlander Au on the German side;
- The groundwater recharge weir Kehl-Strassburg.

For the settlement of all problems that may occur on the Upper Rhine, Germany and France established a "Standing Commission" which has a "Technical Committee" to deal with all technical issues and integrates, if needed, also pertinent working groups. The rules for the operation of the retention facilities are established by the joint French-German "Working Group Manöver". Moreover, it has the task to update the rules in line with the progress of project implementation.

Control strategies were developed by means of suitable model floods. The operating instruction, that was introduced in 1998 by the "Standing Commission" and remains valid until further notice, comprises also the above-mentioned bundle of activities. The criteria for the various modes of operation are all related to certain thresholds of discharge and their exceedance at gauging stations on the High Rhine and the Upper Rhine.

When a discharge of altogether 2.800 m^3/s is observed in the Rhine at Strassburg, the water volume usually stored behind the groundwater-recharge weir Kehl is "(pre)-emptied". In this initial phase at maximum 200 m^3/s are additionally released downstream. As soon as the discharge at Maxau reaches 3.800 m^3/s and shows a rising tendency, the retention of water behind the GW-recharge weir begins with 400 m^3/s at maximum. The retention volume is flow-dependent; the retention gradient is controlled by movable openings in the weir. However, for constructive reasons full-capacity impoundment is not permitted yet (except in explicit emergency cases).

The retention is stopped when the discharge at Maxau drops again below 4.200 m^3/s. If Ns threshold was not even reached, the stoppage becomes effective below Q_{Maxau}= 3.600 m^3/s, provided no new rise is observed at Basel. For a quick recovery of retention volume, the impoundment is emptied immediately after use. However, with a maximum rate of 400 m^3/s this is done in such a manner that the peak discharge prevailing at the beginning of the emptying operation is not exceeded.

The two polders at Altenheim are situated besides the storage of the GW-recharge weir. Simultaneously with the retention behind this weir they are filled at a rate of 150 $m^{3/}s$. The stoppage of filling, respectively their emptying, are controlled by the same rules as those for the operation of the weir.

The special operation mode of the hydropower stations on the Rhine begins when the thresholds of 3.300 m^3/s at the gauge Basel and 4.200 m^3/s at the gauge Maxau are simultaneously reached or exceeded. This action means losses in energy generation, so that it is initiated rather late. It is stopped simultaneously with a possible stoppage of the actions at the GW-recharge weir and in the polders at Altenheim. The re-diversion of flow to the turbines of the lateral Rhine canal is initiated when discharge at Basel is again at least 1000 m^3/s below the previous peak, and when simultaneously discharge at Maxau has dropped below a value of 4.500 m^3/s, but at the earliest 20 hours after the passage of the peak at Basel. In the canal loops, the increase of flow is initiated 20 hours after the beginning of this manipulation in the lateral Rhine canal.

Finally, the polder of Moder is filled when discharge at Maxau exceeds 4.400 m^3/s. Its maximum filling rate is 160 m^3/s, emptying begins when discharge at Maxau drops below 4.000 m^3/s.

This instruction is the result of a great number of simulation computations with a mathematical flow-routing model at the State Agency for the Environment of Baden-Württemberg (*LfU*) in Karlsruhe. With the implementation of each additional retention project (the polder of Erstein in France will be completed next) a new fine-tuned operating instruction will be developed. The aim of the regulation is to prevent overflow of dams as long as possible with the means available (at present a reduction from 5.400 m^3/s to 5.000 m^3/s at Maxau or from 6.500 m^3/s to 6.000 m^3/s at Worms).

Since the conclusion of the contracts on the implementation of the retention capacities on the Upper Rhine, modifications of single measures took place in terms of location, dimension, and planned or permitted operational characteristics, including the new option of ecological flooding. It was necessary to furnish the proof that these modifications will just as well achieve the defined objectives. After completion of all projects, the groundwater-recharge weir and the inlet structures of the polders at Altenheim, as well as the special operation modus of the hydropower stations will be controlled on the basis of a discharge threshold at Maxau. All other facilities become activated according to the discharges measured at the sites or the cumulative discharges in the rivers Neckar and Rhine, unless they are "automatically" activated as in the cases of overflow of dams or dams relocated landwards.

The currently scheduled bundle of measures will make it possible to reduce the 200-year peaks of different flood patterns at Maxau and Worms to the holding capacity of the dams. It ensures moreover that ecological flooding is not interrupted unnecessarily and that water retention is not continued when the flood situation does not urgently require it.

Ecological flooding is begun when discharge reaches about 1.500 m^3/s at the site. This means that already at discharge rates in the Upper Rhine of less than 2 years recurrence

water retention becomes activated and potentially developing floods of small or medium dimensions further downstream are mitigated.

3.2. ASSESSMENT OF THE RETENTION OPTIONS AND THEIR CONTROL

The measures described here have exclusively the purpose to improve the flood situation of the dam-protected reaches downstream of the last impoundment weir in the Rhine. Regulations for the targeted protection of single objects on the Middle Rhine and Lower Rhine are not part of the contracts. Moreover, this would require forecasting lead times which cannot be achieved for the time being. Nevertheless, the measures and activities, which are being implemented for the protection of the population on the Upper Rhine, let expect beneficial effects for the downstream dwellers as well.

The effectivity assessment of flood precautions performed in the context of *IKSR* activities showed that the activation of all retention facilities following extreme situations at site (HQ_{200}) will yield reductions of flood peaks on the southern Upper Rhine in the statistical mean.

Which effects these are in detail could be demonstrated at three flood events during which these measures were activated:

- In 1988, the retention of about 25 million m^3 of water reduced the peak of a flood downstream of the impounded reach by 265 m^3/s (around 23 cm). On the Lower Rhine this effect still amounted to nearly 100 m^3/s.
- In 1990, additional auxiliary measures were activated during a flood event that was relevant only for the Upper Rhine. The effect achieved downstream of the impounded reach was similar like in 1988.
- In February 1999, 60 to 70 million m^3 of water were retained, what effected a reduction of the peak downstream of the last impoundment by some 50 cm. This reduction shortened the recurrence interval of the peak at Maxau from around 100 to 20 years.

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Annex II-2

THE INTERNATIONAL COMMISSION FOR THE HYDROLOGY OF THE RHINE BASIN

The International Commission for the hydrology of the Rhine Basin was founded in 1970 within the framework of the International Hydrological Decade of UNESCO.

In the CHR the national committees of Switzerland, Austria, Germany, France, Luxembourg and Holland work together in the framework of UNESCO's International Hydrological Programme and the Operational Hydrological Programme of the WMO (World Meteorological Organisation)

The languages of communication are German and French.

Today the commission functions as an instrument for the co-operation between the hydrological and water management institutes in the partner states and it supports the cross boundary hydrological research programmes.

The CHR started in 1970 with making an inventory of the Rhine catchment area, which was documented in its first publication in 1978 of a three volume Monograph, Maps, Tables and a Textual part.

With the Monograph finished, the CHR focused on several themes, such as:

- Research in the changes of the discharge pattern;
- Making an operational alarm model for water pollution;
- Description and analysis of extreme hydrological events, like the low water period in 1976 and the extreme high waters in 1983, 1988, 1993-1995;
- Comparison of measuring instruments and measuring methods as well as models for the understanding of the transport of sediment;
- Assessment of the impact of climatic changes and changes of land-use on the discharge pattern;
- GIS (Geographic Information System) of the Rhine hydrology;
- Compilation of a bibliography of the Rhine catchment area.

The task of the commission has changed in the course of time with the development of the problems and needs in the region. In the past the main focus was on the specific matters of collecting data and describing hydrological processes. Today the focus is more on getting a general picture of the interaction between several influencing factors, as well as the relation between man and water.

The goal is to make a basis available for the sustainable management of the waters in the Rhine catchment area.

In the course of the last 25 years the framework of political and institutional conditions have also changed considerably. The European Union sets norms and goals in their Policy on Water, and other international organisations like the International Commission for Protection of the Rhine (IKSR) and the North Sea Conference have gained considerable influence.

MISSION AND TASKS OF THE CHR

- The CHR initiates the research into the principles for the sustainable management of the Rhine and the waters in its cathment area. It collects data of relevant studies in the Rhine riparian states and makes them into generally applicable principles.
- The CHR supports the realisation of sustainable Water Management by:
  - making available the results of its studies to the decision makers in the Rhine riparian states and by:
  - contributing to the evaluation and development of Strategies and Measurements.
- The CHR promotes the best possible use of expert research sources by:
  - promoting the co-operation between the hydrological institutes of the Rhine area ;
  - performing joint researchers as well as standardised procedures for the collecting and processing of hydrological data;
  - working together with scientific and official authorities as weel as international organisations in the Rhine area;
  - promoting the exchange of data;
  - keeping in touch with similar organisations of catchment area's, inside and outside of Europe;
  - working together with IHP of UNESCO and OHP of WMO and letting its research results flow into their programme.

ORGANISATION

The CHR is a permanent, independent international commission and performs its task in the whole Rhine catchment area. It is a foundation, based in the Netherlands.

The CHR consists of permanent representatives of the partner states. These permanent representatives come from leading scientific departments and research institutions. They represent their countries and see to the involvement of their national organisations, public as well as private, working in the field of norm-setting scientific water management. The number of representatives should not exceed 15.

The presidency circulates between the member states. The president supports the work of the CHR, gives new impulses, represents the commission in the outside world and is chairman of the meetings of the commission.

The secretariat is financed by the Netherlands and is housed at RIZA. The secretary supports the president in his work and keeps in touch with the working-groups and rapporteurs.

The CHR has two meetings a year.
This meeting:

- decides on the strategy and the working programme of the CHR;
- works as a forum for strategic questions for the sustainable water management in the Rhine basin;
- forms and ensures good relations with scientific and official authorities in the Rhine riparian states and in the European Union as well as in international organisations;
- decides on projects to be carried out and on the publication of finished projects.

The CHR tunes up its work with the other international organisations, especially those in the Rhine basin. The secretary of the International Commission for Protection of the Rhine (IKSR) takes part in the meetings of the CHR. Individual members of the CHR participate in working groups of the IKSR.

FIELDS AND THEMES OF RESEARCH OF THE PRESENT

- Strategies for a sustainable Water Management:
  Identification of key-factors and discussion of options for action.
- Water management and high water management, especially the hydrological aspects.
- Identification of gaps in normative scientific skills (understanding, data, solutions) for a sustainable water management. The hydrological aspects come first here.
- Runoff quantities (qualities of the catchment area and its streams) for the drainage pattern.
- Sediment behaviour seen in the light of the drainage pattern and the morphological circumstances.
- Ecological functions of the hydrological and morphological processes.
- Models that make it possible to describe hydrological and morphological processes, as well as to understand the impact of the different interventions in the streams.
- Methods for data registration, data processing and exchange of information, as well as hydrological predictions.
- Monographs of hydrological relevant information.

These themes are interconnected. For instance modelling and methods are a precondition for the development of strategies and concepts. Therefore it is important that all themes of research are equally looked into, despite the limited manpower in the CHR.

ORGANIZATION AND FINANCING OF THE WORK

The CHR organizes its work in projects. In some projects CHR takes the lead, in other projects CHR acts as a partner to projects and programmes of other scientific and/or official authorities in Rhine riparian states, the European Union or other international organizations.

In the situation where CHR takes the lead in the project, CHR decides on the realisation of the project, on the project manager, sets up a working group (for large projects) and supports the project manger in financing the project.

In other projects, where CHR is a partner, CHR appoints a project manager for the CHR part and a rapporteur to report on the progress of the overall project.

The CHR finances the projects in general with funds from the institutes that are represented in the Commission and with research funds of the Rhine riparian states, EU and other international organizations.
The members of the CHR donate a yearly contribution, that is mainly used for project evaluation, initiating new projects and publications.

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Annex IV Addresses

- **Wageningen University**
  Department of Environmental Sciences
  Sub-department Water Resources — contact: Mr. W. Boiten, Mr. P.M.M. Warmerdam
  Nieuwe Kanaal 11
  6709 PA Wageningen — phone : +31 317 482 778
  The Netherlands — fax : +31 317 484 885

- **Swiss National Hydrological and Geological Survey**
  CH-3003 Bern
  Switzerland

  visiting address:
  Papiermühlestrasse 172 — contact: dr. Bruno Schaedler
  3063 Ittingen — phone : +41 31 324 77 58
  Switzerland — fax : +41 31 324 76 81

- **Federal Institute of Hydrology (BfG)**
  Kaiserin Augusta Anlagen 15-17 — contact: dr. Thomas Lüllwitz
  D-56068 Koblenz — phone : +49 261 1306 5331
  Germany — fax : +49 261 1306 5302

- **Global Runoff Data Centre (GRDC)**
  Federal Institute of Hydrology
  Kaiserin Augusta Anlagen 15-17 — contact: dr. W. Fröhlich
  D-56068 Koblenz — phone : +49 261 1306 5224
  Germany — fax : +49 261 1306 5280

- **IHP/OHP Sekretariat**
  P.O. Box 309 — contact: Prof.Dr. K. Hofius
  D-56003 Koblenz — phone : +49 261 1306 53 13
  Germany — fax : +49 261 1306 54 22

- **International Commission for Protection of the Rhine (IKSR)**
  P.O. Box 20053
  D-56002 Koblenz
  Germany

  visiting address:

Hohenhollernstrasse 18	contact:	mr. K. Wieriks
D-56068 Koblenz	phone :	+49 261 12495
Germany	fax :	+49 261 36572

- **WL/Delft Hydraulics**
  P.O. Box 177
  2600 MH Delft
  The Netherlands

  visiting address:

Rotterdamseweg 185	director:	mr. Jan Groen
2629 HD Delft	phone :	+31 15 285 85 85
The Netherlands	fax :	+31 15 285 85 82

- **Royal Dutch Meteorological Institute (KNMI)**
  P.O. Box 201
  3730 AE De Bilt
  The Netherlands

  visiting address:

Wilhelminalaan 10	contact:	mr. R. Jilderda
3732 GK De Bilt	phone :	+31 30 2206 69 11
The Netherlands	fax :	+31 30 2210 40 7?

- **Storm Surge Barrier 'Het Keringshuis'**

Nieuw Oranjekanaal 139	contact:	mrs. Patricia de Vries
3151 XL Hoek van Holland	phone :	+31 174 511 222
The Netherlands	fax :	+31 174 540 324

- **Water company 'Brabantse Biesbosch'**

  Petrusplaat 1 — contact: mr. Volz
  4251 NN Werkendam — phone : +31 183 508 444
  The Netherlands — fax : +31 183 508 499

- **Ministry of Transport, Public Works and Watermanagement**

  Water Survey Department
  P.O. Box 9070 — contact: mr. H. Havinga
  6800 ED Arnhem — phone : +31 26 368 89 11
  The Netherlands — fax : +31 26 363 48 97

- **Institute for Inland Water Management and Waste Water Treatment (RIZA)**

  P.O. Box 17 — contact: dr. B. Parmet
  8200 AA Lelystad — phone : +31 320 298 411
  The Netherlands — fax : +31 320 249 218

- **International Commission for the Hydrology of the Rhine Basin (CHR)**

  p/o RIZA
  P.O. Box 17 — contact: mr. M. Meulenberg
  8200 AA Lelystad — phone : +31 320 298 411
  The Netherlands — fax : +31 320 249 218