Development of flood management strategies for the Rhine and Meuse basins in the context of integrated river management

Executive Summary of the IRMA-SPONGE project
3/NL/1/164 / 99 15 183 01

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Preface

This report and the IRMA-SPONGE Umbrella Program

In recent years, several developments have contributed not only to an increased public interest in flood risk management issues, but also to a greater awareness of the need for improved knowledge supporting flood risk management. Important factors are:
- Recent flooding events and the subsequently developed national action plans.
- Socio-economic developments such as the increasing urbanisation of flood-prone areas.
- Increased awareness of ecological and socio-economic effects of measures along rivers.
- Increased likelihood of future changes in flood risks due to land use and climate changes.

The study leading to this report aimed to fill one of the identified knowledge gaps with respect to flood risk management, and was therefore incorporated in the IRMA-SPONGE Umbrella Program. This program is financed partly by the European INTERREG Rhine-Meuse Activities (IRMA), and managed by the Netherlands Centre for River Studies (NCR). It is the largest and most comprehensive effort of its kind in Europe, bringing together more than 30 European scientific and management organisations in 13 scientific projects researching a wide range of flood risk management issues along the Rivers Rhine and Meuse.

The main aim of IRMA-SPONGE is defined as: "*The development of methodologies and tools to assess the impact of flood risk reduction measures and scenarios. This to support the spatial planning process in establishing alternative strategies for an optimal realisation of the hydraulic, economical and ecological functions of the Rhine and Meuse River Basins."* A further important objective is to promote transboundary co-operation in flood risk management. Specific fields of interest are:
- Flood risk assessment.
- Efficiency of flood risk reduction measures.
- Sustainable flood risk management.
- Public participation in flood management issues.

More detailed information on the IRMA-SPONGE Umbrella Program can be found on our website: *www.irma-sponge.org*.

We would like to thank the authors of this report for their contribution to the program, and sincerely hope that the information presented here will help the reader to contribute to further developments in sustainable flood risk management.

Ad van Os and Aljosja Hooijer
(NCR Secretary and IRMA-SPONGE project manager)

Abstract

Water management of the rivers Rhine and Meuse is surrounded by major uncertainties. The central question is then: given the uncertainties, what is the best water management strategy? This raises the need for integrated scenarios that consider possible futures in a coherent and consistent way. Within the framework of IRMA-SPONGE a scenario study was carried out in which physical modelling was combined with socio-cultural theory. Existing climate, land use and socio-economic scenarios, as well as water management strategies have been structured using the Perspectives method. This resulted in integrated scenarios for water management, each representing a different view on the future, together with the according water management style. These were put in a scenario matrix with combinations of world views and management styles, both where these match and mis-match. Using a suite of existing modelling tools the implications of each scenario for the water systems were evaluated. Finally, a comparison of different water management styles under different possible futures was made, showing the risk, cost and benefits of different strategies.

Key words

Water management, Rhine, Meuse, flood protection, land use, climate change, hydrology, modelling, uncertainties, Cultural Theory, Perspectives, scenarios

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1. Introduction and objectives

The aim of this project is to develop a methodology to find integrated, robust water management strategies for the Rhine and Meuse basin. The formulation of water management strategies is complex due to uncertainties in future water management. These uncertainties exist in the future physical boundary conditions for water management, such as uncertainties in future Climate Change. Uncertainties are also introduced as a result of various yet unknown socio-economic and agro-economic developments that will affect water demand (such as population growth, industrial expansion, land use changes, and use of different crop types). These uncertainties are related to future developments in the society, the client of water management. It is the fact that the future is uncertain that makes the formulation of water management so difficult.

Added to these uncertainties are the uncertainties related to the models and concepts we use to formulate and analyse water management. All these uncertainties are related to assumptions and choices of the parties involved in water management.

This project deals with incorporating uncertainties in future flood management strategies in the Rhine and Meuse basins. This uncertain future gives the boundary condition for formulating strategies for water management. Even if we could agree on the set of future conditions for which we should develop water management strategies, we still would face a tremendous set of possible management options. Safety can be obtained by rising dikes and embankments, by widening the floodplains of the river, or by increasing retention in the catchments in all its different forms. Different people appraise these options from different backgrounds and different perspectives, and there is no overall winner amongst the possible strategies. This project outlines a methodology how to analyse these future developments and how to deal with the associated uncertainties. It provides a framework for the analysis for integrating the numerous viewpoints

Why robust strategies? Robust strategies are strategies that remain valid even if the assumptions on which they were based change. Robust strategies are flexible towards the future. Robust strategies explicitly deal with uncertainties, and incorporate the analysis of the uncertainties in the formulation of the strategy.

Although water management has a broader scope than just flood management, the focus of this project is on flood management. Measures for flood management can not, however, be treaded separated from the other functions of the river, so, when needed additional remarks regarding other river functions are made. River flooding and flood risk reduction and mitigation have become major themes in the Rhine and Meuse basins over the past five years. In response to the increasing awareness of flood risk various flood protection measures, landscaping strategies and policy lines for prevention and protection have been put forward.

Objectives

The objectives of this project are:

1. to analyse uncertainty related to climate change and land use change and their hydrological response, and
2. to provide a method for formulating robust strategies for flood management.

These two objectives are within the context of integrated water management, in the Rhine and Meuse basins and under increased uncertainty due to climate change. The focus of the study will be on flood risk management, but possible impacts to other river-bound functions are considered as well.

The project firstly synthesises available material and provides a structured framework for evaluating the effectiveness of already proposed strategies and the identification of policy options for flood protection and mitigation management that are robust under uncertain future conditions. For this purpose, the following objectives were formulated:

- The analysis of uncertainties in existing, available climate and land use scenarios and their assumed hydrological consequences.

- The identification of consistent scenarios of socio-economic and environmental changes in the Rhine and Meuse basins and their associated water management policy strategies.

The second part of the project addresses three important factors determining uncertainties in the changes in magnitude of future peak flows in the Rhine and Meuse basins. The following issues are addressed:
- The establishment of climate change scenarios and downscaling methods for peak flow analysis.
- The establishment of land use change scenarios.

The third part of the study deals with the consequences of uncertainty for water management in the Rhine and Meuse basins. This part elaborates on the analysis of the implication of scenarios on river runoff, and more specifically addresses:
- The analysis of implications of these factors on river runoff, both in small-sized catchments as the entire Rhine and Meuse basins.
- The analysis of the hydrological changes that may result from different scenarios and management strategies and the consequences for the user functions of the water systems, with the focus on floods,
- The assessment of the robustness of different water management strategies under different possible futures. Though the focus is on rivers, the integrated picture is given for all water systems in the Rhine and Meuse basins, since these cannot be considered separately.

Partners and activities in the project

This project has been carried out within the framework of NOP and IRMA. Partners in this project are:

ICIS	International Centre for Integrative Studies,	Maastricht, The Netherlands
UU	Utrecht University, Dept. of Physical Geography,	Utrecht, The Netherlands
WL	WL Delft Hydraulics,	Delft, The Netherlands
CC	Carthago Consultancy,	Rotterdam, The Netherlands
PIK	Potsdam Institute for Climate Impact Research	Potsdam, Germany
VUB	Free University, Dept. of Hydrology and Hydraulic Engineering	Brussels, Belgium
RWS/RIZA	Institute for Inland Water Management and Wastewater Treatment (RIZA),	Arnhem, The Netherlands
KNMI	Koninklijk Nederlands Meteorologisch Instituut,	De Bilt, The Netherlands
BfG/FRG	Bundesanstalt fur Gewässerkunde	Koblenz, Germany

The Climate Change Scenarios and the downscaling of the Climate Change Scenarios were elaborated by KNMI, BfG and PIK.

Land use scenarios for Germany were elaborated by PIK.

The hydrological impacts of changes in land use and climate for small catchments in the Rhine and Meuse basins were contributed by VUB and PIK. The hydrological impacts of changes for the entire Rhine and Meuse basins were evaluated by CC and WL.

The assessments of water management scenarios and the analysis of the utopia-dystopia matrices were elaborated by ICIS, UU, CC, RIZA, WL and KNMI.

2. Methodology: the Perspectives Method

2.1 The Perspective Method

To provide a framework for structured analysis of the uncertainties of future developments, the Perspectives Method has been applied, The Perspectives Method is based on the Cultural Theory by Thomson and the anthropological research of Mary Douglas. The basic rationale of the Perspectives Method is that the uncertainty associated with the assumptions, preferences and choices provides the opportunity for several valid interpretations of how social, economic and environmental processes are currently evolving and will evolve in the future.

The approach chosen in this project is to relate subjective interpretations of salient uncertainties to a limited number of viewpoints or *perspectives*. These *perspectives* reflect the choices concerning structural uncertainties throughout the whole cause-effect chain of social, economic and physical changes in a river basin as a result of human interventions.

The perspectives can be classified according to a typology of cultures or individual's social context or ways of live. These ways of life are the Hierarchist (strong group boundaries and binding prescriptions), the Individualist (weak group boundaries and few prescribed roles), the Egalitarian (strong group involvement and minimal regulation) and the Fatalist (excluded from group membership and binding prescriptions). In addition to these four key orientations a fifth one is recognised in literature: the Hermit, representing the autonomous and ineffectual way of life. The first three perspectives can be characterised as the active ways of life, whereas the latter two are passive. In this project we limit ourselves to the three active Perspectives, i.e. the Hierarchist, the Egalitarian and the Individualist.

2.3 Three Perspectives on water management

In the current project the three active Perspectives have been used as stereotypes which represent fundamentally different, but legitimate viewpoints on future developments. The three Perspectives are considered as extremes: the resulting spectrum that these extreme stereotypes define comprises a variety of less extreme, or rather hybrid, world views and management styles. The Perspectives are described in more detail in Box 2.1. The Perspectives Method was not developed with a specific focus on water management, so the general descriptions of the recognised perspectives has to be specified for water management related descriptions. The heuristic rules in Table 2.1 turned out to be critical in interpreting uncertainties in water management to the general descriptions.

Table 2.1 Characteristics of the cultural perspectives

Perspective Heuristic rules	**Egalitarian**	**Hierarchical**	**Individualistic**
Focus	Nature and the environment	Control and a responsible government	Economy and the individual responsibility
Heuristic rule 1	Nature is vulnerable and environmental risks are avoided; prevention is better than cure.	Stability through regulation, hierarchy and standards; regulation of nature and the environment; acceptance of differences.	Free market mechanism and anti-regulation; economic growth and technical development equal progress.
Heuristic rule 2	Equity.	Avoiding risks and against changes; easy does it, otherwise you'll break the line.	Individual development and material self-interest are motives for action; success is a personal responsibility.
Heuristic rule 3	Economy as a means and not as an objective; conscious consumption.	Authority through expertise and experience.	Problems can be solved; risks produce opportunities and challenges.
Heuristic rule 4	People have solidarity and behave as such; collective interest.	Power and esteem are the motives for action.	

Box 2.1 A typology of perspectives

In the ***Egalitarian perspective***, it is assumed that people are, in principal, good, but that they can be influenced easily. These might be negative influences but humans can be guided positively by means of intimate relationships with other people and nature. Personal development can be obtained by spiritual growth rather than by consumption of goods. The Egalitarian world view implies an attitude of risk avoidance. The management style belonging to this can, therefore, be characterised as being a preventative strategy. The Egalitarian perspective advocates drastic and structural social, cultural and institutional changes in the current capitalistic economic system. Nature is considered extremely vulnerable and small disturbances can have catastrophic consequences. Human activities which affect the natural environment must therefore be avoided.

In the ***Hierarchical perspective***, people are sinful by nature. However, people can be controlled (and educated) by a proper government and institutions. Regulation, management and control must prevent large problems. This management style can be characterised by an attitude of accepting some risks. In this perspective, nature is robust within certain limits: nature is able to overcome small disturbances. However, crossing certain limits causes serious trouble for the way in which nature functions. The hierarchical perspective emphasises the relation between humans and nature where the mutual dependence and balance between both parties is important. In this perspective, an attempt is made to guarantee this balance.

In the ***Individualistic perspective***, human nature is egocentric and based on personal gains. In this perspective, people are considered as rational, self-assured actors trying to satisfy their material needs. Changes and uncertainties are interpreted as challenges and can, in principle, be solved. This perspective is characterised by a large belief in market mechanisms and technology. The management style can be characterised as being adaptive. Nature is assumed to be extremely robust and is able to survive a few disturbances. Anthropogenic influence, even if large, results in mild and harmless disruption. In this perspective people are considered the centre of the world and natural resources are at the service of people and can be exploited.

2.3 Terminology of the Perspectives Method

We define a *Perspective* as a consistent and coherent description of how the world functions and how policy should be carried out. In this definition, a Perspective has two dimensions: a World View and a Management Style. The *World View* is a coherent description of how the world functions. The *Management Style* is a coherent set of preferred policy options. If the World View and Management Style coincide we speak of an *Utopia*. If this is not the case there is *Dystopia* (Figure 2.1)

WORLD VIEW

MANAGEMENT STYLE		**Egalitarian**	**Hierarchist**	**Individualist**
	Egalitarian	*UTOPIA*	*DYSTOPIA*	*DYSTOPIA*
	Hierarchist	*DYSTOPIA*	*UTOPIA*	*DYSTOPIA*
	Individualist	*DYSTOPIA*	*DYSTOPIA*	*UTOPIA*

Figure 2.1 Utopia and dystopia

Dystopias describe what may happen if the world functions according to a perspective different to the perspective on which the policy strategy is based. Or vice versa, where reality functions in line with one's favoured world view, but opposite strategies are applied. Thus, in terms of scenario development and model experiments, dystopias are future pathways involving ‘mismatches’ between world view and management style. In reality, there are often dystopias due to the interplay of forces between actors.

In the present study, World View and Management Styles relate to water management, and thus do not include the world around. Therefore, an *External Context* was introduced, giving the context against which water management is carried out, but which cannot be influenced by a Management Style. In this study, the External Context is as considered from the viewpoint of each perspective. The (exogenous) context variables include climate change, soil subsidence due to the exploitation of natural gas, economic development, agriculture, urbanisation, population growth, water demand, shipping and navigation intensity.

2.4 Qualitative and quantitative methods to explore Perpectives in water management

Because Perspectives have two components, the World View or External Context and the Management style, we can analyse for each perspective whether it is Utopia or a Dystopia situation. The steps to develop and analyse the integrated scenarios and the perspectives are:

1. **Identification of uncertainties:** For the identification of uncertainties with regard to the future of the Rhine and Meuse, three sources of information were used: expert knowledge, contextual knowledge and experimental knowledge.
2. **Development of perspectives for water management**: For the development of perspectives for water, we synthesised the interpretation of uncertainties derived from a stakeholder workshop and the expert interpretation of perspectives, thereby using the identified building blocks from the previous studies mainly to describe the Hierarchist perspective.
3. **Perspective based modelling:** Relevant utopian and dystopian experiments were selected (see figure 2.2). Qualitative water perspectives were translated to values for model parameters and inputs. The models were run with these perspective-based inputs to perform the selected utopian and dystopian experiments.
4. **Discussing the results:** The model results and the qualitative descriptions of the perspectives on water were used to construct Egalitarian, Hierarchist and Individualist scenario families. These scenario families were used to sketch utopian and dystopian images of 2050. A stakeholder workshop was organised to review and evaluate the scenarios from the perspective of water use and users.
5. **Evaluating the perspectives for water management:** The three scenario families were evaluated in terms of the hydrological situation, the consequences for the user functions (safety, nature, agriculture and transport / shipping) and the characteristics of the water system (investments / costs, economic benefits and reversibility). This perspective-based assessment of water-related issues for the Rhine and Meuse river basins has been used to explore recommendations for policy.

Apart from the qualitative analysis through the inventory of existing studies and the expert workshops we also used a quantitative, model-based approach for the analysis of the perspectives.

The first modelling task was to analysis the responses of hydrologic models to changes in the boundary conditions, such as changes in land use and climate change. This modelling task should give insight in the uncertainty due to the modelling concepts, the sensitivity of the models to changes in their boundary conditions and an explanation of the possible response of the hydrologic regime to land use changes and climate changes. The models used for this analysis and the results are discussed in chapter 5.

The second modelling task is to analyse the behaviour of the catchment under the defined integrated scenarios for changes in the boundary conditions, subject to specified management styles. Ideally, the whole utopia/dystopia matrix (i.e., all possible combinations of world view and management style) should be worked out, but for practical reasons, this is not possible. We therefore developed the following criteria for examining a scenario using the models:

- The most extreme scenarios should be calculated so that sufficient variation is maintained.
- The Hierarchist scenarios has been extensively described in existing studies and policy reports.

- Consulting experts and stakeholders yielded several combinations not considered relevant.

Based on the criteria above, the following cases appeared to be interesting to simulate with the models
Case 1: External Context: Individualist, Management style: Individualist
Case 2: External Context: Individualist, Management style: Egalitarian
Case 3: External Context: Egalitarian-wet, Management style: Egalitarian
Case 4: External Context: Egalitarian-dry, Management style: Egalitarian
Case 5: External Context: Egalitarian-wet, Management style: Individualist
Case 6: External Context: Egalitarian-dry, Management style: Hierarchist
Case 7: External Context: Egalitarian-wet, Management style: Hierarchist
Case 8: External Context: Egalitarian-dry, Management style: Individualist

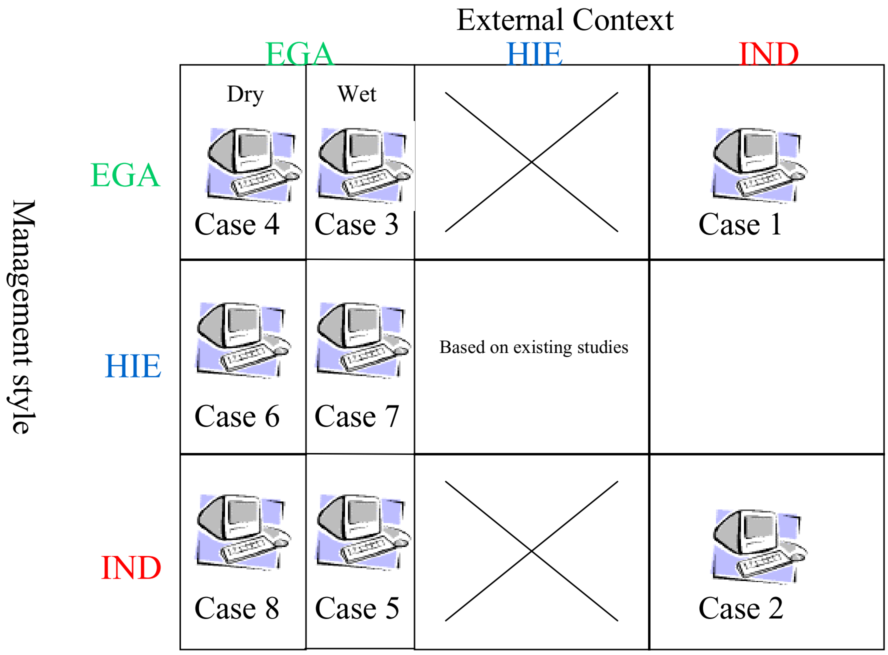

Figure 2.2 The utopia / dystopia matrix: indicated are scenarios that are calculated using the models.

3 Existing studies and policy reports in perspective

To explore whether a sufficiently varied set of integrated scenarios could be derived from existing material we have searched for studies that a) deal with water management in a broad sense, which means that they must take into account economic, socio-cultural, institutional, as well as the nature and environmental aspects; b) relate to the long-term and, therefore, sketch at least one picture of the future and c) deal with the parts of or the whole of the Rhine and/or Meuse river basins.

For all studies it was assessed to which extent they addressed uncertainty and what types of uncertainties they considered. Subsequently, it was determined whether these existing studies provide all the necessary building blocks to establish integrated scenarios. For this purpose, the level of integration (in terms of spatial and temporal scales, aspects and dimensions) and variation (whether sufficient legitimate interpretations of uncertainty are considered) are the key concepts. To gain insight into the range of scenarios that can be distilled from the whole set of studies and reports, we investigated to what extent the scenarios from the analysed studies could be considered to form scenario clusters that share the same critical assumptions with regard to the functioning of the system (world view) and policy option (management style).

3.1 Dutch water management

The main observations from the inventory into existing Dutch integrated studies, plans and visions are the following:

- A total of 16 studies were evaluated for this inventory
- Three aspects are central in almost all of the studies: *safety*, *nature* and *agriculture*.
- The aspects *recreation, transport, water quality, cultural history, housing and working, extraction of raw materials* were present in some but not all of the studies
- None of the examined studies consider the Rhine or the Meuse at the entire river basin scale.
- The majority of the studies describe a time horizon from present until the year 2050. Four studies also offer a view for the year 2100.
- Two studies offer policy recommendations without explicitly examining the future.
- Climate change, sea level rise and soil subsidence are the most frequently mentioned uncertainties in the investigated studies.
- Social factors are identified as an important source for uncertainty in five studies. These social factors include human behaviour, social support and the change of standards and values.
- Three studies explicitly question the reliability of the models.
- One study (the landscape planning for the Rhine branches) mentions the limited knowledge of the complex river system and the methods used as important sources of uncertainty. This study is the only one stating explicitly that a way must be found to deal with future uncertainty.
- None of the studies explicitly addresses uncertainty management in their assessment of water management issues in the future.

Four variants in Dutch water management

Four variants emerge from the analysis of the existing studies and reports. These variants have been explicitly recognised in the '*Aquatic Outlook Future for Water'* report and are elaborated in other studies. These variants are:

- *Current policy*: the policy as formulated in the 3th National Policy Document on water management;
- *Unrestricted Use and Economic growth*: the policy in which facilitating economic growth has the priority;
- *Natural System*: policy in which nature values have priority;
- *Radical Change*: the policy where a change in societal lifestyles leads to a natural balance between the economy and the environment.

Except for the 'Radical change' variant, all variants clusters, and thus the majority of Dutch water management studies, can be categorised as *Hierarchist*. The variant *Current Policy* most strongly represents the hierarchical utopia. The variant *Natural System* accommodates more Egalitarian elements, such as the focus on nature values and sustainability. The variant *Unrestricted Use* includes more Individualistic assumptions, such as the focus on economic functions and technical solutions (figure 3.1).

These variants are all constructed from the point of view of policy and, implicitly, from an associated world view. This means that most variants represent an utopia. The *Natural System* variant is the most dystopian variant, but there are also dystopian elements within the *Unrestricted Use* variant.

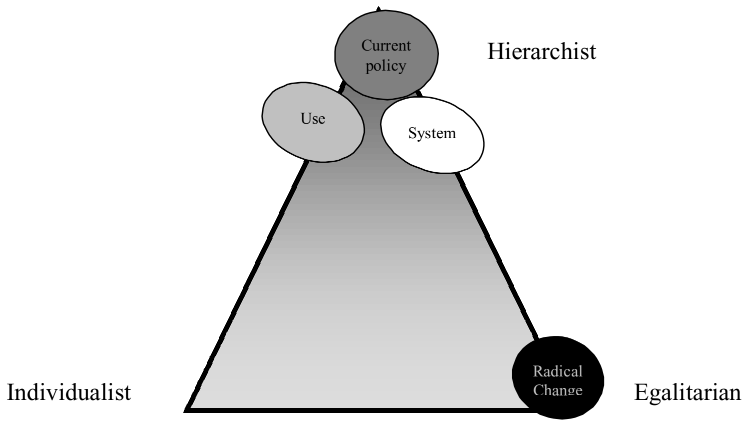

Figure 3.1 Clustering according to perspectives

Although most reports are classified as being a Hierarchist perspective, the existing studies and policy reports should provide building blocks for examining different perspectives with regard to the water management of the Rhine and Meuse. It is therefore necessary to develop integrated scenarios for water which involve a wider set of assumptions, so that there is the sufficient variety necessary to develop robust strategies.

3.2 Belgian and German water management

In this section we extend the analysis of the set of integrated scenarios as developed for the Dutch water systems to the German and Belgian perspectives on water. The main results of the inventory, in terms of the differences and similarities between the national levels are summarised in table 3.1

The result of the literature review and the inventory of existing studies, visions and strategies for Germany and Belgium was relatively poor. This yields the conclusion that that comprehensive and recent German and Belgium surveys of long-term future developments of the Rhine and Meuse are not available. The survey of Belgium and German studies did offer scenario descriptions, but these are essentially an exploration of the technical and physical limits of water management.

Although Belgian and German scenario studies were not available, four relevant international or Dutch studies pertaining to the whole Rhine and Meuse basin were identified:

- 'Rhine basin study: Land use projections based on biophysical and socio-economic analysis', (Initiated by RWS, the Directorate-General of Public Works and Water Management).
- From Worrying about the Meuse to Caring for the Meuse (Initiated by ICBM, the International Commission for Protection of the Meuse)
- The impact of climate change on hydrological regimes and water resource management in the Rhine basin (Initiated by CHR, the Hydrological Commission of the Rhine)
- Wirkungsabschätzung von Wasserrückhalt im Einzugsgebiet des Rheins (Initiated by CHR, the Hydrological Commission of the Rhine)

Because of their decentralised character, and a limited number of integrated studies, both Germany and Belgium seem to have a Hierarchist/Individualist based water management. They are definitely less pronounced Hierarchist than the Netherlands.

Table 3.1 Summary of differences and similarities in water management

	Netherlands	Belgium	Germany
Selection of crucial policy reports	Bill on Embankment (Wet op de waterkering) Space for the River (Ruimte voor de Rivier) Water management in the 21st Century	MINA-2 Living Grensmaas (Flemish Preference Alternative) Water Policy Plan Flanders (in preparation)	LAWA guidelines and Action Plan Flood Defence
General focus	Integrated water management Safety	Water quantity linked to drought problems	Improving retention capacity Water quality
Organisation	Water management is institutionalised Strong hierarchy and centralisation	Water management is recently recognised as a salient issue by the Flemish government Decentralisation	Water management of the Land Government will be harmonised in the LAWA Decentralisation
Common characteristics	The ambition for integrated water management in the context of sustainable development Awareness of flood risks Awareness of the need for a river basin approach Water management is insufficiently integrated in spatial planning Small public interest		

4 Towards perspective based integrated scenarios

4.1 Overall scenarios for climate change

Climate change scenarios for the Rhine and the Meuse basins were developed by KNMI. These scenarios are also used in the Dutch Water Management in the 21st century (WB21), and the 4th National Policy Document on water management (4e Nota Waterhuishouding NW4).

The classical estimates consist of a low estimate, a central estimate and a high estimate. The range between the low and high estimates is supposed to cover the model- and emission uncertainty. As working hypothesis it is assumed that for Europe the range between the low and high temperature estimate represents an 80% confidence interval. As central estimate for Europe a temperature change of +2 °C for 2100 with respect to 1990 is adopted; the lower and high estimates being +1 °C and + 4 °C, respectively (Tables 4.1-4.2). The estimates for Europe are the same as the rounded IPCC Second Assessment Report (SAR) estimates of global warming.

In this study (and also for WB-21) a dry scenario is presented, where temperature and precipitation change are uncoupled. It is assumed in that scenario that the frontal precipitation amount decreases by 10%. In Table 4.1 the dry scenario is presented in combination with the high estimate of the temperature. In this combination it is plausible (but unproved) to assume that the convective precipitation amounts for 2100 remain unchanged and that the probability for high wind speeds decreases. Also, estimates for return periods of precipitation events were developed. These return periods were not further used in the Perspectives method, so their discussion is left to the main report.

4.2 Climate change scenarios in a Perspectives context

The climate scenarios have been related to the 'Perspectives' as follows:

1. Egalitarian (perspective focusing on environment): considers the largest bandwidth of the climate change, in which temperature (T) and precipitation (P) are uncoupled. In the warm/wet and the warm/dry greenhouse scenarios this leads to dT between 1 and 4°C, and to dP between –10 and +40% for 2100.
2. Hierarchist (perspective focusing on control): one would expect the Hierarchist to count with the worst-case = high estimate and to apply this on the long-term plans. Here no-regret strategies take a 50-year time horizon into account. Nevertheless we assume that the Hierarchist adopts the

central estimate rather than the high estimate. The reason is that RWS, being a typical example of a Hierarchist, yet adopts a 60-cm sea level rise for 2100 in accordance with the +2 degree scenario. Typical for the attitude of the Hierarchist is his tendency to investigate everything over and over again, which makes it difficult to come to a real decision. This is another indication that the extreme scenario does not fit always the Hierarchist.

3. Individualist (perspective focusing on economy): estimates potential losses, but takes usually the depreciation and investments into account. In most cases his time horizon is only of order 10 year. Within that time horizon, a temperature rate of 1°C in 50 year is not relevant and the Individualist will not incorporate climate change. Only for planning of a big investment with a long depreciation, climate change effects will be taken into account according to the central estimate.

Table 4.1 Scenarios for 2050 and 2100

	Present	low estimate wet		central wet		high est. wet		high est. dry	
		2050	2100	2050	2100	2050	2100	2050	2100
Temperature		+ 0.5 ^{0}C	+ 1 ^{0}C	+ 1 ^{0}C	+ 2 ^{0}C	+ 2 ^{0}C	+ 4 ^{0}C	+ 4 ^{0}C	+ 2 ^{0}C
yearly precipitation, Netherlands	700 à 900 mm	+ 1.5 %	+ 3 %	+ 3 %	+ 6 %	+ 6 %	+ 12 %	- 10 %	- 10 %
total summer precipitation , Netherlands	350 à 475 mm	+ 0.5 %	+ 1 %	+ 1 %	+ 2 %	+ 2 %	+ 4 %	- 10 %	- 10 %
total winter precipitation, Netherlands	350 a 425 mm	+ 3 %	+ 6 %	+ 6 %	+ 12 %	+ 12 %	+ 25 %	- 10 %	- 10 %
precipitation intensities in showers		+ 5 %	+ 10 %	+ 10 %	+ 20 %	+ 20 %	+ 40 %	0 %	- 10 %
10-day precipitation sum winter Netherlands	amount depends on return period, see table 3	+ 5 %	+ 10 %	+ 10 %	+ 20 %	+ 20 %	+ 40 %	- 10 %	- 10 %
10-day precipitation sum winter Belgium	amount depends on return period, see table 3	+ 5 %	+ 10 %	+ 10 %	+ 20 %	+ 20 %	+ 40 %	- 10 %	- 10 %
evaporation summer, Netherlands	540 à 600 mm	+ 2 %	+ 4 %	+ 4 %	+ 8 %	+ 8 %	+ 16 %	+ 16 %	+ 8 %
evaporation winter, Netherlands	(ca. 100 mm)	+ 2 %	+ 4 %	+ 4 %	+ 8 %	+ 8 %	+ 16 %	+ 16 %	+ 8 %
evaporation year, Netherlands	620 à 720 mm	+ 2 %	+ 4 %	+ 4 %	+ 8 %	+ 8 %	+ 16 %	+ 16 %	+ 8 %
absolute sea level rise, NL		+ 10 cm	+ 20 cm	+ 25 cm	+ 60 cm	+ 45 cm	+ 110 cm	+ 110 cm	+ 45 cm
absolute rise high tide, NL		+ 12.5 cm	+ 25 cm	+ 27.5 cm	+ 65 cm	+ 47.5 cm	+ 115 cm	+ 115 cm	+ 47.5 cm
absolute rise low tide, NL		+ 7.5 cm	+ 15 cm	+ 22.5 cm	+ 55 cm	+ 42.5 cm	+ 105 cm	+ 105 cm	+ 42.5 cm
wind speed and gales, NL		+/- 5 %	+/- 5 %	+/- 5 %	+/- 5 %	+/- 5 %	+/- 5 %	0 to - 10%	0 to - 10%
Linked to Perspective		Individualist		Hierarchist		Egalitairian-Wet		Egalitairian-Dry	

4.3 Downscaling climate change scenarios for German case studies

Currently GCM-model runs itself may, due to their coarse spatial resolution and the lack of appropriate description of the precipitation relevant processes on that scale, not produce realistic precipitation fields for detailed distributed hydrological modelling purposes. Stehlik and Bárdossy developed a suitable methodology for generating realistic spatio-temporal varying precipitation fields using large daily pressure values (simulated or observed) and local scale meteorological variables, which is further developed within this research. The method consists of two steps:

- An optimisation of fuzzy rules for a classification of circulation patterns (CPs), to explain the meteorological conditions that favour mayor flood events in the Rhine basin (Figure 2.1).
- Multivariate stochastic simulation/downscaling of local scale rainfall and temperature fields using probabilities conditioned to the optimised CPs.

Improved Methodology for assessing fuzzy rules for Circulation Pattern classification

The method uses daily pressure data from a suitable geo-potential level on a 5° by 5° resolution for CP classification as well as daily precipitation time series from up to 30 stations to define the objective function for the optimisation. The crucial steps for our purpose are:

- to select precipitation time series from different sub catchments that reflect the precipitation distribution in the Rhine basin in a representative manner,
- to assess criteria that mark critical large scale meteorological situations that favour the occurrence of mayor flood events, such as spatial extend, movement direction and duration of the precipitation field
- to include these criteria into the objective function, in order to assign higher weights to events that match these criteria for critical meteorological situations during the optimisation procedure.

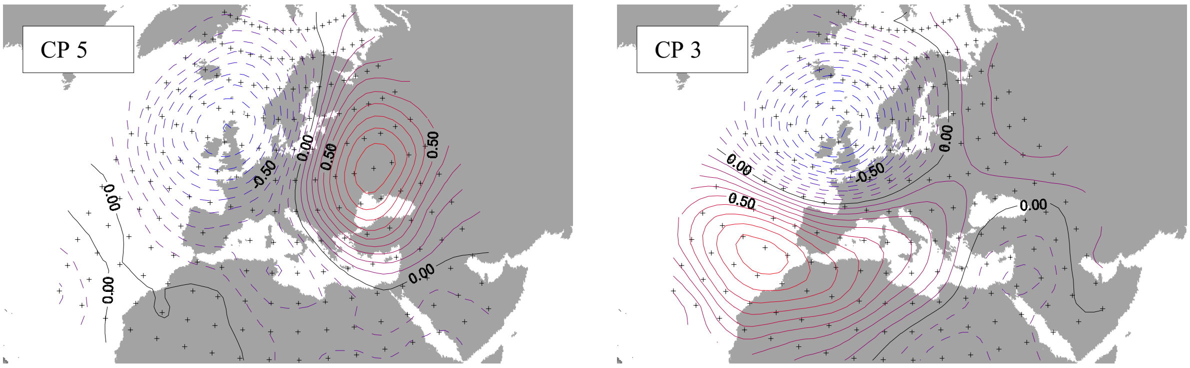

Figure 4.1 *Mean normalized distributions of 500 hPa pressure anomalies averaged over 1970-79.*

In order to identify critical meteorological conditions that caused mayor floods in the Rhine basin the events of 1925, 1970, 1983 1993, 1995 where analysed with emphasis on the precipitation pattern, the role of snow melt and on the occurrence of the flood peaks from the large sub catchments (Mosel, Main or Neckar).

During each of the events constructive interference of flood peaks from different sub catchments took place, this indicates the importance of the flood routing for mayor flood events. This result poses the question, whether a different movement direction of the precipitation field would have caused differences in the occurrence of the flood peaks in the large sub catchments and which could lead to an even higher or a lower flood peak downstream. Simulations of historical flood events with a movement direction turned by 180° lead to a clear shifts in the occurrence of the peak. However, the overall effect may only be judged after the flood routing (Fig. 4.2).

Fig. 4.3 shows that the spatial patterns of the cumulative precipitation of the winter events in 1970, 1993 and 1995 are highly similar, with the highest precipitation amounts in the mid mountains of, especially in the western part of the Mosel catchment. In order to determine which sample of sub catchments is the best to reflect this typical precipitation patterns on the basin scale three cases are compared:

1. the 12 sub catchments with the highest precipitation amounts from different regions,
2. the 12 sub catchmsents with the lowest precipitation amounts from different regions,
3. 6 sub catchments with the highest precipitation and 6 sub catchments with the lowest precipitation amounts from different regions.

A fuzzy ruled based classification of CPs is done in each case, using an set of objective functions based on the precipitation time series of the sub catchments.

For each case, the extend is determined to which the basin scale variability of precipitation may be explained by the resulting CP classifications. The sample of sub catchments that leads to the CPs that explains most of the precipitation variability is used for further improvement of the CP classification.

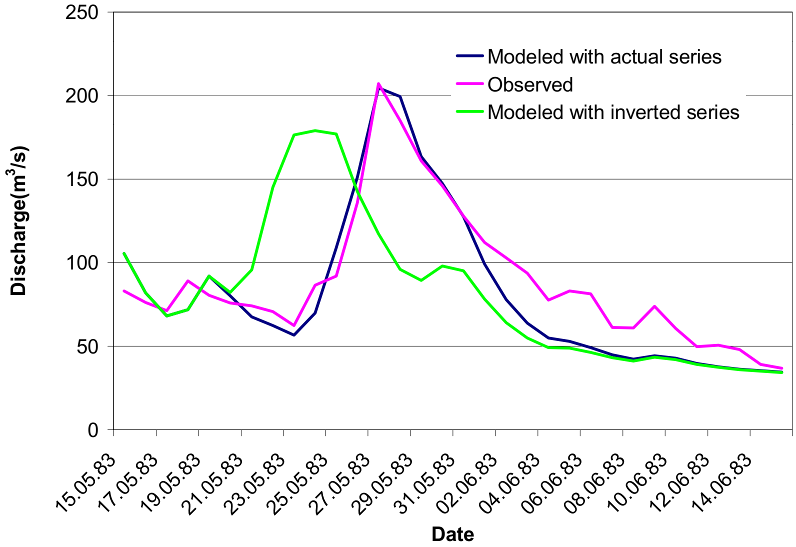

Figure 4.2 *Effect of the inversion of the movement direction of the precipitation field for the 1983 flood event in the Ruhr catchment*

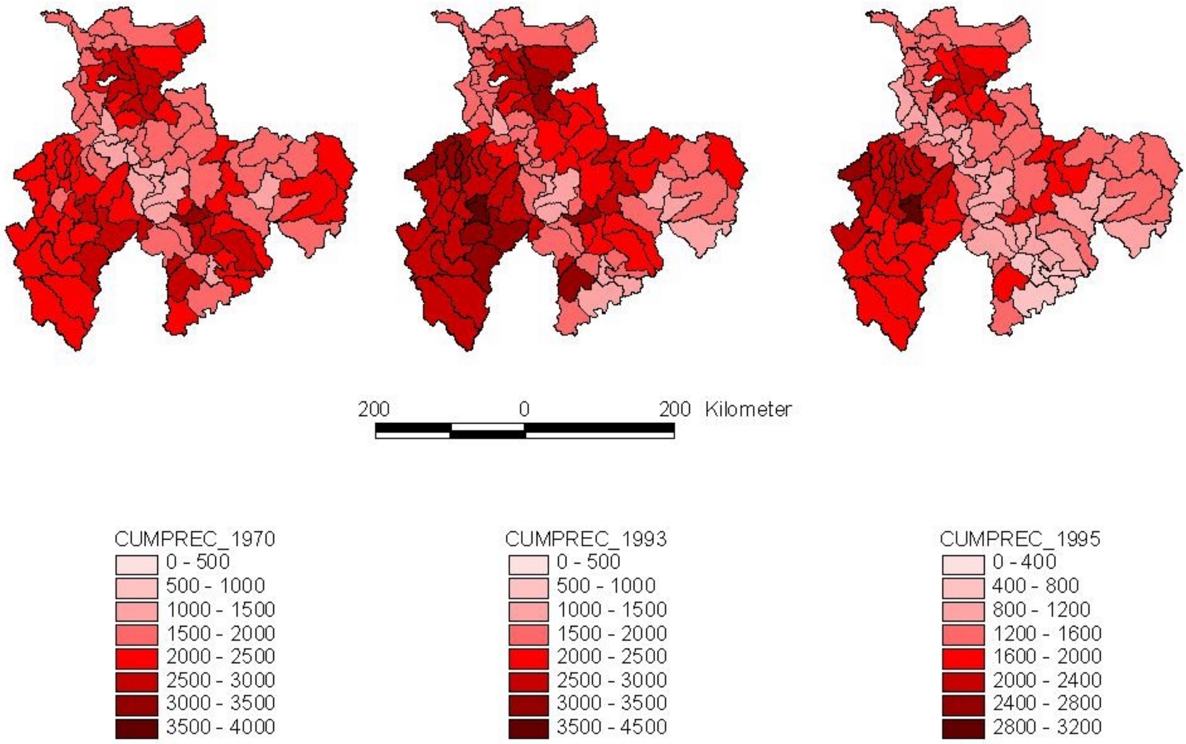

Figure 4.3 *Spatial pattern of the cumulated precipitation of the winter floods 1970, 1993, 1995, the scale unit is 0.1 mm*

Stochastic downscaling of precipitation and temperature

Given the optimised fuzzy rules for CP classification the GCM simulated pressure time series of available climate change scenarios are classified into a daily sequence of CPs. In order to investigate the consequences of those scenarios for floods in the Rhine basin a statistical downscaling of precipitation and temperature is performed. The calibration and validation procedure of the model is described in figure 4.4.

Daily rainfall and temperature are modelled as processes coupled to atmospheric circulation for the entire German part of the Rhine basin. Rainfall is linked to the circulation patterns using conditional probabilities. Temperature is modelled using a simple auto-regressive approach, conditioned on atmospheric circulation and local point or areal precipitation.

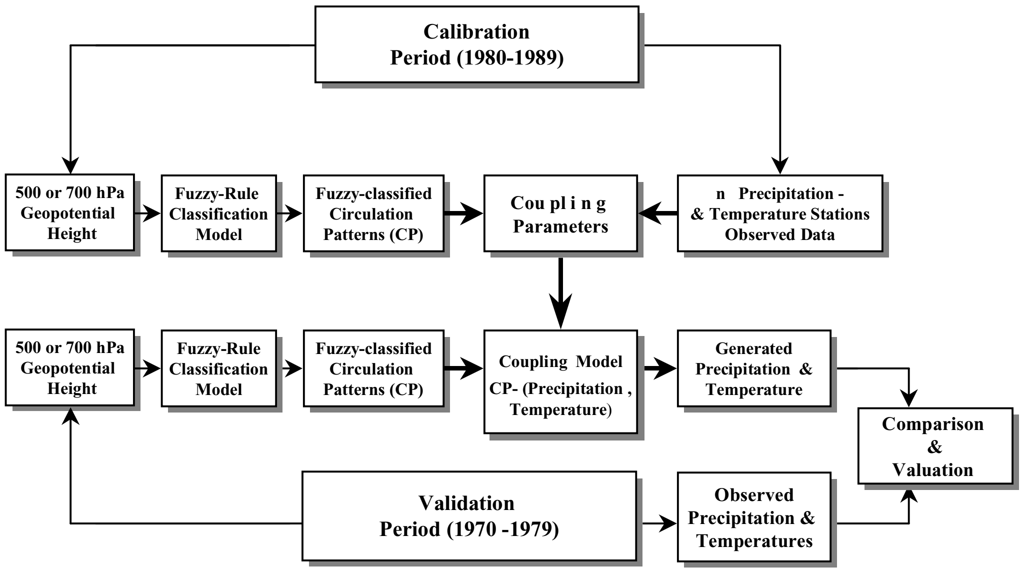

Figure 4.4 *Conceptual framework for the calibration and validation of the Coupling Model "CP-Precipitation & Temperature"*

4.5 Integrated scenarios for basin wide land use change

Since no detailed spatial scenarios for land use change were available, a set of lumped figures was developed to cover the entire region. These figures are very rough estimates, a more elaborate and detailed method for the German part of the basins is described in the next sections.

For the Individualist a strong urbanisation is adapted. As a maximum, 50 percent of the current agricultural area is converted into urban area. No allocation of land for retention purposes is foreseen. For the Hierarchist, 10 percent of the current agricultural land is converted into nature area. Only a small increase in urban area is foreseen. The Egalitarian increases the area for nature with 50 percent, this at the expense of agriculture. Large areas are allocated for retention.

4.6 The development of regional German land use scenarios

In this study land-use scenarios are used for evaluating the influence of land-cover on flood generation. This influence is demonstrated best on the basis of the reaction to changes in existing land-use and land-cover. In the past land-use scenarios for hydrological studies have neglected the topological relations of the landscape that arise from neighbourhood relations between the different land-use patches and their position within the study-area. As runoff generation is not occurring homogeneously within space, the land-use pattern plays a crucial role for evaluating the influence of land-cover on flood generation.

The task of generating spatially distributed land-use scenarios is performed by a newly developed model, the **l**and-**u**se **c**hange scenario **k**it LUCK. This approach embraces the requirements mentioned above by considering both the neighbourhood relationships and the local portion within the study-area. LUCK is a deterministic simulation model, which provides a method for a spatial transformation of given land-use trends into spatially distributed land-use patterns. Figure 4.5 shows the proceeding for the spreading of settlement areas.

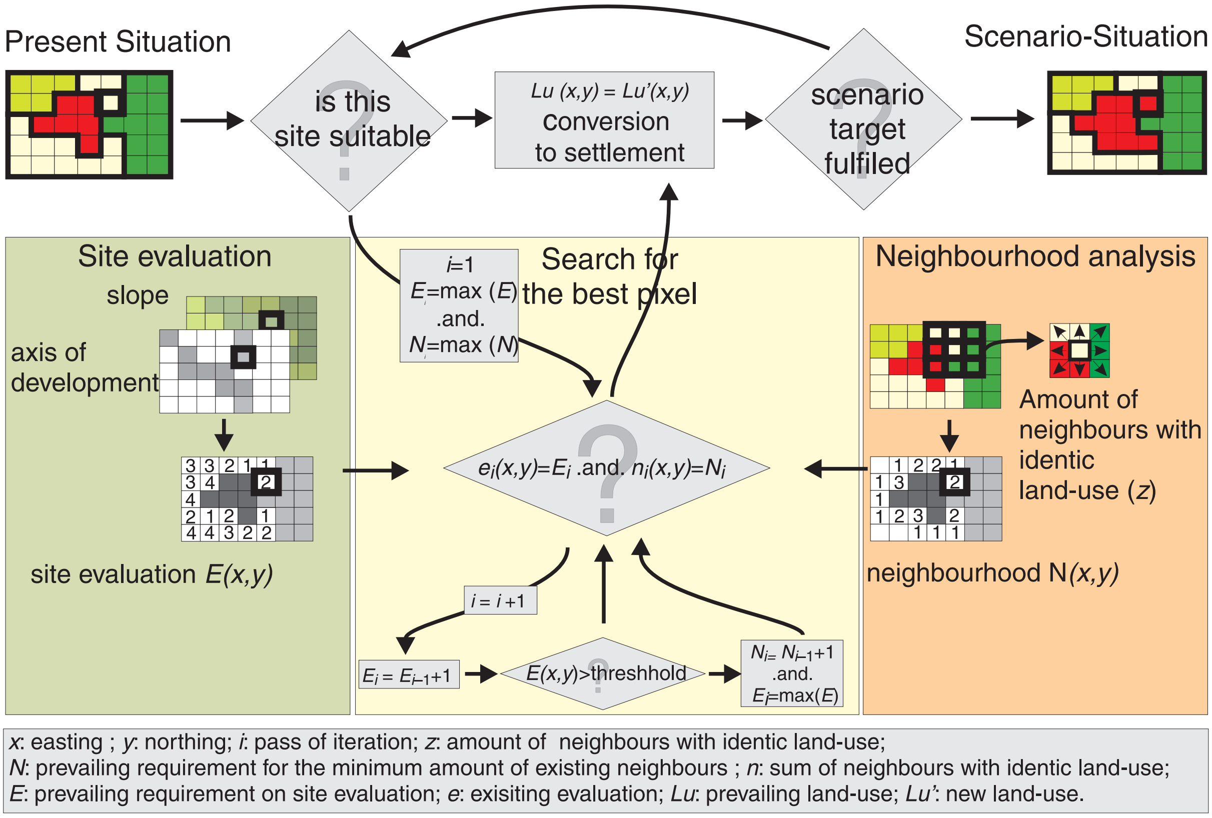

Figure 4.5 Scenario approach for the spreading of settlement areas for the mesoscale

Application of an urbanization scenario to the mesoscale Lein catchment

This method is applied to the Lein catchment. Although this area is predominantly under agricultural land-use, urbanization has become more and more important, because it is the most profitable and therefore most probable driving force for a land-use conversion. Due to the vicinity to a prospering industrial region the study area has experienced a steady growth of built-up areas during the last decade, caused by settlement expansion. Exemplarily, the result of an increase of built-up area in the Lein catchment is shown in figure 4.6. As scenario, an increase of 50% for the settlement from 7,4% up to 11,1% of the catchment area is assumed, which leads the urbanization status of this area close to the German average of 11,8%.

Land-use scenarios for the macro-scale

Sealing of the soil surface exerts the strongest influence of land-use on flood discharge. The existing trend of increasing area consumption for housing, industries, trade and for traffic has lead to an enormous expansion of sealed areas into the landscape. For investigating the impact of future surface sealing on flood generation within the Rhine basin, a status-quo-trend scenario for the settlement development until the year 2010 is used. The calculation is based upon an extrapolation of the statistics derived from the prevailing usage of area in the districts, and a modularisation of the population prognosis for the year 2015. The result classifies all existing districts in nine different types and gives a trend of the percental settlement expansion for each type. On the average, the scenario for the Rhine basin shows an increase from 18% in 1996 to around 20% in 2010. Figure 4.7 gives an overview of the classification within a part of the German Rhine basin reaching from Maxau to Lobith. Figure 4.8 shows the corresponding increase of built-up areas for each district type.

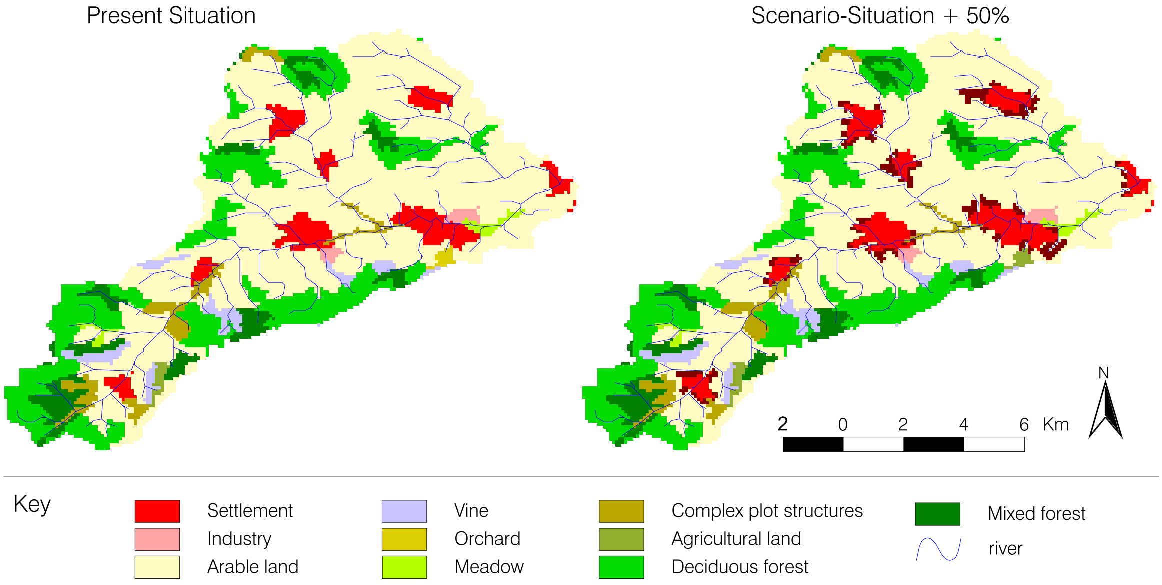

Figure 4.6 Urbanization of the Lein catchment with an increase of 50% of the settlement areas

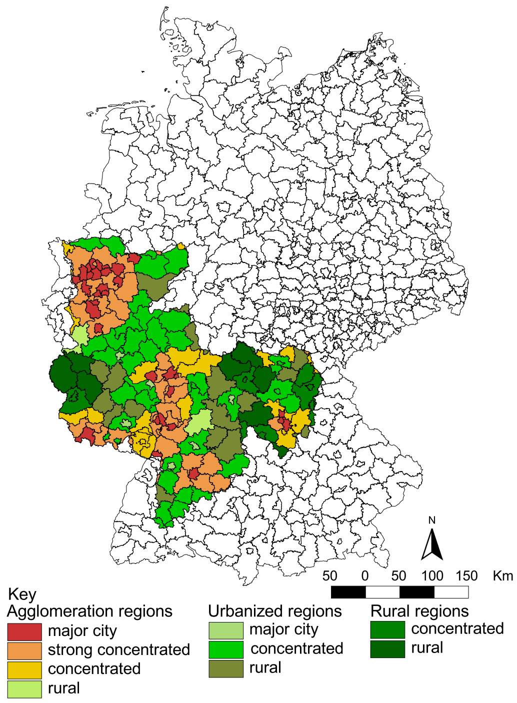

Figure 4.7 Classification of administrative districts in nine different types of prognosed settlement development within the Rhine basin

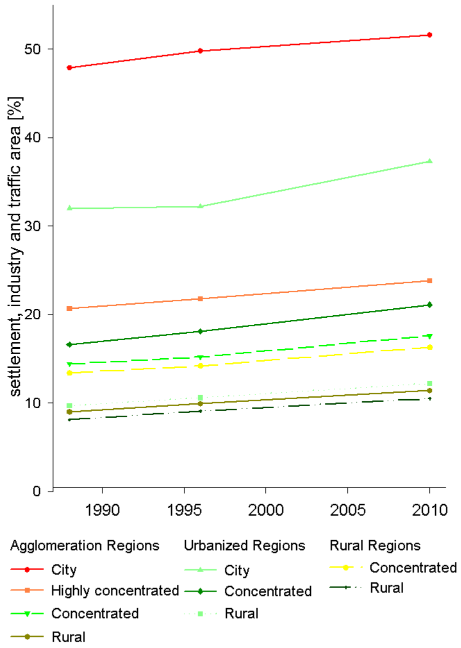

Figure 4.8 Prognosed trends for the different types of settlement development

Greatest increases are expected for the backcountry of agglomerations and in concentrated as well as rural districts within urbanized regions, because building land is available at low prices. A moderate growth is expected for the major cities in urbanized regions and for the highly concentrated surrounding areas of agglomerations. The smallest growth is expected for major cities in agglomeration areas, because the prices for built-up land are very high there. The result for the Rhine catchment is illustrated in figure 4.9

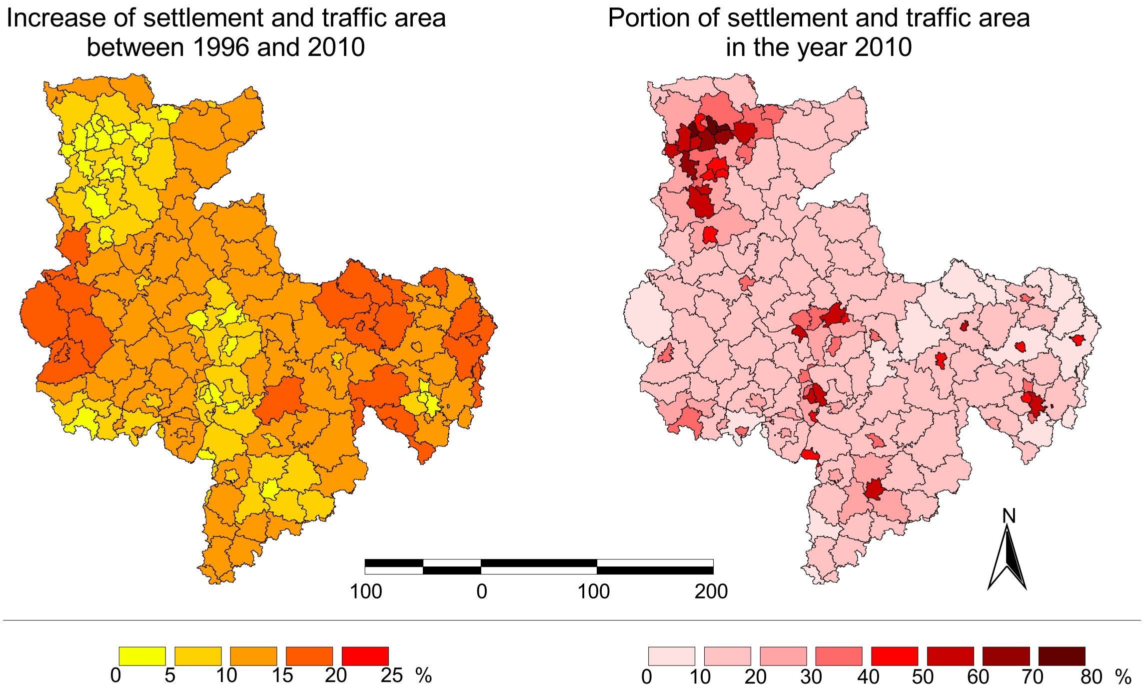

Figure 4.9 Prognosis for the increase of settlement and traffic area in a part of the German part of the Rhine basin reaching from Maxau to Lobith from the year 1996 to 2010

5. Modelling hydrologic responses to changes in climate and in land use

This chapter describes the results of the simulation models. These simulations were used for two purposes. The first purpose is the sensitivity analysis of the models for changes in climate and land use and a detailed research into the reaction of catchments to these changes. The second purpose is to use the model results to elaborate the Utopia/Dystopia matrix of the Perspectives method.

Climate change scenarios applied to all the models cover the full range of perspectives as defined in section 4.2 and section 4.3. Land use change scenarios for the mesoscale models cover increased urbanisation and changes crops for the mesoscale models. For the Rhineflow and Meuseflow simulations, the full range of management styles (of which land use is a part) as defined in section 4.4 was applied.

5.1 Lein catchment study

For simulating the impact of land-use and climate changes on flood runoff, the deterministic and spatially distributed hydrological model WASIM-ETH has been chosen. Similar mesoscale models as for the Lein have also been applied to the catchments of the Körsch and Lenne. This summary only describes the results of the Lein subcatchment. To improve the representation of land-surface conditions on flood-runoff generation within the model, it has been extended to cover relevant phenomena like macropore flow, soil siltation, decentralized retention, and surface sealing in combination with a connection to the sewer system.

Urban areas consist of asphalt or paved surfaces which allow only very little infiltration and are often connected to a sewer system. But they also contain greens, parks, green strips or gardens, where better infiltration and soil storage conditions can be found. Lumping of soil parameters in these areas inevitably leads to an overestimation of the influence of built-up areas on storm-runoff generation and under-estimates the compensating effect of green areas within settlements.

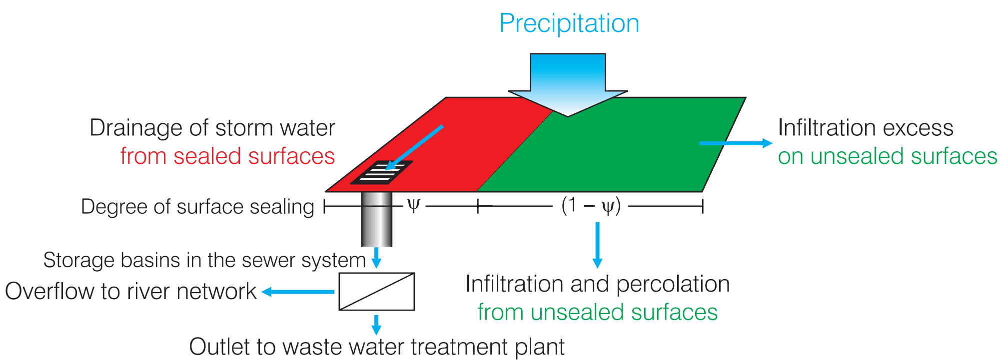

Figure 5.1 Model concept for sealed surfaces within a grid cell and their connection to the sewer system

To take this pronounced form of *heterogeneity* within grid cells (often referred to as *subgrid variability*) into account, each grid cell is divided into a sealed and an unsealed part according to the *degree of sealing* of the cell's actual land-use type (see figure 5.1)

Response to the urbanization scenario

Figure 5.2 shows a comparison of two flood events in the Lein catchment. It contains simulation results for present conditions as well as for the two urbanization scenarios. The comparison demonstrates that the increase in flood volume and peak runoff due to urbanization is much more distinct for the *convective* storm event than for the *advective* one, although the precipitation volume as well as the peak flow is in the same order of magnitude for both events and represents a return period of approximately 2 to 3 years in both cases. The markedly slighter effect on the *advective* event is the result of (1) *higher antecedent soil moisture* which levels differences in soil characteristics as well as (2) *lower precipitation intensities* which prevent an overflow of the sewer system.

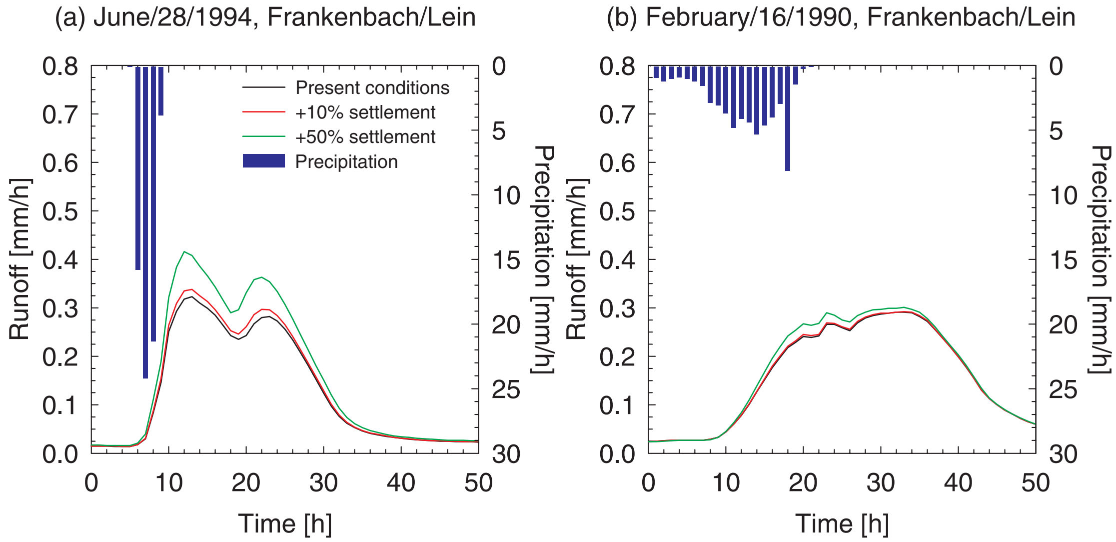

Figure 5.2 *Simulation of two flood events in the Lein catchment (115 km²) as a response to (a) a convective storm event and (b) an advective storm event for present conditions and two urbanization scenarios*

Response to climate changes

Due to their high spatial and temporal variability, global circulation models are not capable of reproducing *convective* storm events. Correspondingly, the same is true for the *expanded downscaling* approach. Therefore hydrological modelling has been restricted to the hydrological winter half year lasting from November to April. During this period, rainfall in this region is mainly bound to *advective/cyclonic* precipitation events.

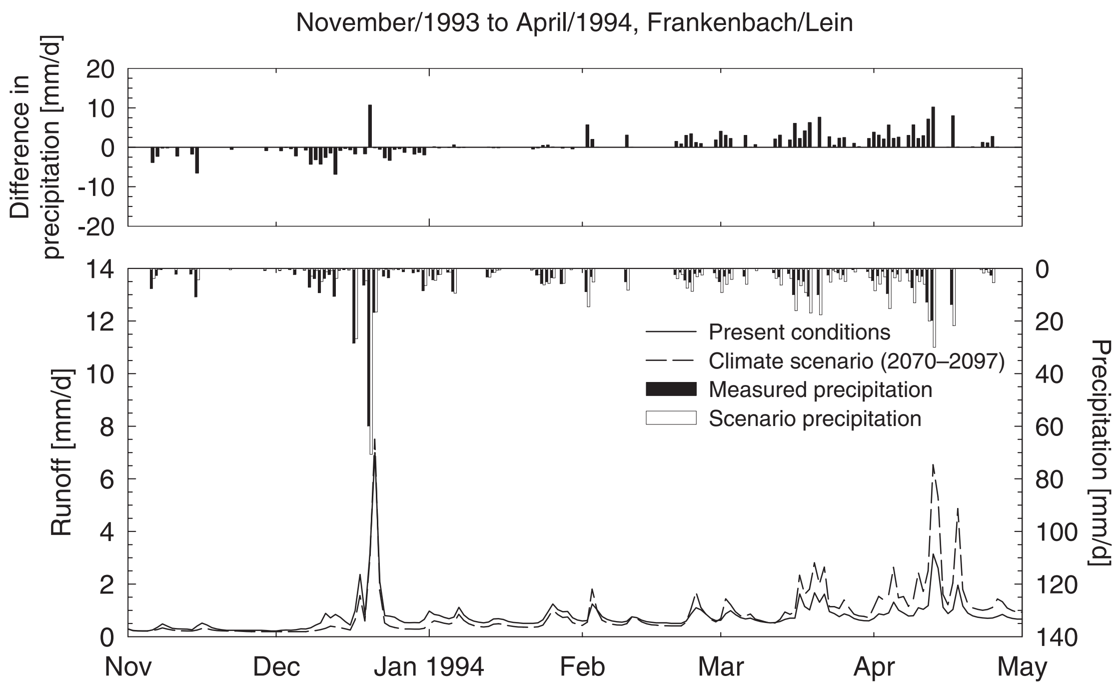

Figure 5.3 *Simulated hydrographs for the Lein Catchment at the gauge Frankenbach for the hydrological year 1994 and scenario conditions 2100*

The upper diagram in f*igure 5.3* shows the *differences in daily precipitation* between the conditions in 1994 and the climate scenario for the end of this century. According to the hydrological simulations, the Lein reacts to the altered climate conditions with a flood event in April, thus increasing the probability for a coincidence with snowmelt runoff coming from the Alps.

Modelling results for the Lein catchment indicate a rising flood risk towards the end of this century. This is due to a *shift in the rainfall regime* from early winter to spring, which increases the probability of a *coincidence* of extensive rainfall and snowmelt runoff – in this case from the Alps. Furthermore, the hydrological simulations illustrate how an increase in *rainfall variability* can lead to higher flood risk despite a general decrease in monthly precipitation.

5.2 Kikbeek catchment study

The Kikbeek is one of the generally small brooks that discharge from the Belgian side into the Meuse (near the city of Maasmechelen; see figure 5.4).

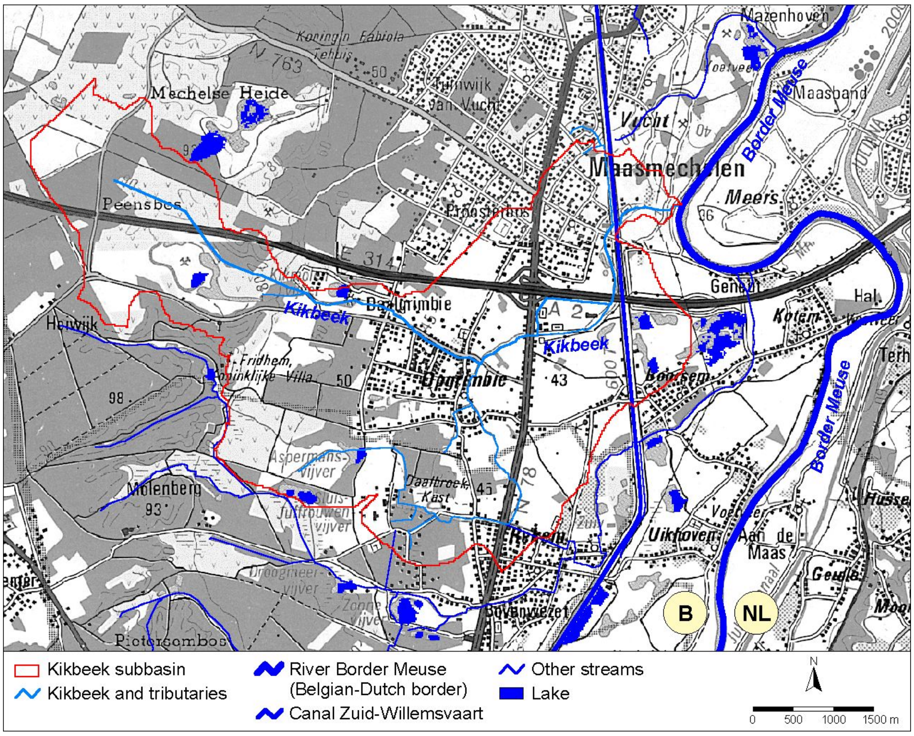

Figure 5.4 Situation of the Kikbeek subbasin

The hydrological characteristics of the Kikbeek subbasin were analysed by way of a hydrological modelling with WetSpass. This is a GIS based, spatially distributed hydrological model, which has been developed at the VUB. With the model, fast and slow discharge coefficients can be calculated from these spatially distributed data, as these discharge coefficients are related to the total surface runoff and groundwater recharge, respectively.

Land use change for the Kikbeek study

In the land use scenarios, the actual land use data were adjusted in such a way that the effects of extreme, but possible, land use changes could be analysed. For instance, all non-urban areas were turned into agricultural land, or all agricultural land and meadows were turned into deciduous forests or urban areas. An overview of the examined land use scenarios is given in table 5.1.

Table 5.1 Description of the land use scenarios

land use scenario code	(a) description of land use changes
A	non-urban areas [a] (except infrastructure, surface waters, and mud flats) replaced by deciduous forests
B	non-urban areas [a] (except infrastructure, surface waters, mud flats, and wet meadows) replaced by meadows
C	non-urban areas [a] (except infrastructure, surface waters, and mud flats) replaced by agricultural land [b]
D	non-urban areas [a] (except infrastructure, surface waters, and mud flats) replaced by maize crops
E	non-urban areas [a] (except infrastructure, surface waters, and mud flats) replaced by open urban areas
F	agricultural land (including maize crops) and (wet) meadows replaced by deciduous forests
G	agricultural land (including maize crops) replaced by deciduous forests
H	agricultural land (including maize crops) replaced by meadows
K	agricultural land (including maize crops) and (wet) meadows replaced by open urban areas

b. non-urban areas include agricultural land (including maize crops), (wet) meadows, deciduous forest, coniferous forest, mixed forest, heather, shrubs, mud flats, surface waters, and non-urban infrastructure
c. all types of agricultural land, except maize crops

Results

The WetSpass modelling of the actual hydrological situation in the Kikbeek subbasin resulted in a set of digital maps (grids) for the Kikbeek subbasin of the calculated average yearly, summer, and winter evapotranspiration, groundwater recharge, and surface runoff. For each of these parameters, the average value for the whole Kikbeek subbasin is tabulated in table 5.2.

The results presented in table 5.2 demonstrate the seasonal differences in the hydrology of the Kikbeek subbasin. In summer, the major part of the precipitation (86.9 %) evaporates (directly or *via* the vegetation) and the rest of it is distributed almost equally between groundwater recharge (slow discharge) and surface runoff (fast discharge). In winter, the situation is completely different. Due to the lower temperatures, then only 31.6 % of the precipitation evaporates. The surface runoff changes, however, hardly (6.8 %), but the groundwater recharge increases dramatically (up to 61.6 %). This implicates that 89.7 % of the groundwater recharge takes place in winter, and only 10.3 % in summer. It also implicates that most part (82.6 %) of the total discharge from the Kikbeek subbasin into the Border Meuse has precipitated in winter.

In the (wet) greenhouse scenarios, most of the average discharge coefficients will not change dramatically with respect to the actual situation. An exception is the average slow discharge coefficient in summer, which decreases significantly with increasing temperature. In the high temperature estimates, it might even become slightly negative (–1.3 %).

Table 5.2 Results of the modelling of the hydrological situation in the Kikbeek subbasin

Parameter	Unit	per year*	summer*	winter*
Precipitation (Pr)	mm	770.4	395.1	375.3
Evapotranspiration (Et)	mm	462.0	343.5	118.5
Groundwater recharge (Re)	mm	257.8	26.7	231.1
Surface run-off (Ro)	mm	53.1	27.4	25.7
Water balance (WB = Pr – Et – Re – Ro)	mm	–2.4	–2.4	0.0
Error in water balance (WB/Pr)	%	–0.3	–0.6	0.0
Slow discharge coefficient (Re/Pr)	%	33.5	6.8	61.6
Fast discharge coefficient (Ro/Pr)	%	6.9	6.9	6.8

* volume per unit area

The dry scenarios, on the other hand, show significant decreases of the average slow discharge coefficients for both seasons. As a result, the average yearly slow discharge coefficient will decrease as well. The average yearly and seasonal fast discharge coefficients will not change noticeably. The decrease of the average slow discharge coefficient will be larger in summer than in winter. In summer, it will be negative, even more than it could be in the (wet) greenhouse scenarios (down to –8.9 %).

The modelling results of the land use scenarios revealed that an expansion of the urban areas can lead to a strong increase of the average fast discharge coefficient in both seasons (up to 14.4 %) and to a strong decrease of the average slow discharge coefficients in winter (down to 54.5 %). An increase of agricultural land (and/or maize crops) will result in an increase of the average fast and slow discharge coefficients in summer, the slow one particularly in case of an increase of maize crops (up to 20.1 %). An increase of deciduous forest will result, on the other hand, in a decrease of the average fast and slow discharge coefficients in summer, but in an important increase of the slow discharge coefficient in winter (up to 65.8 %). Finally, more meadows will result in larger slow discharge coefficients, in summer and winter.

The changes of the average discharge coefficients in the combined climate and land use scenarios with respect to the actual situation were generally a combination of the changes of the average discharge coefficients in the separate climate and land use scenarios. For the average discharge coefficients, the effects of the climate and land use changes could be cumulative or compensative.

5.3 The entire river basins - RHINEFLOW and MEUSEFLOW model runs

Rhineflow and Meuseflow are GIS-based water balance models for the entire Rhine and Meuse catchments respectively. The models use standard meteorological input variables of temperature and precipitation, and geographical data on topography, land use, soil type and groundwater flow characteristics. These parameters are stored in a raster GIS with a spatial resolution of 1x1 km^2. The aim of the models is to give detailed information about the hydrological response of the Rhine and Meuse catchments to climate change scenarios.

Rhineflow and Meuseflow were used with the full set of cases as defined in section 2.5. Figures 5.6 and 5.7 summarise the simulated Rhine and Meuse discharges for the cases. From the tables and figures it becomes clear that three clusters of discharge regime emerge, which are valid for both Rhine and Meuse. These regimes coincide with the External context of the individual cases.

- Regime 1: Case 0 (Current situation), Case 1, and Case 2 (External context: IND)
- Regime 2: Case 3 and Case 5 (External Context EGA-wet)
- Regime 3: Case 4 and Case 6 (External Context: EGA-dry)

Regime 1 (Case 0, Case 1, Case 2) has characteristics similar to the current situation. The external context IND does not give any reason to expect a totally different rainfall or temperature regime and so the input into the hydrological system remains unchanged. Slightly higher maximum and Q95 values can be expected due to a large increase in urban area, which decreases infiltration and increases direct runoff.

Regime 2 (Case 3, Case 5) is characterised by a very significant increase in the high discharges. The maximum discharge, Q95 and mean discharge all show a remarkable increase. This is mainly caused by the changes in precipitation as are associated with the external context EGA-wet belonging to this regime. Furthermore it might be noticed that the minimum discharges are only slightly higher than in the current situation.

This regime does not seem to be very sensitive to management styles. Both the EGA (Case 3) and the HIE management style (Case 5) seem not to be able to provide enough retention and storage in the catchment to mitigate the effects of the increased precipitation. This seems to be logical if taken into account that the extreme high discharges occur when all retention and reservoirs in the catchment are full. This is the case for a totally saturated catchment. Increased precipitation will in those cases always result in increased discharges, and it will be very difficult to find in this situation capacity for extra water storage.

Regime 3 (Case 4, Case 6) is characterised by a significant decrease in discharge volumes. Again, the reason for this is the External Context: The associated EGA-dry Perspective is described as significant decrease in precipitation, linked to an increase in temperature. The total input of water into the catchment is in this situation significantly less than in the current situation, resulting in this decreased mean and minimum flows.

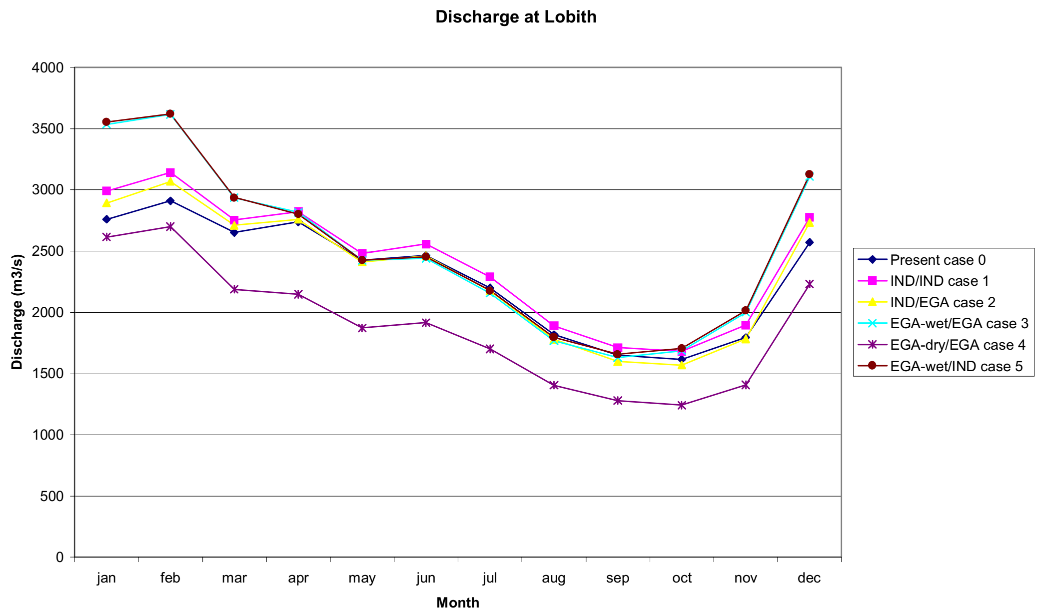

Figure 5.6 Discharges of the Rhine at the Lobith gauging station according to different perspectives

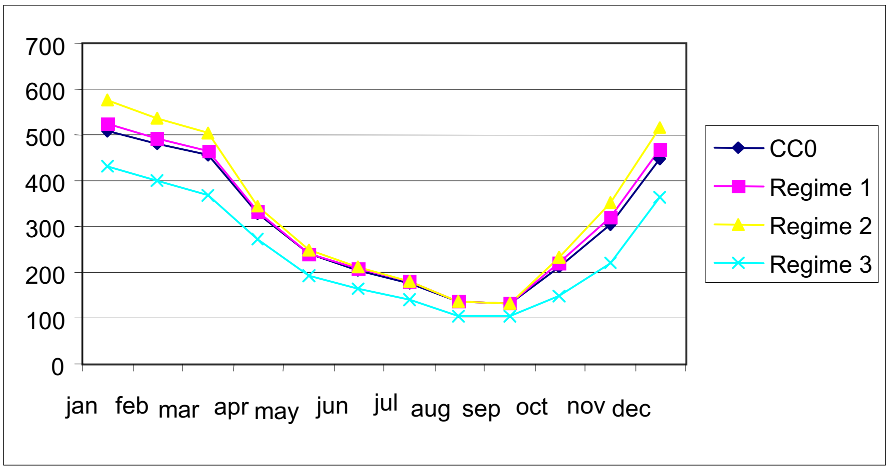

Figure 5.7 Discharges (in m3/s) of the Meuse at the Borgharen gauging station according to different perspectives

5.4 Linking the results of the modelling experiments

The main conclusions of the Lein subcatchment study are:

1. The influence of land-use on storm-runoff generation is stronger for convective storm events with high precipitation intensities than for long advective storm events with low precipitation intensities.
2. Yet convective storm events are of very minor relevance for the formation of floods in the large river basins of Central Europe because usually they are restricted to local occurrence.

3. Precipitation volume as well as antecedent soil moisture conditions and groundwater levels are of major importance for the degree up to which land-use can influence storm-runoff generation. The magnitude of a flood peak or the return period of a flood event respectively are less meaningful indicators in this respect.
4. Disastrous flood events in the large river basins in Central Europe often are the result of a coincidence of flood events in a great number of subcatchments. But the floods do not necessarily have to be disastrous in the subcatchments themselves. Therefore the conclusion that the influence of land-use is principally low for big floods in large basins is not valid.

If we consider the differences between the Rhineflow model and the WaSiM-ETH model the following differences might be noticed:

5. The timestep of calculation for the WaSiM-ETH model is much smaller than the Rhineflow model. The WaSiM simulated with timesteps in the order of minutes and hours while Rhineflow uses timesteps of 10 days. This means that Rhineflow can not be used for simulating the catchment response on convective storms. Events shorter than 10 days are averaged to a 10-day value.
6. The region for which Rhineflow is used is the entire Rhine basin (160.000 km^2), while the WaSiM-model is used for subbasins within the Rhine catchment.

The Rhineflow runs show a very limited effect of changes in landuse on the discharge regime. This is in agreement with the WaSiM runs that show little effect of changes in landuse on advective precipitation. The WaSiM conclusion that the influence of the short convective storms is relatively larger can (in principle) not be supported by Rhineflow since Rhineflow can not simulate effects of individual convective storms. The importance of Antecedent Moisture conditions is supported by both models

6. Evaluating the perspective-based integrated scenarios

The results of the modelling sessions were evaluated for the implications of the management styles in Utopia and Dystopia situations. This chapter outlines the criteria used for this evaluation (section 6.1) and the use of a DSS for this purpose (section 6.2). The presented results were supplemented with models for the Dutch terrestrial areas and the Dutch IJsselmeer system to obtain an overall representation (section 6.3).

The total evaluation thus contains two steps. Firstly, the hydrological changes for the different water systems were determined: Rhine and Meuse basins, floodplains, IJsselmeer and terrestrial areas. Subsequently, the implications of the implemented measures (water management strategy) and of the hydrological changes for the functions were evaluated.

The assessment of the perspective-based scenarios in terms of the defined evaluation criteria provided the basis for informed policy recommendations. Below, the results for the Rhine and Meuse basins as well as for the floodplains are described.

6.1 Evaluation criteria

The evaluation criteria for the model results of each scenario are used as follows:

- *Safety:* the probability that a catastrophic (in terms of risk impacts for humans) flooding of the river polders may occur.
- *Nature:* The area of ‘nature’. Nature values for the IJsselmeer are mainly determined by the length of shallow foreshores along the lake’s dikes. In the terrestrial models wet ecotopes and areas with a high biodiversity are valued high.
- *Agriculture:* the area occupied by agriculture. In addition for the Netherlands damage to agriculture by drought or wetness is determined.
- *Costs:* are the costs of the measures taken.
- *Economical benefits:* The valuation of *economical benefits* depends on the definition of ‘economic’ sectors.
- *Flexibility / reversibility:* The ability of the water system to adapt to the continuously changing conditions, without having taken irreversible measures.

- *Quality of life:* A complex and ambiguous notion. It is beyond the scope of this project to come up with adequate definition. The amount of nature, the possibilities for recreation and type of cultural values are used as rough indicators for quality of life.
- *Resilience*: the ability of the river system, society and ecosystems in the area threatened by floods to recover from a flooding in the area.
- *Inland navigation:* The positive and negative effects of the proposed management strategies on the inland navigation sector.

6.2 Implications for landscape planning of the floodplains

Evaluation of Perspective-based landscaping strategies of the floodplains was based on variants and alternatives from the Landscape Planning for the Rhine (LRP-study) and the Policy Line Space for the Rivers (Ruimte voor de Rivieren, RvR) studies. In addition, strategies from the IRMA-SPONGE project 'Living with Floods' were considered. The conversion of these alternatives to the Perspectives is shown in table 6.1

The landscaping strategies were evaluated with the LPR-DSS, which is a Decision Support System developed for Landscape Planning of the Rhine. Using this DSS, implications of various landscape planning strategies and measures for the embanked floodplains have been tested on their effects on water levels, nature, agriculture and resilience. Model output include flood water level, area with nature, area with agriculture, and costs associated with each strategy.

Table 6.1 Categorisation of LPR and RvR landscaping variants and strategies, as well as evaluation criteria according to the Perspectives. Bold letters indicate a full match with a Perspective, otherwise only the accent of the variant/strategy is in the direction of the Perspective. All are mentioned in order of priority

Perspective	LPR variant	RvR strategy	Living With Floods strategy	Evaluation criteria[1]
EGA	Nature	U&N	**GR, RB**	**R**, Fd
HIE	**LNC**, S	**L&C,** U&N		**Fd**, Fl, R, Fc
IND	S	**DR**, MC		**Fc**

[1] R = Resilience; F = Flexibility, subdivided in l = floodplain lowering; d = dike raising; c = cost

The results of the modelling experiments and their evaluation was summarised qualitatively for the utopia and dystopia scenarios in table 6.2.

Egalitarian

The Egalitarian management style results in major changes of the landscape. The embanked floodplains are converted into nature areas, where large parts are lowered to increase the discharge capacity and to create wetlands at the same time. Agriculture is relocated from the floodplains. Behind the river dikes, large areas are allocated to serve as green rivers and for retention. Although these areas will not be needed for these purposes over many decades (depending on the climate scenario and the stochastic occurrence of floods), these regions lose their economic value. The costs of all these measures are high. The gain, however, is primarily a large increase in the resilience of the river system. The flood risk for regions outside the retention areas has become very low, even in case of severe climate change. In addition, large nature areas are (re)established in the lower Rhine-Meuse delta. These characteristics are well illustrated by the similarity of the evaluation results along the rows in table 6.2 for the Egalitarian, indicating that the implications of this landscaping strategy are mostly determined by the strategy instead of the external context. This indicates a high robustness.

Hierarchist

The Hierarchist management style involves a complex process of design, planning and implementation. The plans serve many users, and are adapted to local conditions. The strategies seek for a reduction of flood risk, nature development, while preserving the landscape simultaneously. The strategy aims at increasing the resilience the river system, but also attempts to maintain a high budgetary flexibility and to avoid irreversible measures such as dike raising and floodplain lowering. In case of moderate climate change, the high cost of these complex landscaping measures will result in a high pay-off: reduction of flood risk coincides with gains for other river functions. However, in case of a major climate change, leading to a design discharge over 17,000 m^3/s, the character of the landscaping strategies has to be sacrificed to flood protection by taking large-scale measures. This may nullify the initial gains of the landscaping plans, and further raises the implementation cost. The overall character of this perspective, i.e. avoiding real choices and attempting to implement multi-purpose integrated plans, results in neither optimal scores nor minimum scores along the rows in table 6.2.

Table 6.2 Qualitative evaluation of the utopia-dystopia matrix for the rivers

Management style	Function	EXTERNAL CONTEXT				
		EGA-dry	EGA-wet	HIE	IND	Overall
EGA	Nature	+	++	++	++	++
	Agriculture	--	--	--	--	--
	Safety	++	+	++	++	++
	Landscape	++	++	++	++	++
	Resilience	++	++	++	++	++
	Flexibility	--	--	--	--	--
	Cost	--	--	--	--	--
	Inland navigation	-	+	0	0	0
	Economy	--	--	--	--	--
HIE	Nature	0	+	+	+	+
	Agriculture	--	-	-	-	-
	Safety	++	-	0	+	0
	Landscape	+	+	+	+	+
	Resilience	+	+	+	+	+
	Flexibility	-	0	-	+	-
	Cost	-	--	-	-	-
	Inland navigation	-	0	+	+	+
	Economy	-	--	-	-	-
IND	Nature	--	0	0	-	-
	Agriculture	-	-	+	+	0
	Safety	++	--	-	0	-
	Landscape	0	0	0	0	0
	Resilience	0	--	-	0	-
	Flexibility	++	-	-	++	+
	Cost	++	+	0	++	+
	Inland navigation	-	+	-	+	0
	Economy	+	-	0	+	0

Individualist

In the Individualist management style, flood protection is obtained by increasing the resistance instead of by increasing the natural resilience. This is because in the individualist perspective land use planning is guided by market mechanisms. This leads to high land prices. Priority is given to the use of land for economic activities over reserving large areas for water retention, which potentially may not happen for many decades. Flood protection should be cheap, fast and implemented by technical structures, thus not hampering other land users and uses. Inland navigation aims at efficient transportation of large flows of goods, using large ships and around-the-clock sailing. If the climate does not change (or only a minor change occurs) this management strategy turns out to be the most efficient economically. However, if the rate and magnitude of climate change are larger than anticipated there is a considerable risk associated to this management style. In that situation it will be very difficult to protect the land from flooding: there is no space left for retention polders and there is little time and money for lowering the embanked floodplains. The only option is further rising the river dikes. This leads to a situation with very low resilience and increased damage potential. In all cases, nature does not benefit at all from measures taken by the individualist. Inland navigation may seriously lose benefits when prolonged and more frequent periods of low flow hinder the large ships. The risk-seeking character of the individualist is well illustrated by the high variability of the evaluation scores along the rows: high scores in case of ideal external context, but low scores in case of dystopias. This strategy may be regarded as not robust.

6.3 Assessing the robustness of the management strategies

The anticipated effects for the various evaluation criteria - the hydrological situation (the Rhine and Meuse basins, the IJsselmeer area and the terrestrial areas), the consequences for the user functions (safety, agriculture, nature and transport/shipping) and the state of the water system (reversibility, economic gains and investments/costs) - have been estimated by the water experts in the project. The judgements were based on the model outcomes, knowledge of the models, interpretation of the modelling result and the stakeholder evaluation. The results are summarised in table 6.3 using a five point scale: very negative (--) (i.e. unfavourable) to very positive (++) (i.e. favourable).

A row-wise comparison of the qualitative evaluation of each management style across the different worldviews is provided. Firstly, the scores have been aggregated into a qualitative average, minimum and maximum values to indicate the overall score for each evaluation criterion (see table 6.4 first four columns). Secondly, we determined the variability of the results of a management style along the different worldviews and associated external contexts. Because of the large dissimilarities in effects this is done for each of the different subsystems (Rhine and Meuse, IJsselmeer, floodplains and terrestrial area). This semi-quantitative evaluation (see table 6.4 last four columns) is used as an indicator for the sensitivity of the management style to assumptions with regard to world view and external context.

Table 6.3 Qualitative evaluation of the effects associated with the various utopias and dystopias

		EXTERNAL CONTEXT							
		EGA-dry				EGA-wet			
MS		Rhine / Meuse	IJssel-meer	Flood-plains	Terrestrial areas	Rhine / Meuse	Flood-plains	IJssel-meer	Terrestrial areas
EGA	Nature	+	++	+	0	++	++	++	++
	Agriculture	--	0	--	-	--	--	0	--
	Safety	+	+	++	N.A.	-	+	+	N.A.
	Reversibility	-	--	--	-	--	--	--	+
	Cost	-	--	--	-	--	--	--	--
	Econ.benefits	-	--	--	--	--	--	--	--
	Inland nav.	N.A.	0	-	N.A.	N.A.	+	0	N.A.
	Quality of life	++	++	++	++	++	++	++	++
HIE	Nature	0	+	0	-	+	+	+	+
	Agriculture	-	0	--	0	-	-	0	--
	Safety	+	0	++	N.A.	-	-	-	N.A.
	Reversibility	0	0	++	+	-	0	-	+
	Cost	-	-	-	-	--	--	-	--
	Econ.benefits	-	-	-	0	-	--	-	0
	Inland nav.	N.A.	0	-	N.A.	N.A.	0	0	N.A.
	Quality of life	+	+	+	+	+	+	+	+
IND	Nature	--	0	--	--	--	0	0	+
	Agriculture	0	0	-	0	0	-	0	-
	Safety	+	--	++	N.A.	--	--	--	N.A.
	Reversibility	++	+	++	++	--	0	+	--
	Cost	++	+	++	++	-	+	+	N.A.
	Econ.benefits	++	0	+	++	++	-	0	++
	Inland nav.	N.A.	0	-	N.A.	N.A.	+	0	N.A.
	Quality of life	--	0	0	-	--	--	-	--

N.A.: the function is not applicable to a particular focus area.

Table 6.3 continnued

		EXTERNAL CONTEXT							
		HIE				IND			
MS		Rhine / Meuse	IJssel-meer	Flood-plains	Terrestrial areas	Rhine / Meuse	Flood-plains	Ijssel-meer	Terrestrial areas
EGA	Nature	+	++	++	+	+	++	++	+
	Agriculture	--	0	--	-	--	--	0	-
	Safety	-	++	++	N.A.	0	++	++	N.A.
	Reversibility	-	--	--	+	-	--	--	+
	Cost	-	--	--	-	-	--	--	-
	Econ.benefits	-	-	--	--	-	--	-	--
	Inland nav.	N.A.	0	0	N.A.	N.A.	0	0	N.A.
	Quality of life	++	++	++	++	++	++	++	++
HIE	Nature	+	+	+	+	+	+	+	0
	Agriculture	-	0	-	-	-	-	0	-
	Safety	0	0	0	N.A.	+	+	+	N.A.
	Reversibility	+	0	+	+	+	+	0	+
	Cost	+	-	-	+	+	-	-	+
	Econ.benefits	-	0	-	0	-	-	-	0
	Inland nav.	N.A.	0	+	N.A.	N.A.	+	0	N.A.
	Quality of life	+	+	+	+	+	+	+	+
IND	Nature	--	0	0	0	--	-	0	-
	Agriculture	0	0	+	0	0	+	0	+
	Safety	--	-	-	N.A.	0	0	0	N.A.
	Reversibility	+	+	++	--	++	++	+	--
	Cost	+	+	+	+	++	++	+	++
	Econ.benefits	++	0	0	++	++	+	+	++
	Inland nav.	N.A.	0	-	N.A.	N.A.	+	0	N.A.
	Quality of life	--	0	0	-	--	0	0	0

Table 6.4 Qualitative results of the evaluation of management styles

MS		Overall score			Overall sensitivity			
		'Average'	Max	Min	Rhi/Mse	Fl.pl.	IJsselmr.	Terr.
EGA	Nature	++	++	0	s-	s-	s-	s-
	Agriculture	-	0	--	s-	s-	s-	s-
	Safety	+	++	-	s-	s-	s-	N.A.
	Reversibility	-	+	--	s-	s-	s-	s0
	Cost	--	-	--	s-	s-	s-	s-
	Economy/benefits	--	-	--	s-	s-	s-	s-
	Inland navigation	0	+	-	N.A.	s+	s-	N.A.
	Quality of life	++	++	++	s-	s-	s-	s-
HIE	Nature	+	+	-	s-	s-	s-	s-
	Agriculture	-	0	--	s-	s-	s-	s-
	Safety	0	++	-	s-	s0	s-	N.A.
	Reversibility	+	++	-	s-	s-	s-	s-
	Cost	-	+	--	s+	s-	s-	s+
	Economy/benefit	-	0	--	s-	s-	s-	s-
	Inland navigation	0	+	-	N.A.	s-	s-	N.A.
	Quality of life	+	+	+	s-	s-	s-	s-
IND	Nature	-	+	--	s-	s-	s-	s0
	Agriculture	0	+	-	s-	s0	s-	s-
	Safety	-	++	--	s+	s+	s-	N.A.
	Reversibility	+	++	--	s+	s-	s-	s+
	Cost	+	++	-	s+	s-	s-	s0
	Economy/benefit	+	++	-	s-	s-	s-	s-
	Inland navigation	0	+	-	N.A.	s0	s-	N.A.
	Quality of life	-	0	--	s-	s0	s-	s-

s- – management style is <u>not sensitive</u> to assumptions in world view and external context, i.e. <u>robust</u> to uncertainty
s0 – management style is for focus area <u>moderately sensitive</u> to assumptions in world view and external context
s+ – management style is for focus area <u>very sensitive</u> to assumptions in world view and external context

The overall score is used to assess which positive or negative effects are associated with each management style and which management styles are undefined. In the case of negative effects, it can be concluded that the particular management style is associated with risks.

The sensitivity scores are indicators for the sensitivity towards uncertainties. If the sensitivity scores are low (s- or s0), the implications of a management style are not sensitive to uncertainties about the future. The management style may be regarded as robust to the interpretation of uncertainty. For these cases firm conclusions can be drawn on the expected positive or negative effects associated with the management style, irrespective of the assumptions pertaining to external context and the functioning of the water system. Uncertainties are now not relevant for decision-making, which implies that decision-makers can disagree about the underlying assumptions while still agreeing about the effects associated with the management style.

In those cases where significant sensitivity is observed (s+), the underlying uncertainties pertaining to external context and functioning of the water system are relevant to decision-makers. For these cases, differences in perspectives do matter for the political debate.

7. Management styles under uncertainty - discussion

7.1 Implications for the management styles

The project basically evaluated the three scenario families, based on the central statement 'water management according to perspective X results in…'. By confronting each management style with different futures, both utopian and dystopian, overall conclusions could be derived for each perspective and associated management style.

Egalitarian management style
The Egalitarian strategy is focused on the causes of water-problems, instead of dealing symptoms and effects (Individualist) or focussing on actors (Hierarchist). The approach to uncertainty associated with this perspective can be characterised as aiming at a high resilience of the water system. The Egalitarian water management strategy involves major environmental and landscaping measures, resulting in sustainable solutions with resilient water systems for flooding, and major restoration and expansion of nature. However, the implementation cost involved are high, and other - mainly economic - functions (such as industrial and urban expansion, inland navigation, agriculture) are subordinate to the protection and expansion of water and nature. In dystopian situations, when no calamities happen, the drastic measures and large costs have been to no purpose. The positive side effects involve a large natural area and a higher quality of life. A negative side effect may be that due to the scarcity of space in the Netherlands, the increasing demands for room for nature and water may indirectly increase the pressure on other nature reserves, such as the Veluwe. Although many landscaping measures are costly and irreversible (digging away floodplains, transforming agriculture areas into nature), it is a strategy more flexible than the Individualist, in the sense that it allows for changing to another water management strategy, if time proves that the risks are smaller than perceived today. The Egalitarian faith is that economic austerity in combination with psychological and socio-cultural well-being will result in a long-term stabilisation or even curbing of climate change, thereby reducing the long term water risks. In other words, this management style suggests futures that are favourable if one does not mind high costs.

Hierarchist management style
The Hierarchist aims at so-called win-win situations. However, the Hierarchist avoids making real choices, and some of the futures associated with this management strategy run the risk of becoming 'loss-loss' situations. Hierarchistic water management is a time consuming and expensive strategy, but it does not yield firm safety guarantees. Furthermore, the Hierarchist strategy implies regular adjustment, which is a major cause for the high expenses. Because the Hierarchist tries to serve all functions but is confronted with limited financial and land resources, it is likely that all functions suffer. If climate change appears to be insignificant, the costs have been for nothing. On the other

hand, over time, this compromise strategy of 'running with the hare and hunting with the hounds'[1] has the most public support. However, per situation and per point in time no stakeholder is fully satisfied. This water management strategy can be characterised as reactive, fully 'controlled' by external factors and incidents, as stakeholders interests may change in response to events. The risk associated with this management style is that it gets stuck in conferences and sluggish decision-making, and that only a few measures are actually implemented, among which likely those that are acceptable but not effective. This water management strategy is actually not so much a vision on water policy, but on how to organise water management. The Hierarchist management style actually addresses uncertainty associated with future developments through incrementalism (versus drastic measures) thereby implicitly creating the flexibility to change to another management style.

Individualist management style
The Individualistic management style can be characterised as passive, and displaying a short-term vision with respect to water management measures. The Individualist aims at reducing cost, stimulating economic benefits, thereby accepting a relatively high, calculated risk. Measures will be implemented as adaptations to changing conditions. However, large adjustments to accomodate an unforeseen drastic climate change will not be possible. This is because this management style leaves little physical space for adaptation. Consequently, it will be difficult to change to another management style, for example, because of irreversible damage to natural systems in the flood plains, or potential retention areas have been occupied by other functions. On the short term, compared to the others this strategy is relatively cheap. However, there is the risk of amplifying feedbacks if the world develops differently then the Individualist assumes (e.g. materialistic growth inducing further climate change). The world associated with Individualistic management is thus extremely vulnerable for calamities, i.e. low probability events happening. In case of extreme flooding, because of high economic value and damage potential along the rivers the economic impacts are large The future associated with the Individualistic management strategy is characterised as wealthy, but even in the utopian case results in a lower quality of life in the broader sense. In the case of water management, it is obvious that the Individualistic approach to uncertainty should be characterised as risk-taking. Summarising: low short term costs, but high long-term risks.

Robustness
Evaluating the assessments over the various management styles we conclude that the Egalitarian management style is the most robust one, mainly due to the aspirations associated with safety and nature. The undisputed price tag is that it involves high cost and large spatial claims.

The Hierarchistic management style fulfils the objectives of integrated (win-win) solutions with nature, safety and reversible measures in most cases. However, in dystopian situations, investment cost will be high without leading to safety and reduced flood risks. In case the external context and the water system evolve according to the Egalitarian wet variant, the applied measures are not adequate, and may lead to loss for nature and other water functions, especially in the floodplains. This management style is thus less robust in view of a changing environment and an uncertain future.

The Individualistic management style is adequately characterised as high risk taking but cost-efficient, at least in the short term. Positive impacts for all relevant functions (except nature) do only materialise in case the external context develops according to the Individualist assumptions and when the river basins systems are as robust as the Individualist assumes. In dystopian cases, technical measures have to be applied to counteract the climate-induced changes, which may lead to high cost. The Indvidualistic management style can therefore be considered as the least robust in view of uncertainties associated with external context and functioning of the water system.

7.2 National policy recommendations

This evaluation of water management strategies through assessment of the water-specific management styles associated with the three archetypal perspectives revealed several general conclusions relevant for water management.

[1] In Dutch: de kool en de geit sparen

The vast majority of current policy plans on water management in the Netherlands falls within the Hierarchist perspective for their management style. It is shifting from Hierarchist to Egalitarian in terms of assumptions pertaining to external context and world view. However, the Hierarchist management style, aiming at win-win situations, is not a-priori the most robust. In case of a serious climate change (> 2 °C temperature rise in the next 50 years), there may be no possibilities left for finding win-win solutions for all water functions. Also, the complexity of the planning process may result in a slow response in case of severe climate change. A major difficulty in the 'cost-benefit' assessment is the weighing of advantages against disadvantages, because they are of a different kind. We need to stress that this is not necessarily a generic statement, but specific for the Netherlands. No management style is superior over all others under all conditions evaluated on the whole set of evaluation criteria.

The balance between safety versus costs is a real policy dilemma that cannot be solved by using an ingenious water management strategy. Political decisions on water management involve necessary trade-offs on normative grounds. None of the discussed water management strategies is preferred, because every management style has its own drawbacks and disadvantages.

The main differences between the extreme perspectives Egalitarian and Individualist are their inherent choices on the implementation cost and accepted risk. The Hierarchist may take an intermediate position. The key question is then whether insights associated with the present project would advocate a different water management style. If Hierarchist water management proves to be more expensive than Egalitarian water management, the Egalitarian management style is advocated, because the latter yields more safety and nature at lower costs. However, if the Hierarchist management style would appear more risky than the Individualist, the Individualistic management strategy is preferred, because it is less costly, and leaves more room for other functions. Similar comparisons may be made on the basis of, for example, resilience, ecological values, or the possibility of combining different functions at all places within the water systems.

The current research results do not provide (enough) evidence to advocate that a change of water management strategy is needed. At present a switch to the Individualistic management style is not advocated, because scientific knowledge indicates that it would be unwise to neglect the possibility of serious climate change in view of the current level of uncertainty. An Individualistic water management strategy decreases the capability to cope with future climate change. From a safety point of view, it can be advocated to switch to the Egalitarian management style, because it is the most robust strategy, however, it is to be discussed whether society is ready/willing to pay the costs in financial terms and in terms of spatial claims. However, it is clear that it would be a bad policy either to put all eggs in the Hierarchist basket. The Hierarchist water management strategy has to be continuously evaluated in terms of relative risk (compared to the Individualist water management strategy) and relative costs (compared to the Egalitarian water management strategy).

A paradigm shift is observed from turning the water ('water keren') to accommodating the water ('water accommoderen'), thus from a Hierarchist management style to a more Egalitarian type of water management with still strong Hierarchist aspects. Our research indicates that also following the water is no panacea for water management in the Netherlands, because of spatial conflicts and shifting pressure to other (vulnerable) areas.

7.3 Methodology and concepts

A major methodological challenge was to explore whether the top-down approach using the concepts and typology of the Perspective-methods would fit to the 'case' of water management in the Rhine and Meuse basins being the subject of the present study. It has become apparent that most of the present-day studies, policy lines and reports in the Netherlands on water management all fall within the Hierarchist perspective. At first sight, this would suggest that the three Perspectives are not able to discriminate between the different views presented in these studies. However, closer analysis of these studies revealed that these have been produced by related institutes, often involving the same authors, many documents are the product of intensive collaboration between institutes and many reports appear to have the same source. This suppresses the development of a broad palette of visions, while it perfectly matches to the Hierarchist world view and management style. Thus, the Perspective-based analysis of these studies well demonstrated the position of current policy in water management in the Netherlands in a wider perspective. In turn, it was questioned whether it was possible to consider the full spectrum of ‘possible’ or ‘thinkable’ scenarios using only three perspectives. From the viewpoint of the stakeholders the three Perspectives indeed do include the extremes in scenario studies:

- The Egalitarian envisages a rather worst case situation in terms of climate change, (both wet and dry extreme events may occur)
- The Hierarchist represents the visions that seek the most plausible scenario, the central estimate, the most likely or most manageable future.
- The Individualist enables to explore the consequences of short-term orientation and a risk-taking attitude. If the Individualist makes the wrong guess, it is a calculated risk, or a bankrupt, after which a new life re-starts.

8. Conclusions and Recommendations

1) At the scale of the ***entire Rhine basin***, climate change impacts cannot be compensated by land use changes, as the influence of climate change on extreme floods is much stronger than the influence of land use measures.

2) Flood risk management in the ***lower river deltas*** cannot be based on the assumption that extreme floods can be prevented by upstream measures. This is because it is not certain that upstream flood retention measures will be implemented *and* that they are as effective as anticipated, especially under very extreme flow conditions.

3) The effects of landuse changes on peak discharges in ***small catchments*** are limited and strongly depend on the type of precipitation (convective vs. advective) and antecedent conditions, implying that …

4) … future peak flows in ***small catchments*** depend on the changes in variability of precipitation. Estimates of changes in extreme precipitation and precipitation variability currently rely heavily on the results of downscaling methods of precipitation obtained from global climate models.

7) Current Dutch flood risk management can be characterised as complying with a Hierarchist management style (cf Thompson)), while German and Belgian management styles have common characteristics with an Individualistic style.

8) Under changing climate conditions, the Hierarchist type of management runs the risk of becoming an expensive attempt to fully control flood risk problems, without actually solving the problems in a long-term view.

8) No flood risk management strategy is superior in all respects and in all circumstances. Flood risk management is not merely a technical optimisation problem: safety versus societal costs is really a policy dilemma. (Win-win situations cannot always be attained).

9) The three Cultural Perspectives applied in the present study do not fully discriminate between all differences in water management when considering the international dimension. Additional dimensions for characterisation differences in national management styles are therefore needed.

10) Considering the present-day and future uncertainties for water management in the Rhine and Meuse basins research should be more aimed at defining integrated and coherent scenarios that can underpin adequate water management strategies given the uncertainties.

11) This should be done by combining *social* sciences with *environmental* sciences, and by combining physical/mathematical modelling tools with expert sessions and participatory stakeholder processes

12) Integration of water management and spatial planning is essential, because spatial claims often collide with claims for water management, which is likely to result in higher risks and higher costs.

13) Perspective-based flood risk management scenarios should not only consider the temporal dimension with different lines of future development, but also should take into account differences in management styles within the river basin.

14) With hindsight the project can be characterised as experimental and challenging. Probably one of the most important results of the project is that it is clear that this type of assessment is worthwhile to further pursue, both from the scientific and the decision-making perspective. The current project provides a conceptual and methodological basis for follow-up research and a more focused set of research questions and hypotheses.