Space for River, Nature and People

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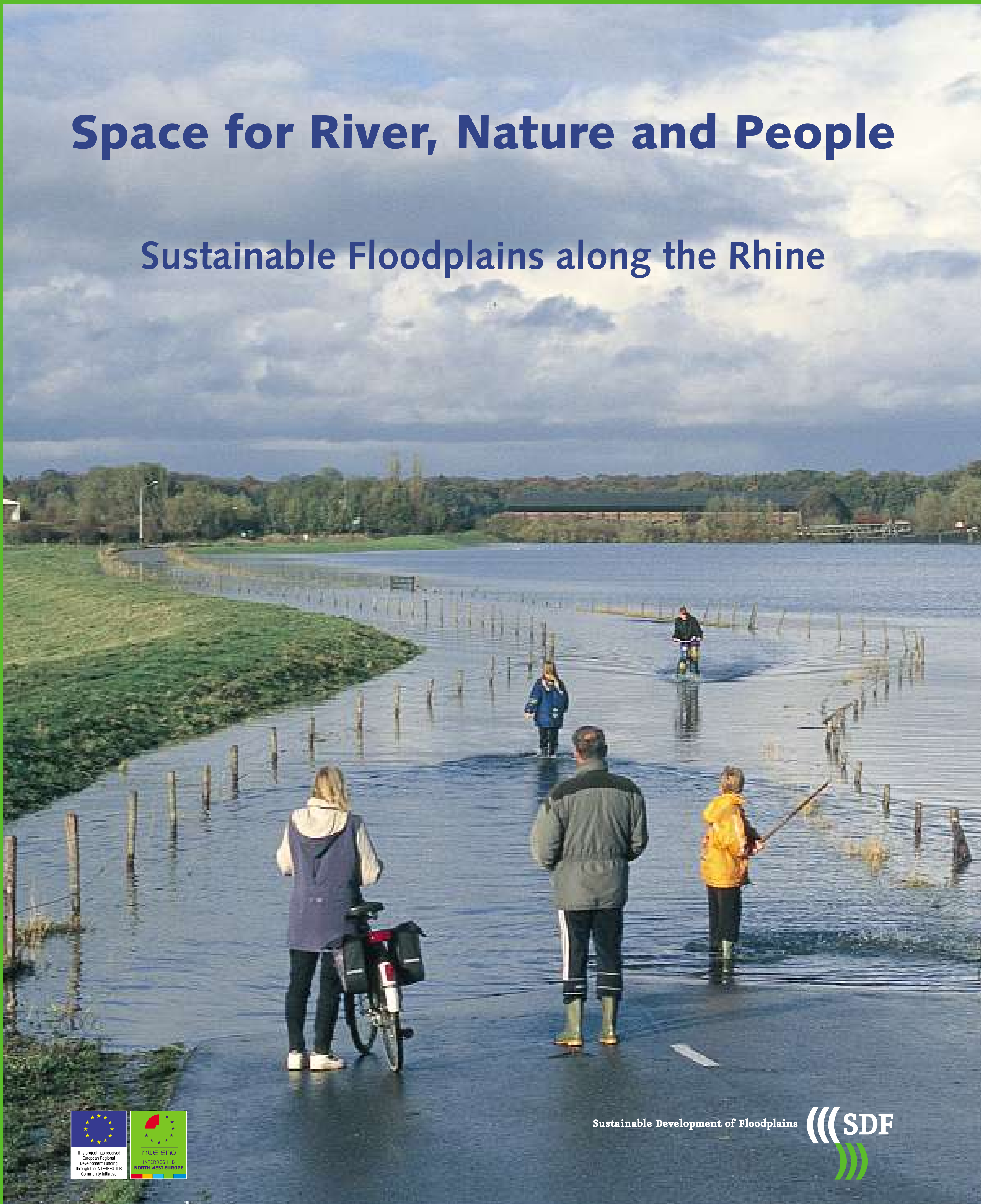
Sustainable Floodplains along the Rhine



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Sustainable Development of Floodplains SDF

Space for River, Nature and People

Sustainable Floodplains along the Rhine

Results and practical experiences from the SDF project 2003-2008

SDF

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Foreword

River flooding is the most common type of natural disaster in Europe. Climate change, including the increasing intensity of heavy rainfall, is projected to make river floods even more frequent, and is likely to increase the risk of casualties, damage to the environment, infrastructure and property.
At the same time, rivers are an important lifeline for cities and the environment. Floods can have important beneficial effects for river ecosystems, groundwater recharge and soil fertility.

Flood mitigation policies and measures need to be implemented to reduce the impact of floods. Creating more space for the rivers will contribute to natural processes while simultaneously reducing flood levels. We need to create a sustainable, viable environment and secure future for generations to come": 'their future, our concern'. We have to intensify our flood risk management efforts. Recognising the often cross-border nature of floods and flood prevention, the European Commission has proposed concerted action on flood risk management.

Since 2003, German and Dutch organisations have been working together on the sustainable development of floodplains along the River Rhine. A wide variety of measures to improve water retention and discharge capacity including the relocation of dikes, the construction of water retention polders and side channels, and the redevelopment of floodplains by changing land use have been planned and implemented.

The work was undertaken within the framework of the SDF project. The SDF project is an EU-funded project as part of the INTERREG IIIB North West Europe programme. The project encouraged collaborative activities in flood risk management, multiple land use in floodplains, nature development and public consultation.

We are all proud of the useful and sustainable results that have been achieved. We have been working closely together for six years. A strong bond has developed between the Dutch and German partners during frequent meetings, a bond that will continue beyond the life of the project.

The partners acknowledged the need to continue cooperation beyond the SDF project in order to consolidate achievements and secure long-term benefits. The successful submission of two INTERREG IVB project proposals, i.e. Adaptive Land Use for Flood Alleviation/ALFA and FloodResilienCity/FRC, creates the opportunity to extend the partnership and transfer knowledge and experiences of the SDF project to river catchments in other regions in Europe.

The European cooperation project provided an excellent opportunity for working across borders and cultures. We wish to thank the INTERREG IIIB North/West Europe programme Steering Committee and Joint Technical Secretariat for their confidence in our project and their support during its execution.

We belief that combined efforts in river catchments, across borders, are a must for the implementation of measures that enable societies to increase resilience to flood hazards.

This book contains the results and practical experiences of six years of intensive and successful cooperation on flood risk management. We sincerely hope that the book will prove useful for the many people in Europe and elsewhere who work in the field of flood risk management.

Henk Nijland
SDF project manager

About this book:

A message from the SDF Partners

The partners of the EU-funded Sustainable Development of Floodplains (SDF) project worked for six years on the implementation of flood alleviation measures in the River Rhine catchment. On the German side, the following projects were involved: Kirschgartshausen, Ingelheim Polder, Lohrwardt, Emscher, Bislich-Vahnum and Emmericher Ward. On the Dutch side, this project consisted of the Hondsbroeksche Pleij, Lexkesveer, Heesseltsche Uiterwaarden, Fortmond, Rijnwaarden and Bemmelse Waard projects. With an European subsidy of 17.5 million euros and a total project value of more than 35 million euros, the SDF project is the largest collaborative project within the INTERREG III Structural Funds.

The SDF project adopted an integrated approach and worked transnationally on the practical implementation of flood alleviation measures. In addition, nature development and communication with stakeholders within the project planning and implementation were major themes for the exchange of knowledge and experiences. During the course of the SDF project, all partners emphasised the importance of the solidarity principle of upstream and downstream in river catchments. Through the collaborative work, the colleagues gained a better understanding of each other's problems. This finally resulted in the cost-saving 'mixed in place' technique, a familiar and often applied technique in Germany, to install a cut-off wall in the Hondsbroeksche Pleij floodplain with a minimum impact at the site. An export item from the Netherlands to Germany was the notion that horses and cows are natural managers in Dutch floodplains.

All partners are convinced that the contacts and networks will be extended in future. In the new EU-funding period, some SDF partners have already concluded new partnerships within north-west Europe and the North Sea Region.

The experience that transnational cooperation can enhance decision making in national and regional budgeting and prioritising projects is still valid. Furthermore, the special exchange meetings with European colleagues from different professions often resulted in more open and broader discussions than simply business as usual. Open minds and a wider view create an open atmosphere and this provides a solid basis for innovative solutions. Flood alleviation will become more and more important in the future due to the expected climate change accompanied by an increase in rainfall. Sustainable solutions have to be found for the densely populated river catchments. A reservation of sufficient floodplain areas is wise, as national programmes in many EU countries are already demonstrating.

An integrated approach in European river catchments and a good mix of specialists (such as civil engineers, spatial planners, environmentalists and legal experts) are favourable instruments for mutual learning and achieve cost efficiency throughout border areas. New Member States can learn from the experiences gained and can attempt to reserve space along their rivers and therefore avoid creating problems similar to those that occurred in western Europe in the past decade.

The SDF partners are proud to present the main results in this book. In finding your way through the vast amount of information presented, you are advised to read the Results at a Glance first. This is a good introduction. Chapter 1 includes a map of the River Rhine catchment and a short description of the projects, the measures involved and provides an overview of the framework of the SDF cooperation. The following chapters (2, 3 and 4) present the three workings group themes flood alleviation, nature development, communication and public involvement. The results and experience gained from the various projects and partners are described for each theme. Chapter 5 deals with special aspects of floodplain projects land acquisition, tendering procedures and public-private partnerships. Chapter 6 summarises the experiences gained in transnational cooperation. The annexes include additional information on the national and international regulations and programmes and construction in floodplains.

Results at a Glance

Working together for a safe and vibrant Rhine

The Rhine flows through large areas of Germany and the Netherlands. In the past, measures to straighten the river resulted in an increased risk of flooding in the Rhine Delta. As part of the European SDF (Sustainable Development of Floodplains) cooperation project, Dutch and German partners restored former and existing floodplains in twelve pilot projects. The close transnational cooperation has created a know-how platform for sustainable flood prevention in Europe.

More room for the river: restored floodplains on the upper and middle sections of the Rhine are intended to reduce the height of the flood waves during future flood events. On the other hand, the aim of the measures taken on the lower stretches and in the Rhine Delta is to ensure that the water drains away quickly. In this case, floodplains are being expanded, lowered or supplemented with new or reactivated side channels.

These measures require close Dutch-German cooperation. If water is retained in floodplains in the upper and middle reaches which are mainly situated on German territory, this reduces the risk of flooding for people living near the lower section of the river which is mainly situated in the Netherlands. In this case, the joint work of the SDF partners has made a start on making the river safer.

Dike profiles, layouts for hydraulic engineering projects and building methods differ among the regions and nations along the Rhine. This provides us with an opportunity to learn from each other, to find the best solution for each situation and to focus on pilot projects. Before planning and construction began, Dutch and German planners together checked how cost and time could be saved by using certain methods. For example, technical aspects of the dike relocation project at Hondsbroeksche Pleij were improved using construction methods from the retention area at Ingelheim Polder.

Cooperation has also borne fruit in the joint development of environmental and socially responsible land use strategies for retention areas and in public participation. By holding joint events, the Dutch Rijkswaterstaat and Germany's Emschergenossenschaft have demonstrated the importance of solidarity between people living near the Upper and the Lower Rhine. For example, they were able to convince people living near the Emscher that more room for the river would offer them a better quality of life and at the same time be able to reduce the risk of flooding for people in the Netherlands.

Another example of people learning from each other is provided by tendering and contract awarding procedures. There are major regional and national differences in this area. It has become clear through SDF that close cooperation between nature conservation and water management offers advantages for both sides in terms of the sustainable development of retention areas. On the one hand, water management pursues many actions which individually reduce the risk potential only slightly and so they cannot all have a high priority. On the other hand, nature conservation budgets alone are often insufficient for completing major projects. Interdisciplinary cooperation with the common goal of nature conservation and flood prevention therefore creates considerable added value for safety and for nature – a win-win situation.

For six years, experts, planners and officials from Germany and the Netherlands have been working closely together to complete the twelve SDF pilot projects. Cooperation has taken the form of three working groups whose members met for a few days twice a year to analyse results, visit pilot projects and exchange experiences. The working groups dealt with topics such as measures to reduce flooding, natural development and the environment and communication and involving the public. A transnational partner group and the steering committee ensured that project implementation progressed smoothly. In addition, local events were held at project locations – to celebrate the laying of a foundation stone or the opening of a building – in order to inform the public of the project and its results.

The personal contact which has grown up over the years among those involved in SDF forms a valuable basis for the further development of a Europe-wide sustainable flood prevention system. A platform has been created for close and even-handed cooperation on transnational rivers, which has implications far beyond the Dutch-German border. Three new partners joined in 2006, while the SDF was still in progress: Institution Interdépartementale des Barrages-Réservoirs du Bassin de la Seine (France), Environment Agency (UK) and Office of Public Works (Ireland).

This has resulted in a further expansion of knowledge and the start of numerous new initiatives, such as the following:

“FloodResilienCity” is a cooperation project – derived from SDF – involving Dutch, French, Belgian, British and Irish partners which aims to facilitate the adaptation of cities to take account of the risks and opportunities offered by rivers.

“ALFA (Adaptive Land Use for Flood Alleviation)”, also a follow-up project from SDF, aims to create additional retention areas to take account of the consequences of climate change.

SDF's activities

Measures to protect against flooding and to upgrade nature and the landscape have been implemented in twelve pilot projects along the Rhine. Depending on the phase of the project, a distinction has been made between planning and implementation projects.

		Project											
Sysmbool	SDF action	Kirschgartshausen	Ingelheim	Emscher	Emmericher Ward	Bislich-Vahnum	Lohrwardt	Rijnwaarden	Bemmelse Waard	Fortmond	Hondsbroeksche Pleij	Lexkesveer	Hesseltsche Uiterwaarden
	Planning			blue, green	blue, green	blue, green		blue					blue
	Implementation	blue	blue				blue, green		blue, green	blue	blue	blue	
	Dike relocation	blue, green					blue, green				blue, green		
	Creation of retention polders		blue, green	blue, green			blue, green						
	Construction of inlet / outlet works		blue, green	blue, green			blue, green				blue, green		
	Creation of side channels				blue	blue			blue	blue, green	blue, green	blue, green	blue
	Removal of hydraulic obstruction											blue, green	
	Lowering of loodplain area								blue, green	blue, green	blue, green		
	Seepage	blue, green	blue, green				blue, green			blue, green	blue, green		blue
	Nature development	blue, green	blue, green	blue, green	blue	blue	blue	blue	blue, green	blue, green	blue	blue, green	blue
	Ecological flooding	blue, green	blue, green				blue, green						
	Feasibility study			blue, green	blue, green						blue, green		
	Management concepts	blue	blue				blue	blue	blue	blue, green		blue	
	EIA			blue, green				blue, green					blue
	Public communication	blue	blue, green	blue, green	blue, green	blue, green	blue, green	blue, green	blue, green	blue, green	blue	blue	blue
	PPP/Contracting/ Land acquisition		blue				blue		blue		blue, green	blue	

● (blue) Measure in project and in book
● (green) Measure is EU co-financed

Kirschgartshausen
Creation of retention area by relocating dikes and building new dikes; natural development achieved through supporting land use strategies.

Polder Ingelheim
The construction of an innovative inlet and outlet structure to create an effective retention area and conditions for ecological flooding; multifunctional land uses make sustainable development of floodplains possible.

Emscher
Planning and environmental impact assessment for retention areas near the Emscher (Rhine catchment area); communication process to encourage the participation of the public and various actors has reduced conflict.

Lohrwardt
Creation of retention area by reconstructing a dike and building an inlet and outlet structure also suitable for ecological flooding and multifunctional land use strategy for integrating different interests.

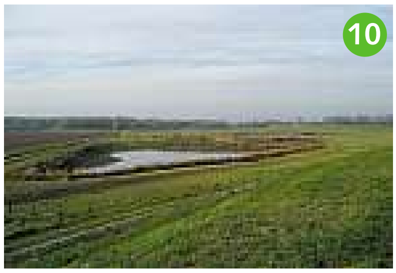
Emmericher Ward
Feasibility study and development strategy for a new side channel as a contribution to flood prevention and to the natural development of floodplains.

Bislich-Vahnum
Feasibility study for an additional continuously free-flow side channel and development strategy as a contribution to flood prevention and natural development.

Rijnwaarden
Planning and environmental impact assessment for the excavation of tracts of land and the construction of a side channel; sustainable land use strategy for the floodplain area.

Hondsbroeksche Pleij
Dike relocation, soil excavation, installation of an adjustable weir and construction of a new high-water channel in the floodplain, multifunctional land use strategy.

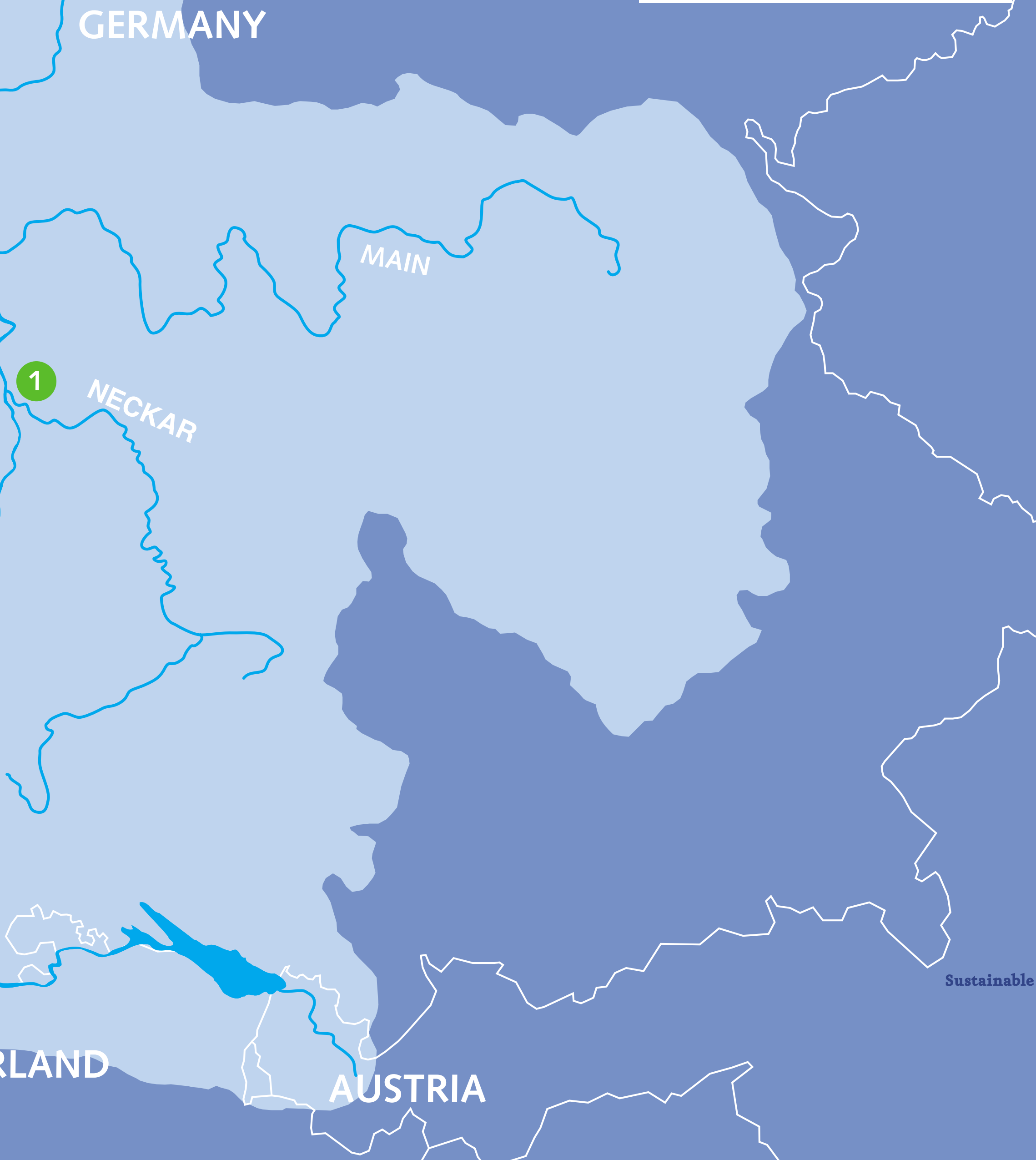
Fortmond
Excavation and lowering of the floodplain, construction of a side channel and development of a natural landscape.



Bemmelse Waard
Excavation and lowering of the floodplain and preparation of a development plan for developing nature and uses for the landscape.

Lexkesveer
Environmental impact assessment, construction of a bridge to remove a flow obstruction, excavation of a side channel, work on a new summer dike.

Heesseltsche Uiterwaarden
Environmental impact assessment and planning of flood protection measures, multifunctional land use strategy.



Sustainable Development of Floodplains SDF

Floodplains create more room for the water

The reclamation of historical floodplains is an important means of flood protection. This is being effected along the Rhine by dismantling or creating an opening in existing dikes and building new dikes further away from the river. Between them a new flooded area is being created: the retention area. In this way, former floodplains are being reactivated.

On the stretches of land that reconnect the river to the floodplain, water is allowed to spread when it exceeds the capacity of the river. It is temporarily retained and drawn from the river. This reduces the height of the flood wave.

The positive effect on ecological floodplain development is at its greatest when the rising water is allowed to flow freely into the floodplains and subsequently flow out again. For example, uncontrolled retention areas are being created on the Upper and Middle Rhine by moving dikes further inland. In this case, the focus is on nature conservation and the effect on the floodwater level is minimal. Many retention areas would have to be created to significantly reduce the floodwater level. Discharge capacities have been increased on the Lower Rhine and in the Rhine Delta by relocating dikes, with the effect of improving flood protection and a positive impact on the environment.

Controlled retention areas are more effective for retaining floodwater. An adjustable inlet control structure controls the inflow of rising water. For example, it is possible to cut the peak height of the flood wave in a targeted manner. When the water level in the river falls, the retention area is drained by means of the outlet control structure and, if necessary, pumping stations as well.

Controlled water inlet systems also have specific uses in nature conservation, because if areas are only flooded every 10 to 20 years with rare, very high floodwater levels and then seriously inundated, this could result in a negative impact on the environment in the floodplain. For this reason, ecological flooding is carried out on a regular basis, even without extremely high floodwater levels. At numerous planning meetings held as part of SDF, the planners integrated the corresponding design requirements for the control structures on the basis of experience gained from other projects. For example, inlet control structures must allow water to flow into the retention area even in the event of minor floods.

As part of the SDF project, four controlled retention areas and three dike relocations or uncontrolled retention areas were planned and created in Germany and the Netherlands. The close cooperation during this process had an optimising effect, especially in terms of dike profiles, inlet and outlet control structures and other design and structural engineering issues.

Which dike is the right one?

The design of new or reinforced dikes has an impact on safety and construction costs. There are regional and national variations in standards for dike construction. Standards from Baden-Württemberg, Rhineland-Palatinate, North-Rhine Westphalia and the Netherlands were compared as part of the SDF project.

The profiles and in particular the techniques for creating a seal below ground were different. Sealing prevents water from seeping underground, flowing underneath the dike and making it dangerously unstable. New and sometimes cost-saving solutions were found for SDF measures by combining different standards.

In the Netherlands, wider dike profiles are generally used. However, the SDF project had positive experiences with the installation of sealing walls in the Dutch Hondsbroeksche Pleij floodplain, which were also used in Ingelheim Polder in Germany and have been planned for Lohrwardt Polder. The installation of these sealing walls saves space for the dikes. For this purpose, bore holes were drilled in the dike alignment and concrete piles were mixed in the actual bore hole. A sealing wall was created under the dike by inserting a closely-spaced series of uncased concrete piles using this mixed-in-place method. In the Hondsbroeksche Pleij area, for example, the wall is 50 cm thick and 8 m deep. This method is considerably cheaper than steel sheet piling. This made it possible to achieve savings of almost EUR 3 million in the Hondsbroeksche Pleij pilot project. In addition, it spares vegetation, as no major earth-moving operation is required. Thanks to the exchange of experiences in SDF, the method is also being used in other places.

Priority was given to dealing with seepage water behind the dikes during floods. Two strategies were tried in the SDF projects. As part of the precautionary strategy, technical devices are used to prevent any seepage. Precautionary measures include seals, seepage ditches, pumping stations and a monitoring system. In the monitoring strategy, measures are taken only if damage occurs. The SDF project partners have tested all the options for the retention areas and dike relocations and have developed an effective combination of different measures. In this way, the transnational partnership is making a contribution to the effective, nature-friendly and cost-saving construction and operation of dikes.

Conclusions/What have we learned?

- Technical solutions often vary from region to region. Cooperation across regional and national boundaries makes it possible to find optimised and inexpensive solutions.
- Compact, narrower dike profiles, combined with sealing walls below ground and a suitable construction, save space, preserve the environment and can be built without compromising safety.
- The mixed-in-place method for the installation of sealing walls underneath dikes is generally cheaper and more environmentally friendly than sheet piling.
- A combination of several measures prevents damage by seepage: sealing walls as a minimum, seepage ditches and pumping stations depending on the situation and a monitoring system. The extent to which monitoring alone and intervention in the event of damage will find sufficient acceptance is primarily a question of law and planning philosophy.

Combined experience makes for better systems

Structures used in flood prevention are usually designed for specific situations. Only after major investments and an extended period of use is it possible to identify any faults. In addition, there are only a few systems and they are seldom put into operation, if at all. Long-standing experience in the construction of flood prevention systems is therefore in short supply. This makes it all the more important to combine regional and national experience on a broad international basis and develop new and improved solutions together.

The SDF project partners have contributed their national and regional experience with the aim of making improvements in the creation of retention areas. Clear potential for improvement has been shown in the case of inlet and outlet control structures through which floodwater flows into the retention area and subsequently flows out again.

The project team made joint visits to structures on the polders at Söllingen-Greffern, Altenheim and Kollerinsel on the Upper Rhine and held working meetings to discuss the planning of the inlet and outlet control structures for Ingelheim Polder. This has been designed so that the polder can be filled in the event of floods, which in statistical terms occur every 5 to 20 years. The inlet and outlet control structure consists of a fish-belly flap weir with two gates, each 13 m wide. Volumes of water can be introduced theoretically at a rate of up to 213 cubic metres per second, until the 4.5 million cubic metres which the polder can hold have been reached. The maximum damming height is 3.30 metres. The design and dimensioning were developed by experimenting with models.

The design of the inlet and outlet control structure and the culvert for Lohrwardt Polder was also supported by model-based simulation. It consists of a box section 3 metres long by 3 metres wide.

The innovative results of this pilot project are that the inlet and outlet structure, and culvert for ecological flooding, the discharge channel, and the return walls on the water and land side were constructed in the same way. This reduced the cost of preparing and implementing the formwork and reinforcement.

The experience gained from these plans and implementations have been used in other polder structures in the SDF project. The plans for the outlet control structure on the Emscher also provided important knowledge for the joint designs.
The dimensioning of the adjustable weir on the side channel of the Hondsbroeksche Pleij floodplain represents a special challenge. At this location, the Rhine splits into the Lower Rhine, the IJssel and the side channel, depending on the discharge rate. Depending on the situation, the flow in the channel is fully or partly stopped or even fully opened. Because the flow rate is sometimes very strong and sometimes weak, the inlet control structure must be both very robust and capable of very precise control to ensure that the minimum amount of water for navigation is properly guaranteed.

Improving construction work

The SDF project partners also learned, improved or adopted important construction techniques, for example when building systems in river floodplains. Floodplains are very sensitive ecosystems which must be protected. On the other hand, there is a constant risk of flooding and rising groundwater. A system of temporary site roads in Germany, not previously in widespread use, was used in SDF pilot projects. The Dutch project partners had been using this technique for much longer. The use of steel plates preserves the floodplain and saves money. German partners will be using this experience in future projects as well.

If measures are jointly planned and implemented, as was the case with the SDF project, substantial cost reductions are possible, e.g. in the management of soil excavation and filling operations between polder projects. At one location, the soil must not be expensively disposed of, while at another, the operators must not buy new material.

Taken as a whole, such supposedly minor optimisations can save a lot of money. This can in turn be used to reduce flood risks even more effectively in many locations.

Conclusions/What have we learned?

- Sustainable floodplain strategies also make increased demands on the inlet and outlet control structures. Examples of successful plans can be transferred to other locations by means of close cooperation.
- Exchange of experience results in innovative and inexpensive dike construction techniques.
- Model experiments should supplement arithmetical simulation when suitable practical innovations are being developed.

New river branches and reactivation of old branches

In the past, meanders on the Rhine were separated from the river over long stretches in order to safeguard the water level in the navigation channel. This made the discharge areas smaller and flood waves no longer discharged properly. The reactivation of old branches on the Lower Rhine and in the delta increases the amount of water discharged, reduces flooding and exploits the environmental potential of the former floodplains. In this case, environmental objectives and flood protection overlap in an exemplary manner.

All the water in a river area comes together in low-lying sections of the river and in the river delta. The risk of flooding is at its greatest in the event of prolonged heavy rain and melting snow, when a large quantity of water is discharged from a large number of side branches at the same time. In such cases, it is no longer possible to hold back the floodwater because the volumes are too great. Besides the retention areas on the upper and middle section which are intended to reduce the simultaneous discharge of floodwater from the entire catchment area, the water in the lower stretches must therefore flow away if possible rapidly and unhindered so that it does not continue to accumulate. A sufficiently large discharge area must be provided to allow for this.

At the same time, however, the river must be sufficiently deep at low water to allow vessels to pass unhindered. Many sections of the river have been straightened and meanders sealed off for navigation so that all the water discharges into the navigation channel. The aim is now to reconnect the old branches so that they can divert the floodwater and thereby reduce the wave in the main river. As it is precisely the old branches that often still have great ecological potential for high-value floodplain biotopes, the restoration of former river branches and side channels provides major opportunities for a sustainable development of new floodplains.

Side channels have been planned or excavated in the Netherlands (Fortmond, Bemmelse Waard, Heesseltsche Uiterwaarden) and in North-Rhine Westphalia (Emmericher Ward, Bislich-Vahnum) as part of the SDF project. Generally, existing floodplains have also been excavated. This increases the volume and connects the old branches and side channels to the main river. At all the locations, the main objective of the measures is nature conservation, but flood prevention will also be drastically improved at the same time. The coordination of nature conservation objectives and water management requirements increases acceptance of the reactivation of side channels even among the responsible technical authorities and experts.

The joint work on the SDF measures has had a substantial effect on

- The design and position of side channels.
- Nature conservation strategies.
- Flow control in the side channels.
- Sediment control.

Whereas in the Netherlands, side channels have been excavated for 10 to 15 years, there are hardly any examples of projects on major rivers in Germany. In addition to the technical design, the strategies differ in terms of the type of flow. Water continuously flows through some side channels whereas in others, the flow commences only at a certain floodwater discharge. As part of the SDF project, the advantages and disadvantages of the strategies have been compared. The rate of flow must be controlled to ensure that no erosion of the bed or banks occurs. On the other hand, the flow rate should not be so weak that it causes sedimentation, thereby blocking the flow. Finally, the volume of water withdrawn from the main river must be consistent with the minimum water levels required in the navigation channel.

During their work, the SDF project planners were able to call on their experience of completed side channel projects: side channels have been operating for 15 years in the Gameren project in the Netherlands. As the responsible partner of the Bislich-Vahnum and Emmericher Ward pilot projects, the German environmental organisation, NABU, has benefited considerably from this experience and has optimised its plans accordingly. The knowledge gained in Gameren of the difficult process of reconciling the interests of navigation and nature conservation also influenced the German pilot projects.

The SDF measures for lowering the level of floodplains and side channels also show possible economic synergy effects: selective extraction strategies for gravel, clay and other raw materials which are in demand would at least contribute to the refinancing of the measures. In this case too, the SDF partners learned a great deal from each other and were able to exploit their shared knowledge profitably.

Conclusions/What have we learned?

- The well-considered planning of side channels can prevent conflicts arising between nature conservation, water management and navigation.
- Up to approx. two percent of the Rhine discharge can be discharged into side channels without causing any negative changes to minimum water levels in the main river.
- The key components of a successful side channel design are: controlling flow rate by controlling inflow, sediment control, nature conservation strategies aimed at species specific to the floodplain and safeguarding water levels in the main river.
- Side channels can be constructed to compensate for the increased roughness of planned floodplain forests.

Integrated land use strategies

The creation of flood retention areas provides a unique opportunity to achieve a positive and sustainable upgrading of nature and landscape in floodplains. The overarching objective in this regard is to exploit once more the vast environmental potential of floodplains.

Nature conservation and water management can benefit equally from the joint planning, financing and implementation of measures to create retention areas and floodplains. This is what is known as a win-win situation as nature conservation often lacks the necessary financial resources to finance major projects to reactivate floodplains alone. On the other hand, water management is often unable to justify intervening in property or land use because a single measure makes only a comparatively small contribution to risk reduction in arithmetical terms.

By adopting an integrated approach, SDF is contributing to the creation of attractive river landscapes. The coordinated planning of water management measures and measures to develop the natural environment improves the transnational environmental network along rivers.

The development of controlled and uncontrolled retention areas by relocating dikes and creating side channels in conjunction with ecological development strategies was the main priority of all SDF pilot projects. Other objectives were to improve the quality of the landscape and to increase the recreational value of the regions. These different requirements, overlapping with the demands of flood prevention and navigation, result in considerable conflicts of land use. In order to resolve them, the SDF project partners developed multifunctional land use strategies for the areas covered by the pilot projects.

For example, during the development of Ingelheim Polder and the dike relocation at Kirschgartshausen, a plan for landscape development was formulated which would

guide nature and landscape development in the future retention area so as to take account of future land use requirements.

On the lower Rhine, near the Dutch pilot projects at Lexkesveer, Bemmelse Waard, Rijnwaarden, Fortmond and Heesseltse Uiterwaarden, the main priority in the creation of floodplains and side channels was nature development. Nevertheless, this required an integrated approach to link nature conservation and flood protection measures. Nature conservation was also the starting point for the planned side channels at Bislich-Vahnum and Emmericher Ward on the Lower Rhine in Germany. Here too, cooperative arrangements and an integrated planning and development strategy for the new floodplain areas enables a symbiosis of both objectives.

A long-term development process in the floodplains begins with a strategy for landscape development. The main component is the model, which describes what the landscape should look like in future. As part of the SDF project, an overarching model for future work on the Emscher was developed as the objective, from which the measures could then be derived to achieve this objective. A number of different actors jointly implemented the measures.

The interests of the people living in the area around the new floodplain are also an important part of any development strategy. Often, the change of use is dictated by the flooding caused by environmentally sensitive floodplain development. Use as arable land is ruled out: no field crops grow in a flood. On the other hand, extensive meadows or unexploited natural habitats would constitute suitable uses. The composition of animal and plant species in the retention areas is changing.

Environmentally sensitive development through ecological flooding
The floodplain-specific vegetation in floodplain areas does not adapt if the areas are flooded rarely but severely. The vegetation will not withstand sudden inundation and will be destroyed by floodwater. For this reason, ecological flooding is carried out in retention areas. Because of this frequent minor flooding, fauna and flora will over time adapt to a natural state typical of floodplains in which they are prepared for floods.

In Kirschgartshausen, Ingelheim and Lohrwardt, the retention areas behind dikes and the control structures were designed to be flooded naturally or artificially even in the case of minor flood events. This method had already been used before in the Altenheim and Söllingen-Greffern retention areas as part of the Integrated Rhine Programme in Baden-Württemberg. The SDF partners visited these projects and made use of the experience gained there. The resulting recommendations are also of great interest to the Dutch pilot projects.

For ecological flooding, the Rhine water is admitted to the area in a controlled way by inlet control structures and is discharged again through outlet control structures. Depending on the design, either the water is freely discharged into the floodplain when a certain water level is reached and is distributed to corresponding channels or the inlet control structure is specifically controlled so that the areas are flooded on a certain number of days. Pumping stations can be used in addition.

Regular flooding gradually creates near-natural floodplains. The development of the floodplain landscape is under way.

Sustainability of retention measures
Retention measures are evaluated according to the criteria of sustainability and feasibility. Suitable standards for Lexkesveer were worked out jointly with SDF partners. The Bislich-Vahnum and Emmericher Ward pilot projects used these criteria as a comparative test.

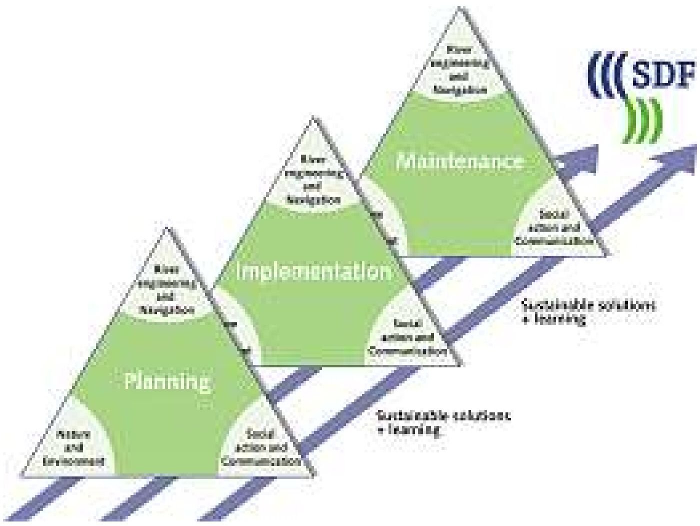
Conclusions/What have we learned?

- Models and strategies for landscape development must structure the natural development process in support of flood prevention plans on the river.
- Ecological flooding is required for nature conservation purposes. It creates near-natural floodplain conditions. SDF experience continues to be applied in connection with the Dutch Room for the River programme.
- Excavations to lower the level of and create side channels in the floodplains increase the dynamics and diversity of the ecosystems, reduce the discharge of water into the river and increase the attractiveness and therefore the recreational value of the region.
- From an environmental point of view, one of the side channels must contain constant smooth flowing water. This provides a protected area for certain organisms in the event of varying water levels.
- Fast flowing water takes sediment with it. Different flow rates in the channels produce a diverse range of vegetation.

Sustainability in the SDF project – an evaluation

The practical SDF pilot projects with their integrated approach are evidence that sustainability in the creation and design of floodplains is not just a buzz word. The SDF partners have studied and evaluated the sustainability of the activities as part of a project analysis.

For present and future generations, sustainable development takes full account of the burdens and benefits. It takes account of environmental, economic and social objectives and weighs them up against each other. This definition was agreed in the Brundtland Report and at the Rio Conference.



Principles of sustainability for floodplains

The SDF project has been analysed on the basis of sustainability targets and indicators. Project-specific, environmental and socio-economic standards were adopted as criteria. The analysis shows that SDF did not create a one-sided technical flood prevention system, but rather took account of the environmental, economic and social conditions and development options in the planning and implementation of all the pilot projects. All aspects of the interaction between nature conservation and flood prevention and social criteria were taken into account. Moreover, further potential was identified for improving effectiveness monitoring and resolving conflicts of land use.

Sustainable Development of Floodplains SDF	Criteria fulfilled **good to very good**	Criteria **partly** fulfilled	Criteria **not** fulfilled
Goals of Project fulfilled			
Project as a whole	X		
Individual Projects	X		
Fulfilment of ecological criteria			
Implementation of ecological measures	X		
Monitoring of success of implemented measures		X	
Protected areas	X		
Implemented strategies to solve conflicts		X	
Fulfilment of socio-economic criteria			
Existing potentials of use and implementation	X		
Future sustainable use of project areas	X		
Achievement and use of synergetic effects (win-win)		X	
Achievement of successful strategies in case of conflicts		X	
Internal communication and interdisciplinary knowledge exchange	X		
Public participation and acceptance among public and in politics	X		

Flood prevention is a principal objective of the project. The following elements of the measures have been developed as major contributions to sustainability:

- Integration of flood prevention into nature and landscape development in environmentally sensitive floodplains.
- Development and rehabilitation of natural floodplains as part of an overarching sustainable flood prevention strategy.
- Prevention or minimising of interventions in areas of a high environmental value.
- Inclusion of sustainable strategies for maintenance of floodplains.
- Raising public awareness of the problem and creating acceptance for the measures.

Conclusions/What have we learned?

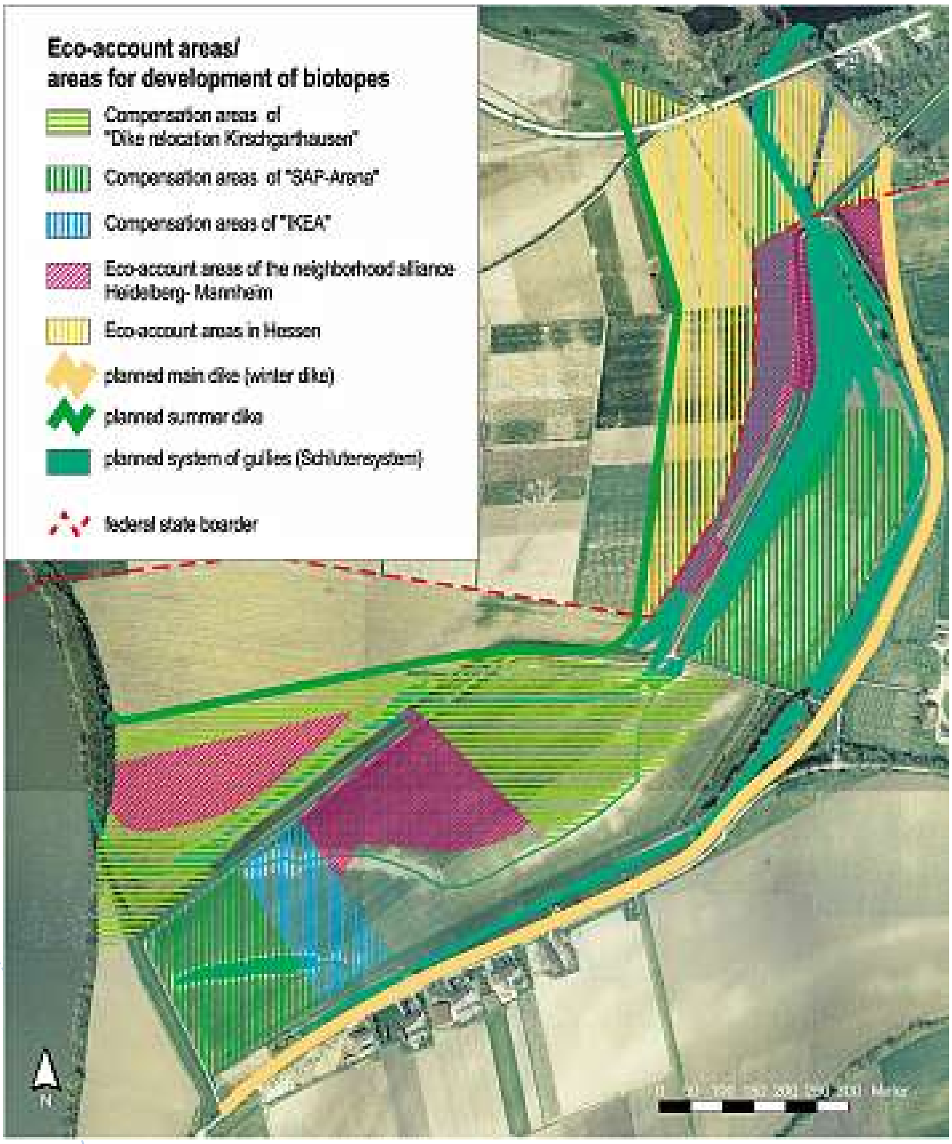
- The conditions have been created for sustainable development by implementing the SDF objectives and measures at all the locations involved.
- In future a monitoring system will be required to evaluate the success of SDF's sustainable strategy.

Land management resolves conflicts of use

Controlled flood prevention measures require large areas of land. However, in the intensively used countryside, it is precisely the attractive river areas which are under severe pressure. Where conflicts of interest arise between different claims on land use and nature conservation, instruments are therefore required to reconcile these interests. One approach to the management of multifunctional and environmentally sensitive floodplains is to involve private and locally-based actors. Farmers make exemplary partners.

A multifaceted use of floodplains and retention areas satisfies various land use claims and nature conservation and water management requirements and ensures that maintenance is economically viable. This kind of multifaceted land use is the target of instruments for striking a balance between users within a region. For example, the SDF pilot projects at Kirschgartshausen, Ingelheim and Emscher are recorded in the regional eco-accounts. Structural measures which contribute to a positive ecological development are credited to the eco-account in the form of eco-points. The sponsor of the measure or the municipality can then use these eco-points at a later date to build structures in another area. By offsetting in this way, the sponsor of a measure to upgrade a floodplain creates a credit for other building projects.

An effective application of the eco-account concept requires a land management system to manage the areas and their uses. It may be the responsibility of either public bodies or private organisations. However, it often makes sense to involve local farmers and residents as well in order to increase acceptance of the measure. In this connection, it is important to buy the land for the flood prevention measure.



In many cases, the economically viable maintenance of the retention areas is achieved by using them as pasture for suitable animals. This requires early and close cooperation with farmers. Local farmers allow their animals to graze all the year round almost unsupervised on meadows in the Ingelheim retention area and the southern bank of the river in Lexkesveer. In this way, cattle breeds such as Galloways or Heck cattle maintain the meadows in the floodplains. The concept results in a sustainable and natural landscape with few human interventions. It provides a new image of the “new wilderness”, as it is known in the Netherlands. In the Bemmelse Waard project, the government forestry organisation manages the conversion of the floodplain from farmland to natural areas with floodplain forests.

The number of cattle in each area is limited in order to protect ground-nesting species. In small areas, dividing the pasture can provide the required protection. The legal and veterinary requirements must be checked in advance.

The Rijnwaarden area has been designated as being mostly managed and maintained by private owners, who follow the guidelines published by the province. A change in attitude has taken place among residents in Fortmond, who are becoming increasingly interested in partly managing the land themselves by turning it into pasture.

Nature has rights too

Work on the project is affected by legal constraints: environmental impact assessments also study the effect of flood prevention projects on the environment. This assessment is a legal obligation. The SDF partners worked out conclusions for the specific design of the relevant project assessments in floodplains through transnational cooperation.

Some SDF activities took place in sites of community importance or special areas of conservation as designated by the European Union. These are areas in the supranational Natura 2000 network of protected areas which covers the protected areas laid down in the Fauna-Flora-Habitat Directive and in the Birds Directive.

Conclusions/What have we learned?

- Multifunctional landscape management requires an early land use strategy in order to reconcile the different land use interests and nature conservation aspects.
- For many actors, economic incentives for participating in floodplain development must be created in order to interest them in cooperation.
- An eco-account provides incentives for investing in nature conservation projects which are otherwise economically unattractive. These also include projects for developing wetlands and restoring floodplains. The benefits and applicability are being tested for the Netherlands.
- In the interests of sustainable management, it has to be ascertained whether private landowners make more suitable managers of the land than public authorities. The bringing together of private individuals and the joint preparation of a management plan may be an effective solution.

From information signs to cooperation: communication strategies

Measures to protect against flooding often arouse concerns. Retention measures affect many local, regional and cross-regional interest groups and actors. A comprehensive programme to inform and engage the public and the actors concerned is therefore an important part of the planning and implementation of sustainable retention areas.

The SDF partners pursued different coordinated communication strategies in their pilot projects and in this way tested the effect of different instruments. They defined the following as the basic requirements for the strategies:

- Timing: information and participation at an early stage.
- Target group: participation of key actors.
- Range: informal participation beyond the legal obligations.

The partners were able to use the experience gained from different planning cultures. In Germany, experts are responsible for drawing up plans. It is not mandatory to involve the public until the approval stage. On the other hand, citizens in the Netherlands can get involved in planning at an early stage. The experience of the Dutch ministry of Transport, Public Works and Water Management shows that key actors should be involved at an early stage in all circumstances.

The instruments used are employed at all stages of participation: from pure information up to the active involvement of actors in developing plans. The experience of the SDF partners shows that it is not necessary to develop new instruments for communication and public participation. However, the existing instruments should be used selectively in a well planned participation process.

The communication plan for individual projects must be geared to the target groups. An allowance should be made for unexpected developments. The political will to accept them must also be present. For example, the communication plan for Hondsbroeksche Pleij was used as a dynamic instrument. Because of this, the public developed a deep understanding of the need for the measures. The name and objective of the project became the region's trademark.

Project advisory boards and working groups supervised the planning of SDF measures. In Bislich-Vahnum, members of the local heritage society and nature conservation groups, landowners and a gravel extraction operator prepared important planning decisions in their role as the project advisory board. In Hondsbroeksche Pleij, the project advisory board consisted of public bodies and non-governmental organisations. Once the building permit had been issued, it was transformed into a liaison group which is being informed regularly about construction progress and annoyance, if any.

Several SDF projects included working groups to which local actors could contribute their ideas and thoughts. The fact that everyone involved had the objectives, the extent of the impact, structures and timetable explained to them at an early stage, guaranteed that people's expectations of the working groups were realistic. In the case of Ingelheim Polder, a consultation process was initiated with 'A region in discussion'. At the same time many public authorities were involved in the planning process. At Hondsbroeksche Pleij, actors from schools, agriculture, nature conservation, industry and tourism contributed their ideas and experience in numerous planning workshops. In this way, conflicts were identified and resolved at an early stage.

Although meetings in small groups or with individuals affected involve considerable expense, they are indispensable for solving individual problems. In Lohrwardt, the responsible parties agreed on land exchanges and compensation payments in individual interviews. In the Lexkesveer and Heesselt pilot projects "discussions round the kitchen table" were held in residents' homes, which reduced the barrier to communication.

An open information policy is also important where participation is only passive. The results should be presented at information events and in brochures: the more flawless the presentation, the sooner the impression will be created that the planning stage has been completed. Public excursions to projects similar to the one planned make it possible for residents and actors to exchange information and clear up many objections.

At Emscher, local politicians were involved at an early stage. They appreciated the benefits for urban development and, consequently, there were hardly any objections during the approval procedure. Objections relating to possible inconvenience during the construction period were alleviated thanks to the credibility of the project management. In addition to communication measures during the pilot project, this success was also based on events at which the Dutch project partners appealed for help in solving their flooding problems – an appeal to solidarity and the response among neighbours showed the positive effect.

Well organised public participation at an early stage – as is evident from the experience gained from the pilot projects – produces a good relationship between the authorities and the public and substantially reduces objections during the approval procedure. Once public trust has been won, it has to be maintained beyond the project planning stage by continuous communication.

The cooperation among the SDF partners has also resulted in personal exchange. For example, representatives of the Dutch Rijkswaterstaat have assisted in the public participation process at the Emscher by playing an active part in events and by doing so have highlighted the cross-regional significance of local measures.

Conclusions/What have we learned?
A successful participation process

- requires considered preparation and continuous guidance.
- requires clear agreements on objectives and responsibilities of the project advisory board and working groups.
- requires credible and sound management of the project and communication.
- must take opposition and objections seriously.
- should be evaluated to improve future processes.

Innovative tendering and contract awarding process, cost-saving implementation

The tendering and awarding of contracts for planning and construction services are the deciding factors for quality, cost and completion. As part of the SDF project, the different tendering and contract awarding procedures of German and Dutch authorities were compared.

Generally, the tendering and contract awarding procedures for major infrastructure projects in both the Netherlands and Germany are completed in two phases. The planning contract is awarded in the first phase. If the implementation plans are available, the construction work is put out to tender and the contract is awarded in the second phase.

Increasingly, integrated contracts are being developed in the Netherlands; the authorities issue a tender for planning and construction as one service and award it to one contractor. The authorities formulate the requirements for the project and set the quality standards.

A more radical alternative was tested for the awarding of the contact for the planning and construction of the adjustable weir in the SDF pilot project for Hondsbroeksche Pleij. The competent authority, Rijkswaterstaat, described the background, objectives, constraints and functional requirements for the construction work and the measures. The complete planning and construction was to be the responsibility of a single contractor. Rijkswaterstaat would be monitoring only the individual steps. For example, the wide-ranging know-how of the private sector was to be exploited and the competition would bring about innovative and inexpensive solutions and relieve the burden on the authorities.

However, the authority would be involved in the consideration of basic alternatives only if this was of benefit to the contractor. The authority is also less familiar with the details of the planning and is less able to estimate the cost. Liability in the event of defects can also be a problematic issue: the failure of flood prevention systems can have serious consequences. It must then be clarified in a complicated process whether or not the defect was ruled out by the specification in the tender document. The residual risk usually has to be borne by the responsible authority. This involves the matter of proper standards and precautionary principles which must be adhered to in detail for general acceptance.

In Germany, planning and construction are specified in detail in several steps when the contract is awarded. The tendering authority enforces standards in individual cases and specifies them as the planning process progresses. All the individual items in the tender must be calculated in the proposal for construction work. The contracted company must carry out the construction work exactly as specified in the tender and the plans. Deviations, e.g. the use of different materials, are only possible through the submission of alternative proposals. In this case, the building contractor must guarantee a comparable quality and is liable in this respect to the authority. However, this may result in cost increases during the construction phase, as deficits in the specification on which the tender was based are always the responsibility of the contracting authority.

Conclusions/What have we learned?

- The procedures for awarding planning and construction contracts are handled differently in Germany and the Netherlands.
- In the Netherlands, the private sector is increasingly involved in the process and at an earlier stage.
- The innovative integrated contract awarding system is being tested in the Netherlands.
- In Germany an integrated contract awarding procedure is still the exception.
- Experience from the Netherlands should be further evaluated to improve future processes in terms of cost, quality and safety.

Facts concerning the SDF project

Sustainable Development of Floodplains (SDF) Duration: January 2003 – December 2008 The project has received financial resources from the European Regional Development Fund through the INTERREG Community initiative.	
Budget:	EUR 35 million, ERDF contribution (EU): EUR 17.5 million
Partners:	7
Pilot projects:	12
New or reconstituted floodplains:	21km^2
Retention capacity created:	26.5 million m^3
Extent of dike relocation:	5,900 m
New side channels:	3
Bridges, ferry crossings replaced:	1
New inlet/outlet control structures:	5
New adjustable weir:	1
Environmental impact assessments completed:	2
Feasibility studies completed:	2
Public-private partnerships:	2
Thematic working groups established (WG):	3: • WG 1: Flood reduction measures • WG 2: Nature development and the environment • WG 3: Communication and public involvement
Working group meetings:	24
Conferences held:	2: • October 2005: "Flood risk management and multifunctional land use in catchment areas", venue: Mainz, organiser: SDF together with the Joint Technical Secretariat for the North-West Europe Programme. • September 2008: SDF closing event "Welcome on Board", venues: Kirschgartshausen, Ingelheim, Rees/Lohrwardt, Arnhem and Hondsbroeksche Pleij/Westervoort, Olst-Wijhe/Fortmond

1

1

1 The SDF project

The Sustainable Development of Floodplains (SDF) project was an EU-funded transnational cooperation between Germany and the Netherlands. It dealt with flood prevention and nature development along the River Rhine to ensure sustainable development of its floodplains. The issues addressed in this project were transnational by nature, because sustainable flood management strategies require interregional and transnational cooperation throughout the river basin.

The SDF project was co-financed by the European Interreg IIIB flood prevention and water management programme. The project invested EUR 35 million in relocating dikes, creating new polders, side channels and inlets, as well as in nature development in an implementation period from January 2003 until December 2008. The EU co-financing meant that various flood prevention plans could be implemented sooner than anticipated. SDFs innovative approach led to improved water retention by increasing the floodplain area and by adopting favourable design solutions in floodplains.

The overall objective of the SDF project was to develop floodplains for sustainable multifunctional use in and along the main River Rhine to reduce high water floods. Three thematic working groups were set up in which the project partners and invited experts worked towards the attainment of the project goals:

- **Improved river engineering** by flood prevention measures and technical designs, contributing to the implementation of the transnational Rhine Action Plan.
- **Improved nature and environment development**, e.g. creating liveable space (sustainable multifunctional land use) by elaborating the multiple land use concept intonatural development strategies and territorial planning policies.
- **Enhanced communication and public involvement**, e.g. setting up a transnational cooperation network of responsible authorities (also to support other future projects) as well as creating a cross-sectoral network for flood management.

On a local level, the SDF partners implemented 12 projects with an operational focus. The implementation of the measures increased the retention volume of the floodplains and improved the sustainable nature development.

The experience gained as a result of the implementation of sustainable floodplains will be used to improve planning, implementation and maintenance in other river basins throughout north-west Europe. Sustainability is essential in order to fulfil the requirements of the EU directives such as the Birds and Habitats Directive and the Water Framework Directive.

As a result of the partner's activities, the retention capacity was increased by 26.5 million m^3 in an area of 21 km^2. In combination with increased discharge capacity, this led to improved protection of the population against flooding. At the implementation areas, the National Ecological Network was improved, as were the concepts for multifunctional use of the floodplains. Due to the communication strategies of the upgraded transnational partner network, awareness of high-water issues was increased among inhabitants, research institutes and administrative organisations.

Box 1.1
Facts and Figures of SDF project

Sustainable Development of Floodplains (SDF) Implementation period: January 2003 - December 2008 The project received European Regional Development Funding through the Interreg III B Community Initiative.	
Budget:	EUR 35 million, ERDF contribution EUR 17.5 million
Partners:	7
Pilot projects:	12
Flood plain area:	21 km^2
Retention capacity:	26.5 million m^3
Dike relocation:	5,900 m
Flood plain area:	21 km^2
Side channels constructed:	3
Bridge, replacing ferry access road:	1
Inlet/outlet structures:	5
Adjustable weir:	1
Environmental Impact studies:	2
Feasibility studies:	2
Public-Private Partnerships:	2

The SDF Partners

The organisations involved were ministries, water boards and one non-governmental organisation (NGO)[1]. The lead partner was Rijkswaterstaat Oost-Nederland in Arnhem, the Netherlands.

Ministerie van Verkeer en Waterstaat
Rijkswaterstaat Oost-Nederland (RWS-ON)
(Hondsbroeksche Pleij, Lexkesveer, Heesseltsche Uiterwaarden)

Ministerie van Verkeer en Waterstaat
Rijkswaterstaat
Oost Nederland

Ministerie van Landbouw, Natuur en Voedselkwaliteit
Dienst Landelijk Gebied-Regio Oost (DLG)
(Bemmelse Waard, Rijnwaarden, Fortmond)

Ministerie van Landbouw, Natuurbeheer en Voedselkwaliteit
Dienst Landelijk Gebied

Struktur- und Genehmigungsdirektion Süd (SGD-Süd), Rheinland Pfalz
(Polder Ingelheim)

RheinlandPfalz
Ministerium für Umwelt, Forsten und Verbraucherschutz

Emschergenossenschaft
(Emscher)

EMSCHER GENOSSENSCHAFT

Deichverband Bislich-Landesgrenze
(Lohrwardt)

Deichverband Bislich-Landesgrenze

Regierungspräsidium Karlsruhe (RPK)
(Kirschgartshausen)

Baden-Württemberg
REGIERUNGSPRÄSIDIUM KARLSRUHE

NABU Naturschutzstation Kranenburg
(Emmericher Ward, Bislich-Vahnum)

NABU Naturschutzstation e.V.

Box1.2 The SDF Partners

[1] During the SDF project period, the following partner organisations were reorganised: Ministerie van Landbouw, Natuur en Voedselkwaliteit (former Ministerie van Landbouw, Natuur en Visserij), Deichverband Bislich-Landesgrenze (former Deichschau Haffen-Mehr), Regierungspräsidium Karlsruhe (former Gewässerdirektion Nördlicher Oberrhein).

Pilot projects

1.1 The pilot projects

SDF consisted of 12 projects with an operational focus implemented by three Dutch and five German partners along the River Rhine (Figure 1.1). Measures to prevent flood damage and to improve nature and the environment were implemented at the different project sites. Depending on the project phase, these pilot projects were divided into planning and implementation projects.

In this book, the 12 local projects provide the basis for the jointly described results. The topics discussed in the transnational partner group were implemented at different local project locations and serve as best practice examples in the following chapters. The common SDF approach for the implementation of the local projects emphasised the combination of planning and implementation of projects to exchange know-how and experience at a specific and practical level leading to joint solutions on addressed issues.

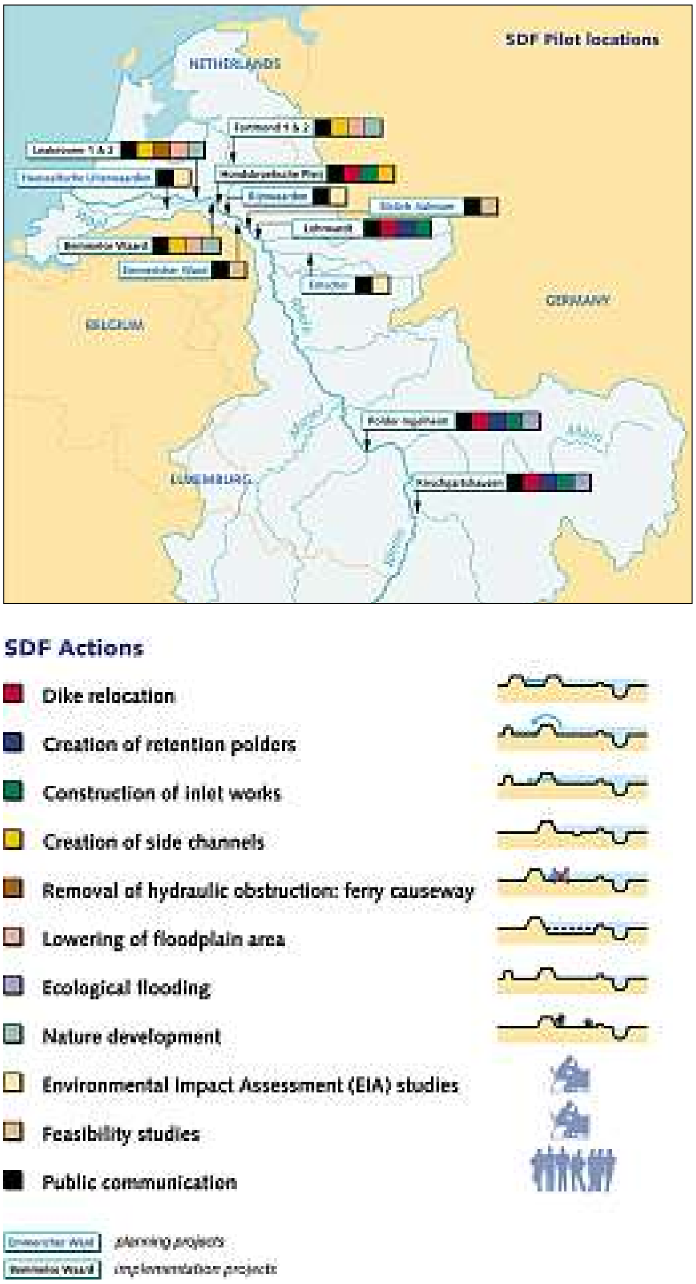


Figure 1.1: SDF project locations

Chapter	Sysmbool	SDF action	Project											
			Kirschgartshausen	Ingelheim	Emscher	Emmericher Ward	Bislich-Vahnum	Lohrwardt	Rijnwaarden	Bemmelse Waard	Fortmond	Hondsbroeksche Pleij	Lexkesveer	Heesseltsche Uiterwaarden
		Planning			● ●	● ●	● ●		●					●
		Implementation	●	●				● ●		● ●	●	●	●	
2		Dike relocation	● ●					● ●				● ●		
2		Creation of retention polders		● ●	● ●			● ●						
2		Construction of inlet / outlet works		● ●	● ●			● ●				● ●		
2		Creation of side channels				●	●			●	● ●	● ●	● ●	●
2		Removal of hydraulic obstruction											● ●	
2		Lowering of loodplain area								● ●	● ●	● ●		
2		Seepage	● ●	● ●				● ●			● ●	● ●		●
3		Nature development	● ●	● ●	● ●	●	●	●	●	● ●	● ●	●	● ●	●
3		Ecological flooding	● ●	● ●				● ●						
3		Feasibility study			● ●	● ●						● ●		
3		Management concepts	●	●				●	●	●	● ●		●	
3		EIA			● ●				● ●					●
4		Public communication	●	● ●	● ●	● ●	● ●	● ●	● ●	● ●	● ●	●	●	●
5		PPP/Contracting/ Land acquisition		●				●		●		● ●	●	

● (blue) Measure in project and in book
● (green) Measure is EU co-financed

Table 1.1: Project measures and SDF book themes

Figure 1.2: Location of Kirschgartshausen project area

KIRSCHGARTSHAUSEN (implementation project)

Responsible partner: Regierungspräsidium Karlsruhe

A large area of the former floodplain has been returned to the Rhine at Kirschgartshausen north of Mannheim. A new flood protection dike has been constructed behind the existing main dike of the Rhine and the old dike has been partially dismantled. In this way, a new floodplain has been developed, which is flooded in accordance with the natural water level dynamics at higher discharges from the Rhine. The ground at the inflow area of the Rhine banks – km 436 – has been lowered. The water flowing in will flow through river arms cut off from the main river towards the north into the east arm of the "*Lampertheimer Altrhein*" and into the Rhine north of Lampertheim.

Aims

- Reducing high water levels and flood damage.
- Developing natural floodplain features and expanding the network of environmentally valuable areas along the Rhine.
- Introducing measures to protect the surroundings against high groundwater levels.
- Improving the functioning of the drainage system.

Activities

1.Flood Protection and Nature Conservation

- New construction and relocation of the main Rhine dike and the summer dike.
- Connection of the new floodplain to the floodplain of the Hessian NSG "*Bieden-sand*".
- Development of trenches and river arms cut off from the main river for drainage of the remaining water.

2.Measures for protection of the adjoining buildings against wetness caused by the rise of the groundwater level

- Draining by means of a drainage system along the "Hoher Weg zum Rhein" towards the Rhine.
- New construction of two water engines including groundwater ponds.

Results

- Retention area: 75 ha.
- Flooding volume: approximately 1.7 million m³.
- Frequency of use: at every flood event.
- Average ground level: 89-90 m above mean sea level.
- Water level at a medium-size flood: 91 m above mean sea level.
- Ecological continuity.
- Improved leisure options in immediate vicinity.

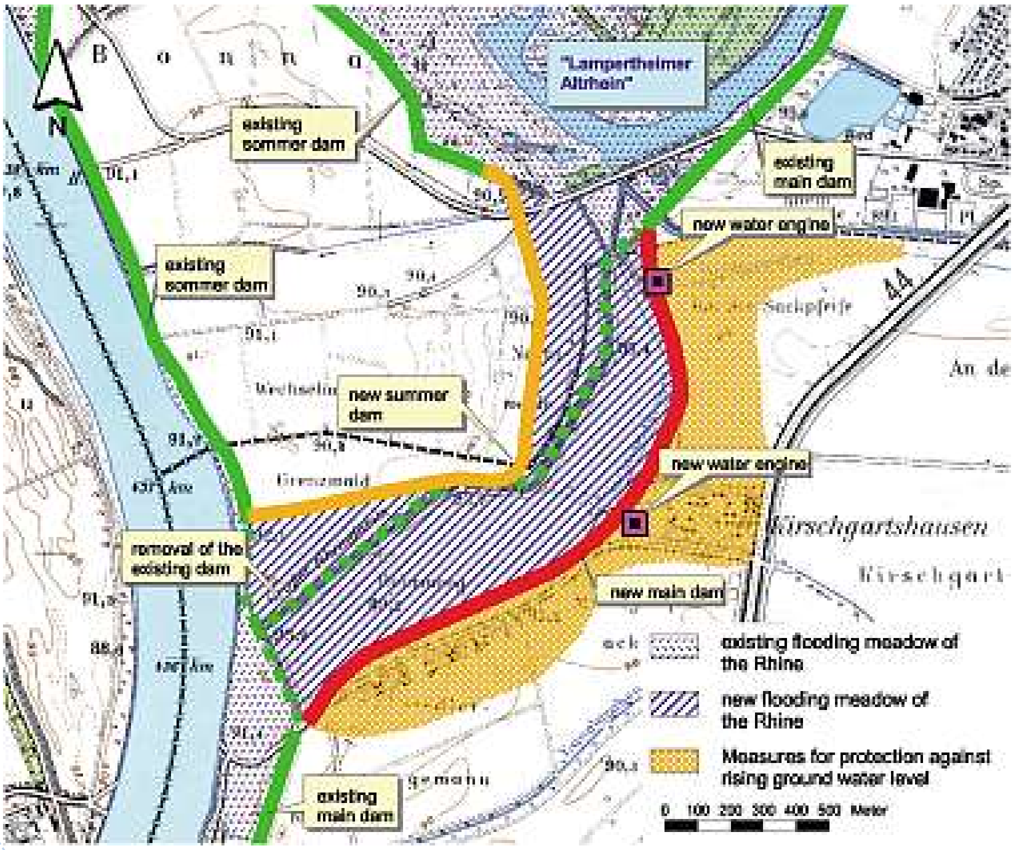


Figure 1.3: Kirschgartshausen development plan

Figure 1.4: Kirschgartshausen project area

Figure 1.5: Polder Ingelheim in the agricultural region between the Rhine and the A60 autobahn

INGELHEIM POLDER (implementation project)

Responsible partner: SGD-Süd Rheinland-Pfalz

The controlled retention area of Ingelheim was one of the projects on the Upper Rhine. It is located in the federal state of Rhineland-Palatinate at Rhine kilometre 517 at the start of the Middle Rhine region (Figure 1.5). The polder has a volume of approximately 4,500,000 m³ and an extension of 162 ha within an agricultural area. The project planning began in autumn 2001. Permission was granted in 2003 and construction started in the summer of 2004. The project was completed in 2006.

The project consisted mainly of one large combined inlet and outlet work built into the Rhine dike, two new dikes and several measures in the landscape, such as the restoration of an old side channel of the Rhine ("*Alte Sandlach*") and the creation of ecological flooded areas (Figure 1.6). A range of wells and two pumping stations were needed to protect part of Ingelheim and various agricultural areas in the east of the retention area from groundwater influence. The project costs amounted to EUR 21 million, including engineering, construction costs for technical buildings and dikes and land acquisition.

Aims

- Reducing high water levels.
- Developing natural riverine features by means of ecological flooding.
- Improving opportunities for nature-oriented recreation.
- Restructuring the area for multifunctional land use.

Activities

- Designing and building the inlet structure.
- Creating new retention areas in the polder.
- Extending recreational possibilities (walking and nature observation, cooperation with local ecological centre).
- Creating new and improved structures for agricultural use.
- Improving the communication processes with the local population and the land owners.

Results

- The polder was opened in the autumn of 2006 with great interest being shown by the public.
- 160 ha of new flooding areas and 4.5 million m³ of retention volume were created.
- A recreational function was established by constructing cycle tracks and walkways on the dikes and by creating an educational function with information about floods.
- A lower water level and a temporary delay of the flood wave were achieved along the Rhine.
- An area of 20 ha has been provided for ecological flooding.
- Part of the polder has been assigned to multifunctional land use and cattle grazing.
- An eco-account for the up-valued interior of the polder has been created.

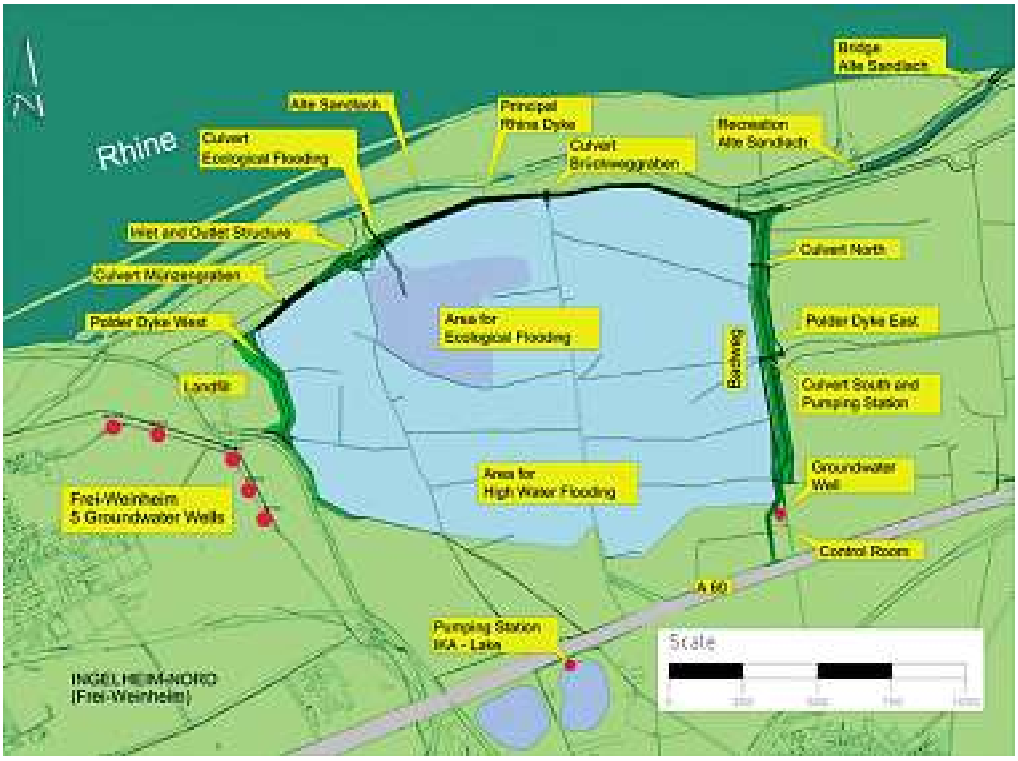


Figure 1.6: Components of the development plan of Ingelheim Polder

Figure 1.7: Project area Ingelheim Polder

Figure 1.8: Location of the Emscher project

EMSCHER (planning project)

Responsible partner: Emschergenossenschaft

The Emscher project differs from the other SDF project locations as it was the only one located along a Rhine tributary (and not directly located along the River Rhine). The Emscher catchment consists of approximately 865 km^2 and contains four sewage treatment plants and 350 km of waste water channels. The Emscher drainage system is being transformed into a natural open water system. The work started in 1990 and will be completed in 2020. Forty percent of the area will have to be drained by approximately 100 pumping stations due to mining activities for about 150 years.
At the start of the project, the required retention volume of up to 2 million m^3 and the area for the floodplain locations were yet to be finalised. Questions had to be answered about integration and control in a chain of flood prevention measures along the river, the ecological options and aims, the detailed project locations and available (or required) property, the technical design and function of the floodplains, the technical design and function of the outlet buildings, the public involvement process and land purchase, etc.

Aims

- Developing a concept for optimising the use of combined measures along the Emscher in order to significantly reduce peak discharges in the Emscher and Rhine
- Optimising the planning measures by means of knowledge transfer concerning ecological development and public participation.
- As new floodplains have an impact on the groundwater level near housing estates, expertise was required regarding the streaming impacts and changes in groundwater levels.
- Winning over public opinion for the measures. The Emscher location partners and the SDF partners will complement one another.

Activities

- Developing plans for new retention areas (63 ha).
- Environmental Impact Assessment.
- Investigations of possible effects of the planned measures.
- Public participation process during the planning phase.

Results

- Planning process was completed and permission to start was obtained.

Figure 1.9: Development plan of Emscher floodplain

Figure 1.10: River Emscher

Figure 1.11: Location of Emmericher Ward floodplain

EMMERICHER WARD (planning project)

Responsible partner: NABU Naturschutzstation Kranenburg

The Emmericher Ward floodplain is located on the Dutch-German border, west of Emmerich, and comprises an area of 310 ha. The floodplain is part of the RAMSAR site and the northern Lower Rhine bird sanctuary. The area is characterised by floodplains, riverbanks, hedges and small floodplain forests. The area is quite natural, although there were excavation activities in the past. Bodies of water remaining after sand and gravel excavation and natural bodies of water are important for flora and fauna. But degradation of the bed level of the River Rhine results in falling groundwater tables and drying up of the area. In 2005, moreover, the groynes along the Emmericher Ward were elongated, so that shallow water zones in the deep groyne fields silt up rapidly. This leads to a decline in the ecological value of the area.

Aims
- Improving flood protection along the Rhine.
- Reducing bed erosion.
- Creating special riverine pioneer habitats on gravel banks by means of erosion and sedimentation processes along a newly excavated gully.
- Optimising natural banks, creating new dynamic gravel and sand banks.
- Using side channels to reduce the dam-up effect of a planned riverside forest.

Activities
A feasibility study and a development plan for a side channel have been prepared. The planned measures are:
- Creating a secondary gully.
- Restoring inundation dynamics in the floodplain area.
- Protecting and developing softwood floodplain forest.

Results
- A feasibility study has been completed describing all relevant technical and ecological aspects and aspects concerning the approval of the project.
- A hydraulic study has been carried out showing the positive effect of the planning on both, the shipping route (reduction of bed level erosion) and the ecological situation (more water in the area and diversification of stream patterns).
- A development plan has been drawn up showing in detail how the side channel can be completed.
- The approval and completion of the side channel were not part of the project.

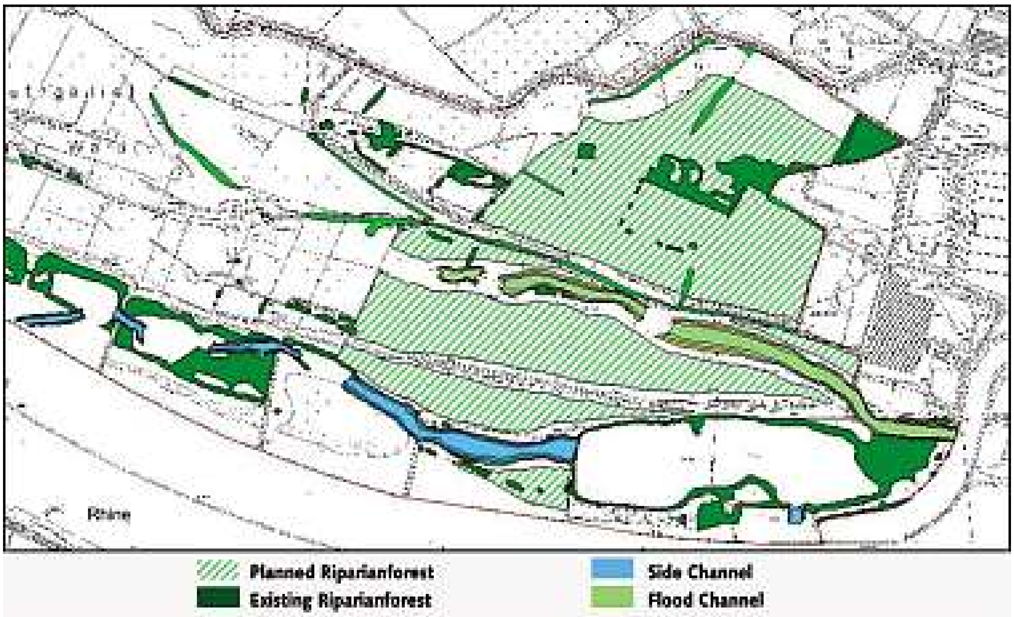


Figure 1.12: Emmericher Ward floodplain with planned side channels and riverside forest

Figure 1.13: Emmericher Ward floodplain area

Figure 1.14: Location Bislich-Vahnum floodplain

BISLICH-VAHNUM (planning project)

Responsible partner: NABU Naturschutzstation Kranenburg

A large floodplain area exists near the village of Bislich owing to the fact that the winter dike is located 500 metres from the bed of the Rhine. The project covers an area of 150 ha. Part of the area is designated as a nature reserve ("*Rheinaue Bislich-Vahnum*"). The floodplain contains bodies of water left behind after sand and gravel excavation.

Aims
- Improving flood protection along the Rhine.
- Creating special riverine pioneer habitats that have come under considerable pressure in the past few decades, by means of erosion and sedimentation processes along a newly excavated gully.
- Creating a habitat for species of fish that depend on flowing waters and dynamic sandbars (particularly Cobitis taenia, FFH species).
- Improving the situation of habitats and species of common interest (Flora-Fauna Habitat guideline).

Activities
A feasibility study and a development plan for this area have been prepared. The planned measures are:
- Creating a secondary gully that should be connected to the river almost year-round;
- A roadway and a driveway to a former military NATO river crossing point must be made permeable or partly removed.

Results
- A feasibility study has been completed describing all relevant technical and ecological aspects and aspects relating to the approval of the project.
- A development plan has been drawn up showing in detail how the side channel can be completed.
- The approval and completion of the side channel was not part of the project.

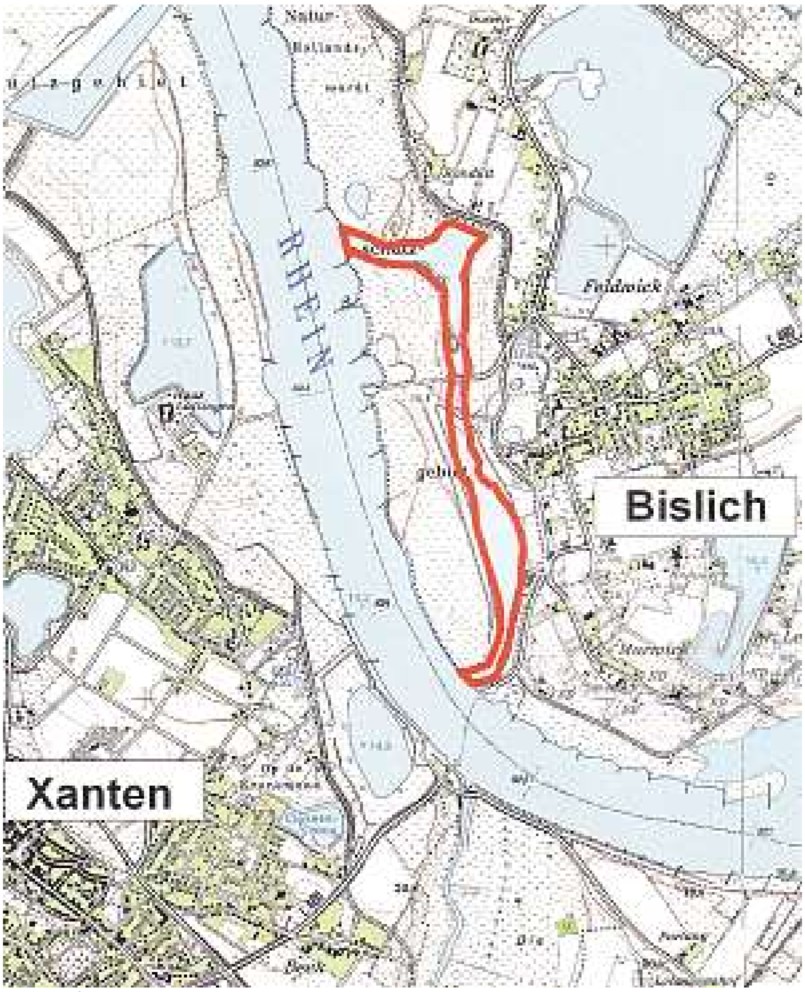


Figure 1.15: Bislich-Vahnum development plan

Figure 1.16: Bislich-Vahnum floodplain area

Figure 1.17: Location of the Lohrwardt Polder

LOHRWARDT (implementation project)

Responsible partner: Deichverband Bislich-Landesgrenze

The Lohrwardt Polder is situated in the eastern Rhine floodplains near Rees, adjacent to the German-Dutch border. It is flood-free owing to dikes. The project covers an area of 270 ha. It involved reconstructing the dikes that until the 1960s used to be located in the Lohrwardt area at some distance from the river. The gravel, clay and sand pits, the bodies of water and the agricultural land situated in the area of the future Lohrwardt Polder were purchased and leased to the farmers at reduced rates by the *Deichverband Bislich-Landesgrenze*. The water intake and outlet facilities planned within the framework of this investment have been constructed in accordance with a regulation relating to nature-oriented river development and maintenance in North Rhine-Westphalia, and therefore included provisions for fish ladders.

Aims
- Improving the natural environment.
- Improving flood protection by effectively lowering high water levels on both sides of the Dutch-German border.
- Protecting property and human life in the polder.
- Creating flood protection, landscape protection and tourism facilities while sustaining conditions for agricultural production.

Activities
- Creating large connected polder areas for water retention.
- Constructing an inlet work, outlet work and a pumping station.
- Building and reconstructing the required channels for dewatering the back land.
- Reconstructing dikes.
- Recreating nature on the Rhine river banks and increasing ecologically valuable areas.
- Concluding leasing contracts between the *Deichschau Haffen-Mehr* (now *Deichverband Bislich-Landesgrenze*) and the farmers relating to cooperation between water management and agriculture.

Results
- Pumping Station Lohrwardt (max.1.9 m^3/s).
- Water intake and outlet facilities including fish ladders.
- Drainage system (channels) for dewatering the back land.

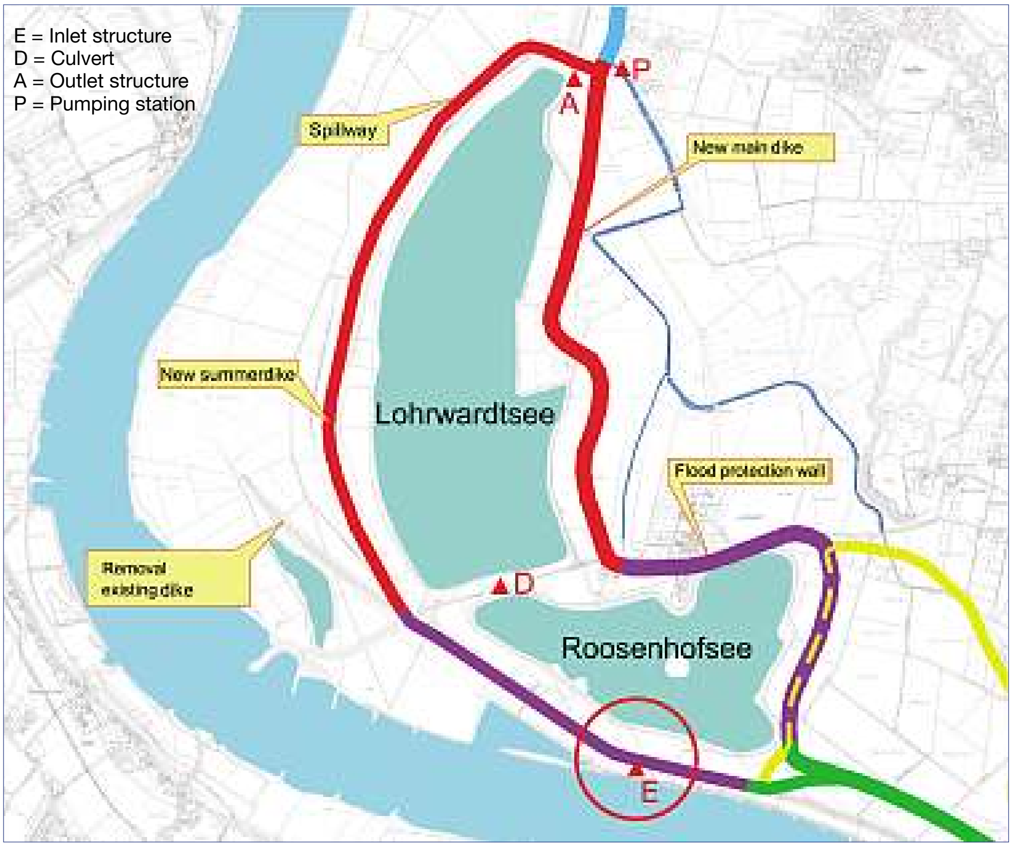


Figure 1.18: Development plan of Lohrwardt floodplain

Figure 1.19: Lohrwardt project area

Figure 1.20: Location of the Rijnwaarden project

RIJNWAARDEN (planning project)

Responsible partner: Dienst Landelijk Gebied-Regio Oost

The Rijnwaarden (including the Green River) is a large floodplain of 1,200 ha close to the Dutch-German border. The Green River has an area of 112 ha, located near the village of Pannerden. At present, it has an agricultural function, while its capacity for discharge reduction is modest. In 2001, Rijkswaterstaat (RWS, Department of Public Works and Water Management) created a masterplan for the entire Rijnwaarden floodplain, with a more detailed plan for the Green River. The plan was created in close cooperation with the Municipality of Rijnwaarden, and particularly the inhabitants of Pannerden. Around the same time, the provincial government of Gelderland set up a commission for Rural Development. The task of this commission is to develop the area known as the *Gelderse Poort*, of which Rijnwaarden is part.

Aims

The Green River has to be transformed into an area with a highly dynamic side channel in order to create:

- Natural riverine features.
- A larger discharge capacity to create more room for the river, while taking account of landscape and history aspects.
- Space for extensive forms of recreation.

Activities

The planned measures are:

- Lowering the agricultural fields.
- Creating a side channel in the floodplain.

Results

- Master plan for the Green River.
- Initial Document for the Environment Impact Assessment (EIA), published in December 2004, including public involvement.
- EIA guidelines issued by the competent authority in October 2007.
- In 2008, the masterplan will be detailed, a management plan will be worked out and the draft for attaining the required permits will be drawn up.

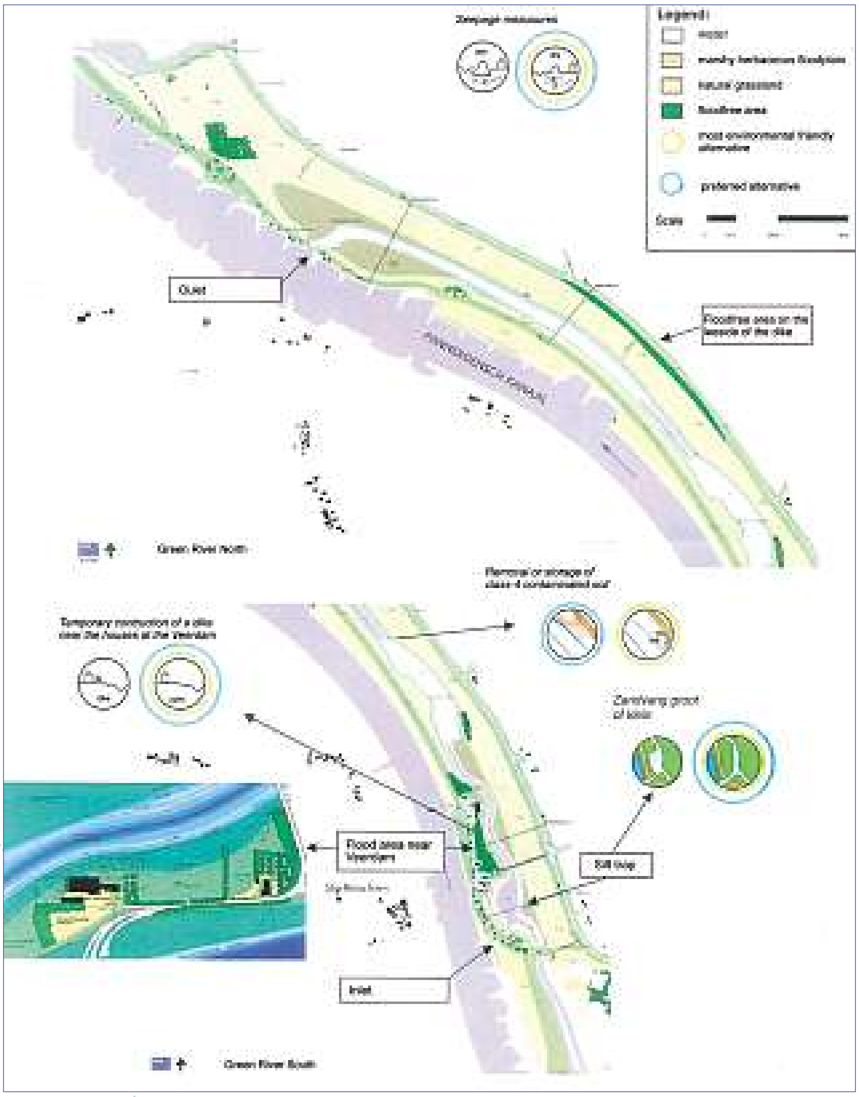


Figure 1.21: Development plan of the Green River

Figure 1.22: The Green River area

Figure 1.23: Location of the Bemmelse Waard

BEMMELSE WAARD (implementation project)

Responsible partner: Dienst Landelijk Gebied-Regio Oost

The Bemmelse Waard is a floodplain on the northern bank of the River Waal, just east of Nijmegen. The project was part of the Ooijpolder Land Consolidation Project and the Gelderse Poort Strategic Landscaping Project (*Strategisch Groen Project*).
The Bemmelse Waard covers an area of 400 ha. The area is characterised by pastures, several sandpits surrounded by willows and a large brickyard.

Aims

- Nature development.
- Increasing the discharge capacity of the Waal and creating room for the river to improve flood protection.
- Improving opportunities for nature-oriented recreation.
- Preserving and redeveloping the landscape.

Activities

- Lowering the level of the floodplain by means of excavation.
- The old course of the River Waal will be made visible by linking existing clay and sand pits in a side channel that is not connected to the mainstream of the river.
- Creating a large-scale river nature area of approximately 270 ha to be managed by the State Forestry Service (*Staatsbosbeheer*) on a cattle grazing concept.
- Concluding a public-private partnership contract to implement the project.
- Creating recreational facilities (walking and nature observation, cooperation with a local centre).
- Considerable expanding of the shallow marshy areas along the side channel.
- Providing a high water refuge for livestock.
- Streamlining the brickwork site.
- Relocating the gas pipe to the brick factory.

These measures will provide for a higher discharge capacity of the river and allow ecological features to develop.

Results

- Public-private partnership contract signed on 26 January 2006.
- Development plan converted into a implementation plan.
- Application for all permits.
- Relocation of the gas pipe to the brick factory.
- Newsletter sent to the inhabitants.

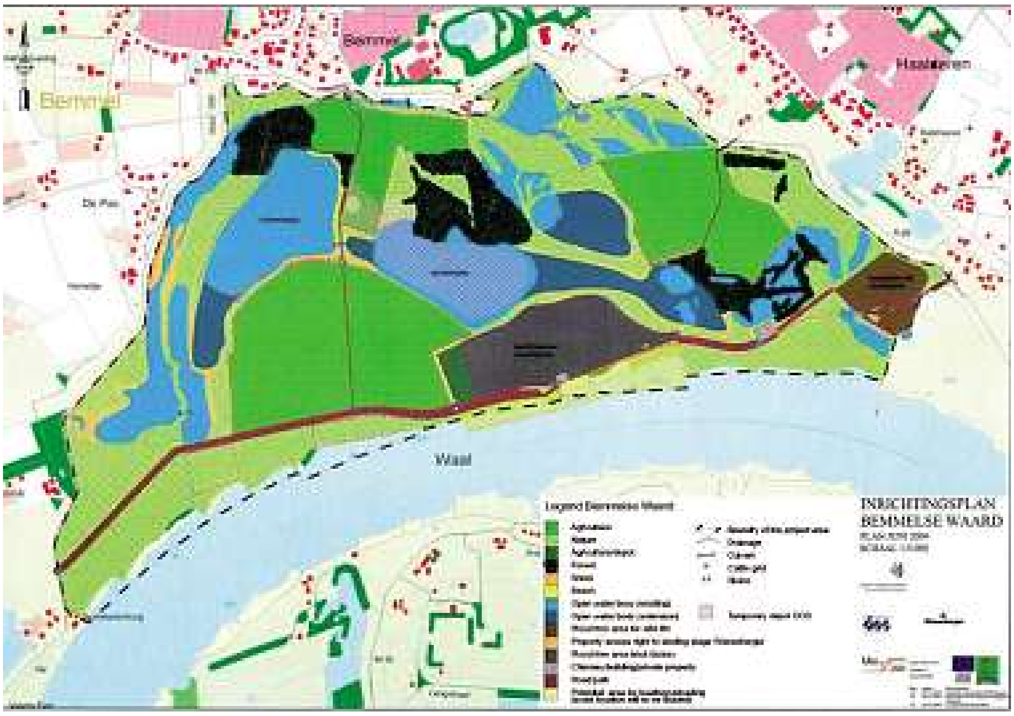


Figure 1.24: Development plan of the Bemmelse Waard

Figure 1.25: The Bemmelse Waard project area

Figure 1.26: Location of the Fortmond project

FORTMOND (implementation project)

Responsible partner: Dienst Landelijk Gebied-Regio Oost

The Fortmond floodplain is an area along the River IJssel between Zwolle and Deventer. The first nature development project in the area, *Duursche Waarden*, was implemented in 1989. A redevelopment plan next to the *Duursche Waarden* has been prepared, which may be divided into three sub areas: *Enk* (45 ha), *De Zaaij* and *Roetwaard* (150 ha). In the *Enk*, two deep secondary channels will be excavated that will both flow into the existing secondary channel in the Duursche Waarden. In *De Zaaij/ Roetwaard*, a deep, isolated body of open water is being created. In the *Roetwaard*, the existing open body of water will be connected to the River IJssel by excavating a secondary channel. New ecological features, i.e. a floodplain forest, are an important objective of the project. Recreation will be enhanced by the creation of fishing spots and walking trails. The activities in the Fortmond area are being implemented in two phases. Phase I involves starting up activities, including implementation, in De *Enk-Noord* and *Roetwaard-Noord*. Phase II involves implementing the remaining part of the total plan. Implementation will start approximately a year after phase I to allow for land acquisition in parts of the sub areas. Due to the impossibility of land acquisition it was not possible to start with phase II.

Aims

- Developing riverine nature.
- Creating room for the river for better flood protection.
- Encouraging public involvement and awareness.
- Improving opportunities for nature-oriented recreation.

Activities

- Preparing construction plans.
- Applying and implementing the Birds and Habitats Directives.
- Constructing side channels and lowering the floodplain to increase the discharge capacity of the River IJssel.
- Creating a large-scale riverine nature area of approximately 15 ha (phase I, *De Enk-N* and *Roetwaard-N*) and 40 ha (phase II, *De Zaaij)* to be managed by the State Forestry Service (*Staatsbosbeheer*).
- Creating recreational facilities (walking and nature observation, fishing).
- Developing an innovative contracting concept (e.g. public-private partnership).
- Public participation during the planning and executing phase.

Results

- Reports on:
  - Soil survey and a soil quality system.
  - Geo-hydrological study on the effects of side channels on the water system and the effects for piping.
  - The effects of storing polluted soil in old sandpits.
  - The ecological surveys and the effects of different walking trails and cycling tracks on nature (Birds and Habitats Directive).
  - The archaeological values in the project area.
  - The presumed effects on the mosquito population.
- An overall construction plan for the entire area of the Fortmond project.
- All underground infrastructure (water pipes, gas pipes, electricity cables) were relocated to make it possible to carry out the excavation work.
- A design and construction contract (innovative) was implemented for phase I.

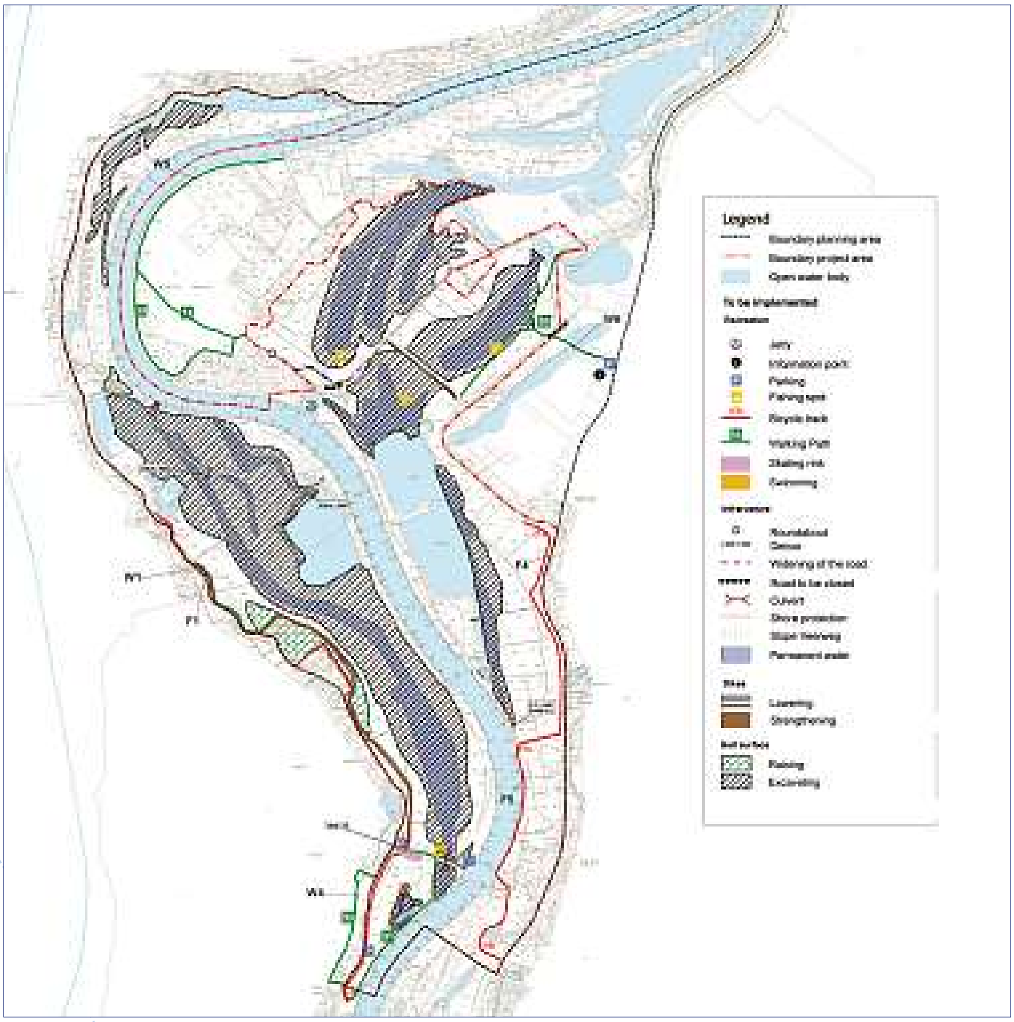


Figure 1.27: Fortmond development plan

Figure 1.28: The Fortmond project area

Figure 1.29: Location of the Hondsbroeksche Pleij project

HONDSBROEKSCHE PLEIJ (implementation project)

Responsible partner: Rijkswaterstaat Oost-Nederland

The Hondsbroeksche Pleij is a former floodplain on the right bank of the rivers Lower Rhine and Ijssel, covering an area of 120 ha. The area is used mainly for agricultural purposes. It is situated at the bifurcation of the rivers Lower Rhine and IJssel and is surrounded completely by dikes. Veerdam Dike lies to the north, the former Westervoortse main river dike to the east, and the present Pleij Dike (along the river) to the west.

Aims

- Protecting against flooding. Part of the Pleij Dike and Veerdam Dike constitute a barrier during periods of high water. The floodplains are very narrow. Moving the dike inland creates more room for the river.
- Regulating discharge at high water levels. To maintain an equal distribution of water over the various branches of the Rhine, an adjustable spillway will be constructed between the old dike and the new dike.
- Nature development. The Hondsbroekse Pleij is a link between nature areas along the Lower Rhine and the IJssel.
- Recreational use of the area.

Activities

The project planning and design process has been completed, including an Environmental Impact Assessment. The development plan for the area includes:

- Relocation of the dike along the IJssel approximately 250 metres farther inland and along the Lower Rhine about 150 metres inland.
- The newly created floodplain will be lowered to allow natural features to develop.
- Construction of a channel in the floodplain.
- Construction of an adjustable weir at the inlet to the channel.
- Removal of a large composting plant from the floodplain.

Results

The first phase of the Hondsbroeksche Pleij project is being executed by market parties on the basis of a Design & Construct (D&C) contract, including the construction of:

- The cut-off wall as part of the relocated dike by applying the mixed-in-place technique.
- The new, relocated dike.
- The adjustable weir.
- The excavation of the floodplain.

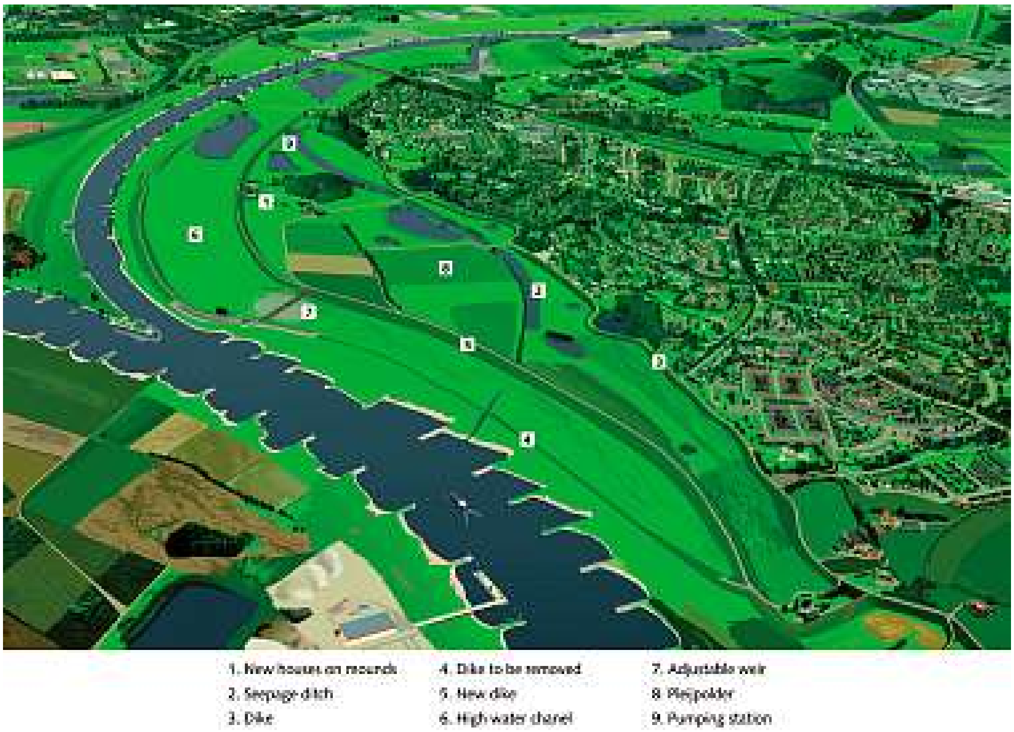


Figure 1.30: Hondsbroeksche Pleij development plan

Figure 1.31: The Hondsbroeksche Pleij area

Figure 1.32: Location of the Lexkesveer project

LEXKESVEER (implementation project)

Responsible partner: Rijkswaterstaat Oost-Nederland

The Lexkesveer floodplain lies on either side of the Rhine within the municipalities of Renkum, Overbetuwe and Wageningen. The area covers 380 ha. At the heart of the area lies the Lexkesveer ferry link, which carries commuter traffic and school children across the river between Wageningen and the villages Randwijk and Heteren. The southern floodplains of the Lexkesveer are part of a transnational strategic nature development project. On the southern bank, the emphasis is on combining safety and nature development. The ferry causeway located here will be partially replaced by a bridge, combined with the excavation of three summer embankments (levees, nearest to the river). Furthermore, a secondary channel will be excavated and extended under the bridge. Part of the floodplain will be lowered. The northern floodplain of the Lexkesveer is part of the *Noordoever Nederrijn* development plan. On the northern bank, the emphasis is on nature development; a seepage marsh will be created, while the Renkumse Beek, a stream that emerges in the Veluwe hills, will feed a new brook marsh before it runs to the river.

Aims

- Developing riverine nature.
- Increasing the discharge capacity of the Rhine and creating room for the river.
- Preserving and redeveloping the landscape.

Activities

- A planning and design process for the project, including an Environmental Impact Assessment.
- Obtaining permits for the construction activities.
- Constructing the bridge, which will replace a major part of the ferry causeway.
- Excavating a side channel.
- Marsh development.
- Excavating and partly replacing summer dams.

Results

- Project was approved by government authorities.
- Required permits were obtained.
- Public support was gained for the implementation of the project.
- Long-term sustainable development of Lexkesveer floodplains.
- A construction contract (D&C) for the bridge, excavation of the side channel, marsh development and the overall nature development was tendered and awarded in autumn 2007. Completion of the project is scheduled for the summer of 2009.

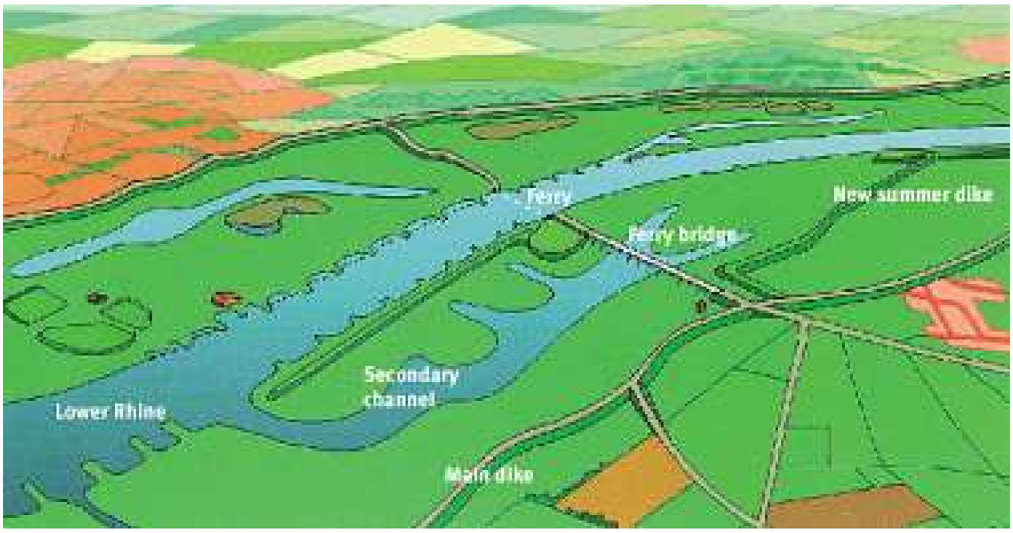


Figure 1.33: Lexkesveer project development plan

Figure 1.34: The Lexkesveer project area

Figure 1.35: Location of the Heesseltsche Uiterwaarden

HEESSELTSCHE UITERWAARDEN (planning project)

Responsible partner: Rijkswaterstaat Oost-Nederland

The Heesseltsche Uiterwaarden is a floodplain along the River Waal, west of Tiel. The area measures about 350 ha and is characterised by a half-open to open landscape. The grazed floodplains alternate with trees and brushwood. Near the village of Opijnen, in the extreme western part of the floodplain, a secondary gully very important for fish exists. Sand and gravel extractions have created stagnant bodies of water that also play an important role as spawning areas.

The Heesseltsche Uiterwaarden project commenced in 1998. The initial aims of the project were 1. nature development and 2. flood protection. The nature development aim was an element of the national nature development programme (*Nadere Uitwerking Rivierengebied/NURG*) to increase the area of riverine nature along the major rivers in the Netherlands. This is part of the national policy to strengthen the National Ecological Network (*Ecologische Hoofdstructuur*) in the Netherlands. The flood protection measure was part of the national Room for the River flood protection programme.

In 2002, an Initial Environmental Impact Assessment (EIA) Document (*Startnotitie*) was published. This Initial Document led to intense discussions with local inhabitants. This resulted in 2004 in the Compromise Plan. The Compromise Plan combines the aims of the project with the wishes of the inhabitants. In 2004 – before the EIA study had started – the project came to a standstill due to debate surrounding the Room for the River programme. After the publication of the Room for the River programme Spatial Planning Key Decision in January 2007, it became clear that the Heesseltsche Uiterwaarden would not be part of the Room for the River activities. In 2007, the Heesseltsche Uiterwaarden project was restarted. As was previously the case, the aims were nature development and flood protection. However, the flood protection now contributes to generating a robust river system. An Environmental Impact Assessment study will be started in 2008.

Aims

- Nature development according NURG programme to strengthen the National Ecological Network in the Netherlands.
- Increasing discharge capacity to generate a robust river system.

Activities

- In the planning and design phase of the project, the following activities will be carried out:
  - Environmental Impact Assessment study based on the Compromise Plan (to be finished in 2009).
  - Design of the preferred alternative of the EIA (to be finished in 2010).
  - Project decision by the State Secretary of the Ministry of Public Works, Transport and Water management (2010).
- Depending on the project decision, the implementation will start in 2010 and will be finished in 2015.

Results

The results of the planning and design phase of the project will be submitted to the State Secretary for a final decision.
The result of the implementation phase of the project will be a new redesigned Heesseltsche Uiterwaarden floodplain, the upkeep of which will be taken care of.

Figure 1.36: Development plan of the Heesseltsche Uiterwaarden

Figure 1.37: The Heesseltsche Uiterwaarden area

1.2 Joint work, themes, working groups (WG)

Learning from the experience of others was one major focus of the SDF partners, but information exchange between specialists, e.g. engineers, landscape architects, biologists, as well as the different administrative levels (national, provincial, local) and the sectors, e.g. agriculture, citizens, nature NGOs, was also important.
The partners worked together on key SDF questions and on innovative solutions for the measures taken at different locations within three thematically transnational working groups which met twice a year.

- WG1 Flood alleviation measures.
- WG2 Nature development and environment.
- WG3 Communication and public involvement.

Consequently, a common approach, common outputs and the exchange/transfer of experience within the partnership and beyond the project were ensured.
The working groups consisted of experts from the partner organisations. Invited experts from other organisations presented particular subjects. Furthermore, the involvement of experts from external organisations, e.g. from other Interreg IIIB water projects, attended working group meetings, contributing to a further exchange of experience and cooperation between Interreg IIIB projects.
The working groups met twice a year, each time at a different SDF pilot location.

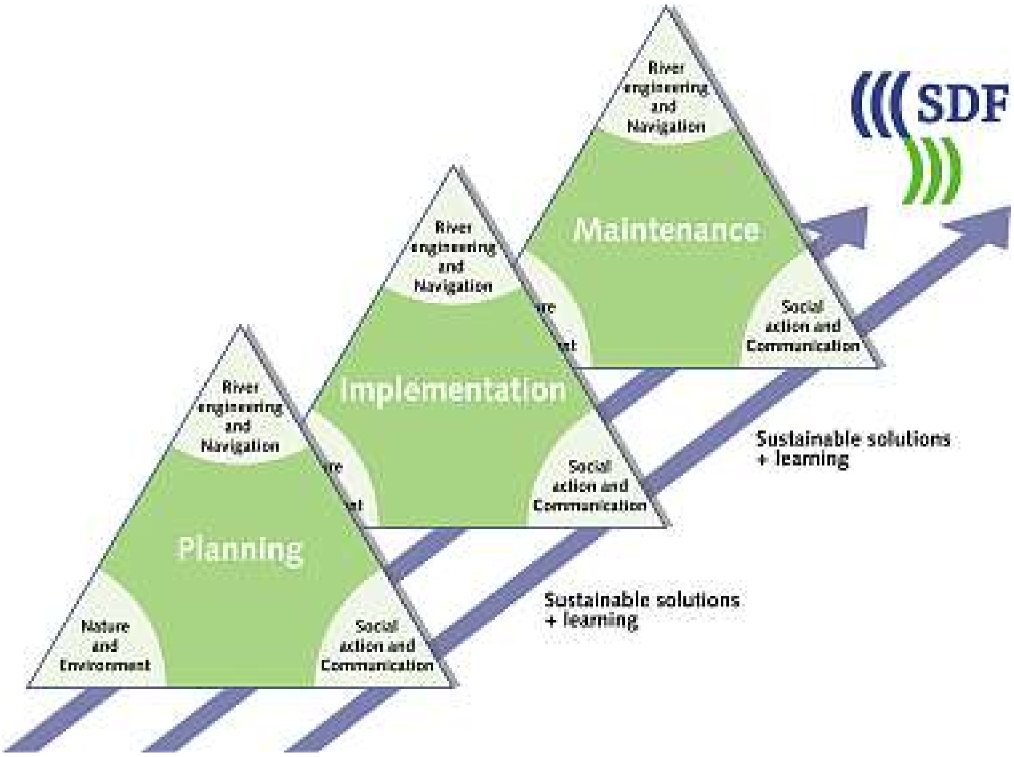


Figure 1.38: Overview of main themes, working groups within SDF and the connecting role of communication

1.2.1 Flood alleviation measures (WG1)

The experience and expertise gained by each partner in the course of its own pilot project were made available to the other partners so that they too could improve their knowledge of river engineering and navigation. The topics discussed in the Working Group covered the common aspects of creating polders, side channels and dike relocations. These measures reduce high water levels and increase the area of the floodplain, leading to safer living conditions in flood-prone areas and reducing flood damage and the vulnerability of goods and property.

The working group assisted partners in finding transnational and innovative solutions for specific local problems.

Subjects addressed:

- Effective design and maintenance of inlet and outlet works and dike construction.
- Common approach to the design of side channels.
- Dike relocation for high water retention and for restoring natural features.
- Designing structures (i.e. small bridges), minimising their impact on water levels.
- Innovative approaches to the function, use and design of retention areas, including the adaptation of retention areas to allow shipping and nature development.
- Expansion of the floodplain to prevent flood damage.

Detailed descriptions of SDF results regarding this subject are described in Chapter 2.

1.2.2 Nature development and environment (WG2)

The implementation of flood prevention measures along the main river were combined with other spatial objectives, such as nature development, recreation, mineral extraction and agriculture. The floodplains offer numerous possibilities for the development of new natural features. Linking new nature areas along the Rhine improved the transnational ecological infrastructure in north-west Europe.

Subjects addressed:

- Possibilities and essential preconditions for sustainable multifunctional land use in new or redeveloped retention areas and floodplains.
- Combination of flood prevention measures with nature development and nature restoration, including river restoration.
- Integration of the multifunctional land use concept with nature development strategies and territorial planning policies.
- Design and exchange of know-how concerning ecological-orientated flooding.
- Benefits of different national and regional eco-pool or eco-account conceptions and policies for sustainable land use.
- Experiences with the implementation of EU Birds and Habitats Directive.

One of the main objectives of the SDF project was to contribute to nature development and sustainable nature conservation. The pilot actions that were part of the SDF project all contribute to the European policy of Natura 2000: conservation and restoration of the biodiversity in the EU. The SDF project contributed to the survival of specific habitat type and bird species which are protected in the Birds and Habitats Directive.

During the planning and executing phase, there were possibilities within the projects to link different interests and objectives. In the case of measures aiming at flood prevention, particularly those with a spatial character, it is almost always possible to create conditions for nature development and the improvement of landscape qualities. These new qualities result in added value for recreational use of the area in which the measures are introduced but often for the wider region, too. For these reasons, flood prevention measures are almost never measures involving a one-sided approach, but are part of an integral approach for an entire area.
Detailed descriptions of SDF results regarding this subject are described in Chapter 3.

1.2.3 Communication and public involvement (WG3)

The overall objective was to raise the awareness of the general public and increase its commitment to the transnational interdependency of flood prevention and to improve cross-sector stakeholder involvement. This was achieved by transferring knowledge and experience and by building up a transnational cooperation network of responsible authorities (to support other projects in the future), thus creating a cross-sector network for flood management.
The involvement of the public in early planning phases was one of the objectives of

Figure 1.39: SDF Working Group meeting

the SDF project. Public involvement can be achieved in two ways, i.e. through the use of:
Formal instruments, such as Environmental Impact Assessments (EIAs), administrative allowances, etc.
Informal instruments, such as information events, project advertising, PR, etc.

Subjects addressed:
- Raising awareness and commitment of the general public regarding the transnational interdependency of flood protection.
- Developing and improving processes of participation (local public, contractors, land users/owners, authorities, etc.).
- Building a transnational cooperation network for the transfer of knowledge and experience between responsible organisations (as well in contact with other Interreg projects).
- Best experience exchange/transfer and working on the development of EU policies (such as EIA, WFD, Birds and Habitats Directive, etc.).
- Developing innovative contract models regarding cooperation between entrepreneurs, land users or owners, competent authorities, etc. (public-private partnership).

Detailed descriptions of SDF results regarding this subject are described in Chapters 4 and 5.

1.3 Framework of SDF operation

In order to manage flood risk in a transnational river basin, such as the River Rhine basin, the varying discharge dynamic from the source to the delta has to be taken into account. At the Upper Rhine, retention capacity should be increased, whereas in the densely populated area of the Netherlands, the water should be drained to the sea as quickly as possible. This limits the options for vegetation in these differently used floodplains. In the Netherlands for example, the growth of floodplain forests is limited to 10% of the floodplain area to ensure a rapid discharge. Along the Upper Rhine, the Rhine Action Programme includes technical retention measures, as well as the reconnection of floodplains and old meanders.
The SDF project deals with the sustainable development of floodplains in the different areas of the river basin. The protection levels against flooding are different in the Netherlands and Germany. The Dutch river dikes are designed to withstand floods with a discharge that can occur once every 1,250 years. In Germany, the protection levels along the river Rhine can vary from protection against flooding by discharges occurring once every 10 to 500 years. In Germany, there is no law on the protection level, whereas in the Netherlands there is a legal obligation.

A floodplain is flat or nearly flat land adjacent to a river formed by the deposition of sediment during periodic floods. Active floodplains still experience occasional or periodic flooding.

In addition to these preconditions defined by the geographical nature of the Rhine river basin, several legal frameworks are relevant to the SDF activities. Be that as it may, these frameworks were not in the focus of the SDF implementation but provided the basis for activities. In the following sub-chapters, European regulations, the preconditions set by the International Commission for the Protection of the Rhine, as well as national regulations and programmes are referred to. Detailed information on these issues can be found in annex 1.

1.3.1 EU regulations relevant to SDF activities

Of the European guidelines, the following are of special importance for the SDF activities: the Water Framework Directive (WFD), the Directive on the assessment and management of flood risks, as well as nature policies such as Natura 2000.
The **European Water Framework Directive** is not specifically focused on flood protection and deals with this issue only marginally. It addresses water quality and transnational river basin management. Nevertheless, a close link between flood protection and the WFD is provided by the practical implementation of the measures.

On 26 November 2007, the **EU Floods Directive** on the assessment and management of flood risks entered into force (Directive 2007/60/EC). The objective of the Directive is to assess, manage and reduce flood-related risks to human health, the environment, infrastructure and property.

This Directive requires the implementation of a three-step approach by the Member States:
1. preliminary flood risk assessment (by 22 December 2011);
2. flood hazard maps and flood risk maps (by 22 December 2013);
3. flood risk management plans (by 22 December 2015).

Consequently, the Member States have to carry out a preliminary assessment of all water courses and coast lines since action will have to be taken in areas only where a significant flood risk exists. Flood risks and hazards will be mapped in these zones. Finally, flood risk management plans will have to be developed and implemented at river basin/sub-basin level to reduce and manage the flood risk. These plans should include the analysis and assessment of flood risk as well as the definition of the level of protection.

The **Natura 2000** network is the European network of protected areas which was established to preserve species and habitats. It is based on two EU directives:
Flora, Fauna and Habitats Directive (Habitats Directive): Council Directive on the Conservation of natural habitats and of wild fauna and flora.
Birds Directive: Council Directive on the conservation of wild birds. The cornerstones of the Directive are Special Protection Areas – SPAs. These include special protection areas which must be designated for the protection of bird species described in Annex I to the Birds Directive (contains 181 brooding species) and migrating species.
According to Article 2 para.1, the aim of the Habitats Directive is "to contribute towards ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the Member States". This aim is mainly achieved through the designation of Special Areas of Conservation which together with the EU special protection areas form the coherent and Europe-wide network of protected areas, Natura 2000. In chapter 5.3 and in annex 1 the experiences gained with the European nature policy are described and further information is provided.

1.3.2 Plans and programmes of the International Commission for the Protection of the Rhine (ICPR)

The International Commission for the Protection of the Rhine (ICPR) was founded in 1950 on the basis of international law by the following contracting bodies: Switzerland, France, Germany, Luxembourg, the Netherlands and the European Community. In 1987, the Rhine Ministers approved the Rhine Action Programme (RAP) in Strasbourg. It focused on improving water quality and biodiversity and it was designated to achieve its targets by 2000.

The Rhine Action Programme was followed by the Rhine Action Plan on Flood Defence, which was adopted in 1998 by the five countries bordering the Rhine, setting up a plan for precautionary flood protection for the next twenty years.

By 2005 (the set milestone), an evaluation of the implementation of the action plan on floods had been provided by the ICPR. It indicated the great success of the action plan. Nearly all planned measures had already been implemented by then, the changes in damage potential showed larger reductions in areas without dikes than with dikes and the Rhine Atlas showing flood risk and flood potentials maps raised public awareness.
For the period following 2000, a new programme – Rhine 2020: a programme for the sustainable development of the Rhine – was adopted in 2001 by the Rhine Ministers. This programme focuses on ecology, nature protection, flood prevention and groundwater protection. It follows the plan to open the old alluvial areas to the river and to combine nature protection and flood prevention.
In line with this history, the SDF project was set up in agreement with these plans and conventions officially in place in the Rhine river basin. It allows even more nature development and raises public awareness while focussing on the implementation of flood alleviation measures providing an important input for the implementation of the ICPR's programmes and plans (for more detailed information, see annex 1).

1.3.3 National regulations and programmes

In **Germany**, the federal ministry of the environment is responsible for setting up the legal framework for water management (Water Framework Act) and for the coordination of the implementation, if relevant at national level. Apart from the statutory requirements, the federal government also ratifies programmes and issues guidelines. The federal states (*Bundesländer*) are responsible for the specification and enforcement of the law and for the implementation of all water management issues. The coordination between the federal states and national level is organised by the Standing Working Group of the federal states on Water Issues (LAWA), including representatives of the federal ministry.
Similar responsibilities are split between national and federal state level regarding spatial planning. In this case, the Standing Conference of Federal and State Ministers Responsible for Spatial Planning (MKRO) guarantees coordination. The Standing Conference agreed the guidelines for sustainable flood protection in 2000. These guidelines have to be implemented by means of spatial planning in line with the flood protection concepts of the federal states.

With regard to the SDF project, it should be pointed out that the sole responsibility for the construction and for the sustainable development of the floodplains lies with the federal states, although the national ministry offers funds for implementation in special cases, e.g. for international commitments (such as the Upper Rhine).

Detailed information on the Flood Strategy Baden-Württemberg, Flood Protection Concept Rhineland-Palatinate and the Flood Protection Concept North Rhine-Westphalia is provided in annex 1.

In **the Netherlands**, water policy is drawn up and implemented at both national level and at provincial and water board level. From a historical perspective, provinces, water boards and municipalities have a fairly autonomous jurisdiction. However, in the second half of the twentieth century, their autonomy was increasingly framed in terms of a model of close cooperation with central government. In this model, central government takes the initiative in policy making and decentral authorities cooperate by additional policy making and implementation within the national policy framework.

An integral plan regarding the connection between water management and land use planning was adopted in 1995. This plan states that more space around rivers is needed, particularly in response to flood problems in river flood plains and for improved anticipation of climate change. When competing with other spatial claims, water and its natural movements should become key determining factors in land use planning. This paradigm change in flood protection is also a reinforcement of the ecological restoration of water systems. Natural protection is preferred to artificial protection. In 1998, this new policy approach formed the basis for the **Fourth National Water Policy Plan**, which focuses on climate change and restoration of the natural dynamics of water systems. A remarkable movement during this phase is that the national regime retreats from an integrated regime into a complex regime due to a further increase of extent and a decrease of coherence. The reason for this is that in the early 1990s, policy makers started linking water resources to spatial resources. This introduced the need for an extra integration effort in order to bridge the gap between water management and spatial planning.

At national level, water policies are co-ordinated by the Ministry of Transport, Public Works and Water Management. This is the leading ministry which also supervises *Rijkswaterstaat*, the water engineering department handling all state waters and the state water infrastructure. The main (navigable) rivers and canals, all coastal waters and estuaries, the territorial seas, and the inland IJsselmeer fall under the jurisdiction of this ministry. The other regional waters fall under the jurisdiction of the water boards, with an exemption for regional navigable waters, which come under the jurisdiction of the provinces, and local waters (e.g. harbours, city canal systems), which fall under the jurisdiction of the municipalities.

While water quantity management at national level is supervised entirely by the Ministry of Transport, Public Works and Water Management, water quality management is in the hands of the Ministry of Housing, Spatial Planning and the Environment (VROM). However, it is coordinated by the Ministry of Transport, Public Works and Water Management. In so far as water management has a recognised relationship with agriculture and nature conservation (which was first acknowledged in the 1980s), the Ministry of Agriculture, Nature Management and Food Quality is also involved in national water policy making.

The main aim of the **Policy Programme Room for the Rivers** (*Beleidslijn Ruimte voor de Rivier, 1997*) is to reserve space for the Rhine (which in the Netherlands branches into the Nederrijn, Waal, IJssel, and Lek) and Meuse rivers. This policy acts as an evaluation framework for activities in the winter bed of the major rivers. The policy, instituted after the flooding in 1993 and 1995, is restrictive in nature.

A combination of spatial and technical measures is needed in the areas around the rivers to create extra space for the rivers with a view to the expected higher levels of river discharge. Extra space can be found both inside and outside the dykes. River-expanding measures can be introduced in the winter bed within the short term; these can also be perceived as a reserve for more long-term measures. Emergency overflow areas also need to be available in case of impending flooding. The areas inside the dykes that may be needed to expand the winter bed, reinforce the dykes or for water storage or emergency overflow purposes will be exempt from developments that might interfere with these functions. New residential neighbourhoods and other large-scale developments will not be permitted there. The national government will assess provincial and municipal plans to determine whether this guideline is being followed.

Spatial planning key decision 'Room for the River'
Room for the River, a spatial planning key decision, in which the spatial planning for the entire area related to the Rhine delta is set out was submitted to the Dutch parliament in 2006. The document presents an integrated spatial plan with the main objectives of flood protection, master landscaping and the improvement of overall environmental conditions. Completion of a basic package of about forty project is foreseen for 2015, with a budget of EUR 2.2 billion. The plan is an initiative of three ministries: Ministry of Transport, Public Works and Water Management, Ministry of Spatial Planning and the Environment and the Ministry of Agriculture, Nature and Food Quality. The provinces and municipalities in the programme area play a major role in the development of the spatial flood control measures. The programme area extends along the arms/tributaries of the river Rhine: Waal, Merwedes, Nederrijn, Lek and IJssel and covers a large part of the Netherlands. The safety of four million people at risk from flooding is at stake.

Nature policy is organised at national level through policy instruments and quantitative targets. At provincial level, the Provincial Nature Plan is being implemented done in 12 separate provinces. The most important part of the nature policy plan is bring about a National Ecological Network. The existing nature areas and new nature areas will be connected.
In the floodplains, about 7,000 ha of new nature will be created as part of the National Ecological network. Since 1993, the Ministry of Transport, Public Works and Water Management and the Ministry of Agriculture, Nature Management and Food Quality have been cooperating on the implementation of this nature development programme. Since 1995, the objective of nature development along the rivers has been closely related to the objective of increasing space for the river (safety objective).

2

2 Flood alleviation measures

Flood alleviation measures can be divided into structural and non-structural measures[1]. In the SDF project, structural measures were developed and implemented to reduce flood levels during high water events by increasing flood conveyance and providing more retention area for the river. Within the meaning of this project, flood alleviation measures are actions that restore old or create new floodplains. Structures such as dikes and walls, which solely protect certain urban areas without reducing the flood peak level, were not considered for this project. In addition, risk management measures intended to prepare for the phases before and after floods or predictions and flood event management with regard to civil protection, etc. will not be considered in this chapter. However, this does not mean that these risk management measures are unimportant for the reduction of flood risk. The fact is that the SDF project focused on certain selected measures as defined above.

[1] Non-structural measures are measures concerning flood preparedness (flood proofing, flood warning systems), emergency response (legislature, financing), flood recovery (flood insurance, rehabilitation)

2.1 Dike relocation and construction of retention areas

2.1.1 Concepts and mode of operation

The relocation of dikes and the control of water discharge into and out of retention areas are generally implemented in order to reduce the maximum discharge in combination with the slow down of the runoff wave. These measures are used in upstream areas of river systems to effect downstream stretches. Dike relocations are performed by opening the main dike close to the river and by building new dikes on the rear side of the old dikes. This creates areas between the river and the new dike, or between old and new dikes, which can be flooded. As a result, the areas to be flooded (floodplains) are reconnected to the river's flood dynamics. They will be flooded successively with the rising water, which meets the natural conditions in flooding areas. Besides the positive flood protection effect, this also enables the development of floodplains more in line with nature.

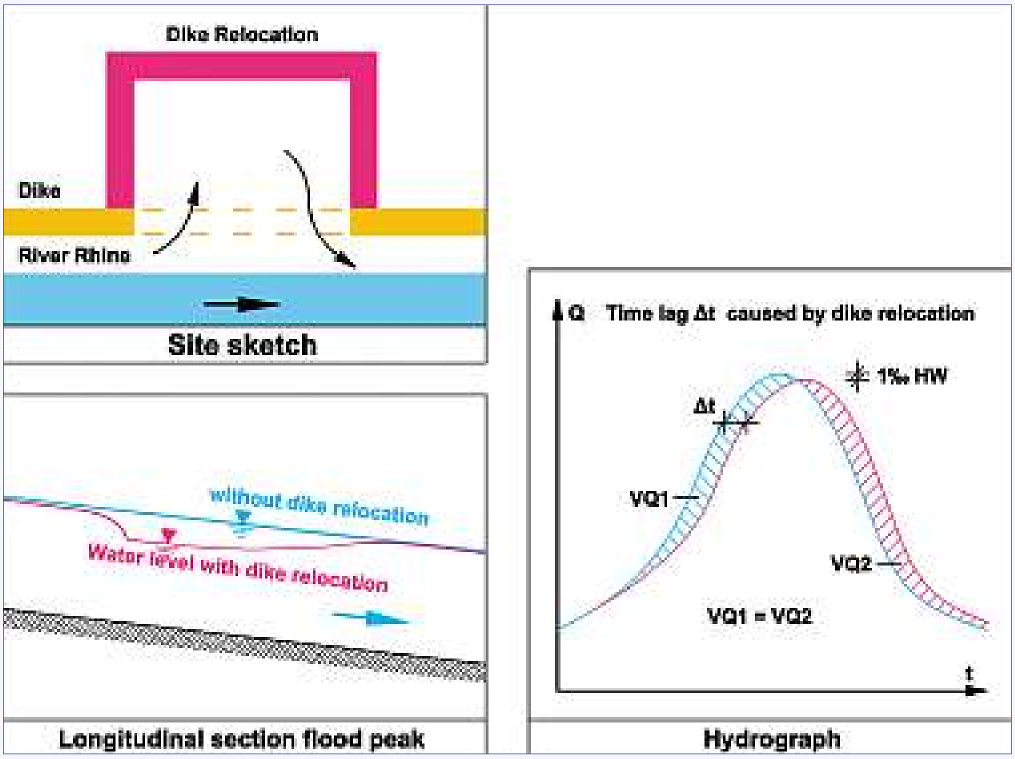


Figure 2.1: Effects of dike relocations (uncontrolled retention) on the flood peak

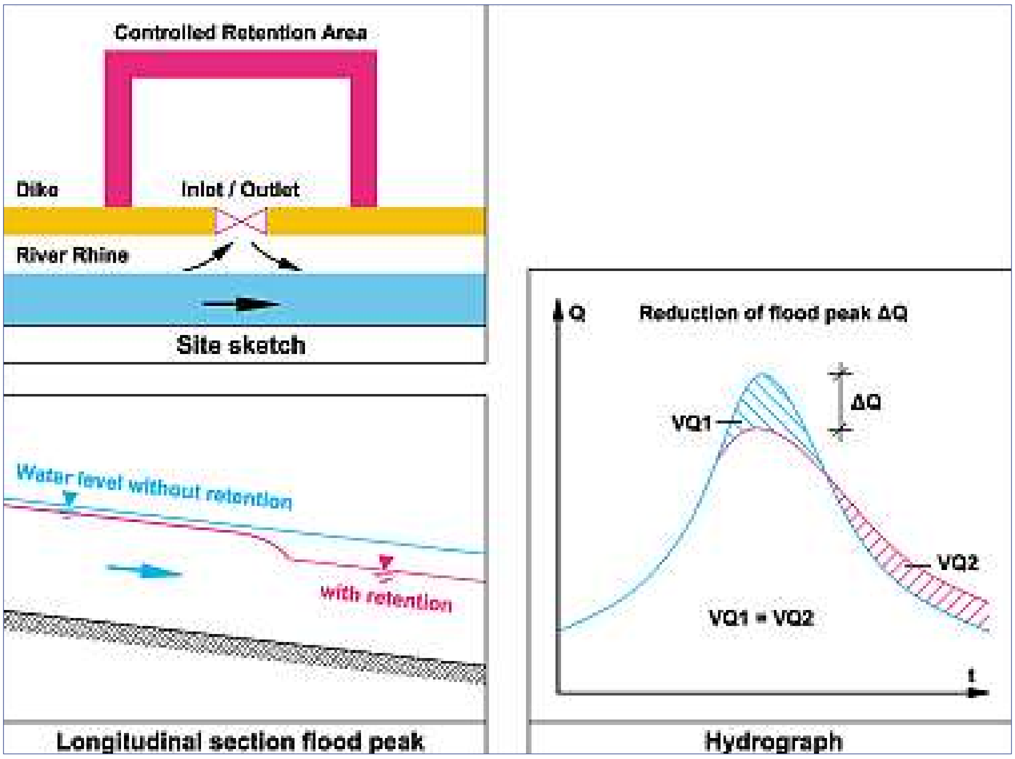


Figure 2.2: Effects of controlled retention on the flood peak

In principle, controlled retention areas differ from dike relocations in that the flooding starts at a pre-determined flood level. The flooding of the retention area is controlled by the construction of an overflow threshold in a certain stretch of a summer dike. This may be an overflow structure or an inlet and outlet structure with movable weir, which may be opened when required. The inlet is usually opened shortly before the forecasted flood peak arrives near the retention area, depending on the operation criteria. The operation starts, for example, with the 1/10 year event (Ingelheim Polder) or the 1/20 year flood (other polders on the Upper Rhine). The flooding area is surrounded by dikes in the case of the controlled retention method. To increase the frequency of flooding and to simulate more natural conditions, additional floods are created by opening weirs. This principle is referred to as ecological flooding (see chapter 3.1.2).

A retention area generally consists of the following components:

- Old dike, relocated dike.
- Inlet, outlet.
- Pumping stations.
- Retention area, land use in retention area (can be divided into different zones).
- Measures to prevent seepage (drainage, pumping station, sealing walls).

These parts are shown for example for the SDF pilot project Ingelheim Polder in Figure 1.6.

Figure 2.3: Example of a controlled retention area: Ingelheim Polder, left ecological flooded, right HQ200 flooded

Dike relocations are uncontrolled retention systems and have, in principle, a different effect on the flood wave than controlled systems. When the flood rises, a partial flow runs into the new floodplain. This causes a small reduction of discharge downstream. Widening the outlet's cross-section at the former main dike causes local lowering of the water level. The sinking curve may influence the surrounding upstream areas up to a distance of 20 km.

In the case of a controlled retention with targeted flooding based on a certain flood level, very high volumes of water (e.g. approximately 200 m^3/s at Ingelheim Polder) are abruptly led into the flooding area. A stilling basin has to be constructed to reduce the energy of the water bursting into the retention area through the inlet structure. The sudden reduction of the runoff in the river results in a visible lowering of the water level downstream. In general, the inlet and outlet structures are imitated fully as physical hydraulic models in order to calibrate and optimise these structures.

Box 2.1: Increasing the effects of retention areas along the Upper Rhine by integrated operation

Increasing the effects of retention areas along the Upper Rhine by integrated operation
As a result of the development of the Upper Rhine area in the second half of the twentieth century, the peak discharge was accelerated by 36 hours in the case of a 200-year flood event (HQ200). The discharge increased by 800 m^3/s from 6,000 to 6,800 m^3/s (at Worms) and the water level was raised by 70 cm. The effects of single retention measures in this context are very limited. The intended and already completed retention areas have to be coordinated. A considerable effect can be achieved only by the integrated operation of all 25 controlled measures on the Upper Rhine between Basel and Ingelheim. One aim of dike relocations is to slow down the runoff wave considerably to approximate the former conditions as closely as possible.

The system of retention polders in the Emscher catchment

Figure 2.4: Flood retention measures in the Emscher system

In North Rhine-Westphalia, about 75 % of the inhabitants live in the catchments of Rhine or Meuse tributaries, where ten water boards are responsible for water management aspects such as flood prevention. In the densely populated Emscher catchment (865 km²), flood risk management includes a large number of retention areas with graded safety demands. Depending on the land use and structure (agricultural land, forest, sparsely populated, densely populated, industrial use, etc.), the Emscher surrounding and its tributaries are designed for a safety level up to 1/200 years return interval.

Due to former mining activities, dikes with a height up to 10 m are occasionally required. For historical and availability reasons, many dikes were constructed with durable Waschbergematerial (stone material resulting from hard coal mining). For the restoration of the Emscher system, a combination of decentralised retention measures in the entire catchment and centralised floodplains along the Emscher (e.g. the two locations Mengede and Ellinghausen in the SDF project) is planned. The decentralised measures are partially completed and are ready for use, others are under construction or planned. In addition to safety for settlements, the goal of the flood retention is to protect newly developed river beds against excessive erosion. In future, the entire Emscher system will be free-flowing without any obstacles such as weirs or dams. A stable floodplain structure is necessary in order to keep the cost of maintenance relatively low.

Box 2.2: The system of retention polders in the Emscher catchment

It should be noted that the flood wave damping and discharge contributions from streams and tributaries reduces the impact of a retention polder. However, the impact downstream of retention polders may be felt to several hundred kilometres downstream. The flood level lowering effect of a retention polder in the *Rijnstrangen* area (between Lobith and Pannerden) is estimated at 20 cm in the entire Dutch Upper Rhine system, which is more than two-thirds of the Room for the River goal. Computations also show that the existing German schemes for flood protection, counting several retention polders, have a maximum effect of only 5 cm on the flood levels in the Netherlands.

2.1.2 Comparison of dike design

Dike structures have long traditions in all regions along rivers and coasts. But due to regional differences, a large number of standards and design types have been developed throughout the world. In Europe and even in the Rhine River basin the dikes differ from country to country and from region to region. The German Industry Standard (DIN) 19712 River Dikes aims at standardisation for the construction of dikes. It deals mainly with the criteria of stability in relation to the materials used, intersection zones of the dikes and the design water levels and water flow. However, due to a long history of dike development and responsibility of the federal states, each state adjusts the standards to its needs. A similar development may be described for The Netherlands. This is explained below. One goal of the SDF actions was to compare the design of the dikes of the partner regions and to draw conclusions regarding experiences, advantages and disadvantages. This comparison was used when planning and building the dikes in various pilot projects.

Design of dikes in Baden-Württemberg, Germany

Standards for dikes are developed individually for the federal states in Germany. The main Rhine dikes in Baden-Württemberg downstream of Iffezheim are more than 100 years old in their core areas. They consist of varying layers of clay silt soils, as well as sand and gravel sand, according to the way dikes were constructed at that time. During a persistent flood, the dikes and the subsurface endure seepage in gravel sand areas. Investigations in previous years have shown that more and more micro-size particles are being rinsed. During a flood in the Rhine (May 1999), the outflow of seepage water was already visible in the form of small sand craters (Figure 2.15). This phenomenon is intensified by the fact that flood water exceeding 4,000 m³/s is drained off at the Maxau water gauge more often than at the development of the Rhine up to Iffezheim.

In the case of persistent high water over long periods of time, there is a risk that the dikes cannot withstand the strain in the long run. The risk of dikes bursting is restricted in the first place to those areas already showing these phenomena. But in the long run, risks in other dike areas, which have only experienced a low amount of seepage so far, can no longer be excluded. The required dike height is determined by the design water level. This water level results from a Rhine water runoff of 5,000 m³/s at the Maxau water gauge. In principle, the free board measurement (the difference between the Rhine's water level at a discharge of 5,000 m³/s and the dike's crest) amounts to 80 cm.

The development of the cross-section of the dike profile depends on the soil-mechanical parameters. In general, this results in a slope inclination of 1:2 up to 1:2.5 on the Rhine side and of 1:2.5 up to 1:3.5 on the landside.

The actual embankment is created using gravel. At unfavourable subsoil conditions, a small wall (vertical sealing element) must be introduced into the dike area. This wall will extend approximately 4-6 m underneath the in-situ clay layer of the floodplain.

As a rule, the dike's crest will receive a gravel pavement with the protective strip on the landside being paved with bitumen to serve as the dike defence path. A seed mixture rich in species of grasses and herbs will be sown on the dike slopes.

As a result of the Baden-Württemberg Water Act, the Regional Administrative Authority of Karlsruhe enacted the decree for safeguarding and maintaining the main dikes along the River Rhine on 12 May 1993 (decree for the protection of the dikes). This decree meant that a standardised regulation for safeguarding and maintaining these main dikes was established in the administrative district of Karlsruhe.

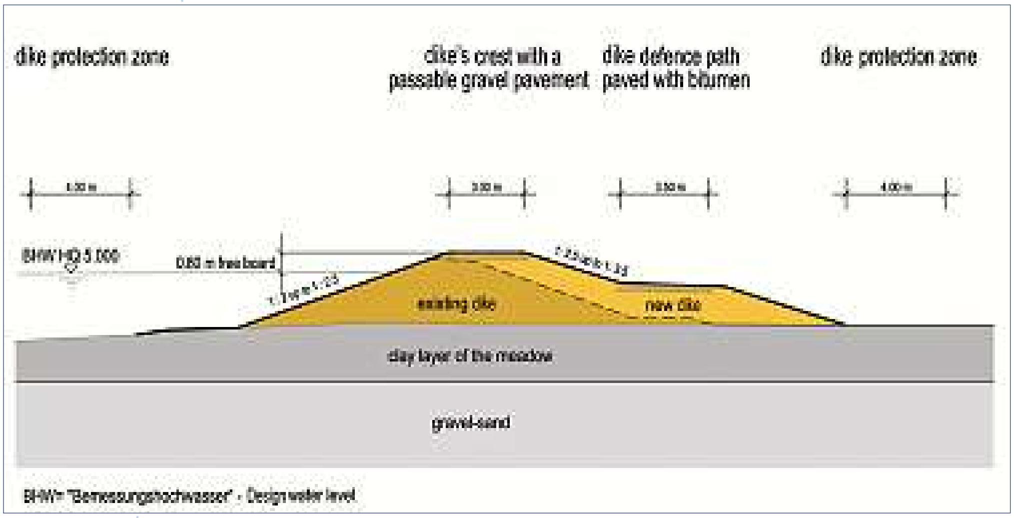


Figure 2.5: Standard cross-section of the dikes on the right side of the Rhine

The length of the dikes affected by this decree amounts to 246 km and stretches from the Iffezheim barrage to the district border north of Mannheim.

The central issues of this new decree are prohibitions for the protection of the dikes. Dike protection zones are prescribed on both sides of the dikes. These start at the foot of the dike and include a strip of 4 m. The new decree prohibits performing excavations or other earthwork on the main dikes and protective strips on both sides of the dikes. It also prohibits damaging turf, planting trees and bushes, horse riding or grazing by animals in these areas. Furthermore, traffic on the dike's crest – unless permitted by road traffic regulations – is forbidden.

In order to safeguard the dikes against undermining, base failure, spring formation, etc., dike protection zones have been defined in accordance with the protective strips on both sides, whose width is 35 m. Within these dike protection zones, interventions in the subsurface of more than 0.5 m are forbidden.

The dike strengthening measures referred to in the programme are required for the permanent safety of the dikes and serve to protect communities along the Rhine against floods. The Rhine's potential discharge volume has not been increased by these measures. In February 1991, the maximum permitted heights of the dike crests on both sides of the Rhine were contractually laid down in an administrative agreement between the territories of Baden-Württemberg, Rhineland-Palatinate and Hesse.

Design of dikes in Rhineland-Palatinate, Germany

The dikes in Rhineland-Palatinate are not standardised. In the Ingelheim SDF pilot project, the dike's structure with sealing body and superimposed load filter (supporting shell) meets the standard development profile of the regionally responsible authority (SGD Süd). This profile is generally used when constructing new dikes as there is an almost unending supply of the low-cost sealing material at the builders' disposal. This type of structure presents a higher protection against rodent infestation than dikes with a core of sand and limited sealing zones. In order to avoid the lift on the landside of the dike endangering its stability in the case of flooding, it was equipped with a cut-off wall in areas with inhomogeneous covering layers, which consist of 2 m thick silt layers in the Rhine plains. This was carried out to extend of the seepage path and to reduce the pressure. In this case, a small bentonite wall embedded in the dike was installed. In other areas where the covering layers are homogeneous, e.g. at Ingelheim Polder west dike, there is no need for such cut-off walls.

The dikes in Rhineland-Palatinate are constructed according to a quality assurance plan adapted to the special requirements. This plan includes the constant checking of the bulk material for its suitability. It also involves the checking of the installation and the compacting by the contractor, as well as third-party monitoring by an independent geotechnical institute ordered by the *SGD Süd*. The structure as well as the adherence to given geometrical values has also been monitored by surveying.

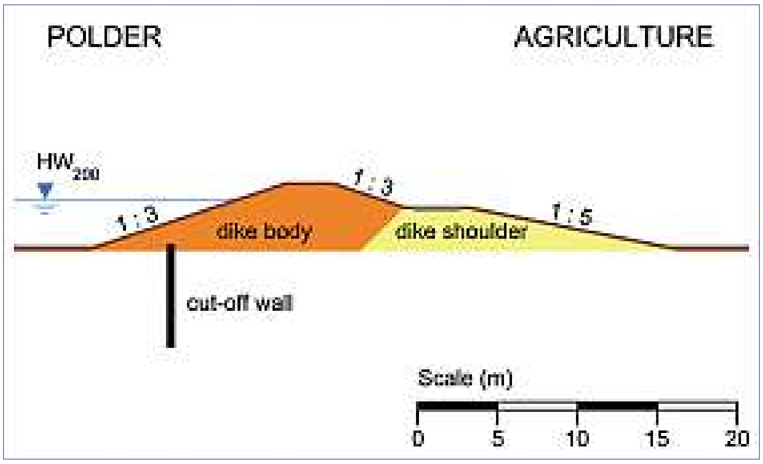


Figure 2.6: Dike structure Ingelheim Polder east dike

Design of dikes in North Rhine-Westphalia, Germany

The dikes in the Lohrwardt Polder pilot project were designed as three-zone dikes in accordance with the German standard DIN 19712 (river dikes). The dimensioning and shaping of the dikes was in line with the dike standard section of the State Environmental Agency Krefeld (*StUA-Krefeld*). Besides the decisive measured flood 2004 and/or 1977, a freeboard of one meter was taken as basis as the dikes usually have a medium height of 4.5 to 5.5 m between the foot of the dike on the water side and the crest of the dike. The crest width usually amounts to 5.0 m. If crest paths are included or need to be included, the crest width may amount up to 10 m or more. The slopes on the waterside and on the landside are constructed with an inclination of 1:3.5 to 1:6. This relatively slight slope makes it possible to use machines for the maintenance of the dikes. The dike shoulder height and width is determined geo-technically. The dike shoulder height lies at least 1.0 m above the maximum landside water level as can be expected. Dike shoulder heights of up to 2.5 m are generally reached in the planning area. The dike shoulder width is equivalent to at least twice the height of the dike on the waterside.

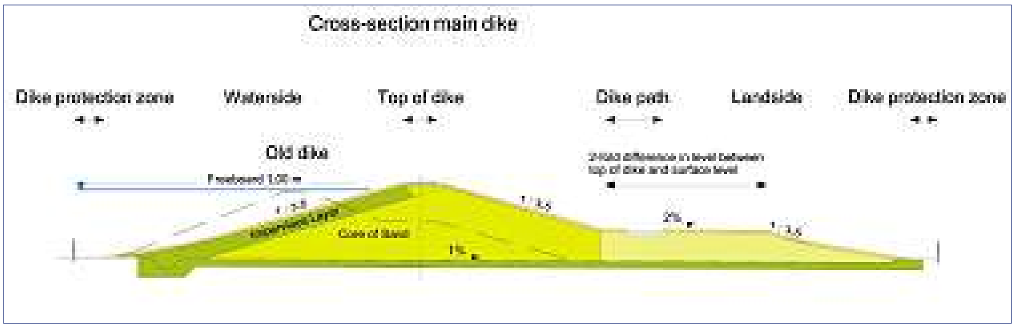


Figure 2.7.: Lohrwardt Polder: cross- section main dike

The dike paths, which are usually located on the landside of the dike shoulders ("*Auflastberme*"), are constructed for heavy traffic (SLW 60) with a paved width of 3.0 m and are equipped with bays for passing vehicles at distances of about 400 m. In practice, however, it turned out that dike paths would have to be built with a width of about 5.0 m if they are for agricultural purposes. This would provide sufficient space for large agricultural vehicles to be driven and would prevent pavement edges from being destroyed.
The stability for the safety of the dike is in line with DIN 19712. In practice, additional proof of stability must be provided. For example, the differences in permeability between the 3 zones (cohesive external packing, sandy supporting body, pebbly superimposed load filter) at dk > 100, (that means, for example, $k^{supporting\ body} > 100 \times k^{sealing}$), has to be proven at the submission of the bid.

For a construction services contract to be awarded, a delivery contract must be presented. This describes the quantitative and qualitative features of the dike construction materials offered and confirms that they meet the specifications. It also provides an assurance in the form of a product and quantity liability until completion of the construction work. The quality requirements are checked and ensured by means of a quality assurance plan monitored by the contractor's own employees as well as third party employees. The local construction supervision is performed by means of full-time monitoring of construction work by the engineer responsible for the supervision of construction. For reasons of quality assurance, this is in line with the conditions set out in the planning approval notice, and also ensures the coordination of the work and measurements taken of the movements of excavated volumes, etc.

If mowing is to be performed by machines, it is particularly important with a view to maintenance that the slopes are made suitable for machinery. This requires low-gradients and with as little fencing and fixed objects as possible. Parallel routes to the adjoining land will also have to be provided. In order to reduce and/or avoid costs for maintenance, agreements for use of the dike areas were concluded with farmers having land adjacent to Lohrwardt Polder. In this way, dike maintenance can be performed in accordance with the regulation for the protection of dikes.

Design of dikes in the Netherlands

The preliminary design of the Hondsbroeksche Pleij dike was traditional, i.e. a dike with clay core and wide shoulders (Figure 2.8). This typical design is used in the Netherlands at places were the subsoil is sand or gravel and the seepage is strong. It requires a great deal of clay and transport to get the materials to the site. The modification and optimisation of this traditional design has been undertaken using Germany experience, with a vertical screen (cut-off wall) constructed using the mixed-in-place technique.

The stability of the dike, the water pressure and the seepage are important elements taken into account in the dike design. The soil profile in the alignment of the new dike consists of a thin top layer of sandy clay. A layer of coarse sand of 25 m thickness lies below the top layer. This will result in a seepage flow at high river discharges. It is important to decrease the velocity of the seepage and to prevent piping. Piping can be prevented by increasing the seepage length to such an extent that the critical slope is not reached. In the Netherlands,

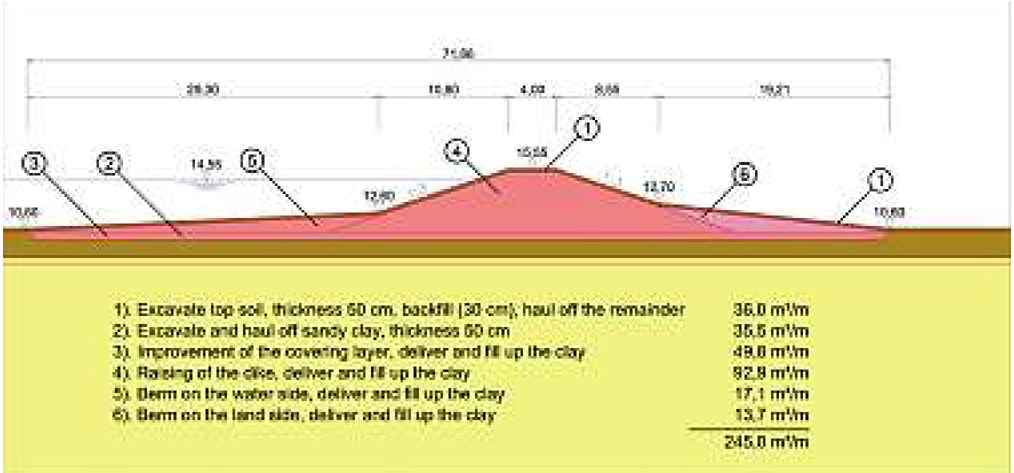


Figure 2.8: Traditional dike construction in the Netherlands

this is achieved by applying an impervious clay layer (shoulder) on the river side of the dike. The seepage water entrance area is further away from the dike. According to calculation methods used by Bligh and Sellmeijer, the horizontal seepage length for dikes in the Hondsbroeksche Pleij area must be approximately 70 m. The design water level is then 5 m above the soil surface.

The preliminary design of the dike included clay shoulders to prevent piping. The soil investigations in the project area showed that there was not enough clay to construct the dike according to the preliminary design. Clay would have had to be transported to the area from elsewhere, which would have been inconvenient for local inhabitants.

A dike consisting of sandy clay or sand was therefore preferable. The outside of the dike body consisted of an impervious clay layer of 1 m thickness. The permeability of the soil increases from the outside to the inside, so that seepage water cannot easily flow through the core of the dike. The inner shoulder was constructed using sandy soil, but it had to be thick enough to prevent surface erosion.

2.1.3 Innovations in the design of dikes in SDF pilot projects

The exchange of experience and the joint approaches in the pilot project planning phase resulted in different improvements in the design of the dikes. Innovations were planned and put into practice relating to the use of sealing walls and, consequently, the design of the dikes. This is closely connected to the use of mixed-in-place techniques, which were also innovative in SDF pilot projects.

Innovative use of mixed-in-place (MIP) techniques for sealing walls

In Germany, the sealing walls in some cases are being constructed using the in-situ mixing method (MIP). This method is executed as follows. A large hydraulic excavator is equipped with three soil augers. The soil augers are fitted next to one another. The shaft of the centre auger is hollow. A mixture of cement and bentonite is injected into the soil through the hollow shaft. The soil augers can be operated separately, they loosen the soil. The injected mixture of cement, bentonite and soil forms an earth/concrete wall. The drilling positions overlap so that a wall results. A wall thickness of 0.55 m may extend to a depth of 16 m.

This solution on the basis of the MIP principle has many advantages. The barrier may be installed without soil being excavated. Wide dike shoulders will not be necessary, which makes the management zone of the dike smaller. Less management input will be required and there will be less restrictions outside the management zone regarding the use. Little suitable clay for constructing the dike is available within the Hondsbroeksche Pleij project area and clay will need to be brought in from elsewhere. The vertical MIP solution requires much less clay, which is a significant saving for the entire dike design. According to a SDF feasibility study (ICON, 2005), the savings, based on a regular pre-tender estimate, amount to EUR 3.17 million for approximately 3 km of dike at Hondsbroeksche Pleij.

The width at the base of the dike became 50 meters instead of 70 meters. The number of transport movements and the amount of excavation work that will be required will also be significantly less, thus reducing the nuisance to local residents during the construction phase. This also has the advantage of considerably less inconvenience for local inhabitants. In addition, less space is needed for the dike alignment and the maintenance of the dike.

The MIP cut-off wall has certain disadvantages too. The quality and impermeability of horizontal dike shoulders are easy to test during and after construction, and faults can easily be corrected. In the case of a vertical cut-off wall, testing and repair are far more difficult. The quality of such a cut-off wall depends on careful construction and effective quality assurance. Determining the nature of the soil layers and the associated mixture proportions during construction is extremely important. The durability of the wall mixed in-situ may be less than the durability of an impervious clay shoulder on the riverside of the dike.

Another disadvantage is that downward extension of a vertical MIP barrier after construction is not possible (although a new barrier may be constructed alongside the existing one). However, these disadvantages count for little compared to the advantages. Based on experiences with in-situ mixed cut-off walls, it is estimated that the wall will last at least 50 years. This method might very well be suitable for the reinforcement of old dikes, so that landscape, nature and cultural values can be better preserved.

Innovative sealing wall construction to overcome seepage problems

Seepage problems may also be solved by the installation of impervious sealing walls (sheet piling). This is usually effected at dike sections where there is insufficient space to construct clay shoulders. Sheet piling is more expensive and is only applied in exceptional cases. As result of the satisfactory experiences and the increasing use of sealing walls in Germany, a feasibility study for an innovative way of installing a sealing wall in the new dike construction at the Hondsbroeksche Pleij project was detailed.

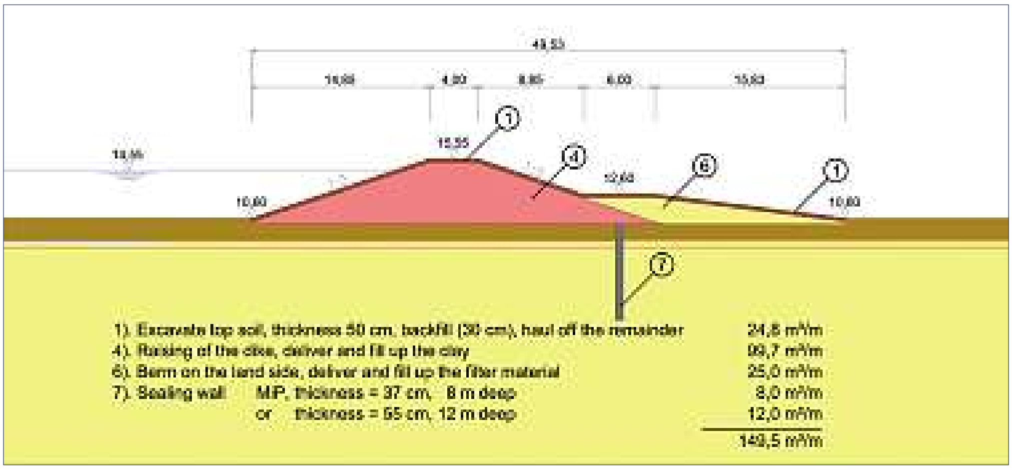


Figure 2.9: Alternative dike construction with sealing wall (Hondsbroeksche Pleij)

Figure 2.10: Dike construction (Hondsbroeksche Pleij, July 2008)

The feasibility study showed that the outside shoulder of the dike could be replaced entirely by a sealing wall up to a depth of 8 m. The sealing wall will be constructed on the landside of the dike (Figure 2.9). This innovative dike design was assessed and compared to a traditional dike design. The seepage flow beneath and through the dike was tested in a geo-hydrological model. The landside shoulder is vital for stability and can be constructed of sandy material. It is important that the dike foundation up to the sealing wall is made impervious with clay. The innovative design was tested according to the Dutch guidelines for dike construction (*Technische Adviescommissie voor de Waterkeringen/TAW-richtlijnen*). Tests showed that the design meets these guidelines. Finally, the cost of an in-situ mixed sealing wall is approximately EUR 30-35 per m², which is far cheaper than sheet pilings of steel. It was estimated that the in-situ mixing method would save approximately EUR 3 million for the Hondsbroeksche Pleij project.

Monitoring of the quality during construction of the mip wall

The German consultant of the feasibility study was awarded a contract by Rijkswaterstaat to perform the quality control for the earth retaining wall (cut-off wall). This cut-off wall was the first part of the construction of the relocated new dike of the Hondsbroeksche Pleij. The cut-off wall was completed in the second half of 2007. Site visits including meetings, consultations, quality reviews and the taking of samples have been held and carried out to check the quality of the installed cut-off wall.

Figure 2.11: Construction of the MIP cut-off wall

Figure 2.12: Excavated test section

Figure 2.13: Sample of the finished MIP wall

The quality controls were performed by random sampling. For this purpose, the performance of the work on the MIP wall was checked during each site visit and the ongoing dike construction measures were evaluated. For evaluation of the consistency of the MIP wall, a test section was selected at random and excavated when suspension was set. The quality presented no problems.

When checking the construction of the MIP retaining wall, the MIP injection chainages, as well as the depth data of the individual lamellas (actual values), were evaluated and compared to the rated values. The location of the individual MIP wall lamellas in the dike sections was represented graphically and the satisfactory overlapping of the individual lamellas was checked. Material samples were taken during every site visit to test the material aspects of the MIP wall. The 1-axial compressive strength (qu) as well as the water permeability coefficient was determined in the Institute for Soil and Rock Mechanics laboratory in Karlsruhe. All samples showed that the required values had been maintained.

Importance of hydrogeology for dike relocations (Kirschgartshausen, Germany)
As a basis for decision making, a geo-technical assessment for the dike relocation in Kirschgartshausen was carried out (including alternative alignments, Figure 2.14).

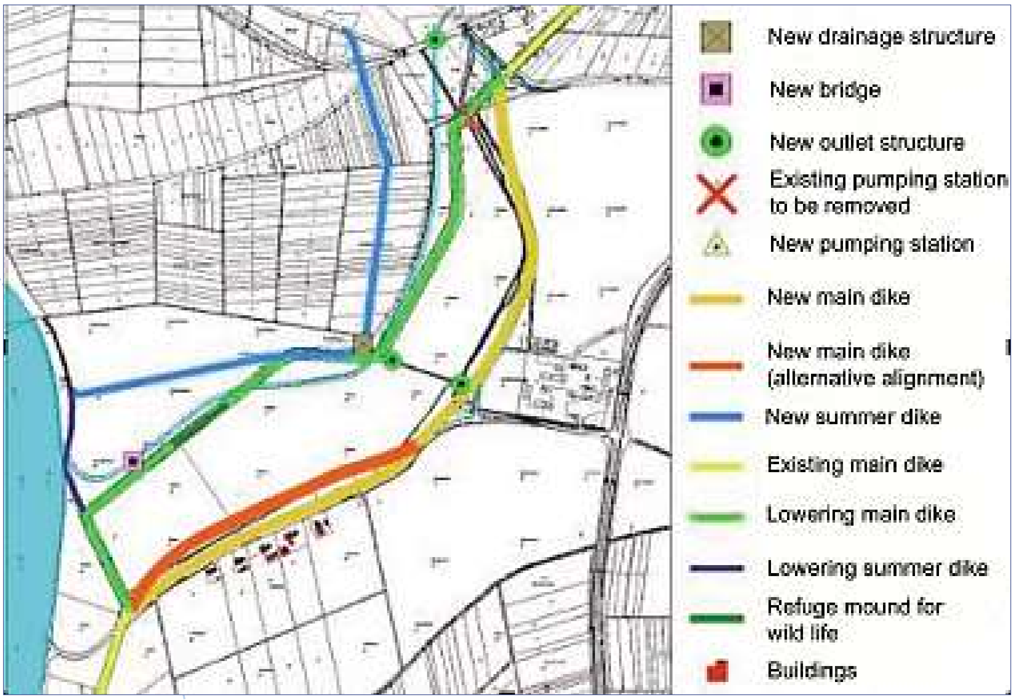


Figure 2.14: Alternative dike alignments in Kirschgartshausen

Figure 2.15: Sand craters in the hinterland of the Rhine winter dike close to Hördt, Germany

In the area of Kirschgartshausen, sub-erosion does occur along the River Rhine. One feature of the landscape that helps detect sub-erosion problems is the existence of sand craters (Figure 2.15). Sand craters can lead to a hydraulic short circuit, and they are very problematic when occurring on the landside dike shoulder.

Figure 2.16 shows a simplified cross-section of the area Kirschgartshausen with soil layers. The Holocene layers are clay and loam of 5 m thick. The lower layer is 10-15 m thick and is an intercalation of sands and gravel sands dating from the Holocene and Pleistocene era.

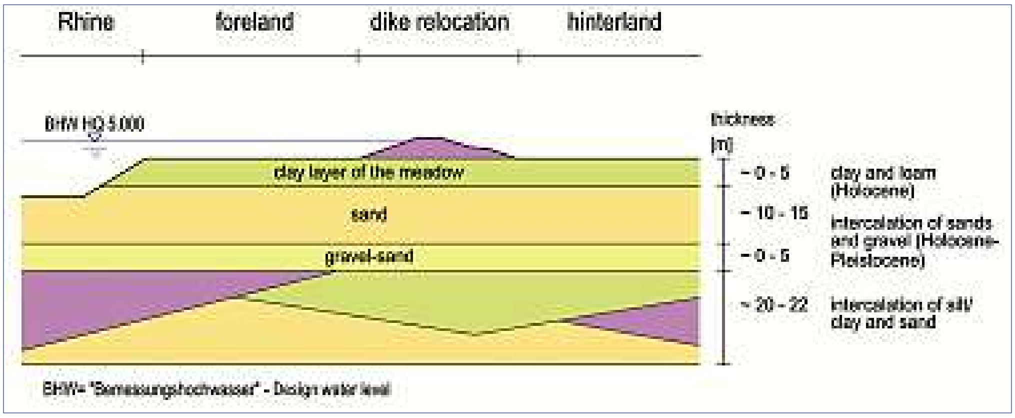


Figure 2.16: Soil layers in Kirschgartshausen

The intercalation of sands and gravel sands forms the aquifer. The grain size analyses of the sands have shown that they are well-sorted and could contain up to 15% of fine particles. The topsoil layer shows normal mechanical values for an almost non-permeable soil. But pumping tests in the area have resulted in higher permeability values than expected from the grain size analyses. The dike shoulder (*Berme*) should receive 20 to 30% of the rest water. Guarding against the distortion of the dike shoulder and the farmhouses is essential.

The dike shoulder can be protected by the use of an MIP wall (mixed-in-place), sheet piling, or synthetic building materials. The risk of a hydraulic short circuit must be prevented in any case. Consequently, the implementation depth and a proper design must be chosen. A very important aspect is to avoid closing the entire aquifer in full, because seepage would be dammed. In the case of dikes subjected to sub-erosion, they could be stabilised centrally and in certain cases object protection might be the best solution. Another possibility is to raise the dike shoulder and the agricultural fields. In the case of sheet piling of 4.5 m, the aquifer still has a thickness of 15 m. When a sheet piling is implemented to combat infiltration, sand craters may still occur but they will not be a threat to the stability of the dikes.

The dike shoulder will be raised with a non-permeable soil layer of 1.5 m thick. Digging by various animals reaches a maximum depth of approximately 70 cm. The remaining layer is a safe protection layer. On the water side, a road will be constructed to carry out management tasks, such as maintenance.

Lessons learned from the visit to the Söllingen-Greffern Polder

In 2005, a SDF Working Group visited the Söllingen-Greffern Polder at the invitation of the Karlsruhe Regional Administrative Authority (*Regierungspräsidium Karlsruhe*). The controlled retention area with retention volume of approximately 12 million m³ has now been completed. Of special importance for the SDF project was the discussion regarding experiences with the inlet and outlet works of this polder, as the implementation phase provides a great many pointers for the planning phase of the SDF projects.

Figure 2.17: Aerial photo of Söllingen-Greffern Polder

Figure 2.18.: The N inlet construction (Söllingen-Greffern Polder)

An engineering solution has been applied at the 'N' inlet work to provide ventilation of the water flow in the structure and to avoid under pressure. Under pressure would reduce the efficiency of the inlet structure and could cause dangerous vibrations.

In order to optimise the in and out flow areas hydraulically, model tests were performed in the hydraulic laboratory of the University of Karlsruhe. As water is constantly flowing through the Söllingen-Greffern Polder, a fish ladder has been integrated into the structure. Ecological flooding is performed on a regular basis with enough water being available at any time due to the difference in water levels (about 3 m) between the River Rhine and the Polder.

The Söllingen-Greffern Polder is located in the floodplains as a type of bypass with two dike sectors. This results in a clear separation from the river and ecological flooding can be performed more easily. This could be a model for the planned green rivers included in the Dutch programme Room for the River. The dikes in the Söllingen-Greffern area protected against seepage at exposed points by means of cut-off walls. For this purpose, the Dutch construction methods in the past favoured the formation of a wide dike basis. The German solution by means of a cut-off wall in accordance with the model of the Söllingen-Greffern Polder will be used for the first time in the Netherlands as part of the Hondsbroeksche Pleij SDF project.

The guidance system for transfer of data and control of the individual components of the Söllingen-Greffern Polder served as model for the Ingelheim Polder. The basic principle of the system from Baden-Württemberg was adopted and further developed, particularly in terms of the components' network techniques, integration of different data services as well as local monitoring of processes and operation. Further and more detailed information about the Söllingen-Greffern Polder can be found in Annex 3.

Box 2.3: Lessons learned from the visit to the Söllingen-Greffern Polder

2.1.4 Technical layout of inlet and outlet works

The layout of inlet and outlet works is of great importance for controlled polders. This is because the time and the level of flooding will be controlled by opening and closing these central structures in the retention area. In the Ingelheim, Lohrwardt and Hondsbroeksche Pleij SDF pilot projects, experience was gained and shared on this subject.

Design and function of inlet/outlet works at Ingelheim Polder
The polder has been dimensioned for a 200-year flood (HQ200) of the River Rhine. This corresponds to a water level of 84.29 m above mean sea level. All dikes and structures have been designed for that water level. It is intended to flood the Ingelheim Polder at 10-year flood events, but the flooding can also be performed shortly before the extreme water level is reached. The polder is filled and drained via the inlet and outlet structure (Figure 2.20), a fish-belly flap weir consisting of two sections, each 13 m wide. The structure has a design discharge of 213 m^3/s at a damming height of about 3.30 m above the intake threshold (200-year flood event).

The filling and draining operations were simulated with a two-dimensional mathematical model. The simulation showed that it would take about 8 hours until the interior of the polder is completely filled. Extreme drainage conditions occur, in particular, during and shortly after the opening of the flaps.

Figure 2.19: Inlet structure Ingelheim Polder, view from riverside.

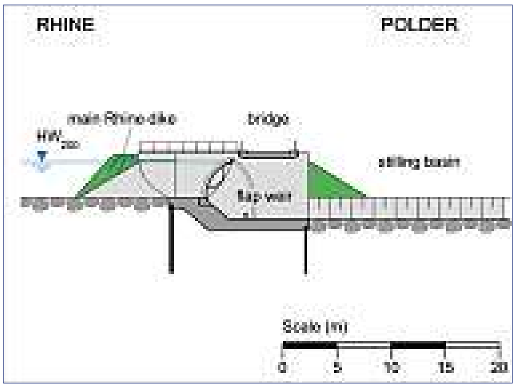


Figure 2.20: Cross-section of a weir flap

Measures for protecting the structure and the surrounding areas are required. The flap weir connects to a stilling basin 2.00 m below, which works as a whirlpool basin reducing the energy of the water flowing in and ensuring an equal distribution of the flow (Figure 2.20). The stilling basin was stabilised using heavy stones for water structures, classes IV and V (edge length up to 100 cm) and is enclosed with sheet piling, with a reinforced anchoring. The reinforced anchoring was necessary due to the heavy pressure applied during the construction phase. The sheet piling was installed into the tertiary clay to a depth of about 7 m. The clay layer serves as a barrier layer, preventing water from seeping out of the stilling basin, which ensures that the stilling basin remains filled with water. This is a positive effect from the nature protection point of view, as a new biotope for amphibians has now been developed.

The building on top of the centre column houses the switchgears for the inlet and outlet structure that are connected to the central control system via a control system. The hydraulic drives of the two flaps of the weir are located inside this column.

Prior to flooding of the polder, all culverts in the dikes are closed and the pumping station for inland drainage of the areas in the east is activated. For filling the polder, the fish-belly flaps are fully let down and remain open until the polder area has been drained in full once the flood wave has receded. The flap weirs are not closed as long as the polders are filled. In general, the retention of water in the polder in the case of receding flood waves on the Upper Rhine has not been provided for in polders in Rhineland-Palatinate. Moreover, such retention would not even be feasible due to the weir's construction, which can take pressure only from the front side.

Lessons learned from Kollerinsel Polder
The Kollerinsel Polder was the first controlled retention area in Rhineland-Palatinate ready for operation. It has a retention volume of approximately 6.1 million m³. Many experiences gained from the operation of this system were incorporated into the design of the Ingelheim Polder. In 2004, a SDF Working Group visited the Kollerinsel Polder. The inlet and outlet works are similar to the Ingelheim Polder. Both the hydraulic modelling and mode of operation were detailed by the University of Karlsruhe.
Fish-belly flaps were used for the first time at the Kollerinsel project. The design and ventilation of these flaps were adopted for the design of the inlet structure in the Ingelheim Polder. However, the Kollerinsel Polder is located on an uninhabited Rhine island, while the Ingelheim Polder is located in the densely populated Rhine plain between Mainz and Bingen. Consequently, the design of the Ingelheim Polder was further developed with respect to its readiness for operation and monitoring. The Ingelheim Polder is, for example, equipped with a guidance system for control and data transfer. The inlet and outlet works have a building housing the switchgear and a staircase for entrance into the inside of the middle weir column, which houses the weir flap drives.

Box 2.4: Lessons learned from the Kollerinsel Polder

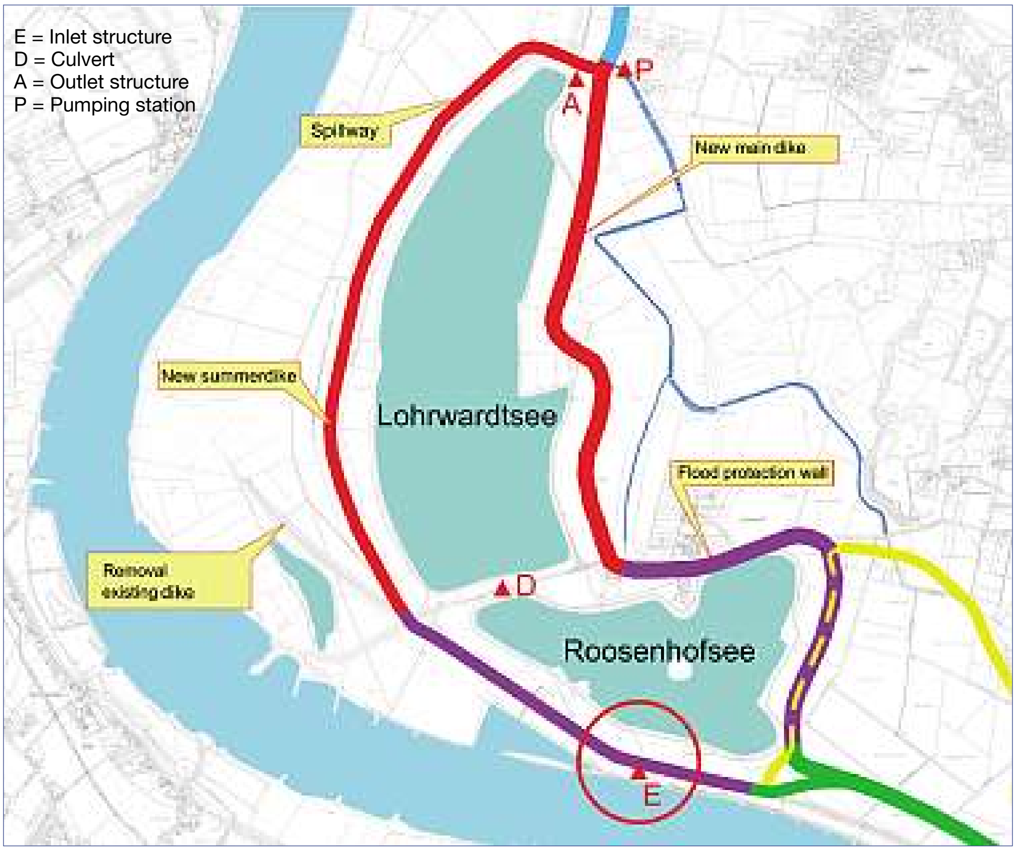


Figure 2.21: Position of the inlet structure within the Lohrwardt total dike relocation system and Lohrwardt summer polder

Inlet and outlet works in Lohrwardt Polder

The design of the inlet works was influenced by the selection of the location of the structure. From the hydraulic point of view as well as from the Water and Navigation police's point of view, the optimal location was determined for the structure. The structure was reviewed by the Duisberg Water and Navigation Authority. The development criteria resulting from the construction and operation of the structure, and the connection of the structure to the River Rhine meet the EAU geo-technical and static conditions.

All foundations of the structures in the Polder (pumping station, inlet, passage and outlet works, including outlet channel) were constructed as spread foundations. This was the result of the geo-technical investigations and foundation consultation, evaluation of the alternatives and the invitation for bids. The spread foundation, as well as a sheet piling foundation were included in the bidding procedure. The return walls of both the inlet and outlet areas are cantilevered retaining walls with a massive rear spur, as well as a smaller front spur for receiving the clinker layer and reducing the tension peaks at load transfer. The decisive factor for the final design of the cantilever retaining wall according to DIN 1054 and therefore for the dimensions is the stability, in particular, the resistance to tipping.

The construction of the structure close to the River Rhine (about 50 m, Figure 2.22 and 2.23) in the axis of the old dike required appropriate measures to protect the construction site. The foundation is independent of the water level by means of ensuring a buoyancy in accordance with the construction progress, including water management. The construction work had to be executed on schedule, taking into account the water level in the River Rhine. A dike was constructed on the water side to protect the construction site against floods. The materials from the old dike and additional high-quality materials were used to construct the dike.

Figure 2.22: Inlet structure, construction November 2006, close to the Rhine

The dimensioning of the structure was based on the minimum measures according to the Blue Guideline with a 3.0 m x 3.0 m in-situ box form for the free passageway. The inlet, passage, and outlet works, as well as the discharge channel, the return walls on the water and landsides constructed for the ecological flooding (Figure 2.24) were planned in the same way. This reduced the cost of preparing and implementing the formwork and reinforcement.

The inlet structure may be closed from the Rhine side as well as from the polder side. For redundancy reasons, a total of 7 seals were provided for on the Rhine side towards the polder side at the request of the State Environmental Agency: dike gate, slide valve, double bulkhead gate seal, double bulkhead gate seal and slide valve. Moreover, two additional bulkhead gate seals are provided for on the Rhine, as well as on the polder side for inspection purposes.

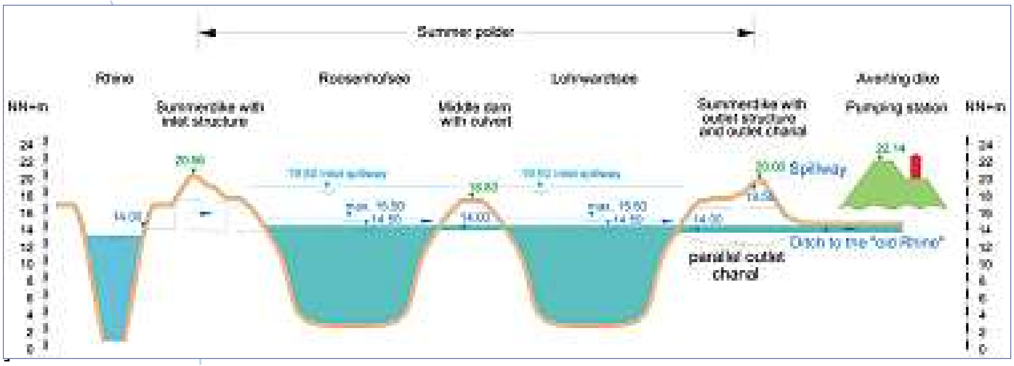


Figure 2.23: Inlet and outlet structures, cross-section of the summer polder

Figure 2.24: Inlet structure, return walls (left to right): formwork, concrete, clinker layer

The dimensions of the bulkhead gates (3.0 m x 3.0 m) are the same as for the Lohrwardt Polder pumping station so that they can be stored centrally inside the pumping station building and used wherever they are needed. Besides the fact that the equipment and control systems are identical to the pumping station's systems, the low-maintenance incorporation of the structure into the existing and/or future flood protection dike plays a very decisive role for the inlet structure (as well as for the outlet structure and the discharge channel) during both the design, the construction, and for the later maintenance. This incorporation had to be planned in such a way that the structure can remain tailed into the existing main dike until reconstruction of the main dike into a summer dike far from the Rhine has been completed (compare Figure 2.25).

Model tests for layout and dimension of inlet/outlet works

Inlet and outlet works are designed on the basis of either hydraulic calculations or hydraulic modelling. The SDF activities in pilot projects and the international exchange have shown that modelling serves as a better knowledge base for effective calculations and design. This was especially the case in Ingelheim and served as an example for Hondsbroeksche Pleij. The dimensions of the structure and the erosion protection measures on which the construction of the inlet and outlet structure is based should be determined by means of model tests. For the Ingelheim pilot project, these tests were carried out by the University of Karlsruhe (*Institut für Wasserbau und Kulturtechik, 1995*). Performance of hydraulic engineering model tests constitutes the best prerequisite for optimisation of the design planning. The results of the numerous tests performed in the *Theodor-Rehbock-Laboratorium* at the University of Karlsruhe prove that – depending on local conditions – using model tests is not only recommended, it may also be unavoidable.

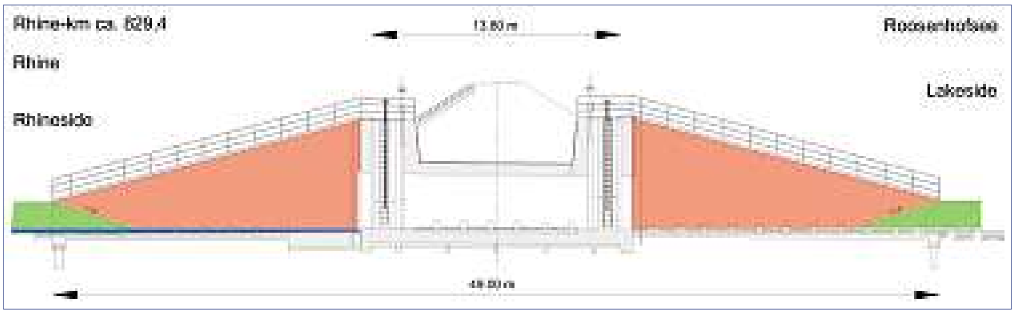


Figure 2.25: Inlet structure, cross section with illustration of temporary adaptation to the averting dike

Figure 2.26: Model of the weir flap

Figure 2.27: Model of the stilling basin

The different flow conditions at pressurised and free-surface flow, the influence of the main stream in the River Rhine on the flow coming onto the structures, the flow through the river and the discharge into the downstream water, as well as the problems with the erosion in the adjoining areas, were all considered in the model tests. For the tests a distinction was made between the hydraulic conditions in the intake area, in the structure itself and in the discharge area. In the intake area, the acceleration and detachment effects having an impact on the structure performance influence the discharge control.

Figure 2.28: Trial operation of the weir flap

Figure 2.29: Stilling basin Ingelheim Polder – ready for operation

Furthermore, questions regarding the safe operation of the gates, the influence of the aeration, as well as determining the current's force for dimensioning the gate were discussed. If scouring in the discharge area cannot be permitted, the procedures should be changed and pure technical solution approaches (traditional types of whirlpool basins with energy dissipaters) should be abandoned in favour of construction types that take ecological aspects into consideration (stilling basins).

Hydraulic simulation of the filling and draining processes

The hydraulic simulation of the filling and draining processes at Ingelheim Polder was performed with the help of Arc View GIS update 'FLOODAREA' for the following stipulated flood hydrographs:

Ecological flooding.
- Damming of the Polder: HQ5 wave 1984 controlled to HQ5.
- Damming of the Polder: HQ200 wave 1988 controlled to HQ5.
- Damming of the Polder: HQ200 wave 1988 controlled to HQ200.

Laser scan measurements performed within the scope of the study for the design area served as a basis for the computations. Measured geodetic points supplemented this model of the terrain, in particular near ditches and dikes. In addition, the planned structures (inlet and outlet works, structure for ecological flooding, west and east polder dike), the connection of the *Alte Sandlache* upstream, as well as the incorporation of the adjustment of the terrain *Im Mörs* into the terrain model were included in the hydraulic calculations.

The design of the outlet works at the Emscher Floodplains

The function of the Emscher floodplains is different to that of other SDF locations, as they are located at a Rhine tributary and not at the side of the river (like side channels or retention ponds), but the Emscher is completely dammed up during flood events.

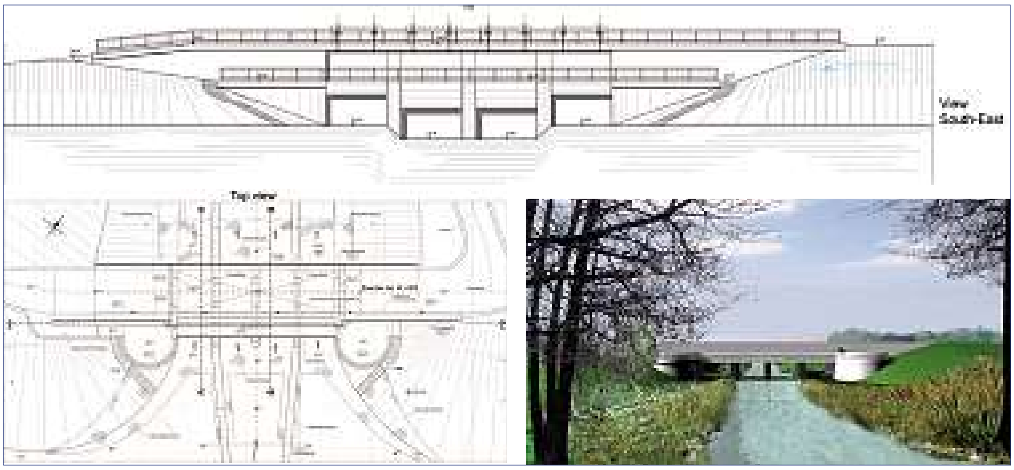


Figure 2.30: Design of the Emscher outlet building

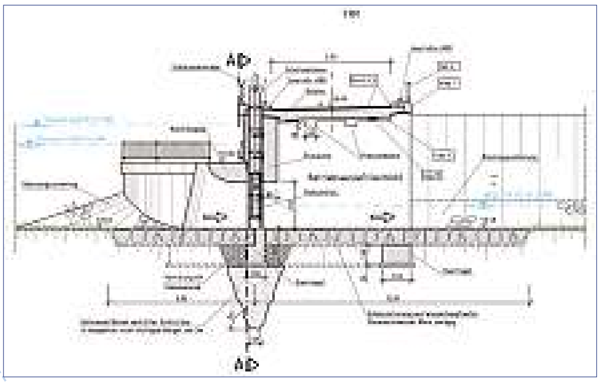


Figure 2.31: Cross section of outlet work in the Emscher retention area

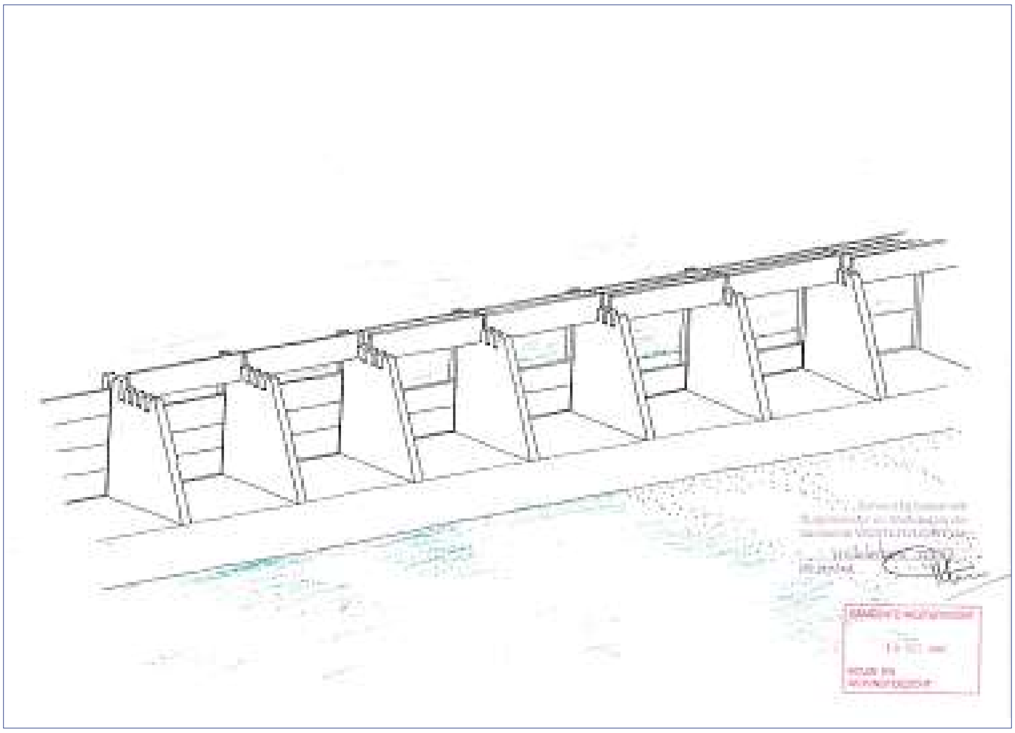
Figure 2.32: Design of the building

discharge downstream and dams up the water in the Emscher (coming from upstream) in order to store it.

At first, the outlet was planned more technically, with the idea of adding architectonic or design elements in a later phase. Due to the intensive public participation process in 2006, a public workshop was organised by the Emschergenossenschaft, particularly regarding the design aspects of the structure. The solution chosen by jury members was a more transparent bridge. Walls and maintenance buildings are constructed with bricks (instead of concrete) with an observation platform, stairs and gangplanks providing access to the surface of the flood basin.

The adjustable weir structure of Hondsbroeksche Pleij

The discharge distribution at a river bifurcation is largely determined by the geometry and hydraulic roughness of the river downstream of the bifurcation. The Dutch Rhine bifurcations are not equipped with bypasses and movable weirs, which are needed to manipulate discharge distributions.



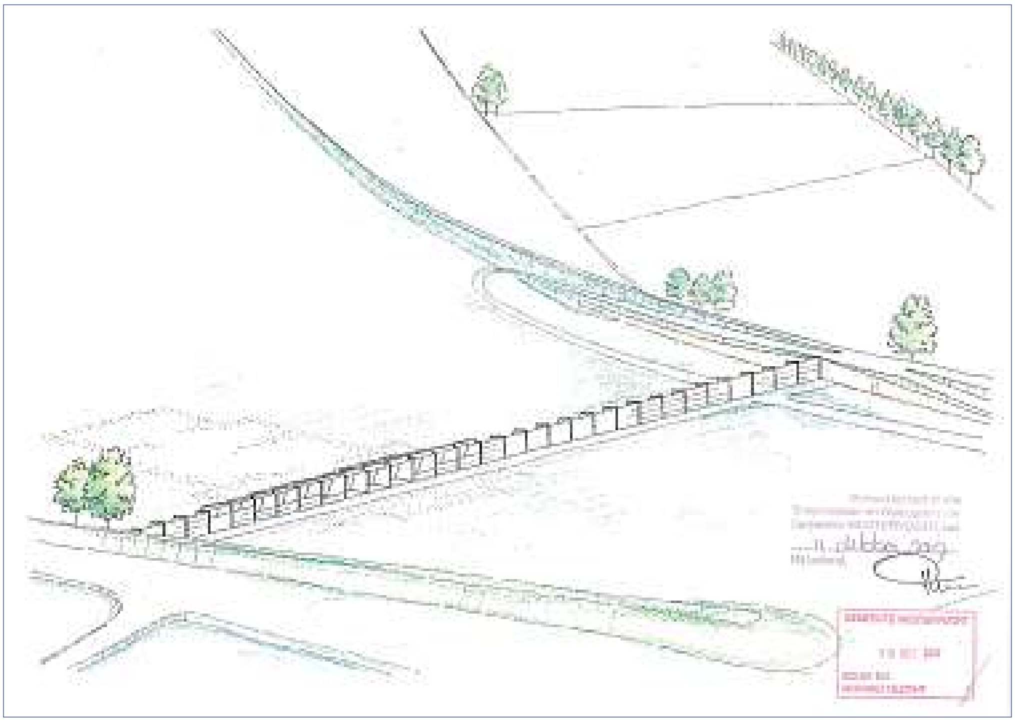


Figure 2.33: Hondsbroeksche Pleij adjustable weir structure

Figure 2.34: Construction of the adjustable weir structure, Hondsbroeksche Pleij, July 2008

An adjustable weir has been constructed at the inlet of the flood channel. The structure will consist of vertical pillars at a distance of 5.0 m. Each opening will be filled with 4 stop-logs if the weir should be closed. The stop-logs per section can be stored on top of the pillars. This makes it possible to adjust the opening of the weir easily with a small crane. After completion of the project, the water levels during high floods can be lowered by approximately 0.2 m and the discharge distribution over the Lower Rhine and IJssel branches can controlled to some extent (Figure 2.35).

Figure 2.35: Layout of the Hondsbroeksche Pleij project

During floods, the dikes along the upstream part of the River IJssel present a hydraulic bottleneck. Along this stretch the flood levels should be lowered (Figure 2.36.). To this end, a new dike will be constructed further inland to create more space for the river. The flood channel between the old and new dike will discharge extra water into the River IJssel.

Figure 2.36: Present situation at Hondsbroeksche Pleij

Figure 2.37: Future situation at Hondsbroeksche Pleij

2.1.5 Solving seepage problems and landside drainage

Seepage is the slow flow of water through a dike or structure and is one of the critical problems for the construction of retention areas, and the acceptance by the public. Seepage can:

- Have dangerous effects on foundations.
- Raise opposition to polders due to the fear of house owners behind new dikes of being affected by rising groundwater levels.

The occurrence of seepage depends on several factors, including permeability of the soil and the pressure gradient. Permeability can vary over a wide range, depending on soil structure and composition. When the seepage velocity is great enough, erosion can occur.

Within SDF, three alternative methods were used to deal with seepage problems:

a) Installation of wells and pumping stations in connection with the construction of a retention area to lower the groundwater level and therefore to avoid seepage rising close to or above ground level.
b) Construction of ditches and pumping stations to drain seepage water out of certain areas.
c) No preventive measures, but installation of monitoring systems and an agreement to solve problems if they occur.

Combinations of a, b and c are of course possible.
In Lohrwardt, the seepage problem has historical reasons. It was therefore agreed with stakeholders to install a monitoring system. It was further agreed that if any negative impacts arise, design improvements would be made. No groundwater modelling was effected. This was sufficient to reach an agreement with the stakeholders.
In Kirschgartshausen, seepage is a problem of great importance for the planning phase. The groundwater model was installed and run for estimates. This changed the design and the alignment of the new dike (further way from existing buildings).
In Ingelheim, seepage also plays an important role. A groundwater model was set up. It was urgently necessary to demonstrate to all stakeholders in presentations how the model works and what the effects would be like. In the Netherlands, in particular, considering land drainage is extremely important. When drained areas of land are below sea level, the water must be pumped into channels that finally drain into the sea. In these areas, pumping stations are installed. In the Hondsbroeksche Pleij pilot project, a drainage system will be installed in combination with an agreement on compensation in case of seepage damage.
For Fortmond, a hydrological model was set up, which showed the effects of the side channel behind the dikes. The special approach here is that potential damage was calculated for the construction phase and for flood events (damage to agriculture land and buildings). It was agreed that funds will be made available to compensate any damage.

In the following chapter the situation and solutions at Kirschgartshausen Polder, Ingelheim, Hondsbroeksche Pleij and Heesseltsche Uiterwaarden will be described.

Seepage and groundwater at Kirschgartshausen

As a result of the dike relocation, the River Rhine comes very close to farms and the estate during flooding. There were few problems with high groundwater levels before the dike relocation. A groundwater model was established prior to the planning of the dike relocation. This model showed that the groundwater levels would rise to such an extent during flooding that basements of houses near the relocated dike and the agricultural areas would be water logged unless measures were adopted. In order to limit the rise of the groundwater level, the following preventative measures will be adopted:

- Improving the agricultural drainage system.
- In the space created between the new dike alignment and the *Hoher Weg*, a trench of about

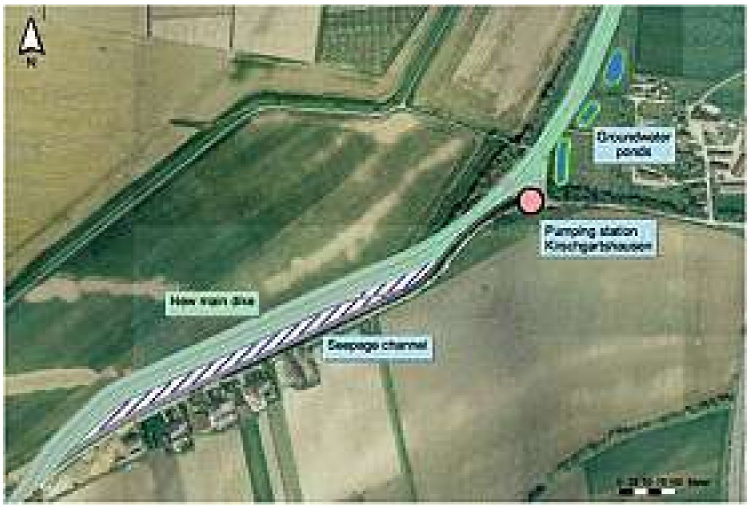


Figure 2.38: Adjustment measures for groundwater preservation

600 m length will be constructed including an infiltration body, which is connected to the aquifer through a highly permeable dry packing. The groundwater rising behind the dike will be collected in the trench and drained off into the pumping station near the estate.

- Creating three groundwater ponds at Kirschgartshausen estate. The ponds are connected to the aquifer through a highly permeable dry packing to be able to take up groundwater in case of a flood event and to feed it to the pumping station near the estate.
- Constructing two pumping stations.

Figure 2.38 shows an overview of the preventative measures for the protection of farms and the estate.

The extract from the groundwater model in Figure 2.39 shows the positive effect of the drainage system. The groundwater flows out into the trench and drainage system as well as into the ponds and then flows towards the pumping station by gravity flow. The operation of the pumps will guarantee a continuous pre-flood level during high water periods.
In this way, the rise of the groundwater level in the case of a flood event can be kept to a harmless level within the area (in the area of build-up buildings with basements the rise does not exceed approx. 20 cms).
It was originally planned to control the groundwater levels in the building area by pumped wells. The geologic subsoil conditions described in chapter 2.1.3 did not allow for an economic implementation of that plan, as four wells with a depth of up to 20 m and a diameter of more than a meter would have been required for that purpose. Furthermore,

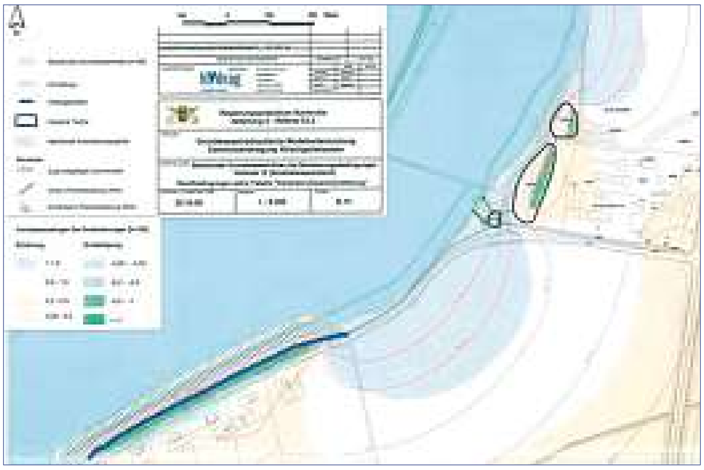


Figure 2.39: Positive effect of the adjustment measures for preservation of the groundwater

Figure 2.40: Drainage system location (hatched in blue)

damage to the buildings would probably have to be taken into account as a result of subsidence. The pumping of the groundwater will lower the water level near the wells. The trench, the drainage system and the ponds, which cover a large area, do not require a great deal of adjustment near the houses in order to limit the rise of groundwater. Consequently, damage to buildings due to subsidence can be prevented. Figure 2.40 shows the location of the trench and drainage system between the new dike and the housing area.

Figure 2.41 shows a representative cross-section of the system to control the groundwater level. If the groundwater level rises over the level of the horizontal drainage pipes, the surplus groundwater will flow towards the pumping station. Due to the large outlet area, the efficiency is guaranteed at comparably slight differences in water levels between the groundwater and the drainage system.

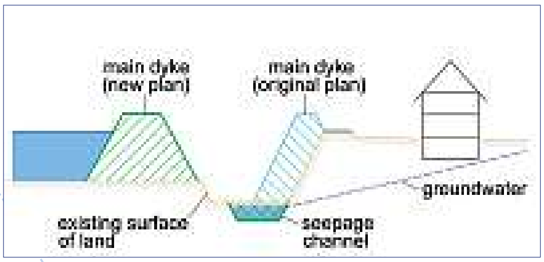


Figure 2.41: Cross-section of the drainage system

Figure 2.42 shows the location of the three ponds. The groundwater is controlled according to the same principle applied in the case of the trench and drainage system. Even in the case of slight differences between the groundwater level and the pond's water level, which has been lowered via the pumping station, rising groundwater flows out into the pond through the large bed area. The existing subsoil conditions and the availability of an area large enough to construct ponds made it possible to use this solution. In the northern part of the new dike alignment, this solution could not be applied.

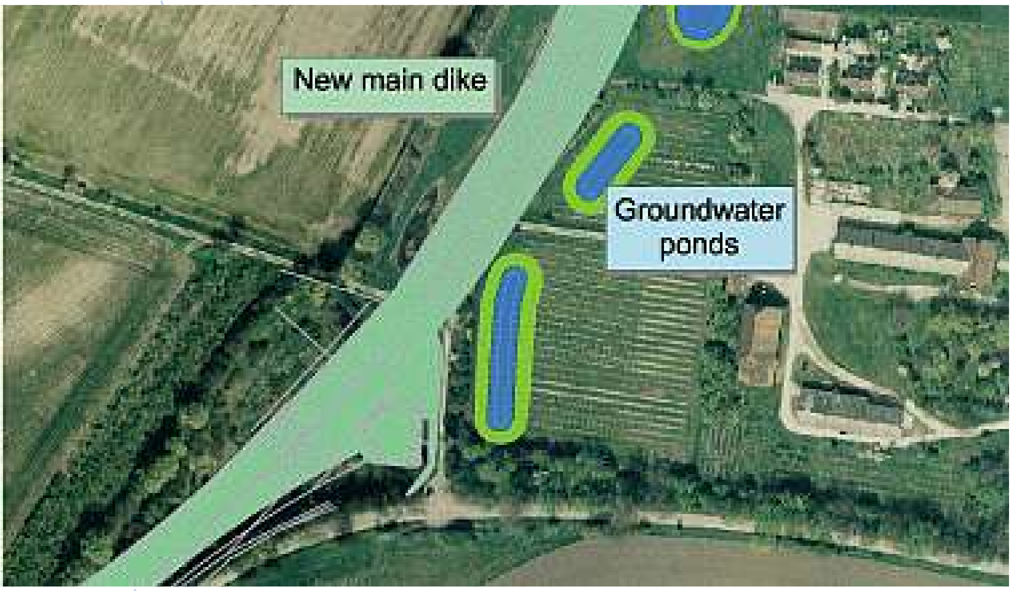


Figure 2.42: Location of the groundwater ponds

Solution of seepage problems and groundwater effects in Ingelheim Polder

The effects of the Ingelheim Polder on the groundwater conditions were evaluated by means of a groundwater model. The groundwater flow in the quaternary sands and gravel layers in the retention area is naturally oriented towards the River Rhine. The River Rhine also influences the fluctuations in the groundwater level in the investigated area; in some areas drinking water wells also influence the groundwater conditions.

The numeric groundwater model simulated the existing groundwater conditions. The expected effects of the flooding of Ingelheim Polder on the groundwater levels were mathematically simulated. The calculations were based on the conditions prevailing during the 5 and 200-year floods (HQ5 and HQ200). The calculations showed that the retention area would influence the groundwater levels in the investigated area in the case of a flood.

The groundwater model forecast an increase of seepage and a temporary increase in the pressure by approximately 25 to 50 cm in the planned industrial area Ingelheim Nord as a result of the flooding. A row of 5 wells was constructed as a compensatory measure to be operated during flooding. Additional preventative measures such as ditches east of the polder, a well for lowering the water level at the Badweg water works and the creation of open water management at IKA lake were introduced on the basis of the findings of the groundwater model.

After completion of the construction work on the row of wells, new model calculations were performed based on the collected aquifer data and the results of pumping tests in order to verify the operation regulation. As a result, the groundwater lowering measures can be halted after a flooding as soon as the retention area has been emptied. Lag times are not required.

Row of wells and pumps for groundwater protection

The polder flooding effects and the consequences for the surrounding areas due to water under pressure have to be computed for large areas in advance by means of a groundwater model. This was effected in the case of Ingelheim Polder by simulating a flow hydrograph comprising of five years, which includes the actual occurrences and a hydrograph extrapolated to the 200-year flood. The model takes the geologic, hydro-geologic and topographic conditions into consideration and also incorporates the processes of the new formation of groundwater as well as water flowing in from adjoining zones. As a result of the simulation findings, it was decided to implement the following preventative measures.

In order to avoid an additional harmful rise of the groundwater level resulting from flooding of the polder and to protect the district of Frei-Weinheim, five wells were sunk along the west-side Selz dike for reducing the groundwater level. Due to the small aquifer thickness (between three and five meters), the wells have a drilling diameter of 2,300 mm and a filter pipe diameter of 1,500 mm at a depth of a maximum of only 12 m. The maximum discharge of well no. 1 is 55 l/s. Wells nos. 2 to 5 each discharge 25 l/s.

Figure 2.43: Well No. 3 with building for switchgears

Figure 2.44: View into the well chamber

The row of wells is put into operation during the flooding of the polder and automatically controls the groundwater level. The pumping capacity is more than actually required. Although only one pump is required to achieve the required lowering of the groundwater level, a second pump is kept on stand-by. This ensures a maximum operating safety. The groundwater flow from the Frei-Weinheim row of wells is discharged directly into the Selz, a small tributary of the Rhine, and into the Rhine by means of a pressure line. A network of groundwater measuring points has been installed to monitor the lowering the groundwater level.

Following the drainage of the polder, the pumps must still be kept in operation for some time. The exact time will be determined on the basis of additional computations depending on the flood event.

At the *Badweg* water works building, which is a historic monument that must be preserved, another well with an output of 25 l/s was sunk to protect the structure against uplifting.

Figure 2.45: Well filter pipe DN 1500 (at the *Badweg* water works)

Figure 2.46: IKA lake

A pump with an output of 20 l/s has been installed at IKA lake to maintain the water level in the lake and therefore prevent damage to structures. The pump was installed underneath the landing stage protruding into the lake. The stage is hinged and is constantly kept at the IKA lake level by means of a floating body. The protective measures are put into operation only during flooding of the polder. All wells, pumps and groundwater measuring points are incorporated into the control system so that their operation can be monitored from the control room.

Landside drainage and pumping stations at Ingelheim Polder

At high water in the River Rhine, the agricultural areas east of the polder are subject not only to an additional amount of rain water, but also increased seepage due to the flooding of the polder. The discharge from the area is guaranteed by means of two culverts (Figure 2.48). The natural discharge is no longer possible during the flooding of the polder since the culverts are closed. In such a case, the pumping station (Figure 2.47), mainly located underground and equipped with submersible pumps, starts operating.

Figure 2.47: Underground portion of the pumping station with submersible pumps

Figure 2.48: Culvert Dike East under construction with incorporated sheet pile walls

The pumping station consists of a feeding area with sand/rubble trap and a rack, a pump sump with technical equipment and pipes, as well as a structure above ground for housing the switchgears. The pump sump houses three submersible centrifugal pumps with a discharge capacity of 20 l/s, 90 l/s and 285 l/s. Directly next to them space is reserved for another pump, with a discharge capacity of 285 l/s. Above the pumps there are inspection openings with lockable covers. The pump mains on the pressure side are equipped with gate and check valves and tie into a joint pressure pipe. The pressure pipe ends in the culvert's structure housing the valves, and the pumped water flows into the polder from that point. As soon as the culverts in the polder dike east are closed, the pumping station will switch to automatic operation and the pumps will be put into operation depending on the filling level of the pump sump.

Box 2.5: Landside drainage and pumping stations at Ingelheim Polder

Measures to combat seepage problems at Lohrwardt Polder

Seepage resulting from a summer polder is a historical problem at Lohrwardt Polder. A summer polder already existed in the planning area up until about 1960; the new dike close to the Rhine lies in the path of the former summer dike (compare Figure 2.49).

Agriculture uses and other land uses are affected by seepage. In connection with the purchase of land, interdisciplinary investigations and planning of alternatives for the new structures were effected, including impact on groundwater, surface and seepage water, as well as inland drainage measures.

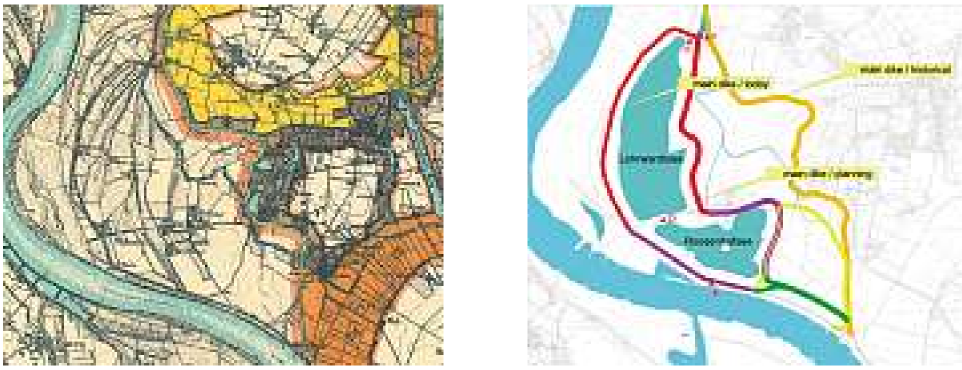


Figure 2.49: Lohrwardt inland drainage, left: main dike around 1900; right: main dike, today, planning and historically

Consequently, solutions had to be found during the planning process for inland drainage and ecological flooding in view of the above technical, ecological, as well as economical aspects.

The following aspects and basics were considered:

- The historic conditions (e.g. distance between soil surface and the groundwater level before and after the construction of the main dike in 1960).
- Inclusion of the local situation (e.g. lack of slope packing Lohrwardt lake).
- Location and hydraulic efficiency of the existing drainage ditches (Figure 2.50).
- Property-law matters (availability of the areas and inclination of areas for water logging, etc.).
- Marginal geo-technical and static conditions.
- Investment/maintenance costs and benefits.
- Ecological aspects.

Figure 2.50: Lohrwardt inland drainage, existing drainage ditches, situation 2006

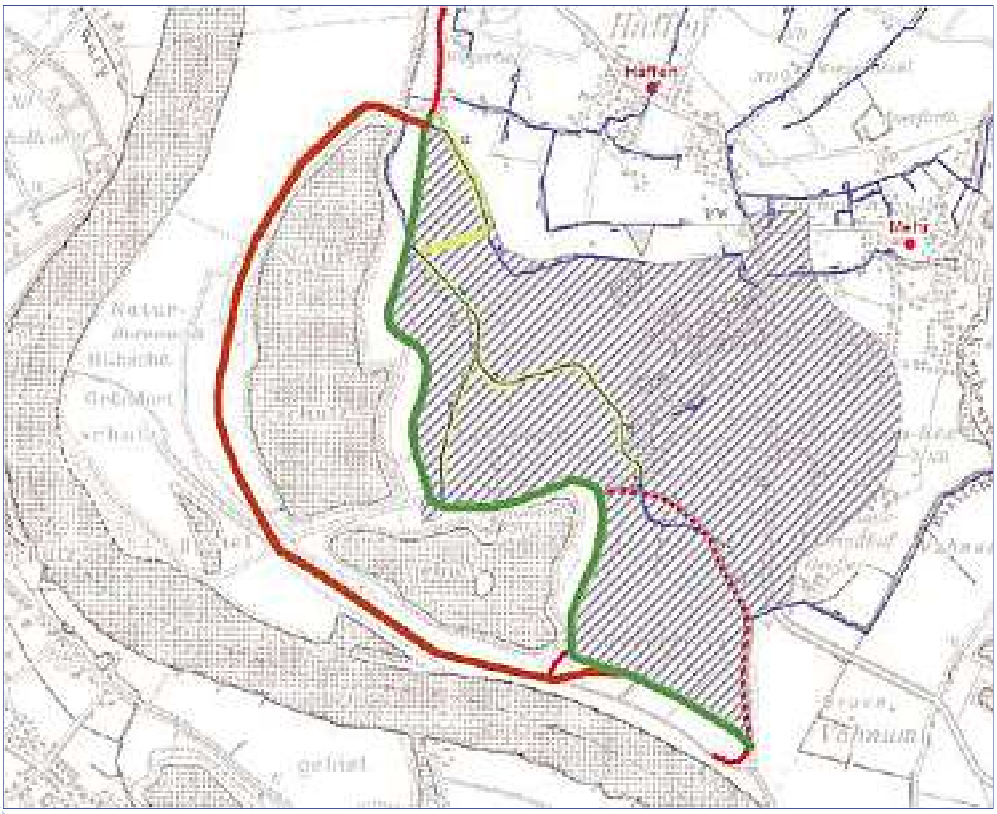


Figure 2.51: Lohrwardt inland drainage, reactivation and new construction (marked in yellow)

Due to the above evaluations regarding the operation of the polder and the considerations relating to the flooding of low-lying agricultural areas, various measures for securing hydraulic evidence were performed. These included precautionary measures, such as water level measurements in the drainage ditches and standing waters, establishment of groundwater measuring points and incorporation into the process-control system of the polder, as well as sealing of the slope of the Lohrwardt Lake, together with the creation and strengthening of the inland drainage and the construction of the pumping station (with regard to the water system, compare Figure 2.51).

The evaluation of the water levels at the groundwater measuring points of the State of North Rhine-Westphalia (NRW) close to water bodies (nos. 080200059, 080200047, see Figure 2.52) for 1940 to 2002 shows the effect of relocation of the main dike to today's alignment close to the Rhine. The present main dike was constructed around the mid-1960s. Since then, the groundwater levels have been about 0.5 m lower than prior to the dike relocation of the 1960s.

As a result of the construction and/or operation of Lohrwardt Polder, it must be assumed that groundwater levels will again increase to the levels that existed before 1960.

The Lohrwardt Polder pumping station was constructed in 2005/2006 in order to:

- Preserve the water management status quo.
- Avoid negative impacts during flooding of the polder up to design level (BHW).
- To improve the drainage situation at the Haffen sewage plant.

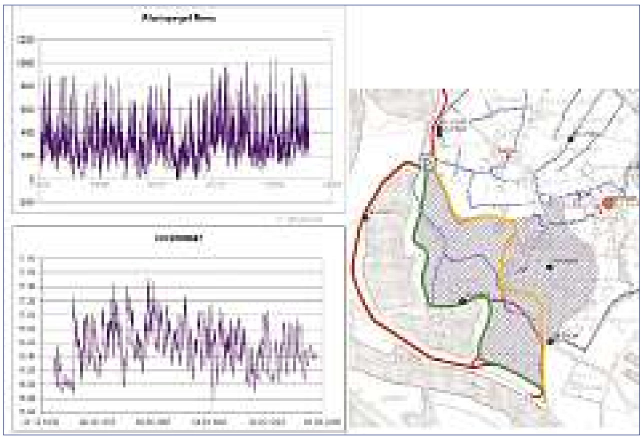


Figure 2.52: Hydrograph of groundwater observation points 080200047 from 1939 to 2006, Rhine observation Rees and position of groundwater observation points (in orange: 080200047)

The securing of evidence at interventions in the groundwater balance of vegetated locations was performed on the basis of the corresponding DVWK leaflet.

In the course of the planning of the new drainage ditch and/or preparing of the maintenance plan for the rehabilitation of the inland drainage, the DVWK leaflet methods and ecological effects of the water maintenance by means of machinery and the criteria of the Blue Guideline of the MUNLV for nature-oriented development and maintenance of running waters in NRW were considered.

The maintenance of the inland drainage, in particular, is to be performed by machinery for economic reasons. Therefore, special emphasis was placed on:

- A one-sided shading with trees and bushes of the drainage ditch, adapted to the location.
- The purchase of a maintenance strip with a width of 5.0 m on both sides of drainage ditch for easy maintenance.
- The reduction of diffuse deposits in the water, e.g. from agriculture.

The maintenance strips are taken care of by local farmers, while avoiding fertilisers and preserving plants. To remove up-keep costs for the maintenance strips, agreements were reached with farmers regarding use of the area, i.e. the strips may be used in accordance with the principles of the shore shoulders programme.

Lohrwardt Polder pumping station
In principle, the above comments regarding the inlet structure apply here too.
The capacity of the pumping station was based on:

- Discharge from the catchment area.
- Seepage water quantity assumed in accordance with values experienced per km of dike: 50 l/s.
- Seepage water quantity assumed in accordance with values experienced: 50% of the seepage quantity.
- Approved discharge from the Haffen sewage plant.

The system was designed for two pumps with 1.5 redundancy factor. If one pump fails, the pumping capacity is reduced to 75% of the designed discharge capacity of the pumping station. To cope with such a situation during a longer pumping period, an additional flange connection is available to connect an efficient external pump to the existing delivery pipe DN 1000.

Figure 2.53: Lohrwardt Polder pumping station, completion ceremony April 2006

Figure 2.54: Lohrwardt Polder pumping station, formwork November 2005 and reinforcement passage June 2005

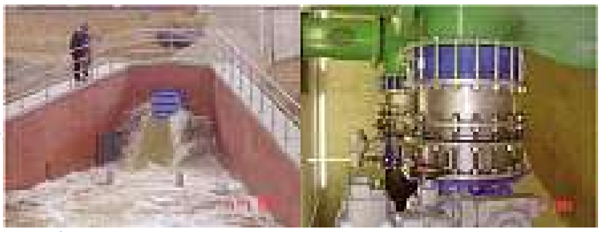


Figure 2.55: Lohrwardt Polder pumping station, trial operation June 2006 and pipe-basement June 2006

In order to protect the pumps against bulky course contamination and flotsam of any kind that could be brought up through the Bislicher Ley, an automatic portal grabber rake, which is incorporated into the technical process control system, has been installed in front of the pumping chambers (compare Figure 2.53).

The Lohrwardt Polder pumping station, as well as the inlet and outlet structure, is supplied with electrical power from the 10 kV network of the responsible energy supply company (EVU).

The required power is made available via a 10 kV medium voltage cable loop into a transfer station owned by the pumping station operator. It was contractually arranged between the EVU and the *Deichschau Haffen-Mehr* that there would be no costs for making the electrical system available; only the actual energy consumption is charged. A supply option via a mobile emergency power unit is provided for to ensure the energy supply in case of regular power supply failure. The mobile emergency power unit can be placed next to the pumping works and can supply the system with 100% of the electrical energy via a peripheral housing, if required.

Dealing with seepage in the case of Hondsbroeksche Pleij

Seepage is a very big problem in the Hondsbroeksche Pleij area. The pumping station will have a capacity of 160 l/s.

Relocating the Hondsbroeksche Pleij dike towards the inhabited area will increase the pressure of seepage water during high river water levels. This means that the groundwater level in the centre of the village of Westervoort may be higher when the water level in the river is high, leading to problems with damp in houses. In fact, there are already problems with seepage in Westervoort. Effective measures are therefore needed to compensate for the expected rise in groundwater level. The problem is to find effective and sustainable methods at minimum cost and with minimum disruption to the surrounding area. Extending watercourses or installing extra drainage facilities in the existing urban area is difficult. Westervoort is heavily built up and there is no room for extra drainage or larger water courses. Taking appropriate measures at some distance from Westervoort would be less effective and would generally require greater pumping capacity. Overall, the seepage problem when a dike is relocated depends on the type of land use and the level of the land on the landside of the dike. It is useful to share experiences in this regard.

Exemplary solution: seepage ditch with pumping station

A decision has been taken that no measures to reduce the future seepage pressure in Westervoort due to relocation of the dike should be carried out directly in the residential area. There is not enough space and the nuisance caused to local residents would be too great. Outside the old Rhine dike in the Pleij polder, there is an entirely silted up former channel of the River IJssel. This still includes an intensively cultivated drainage ditch. If the former channel is excavated, it can act as an extremely effective seepage ditch. Figure 2.56 shows the location of this seepage ditch. The stratification of the subsoil and its relief are such that the former river channel can effectively drain the surrounding area. In addition, this would improve the natural and landscape features of the area. Until 1816, the former channel marked the political boundary between Prussia and the Netherlands. Excavating it would add heritage elements to the landscape. All in all, this would be a good solution providing high special quality.

Figure 2.56: Location of the seepage ditch

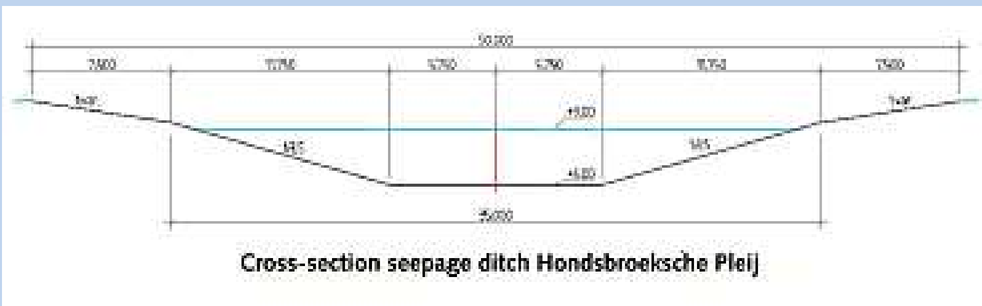


Figure 2.57: Hondsbroeksche Pleij seepage ditch

Box 2.6: Exemplary solution: seepage ditch with pumping station

Figure 2.58: Hondsbroeksche Pleij seepage ditch construction

The water level in the seepage ditch can be controlled by means of a new pumping station. The extra groundwater pressure in the Westervoort residential area will need to be compensated in full.

Groundwater levels have been recorded over a long period using continuously registering monitoring wells. On the basis of this monitoring and extensive soil investigation, it has been possible to construct a precisely calibrated geo-hydrological calculation model. Investigation had shown that when the representative high-water discharge level is reached, the pumping station will need to pump out a minimum of approximately 5,000 m^3/day in order to compensate for the negative effects of relocating the dike. There will still be a local rise of the groundwater level of a few centimetres in some places. If absolutely no rise would be allowed and if all uncertainty regarding effectiveness must be excluded, then the capacity will need to be some three times higher. In many places, the seepage pressure would then be even lower. There are already problems with seepage in Westervoort when the water level is high. A reliable capacity of 15,000 m^3/day has therefore been decided on, and will be achieved by installing two pumps, each with a capacity of 15,000 m^3/day. The investment required for this extra capacity is very low but the positive effect on Westervoort will be high. Compared to normal pumping stations, the capacity is only very small. There will be sufficient capacity to control the water level even if there is a malfunction in one of the two pumps when the water level is high. Energy consumption can be reduced by running the pumps at lower power and only at intervals.

Facing seepage problems in Fortmond

Consideration must be given to important effects of new side channels on hydrology in and outside floodplains. During several information meetings, inhabitants and farmers of the Fortmond area and surroundings discussed the effects of side channels on the groundwater system. There were three main topics:

- The effects on agricultural use (decrease of yield).
- The effects on buildings and houses (subsidence).
- The effects on cellars (flooding of cellars).

A Dutch engineering company carried out an investigation on the groundwater effects and constructed a hydrological model. This model formed the basis of a response to all questions about seepage and subsidence:

- before excavation;
- during excavation;
- after excavation.

Effects on the groundwater system were determined as follows.

By excavating side channels, the basis of the drainage system comes closer to the dike. Before excavating, the river was the main drainage system. After excavating, the side channels also have a drainage function.

In times of low water levels, extra water will drain to the side channels. The groundwater level becomes lower after implementation of the plan. Most effects are expected between the dikes (winter bed) and moderate effects on the landside of the dikes.

In times of high water levels, there are two effects. First during times of high water, the increase of the groundwater level of the area between the dikes increases by 0.25 m. On the landside, the effects are rather small. A second effect can be seen directly after high water. The groundwater level lowers faster than before the implementation of the plan. The main reason is that the level of the river increases faster than the groundwater level. The side channels provide extra drainage capacity.

Measures to protect agriculture were developed. In some small areas, an increase of yield is expected due to the lowering of the groundwater level. In cases where farmers have a demonstrable loss of yield after the side channel construction, a budget is reserved for compensation.

There are no major effects expected from an increase in groundwater level. To monitor the groundwater system, a monitoring network will be built. About 40 groundwater observation wells will be installed. Measures had to be developed to protect about 50 buildings in three areas (as well between the dikes as landside) that might face damage due to subsidence of the subsoil. The risk results from subsidence of up to more than 2 cm, or 1 cm difference between the front and rear of a building. About 10 buildings may be inconvenienced by an increase in groundwater level. The calculation is made according to a worst case scenario. To monitor the buildings at risk, a technical report has been made, including a measurement. If owners report damages to their buildings, an inventory of the damage can be drawn up and compensation can be paid.

Seepage and the effect of the groundwater at Heesseltsche Uiterwaarden

The inhabitants of Heesselt are quite worried about the risks of increasing seepage of water under the dikes. Seepage problems are already occurring at the north side of the dike under high water circumstances. People fear that this will increase due to digging. In the study, the effects on groundwater will be investigated. If there are significant changes, the possibilities will be listed. If possible, the plan will be adjusted to avoid problems with seepage. The compromise plan is an attempt to allay fears by creating an intermediate and low dynamic zone, where no large-scale excavation will take place. The digging is concentrated at a far point from the dike.

If the seepage cannot be prevented entirely, the discharge capacity of the inland water system will be checked to see if the extra amount of surface water can be accommodated within the existing drainage system. If not, extra measures will be required. Those measures have yet to be drawn up.

2.1.6 Operation of polders and adjustment of operation plans

Maintaining and operating a retention area is crucial for the effectiveness of a controlled retention area. Operation of polders includes two aspects:

- getting ready for action;
- local, regional and interregional adjustment of operation plans.

In the SDF project, the optimisation of the operation concept can be demonstrated for the Ingelheim Polder control centre and the course of operation and reporting in the case of a flood event. Even in non-flood periods, a polder needs to be maintained regularly. Furthermore, the complex electro-technical equipment has to be adjusted to the needs of operation. These aspects were surveyed and implemented at the SDF Ingelheim and Lohrwardt Polder pilot projects in Germany and at Hondsbroeksche Pleij in the Netherlands.

Strategies for control of the retention areas on the Upper Rhine

Within the scope of the activities of a German-French working group, a set of regulations binding on the operators of the retention areas has been developed for flood retention measures and has been in operation since 2006.

1. A Comparison of the Flood Prevention Measures on the Upper Rhine
The polders located along the development route of the Upper Rhine between Basel and Iffezheim can generally be filled completely as there is a sufficient pressure head due to the individual height of the water level within the barrage. Normally, draining is also feasible without any problems and it is not even necessary for the flood to have fallen. This is not always the case with the polders along the free route of the Rhine downstream of Iffezheim, as the attainable damming level at these locations is dependent on the flood level.

The Breisach and Kehl weirs act as restraining features in the Rhine. By closing the segments at the weir, the Rhine is dammed up to a higher level and additional water is therefore held back. Both weirs have controllable segments as well as a fixed threshold via which the water can run off into the Rhine at fully closed segments. As a result of the fixed threshold, the volume which can be cultivated is dependent on the flood event.

South of Breisach, approximately 3 to 8 m of gravel will be provided over a length of about 45 km of the right-hand bank and an average width of 90 m. The height of the gravel will equal the water level before the implementation of the Rhine regulation. This enables a retention of up to about 25 million m³ starting at runoffs of 600 m³/s in the Rhine (that means the total runoff in the Rhine and into the Rhine's side channel amounts to approximately 2,000 m³/s). This measure, called '90 m strip' can be compared with a dike relocation. It is generally known that such an uncontrolled measure does not result in such a strong effect locally as a controlled measure would during slowly rising flood events. However, it has a delaying effect on the flood wave. This will counteract an essentially negative component of the Rhine development, especially in the southern region of the Upper Rhine. The development of the Rhine area caused an increase in the flood peak mainly by speeding up the Rhine wave and therefore resulting in an unfavourable overlapping with the tributaries' waves hurrying ahead. The '90 m strip' variant in the south will counteract this effect.

Since the total inclusion of the flooding areas lost by the development of the Rhine (130 km² upstream Worms) is no longer possible for technical and hydraulic reasons, the past retention volume can no longer be used and employed in an uncontrolled manner as was done previously. Increasing flood protection by using partly the vast flooding areas in existence can only be realized by means of the measures on the Upper Rhine if the measures are implemented in a controlled way. This means that the time of the implementation, and, in so far as possible, the retention gradient of each measure, is to be optimised and defined.

2. Evidence of Efficiency of the Flood Protection Measures
An optimum and effective set of regulations was developed at the Maxau and Worms gauges with regard to the decrease of the peak level of the 200-year flood event for the existing as well as for the planned retention measures. When developing the set of regulations, it was important that an optimum coordination of the effects on the areas from south to north would be achieved. Furthermore, with just one set of regulations, the increase of flood protection had to be achieved with regard to both the Maxau and Worms gauges. That means that the Rhine's peak level will have to be reduced for the Greater Karlsruhe area. Generally, there will be a new peak forming at the Worms gauge by the overlapping of the Rhine and Neckar rivers. Consequently, a lowering of the peak at the Worms gauge will be achieved only if a long-term reduction is attained in the upper area where the Rhine wave rises.

3. Regulation Optimisation of Usable Retention Areas
In order to be able to achieve the maximum possible flood protection with the measures available in each case, an optimum regulation adapted to the respective status of implementation must be ascertained. For that purpose, the respective marginal conditions with regard to shipping, electrical power production, technical limitations of the individual areas, such as the regulation possibilities of individual structures, as well as the conditions set forth in the planning approval process, must be observed. It is also important to ensure that there is no increase in the flood runoff volumes as a result of the discharge above Iffezheim.

The regulation optimisation will be elaborated in an international working group in the scope of the German-French contract, the required calculations will be performed by the LUBW State Office for the Environment, Measurements and Nature Conservation Baden-Württemberg. The instruction optimised for each measure in the network of usable areas is binding on the individual operators in France, Baden-Württemberg and Rhineland-Palatinate. Runoff criteria at the Rhine gauges in Basel, Breisach, Kehl-Kronenhof, Lauterburg, Maxau and Worms are applicable to the different types of operation, such as halting the ecological flooding, preliminary lowering (establishing the normal damming level of the weirs), retention, halting of the retention, restarting of the retention and emptying. Furthermore, the regulations also include forecast criteria in order to guarantee an optimum implementation adapted to the individual flood event or to avoid superfluous operations (connected with costs).

4. Previous Implementation of Flood Retention Measures on the Upper Rhine
Until now, flood retention measures have been successfully implemented during four large flood events (March 1988, February 1990, February 1999 and May 1999). Furthermore, due to the reliable predictions of the Prediction Centre for Floods (*Hochwasservorhersagezentrale HVZ*) during the last 15 years and five larger flood events, it was possible to prevent the unnecessary activation of the Kehl weir and the Altenheim Polder. This is also applicable for the Rhine discharge below Worms.

Box 2.7: Strategies for Control of the Retention Areas of the Upper Rhine (Extract from a publication of: Dr. Peter Homagk, Dr. Manfred Bremicker, State Office for the Environment, Measurements and Nature Conservation Baden-Württemberg, 2006)

Operating phases and times

To gain an impression of the phases and times, the following table (from Ingelheim Polder) provides an overview of the filling and emptying times as well as of the damming time, height and volume. It shows the results of the modelling as carried out in the planning phase (see chapter 2.1.3). The times listed refer to the water level hydrographs on which the computations are based. The times cannot automatically be compared with other flood events.

Item No.	Operating Phase	Ecological Flooding	5-year Flooding (HQ5 Wave 1984)	200-year Flooding (HQ200 Wave 1988)
1	Filling time	20 h	9 h	8 h
2	Damming time at the maximum damming height	-	14 h	24 h
3	Emptying time	5 h	approx. 8 days (196 h)	approx. 13 days (317.0 h)
4	Seepage time of the remaining water (without the seepage of the flat water biotopes within the polder area)	35 days (840 h)	50 days (1,200 h)	50 days (1,200 h)
5	Duration of the entire operating phase (total of items 1 to 5, inclusive)	Duration of the entire operating phase (total of items 1 to 5, inclusive) approx. 36 days (865 h)	approx. 59 days (1,419 h)	approx. 65 days (1,549 h)
6	Average damming height [m]	0.18 m	0.97 m	2.72 m
7	max. damming height [m]	0.40 m	3.39 m	5.52 m
8	max. damming area [ha]	20.0 ha	136.3 ha	162.2 ha
9	maximum water volume [m³]	30,000 m³	1.323 Mio. m³	4.454 Mio m³

Table 2.1: Ingelheim Polder flooding data

The simulation of the ecological flooding was performed in reference to the water levels up to a recurrence interval of approximately 2-3 years. At this water level, approximately 29,500 m³ of water had already flown into the polder area at the hydrograph considered.

The 5-year flood event was simulated due to previously planned operation alternatives. In the simulation, the 5-year-flooding of the polder starts when a water level of 82.41 m above mean sea level is reached at Rhine kilometre 517.2. After opening of the inlet and outlet works, approximately 44 m³/s flows into the polder area. The filling time up to a maximum damming volume of 1.323 million m³ is about 9 hours. Approximately 20 hours after opening of the inlet and outlet works, the water level within the polder is levelled out and an area of 136.3 ha is covered with water.

The drainage time at the 5-year flooding simulation in reference to the simulated wave amounts to about 8 days. Thereafter, the water level in the polder lies below the threshold height of the inlet and outlet works. In normal operation, the structure for the ecological flooding will be opened when the height falls short of this level. If required, the possibility to speed up the run off of the flood wave by opening of the closure structure also exists.

Some areas within the polder cannot be emptied completely due to their topography. For these areas, an average seepage and evaporation of one centimetre per day was assumed.

Depending on the weather conditions and the development of the water levels of the River Rhine, subject time frame may vary.

In the 200-year flood simulation, the inlet and outlet works were opened at a Rhine water level of 84.61 m above mean sea level. The filling time of the polder amounts to approximately 8 hours. Altogether, an area of 162.2 ha with a maximum volume of 4.454 million m³ and an average flood height of 2.72 m is flooded. In the Im Mörs area, the maximum flood height amounts to 5.50 m. Twenty hours after opening of the inlet and outlet works, the water level of the polder has been levelled out with a maximum extension. The drainage time of a 200-year flood simulation amounts to about 13 days, with the water level at levelling out being only slightly higher in the polder than the water level in the polder foreland and/or in the Rhine. Taking into account the seepage and evaporation, an overall operation duration of 65 days results.

Control and emergency centres

The control centre of Ingelheim Polder monitors and controls the polder centrally. Besides the room containing the control equipment, the control centre also houses a meeting room, sanitary facilities, a kitchen, as well as a storage room.

The control centre serves as a local central station for an upcoming operation of the polder. After everything has been prepared, the on-site team will be stationed here until further decisions are made. All operating conditions of the polder equipment will be transferred from here to the central control station where everything is protocolled and visualised. For flooding of the polder (lowering of the fish-belly flaps), the drives must be released in the control centre before the personnel on site at the inlet and outlet structure can perform the lowering.

At the Lohrwardt Polder, the pumping station houses not only the technical equipment, but also an emergency centre with meeting room and control station as well as an archive. All information on the design, the development, the operation and data from the pumping stations will be archived.

Adjustment of operation plans and reporting chain

The registering water gauge for the Rhine at Kaub, as well as the prediction of water levels for this particular gauge in the case of floods (flooding of the polder area) will serve as flood reference levels. The water levels are constantly controlled by the *SGD Süd* Mainz as well as the *Deichmeisterei*. Furthermore, an evaluation of the polder control can be requested by the State Office for Environmental Matters, Distribution of Water and the trade board Rhineland Palatinate at any time.

The following water levels at the Kaub gauge are relevant for the implementation criteria:

- Implementation Step I: Preliminary alarm
  Water level (WSP) at the Kaub water gauge > 5.20 m and prediction that the water level will continue to rise.
  Preliminary information to the responsible employees of *SGD Süd* Mainz and Ingelheim that a flooding of the polder has to be taken into account (preliminary phase up to the potential flooding about 36 – 48 hours).

- Implementation Step II: Preparing everything for operation
  Water level (WSP) at the Kaub water gauge > 6.00 m and prediction that the water level will continue to rise.
  Evaluation that flooding of the polder might be required.
  Formation of the team and initiation of all measures required for the polder's readiness for operation (preliminary phase up to the potential flooding on the average about 24 hrs).

- Implementation Step III: Flooding of the polder
  The polder is flooded when the water level at the Kaub water gauge reaches 6.9 m.

In principle the water levels for the individual implementation steps as mentioned above have been determined on the basis of statistical evaluations of the water levels. However, the sequence of events relating to the flood wave can vary. Therefore, an evaluation of the flood prediction and of the weather predictions is required for all decisions to be made. At rapidly rising floods, the preliminary phases may be shortened considerably. The measures required upon reaching the individual implementation steps are described in detail in the Instructions for Operation of the Ingelheim Polder.

Discharge distribution at bifurcations at Hondsbroeksche Pleij

The Dutch Ministry of Transport, Public Works and Water Management, responsible for a safe discharge of water along the River Rhine, maintain the agreed discharge distributions at bifurcations in order to safeguard the flood protection downstream. The Room for the River projects along the Lower Rhine (floodplain lowering at Driel, removal of an hydraulic obstacle near Oosterbeek and dike relocation and floodplain lowering at the Bakenhof in Arnhem) directly downstream of the bifurcation and implemented in the past years, have led to a change in the discharge distribution (Figure 2.59). Therefore, the discharge distribution at the bifurcation point of Lower Rhine and IJssel needs to be regulated.
The adjustable weir is not only required to divide the water volume, it is also important to divide the sediment load and the division of ice during winter. The dike along the IJssel will be relocated approx. 250 m farther inland and the dike along the Lower Rhine approx. 150 m inland. The dike relocation in the Hondsbroeksche Pleij project creates space for the flood channel at the bifurcation of the Lower Rhine into the river branches of the Lower Rhine and IJssel. During high floods, water will flow through this channel. The existing dike along the River IJssel will be partly maintained. The remaining dike section (which will then act as a diversion dam) and an adjustable weir at the mouth of the River IJssel together constitute the Pleij project construction – the *Pleijwerk* as it is termed. The discharge through the channel will be regulated at the upstream end by an adjustable weir. Adjustments of the conveyance (inlet profile and height) are made before the flood season.

In 2001, the design discharge (DD) was set at 16,000 m³/s at Lobith, with a frequency of recurrence of once every 1,250 years. This means that in the present situation, according to discharge calculations using the WAQUA hydro-dynamic two-dimensional model, the maximum discharge of the Lower Rhine will be 3442 m³/s and 2500 m³/s for the River IJssel (Figure 2.60 and 2.61). The River IJssel mouth is very narrow and has a steep slope. In this part of the river, the water level falls by about 1 m over a stretch of 1,840 metres.

Figure 2.59: Room for the River projects along the Lower Rhine

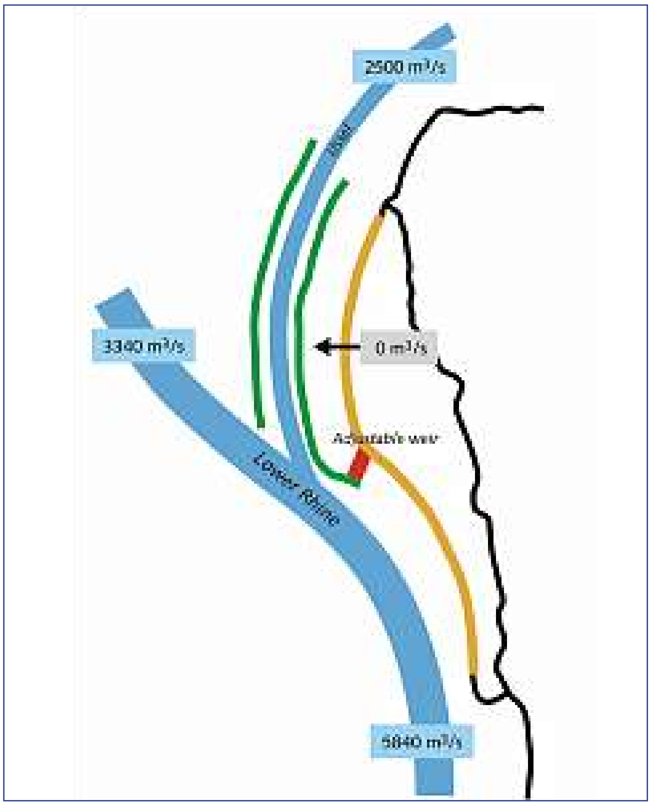


Figure 2.60: Discharge distribution (DD 16,000 m³/s, closed weir)

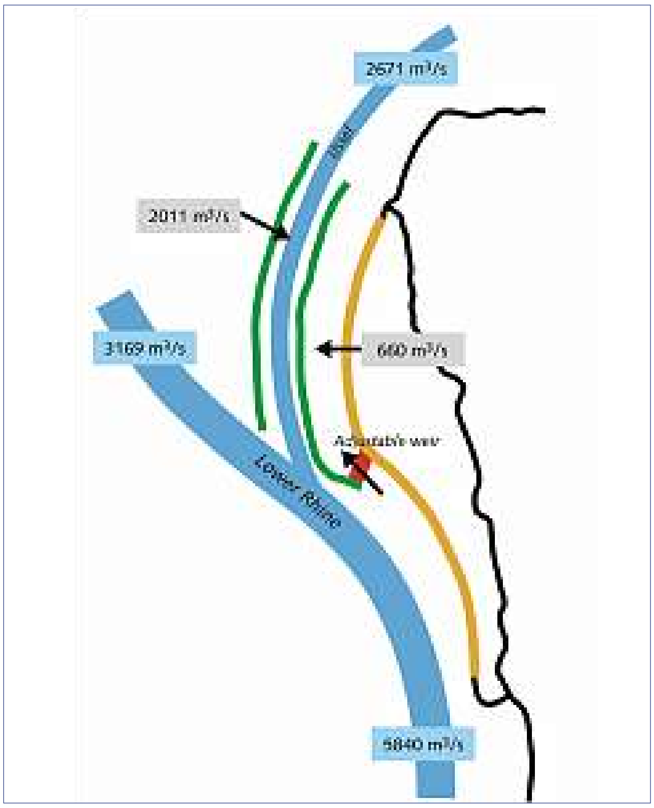


Figure 2.61: Discharge distribution (DD 16,000 m³/s, open weir)

The effect of the relatively short diversion dam on the discharge distribution is relatively large. Maximum discharge distribution ranges have been calculated using the WAQUA two-dimensional model. The discharge-water level (Q-H) relationships in the model have been adjusted taking into account the flood level lowering effects of the Room for the River projects. The maximum discharge distribution ranges can be calculated in the model by a completely open or closed weir. Model calculations have been made for the present situation along the Lower Rhine and IJssel and for possible future situations:

- Room for the River projects completed along the Lower Rhine, but not along the IJssel.
- Room for the River projects completed along the IJssel, but not along the Lower Rhine.
- Room for the River projects completed along the Lower Rhine and the IJssel.
- Room for the River projects completed along the Lower Rhine (DD= 16,000 m^3/s) and along the IJssel (DD= 18,000 m^3/s).

The calculations show that the discharge distribution range does not differ very much for the simulated situations. The maximum increase of the River IJssel discharge ranges from 167 m^3/s to 174 m^3/s in the various situations.

The maximum discharge of the weir and the flood channel varies from 619 m^3/s to 658 m^3/s. Should the design discharge be increased to 18,000 m^3/s, the River IJssel discharge increases by 217 m^3/s, with a maximum discharge of 694 m^3/s through the flood channel.

After completion of the Room for the River projects along the Lower Rhine, the discharge cross-section could be opened to the maximum. The maximum wet cross-section is then 585 m^2, at a width of 150 m, with the crest of the weir at soil surface level being 11 m + NAP reference level in the Netherlands.

As the lay-out of the Lower Rhine and IJssel Rivers will change only slightly, no serious morphological changes are expected. In a flood situation when the flood channel is closed, some erosion may be expected in the main channel. The bed stability of the bifurcation point and the furthest upstream section of the IJssel need attention. However this situation will not be aggravated by the Hondsbroeksche Pleij project.

The adjustable weir at Hondsbroeksche Pleij
The wet cross-section of the adjustable weir can be manually adjusted using a large number of stop-logs that fit between the vertical pillars. By adjusting the number and location of the horizontal stop-logs, the flow profile of the weir can be changed. The weir should be adjusted before the flood season, preferably in the summer. If necessary, the weir can, with extra measures, be adjusted during extreme floods but damaging the structure is a risk during such action. After construction, the adjustable weir will be tested during various discharges. The water levels and discharges will be measured at different weir control levels. The data are used for adjustment of the weir and calibration of the mathematical simulation models. Model calculations will take account of the impact of the Room for the River projects that will be executed in course of time. If needed, the weir will be adjusted accordingly. An energy dissipater (fascine construction) will be built immediately following the weir for flood channel scour protection. In view of the fall that may occur, velocities up to a maximum of 4 m/s have to be taken into account.

Self-regulation of an uncontrolled retention area

In contrast to Ingelheim Polder, the Lohrwardt Polder is basically an uncontrolled polder as regards retention. As a rule, the control of the inlet, passage and outlet structures is performed for the purpose of the ecological flooding and the connection of the old Rhine arm to the Rhine (water level of the lake min. 14.50 m above mean sea level). If the lake's water level exceeds a defined mark (15.50 m above mean sea level), the slide valves of the inlet and outlet structures will be closed. The control of the slide valves is performed centrally from the central monitoring station inside the Lohrwardt Polder pumping station, which was constructed specifically for this purpose. In case the control is required, a member of staff will be present for safety reasons in order to monitor the proper closing procedure. In addition to the slide valves, the flood protection gates of the structures will also be closed at a rising water level as an additional safety precaution. If the water level in the Rhine reaches 19.5 m above sea level at the overflow threshold of the summer dike, the retention area will be flooded via the threshold.

Box 2.8: Self-regulation of an uncontrolled retention area

2.1.7 Maintenance of polders

The maintenance of Ingelheim Polder is the responsibility of the *SGD Süd* Mainz and its associated *Deichmeisterei Budenheim*. During its major operating condition 'polder out of operation', the polder is checked on a monthly basis by the *Deichmeisterei*.

- Checking of the control centre, activating the control system, checking for disturbances, reading of values measured.
- Visually inspecting all polder dikes, checking for obvious damages such as cracks, slides, damages by erosion, damages by vehicles, damages to the signs, barricades and so on.
- Visually inspecting all structures for damage. Checking to ensure that all access paths, maintenance openings, gratings, etc. have been closed properly. Inspection of all contamination in the area of culverts, slide controls, etc.

Twice a year, the polder is inspected closely by the works manager of the *SGD Süd* and the *Deichmeisterei*. These inspections should be performed in late autumn prior to start of the flood season and in late spring after the spring floods.

- Detailed checking of the control room/adjoining rooms including the technical equipment. Inspection of the locking systems, activation of the control system, checking error logs. Checking whether the required maintenance services have been performed in the past half year. Creating data back-ups, monitoring of the functional tests at the control system. Checking of the exterior systems including fence and gate systems. Once a year the wells are to be tested for operational readiness.
- Intensive visual inspection of all polder dikes during a walkthrough, moving should take place prior to this sample check.
- Inspection of all polder systems, visual inspection of all structures and technical/electro technical equipment. In so far as required, tests on operational readiness by the maintenance companies should be incorporated into the inspection of the systems or should be performed prior to the walkthrough, but as closely as possible to the inspection date.

The work to be performed on the machines and electro-technical equipment in accordance with the inspection and maintenance plan will largely be performed by skilled and experienced companies within the scope of maintenance contracts, which have been concluded for a period of five years for:

- the electro-technical system and the control system;
- the row of wells; and
- the flap weirs.

For Lohrwardt Polder, the company that provided the original equipment receives the contract for the maintenance of equipment delivered and installed for the electrical system for a guarantee period of five years. The maintenance includes measures ensuring the desired condition, such as testing, readjusting, exchanging, cleaning, etc. Maintenance is performed at least once a year unless individual system components require maintenance more often.

Floodgate attendant at the Lohrwardt Polder

In addition to the maintenance work, a floodgate attendant was engaged by the Deichverband. The following tasks and duties have been contractually agreed upon for the listed structures:

- Lohrwardt Polder pumping station.
- Inlet, passage, outlet structures, including fishing and fish monitoring devices.
- Flow-off channel.
- Devices for measuring the water level and the flow rates.
- Process control system and system process monitoring.
- Required expansions and supplements on demand, if necessary.

The following tasks have to be performed on the basis of the specification.

1. Regular inspection of the operating and ancillary systems, including exterior and interior cleaning.
2. Cleaning, etc. in the pumping station.
3. Safeguarding the site and the systems against extreme weather conditions and vandalism.
4. Winter servicing on the operating sites of the pumping station, if required.
5. Coordination of required repair and maintenance work.
6. Functional testing in accordance with the maintenance and operation regulations.
7. Activating or deactivating the system, if required.
8. Correction of error messages and/or notification of the responsible parties.
9. Documentation of the work performed in accordance with the specification, either as a log book or in the form of photographic documentation, etc.
10. Tabular, clearly arranged and punctual summary of the documentation of costs and receipts, etc. accrued for care, maintenance, etc. of the structures and systems.

Box 2.9: Floodgate attendant at the Lohrwardt Polder

Lessons learned regarding the design and construction of retention areas

- Innovative and cost-effective concepts for the design of dikes were jointly developed and transferred.
- The construction of sealing walls with mixed-in-place methods is not only cost-effective but also allows designing dikes with a smaller base area (which can be of great advantage in areas with little space available).
- Lessons learned regarding seepage problems are gained from the comparison of different solutions in the pilot projects. Technical solutions with sealing walls are necessary in any case. Additionally, the use of wells, drainage systems and pumping stations varies significantly from region to region. The best solution depends largely on the ground and soil conditions, the land use in potentially affected areas, and the opposition or stakeholders and local inhabitants. There is no best solution regarding this issue. But good practise could be achieved in SDF.
- Do seepage problems have to be prevented beforehand in any case (which is mostly the case in Germany) or is the creation of a compensation fund for the benefit of owners an alternative (of which there was one example in the Netherlands). Here planning philosophy plays a key role.

2.2 Side channels and lowering of existing floodplains

Side channels and lowering of floodplains are other options for sustainable flood alleviation. Contrary to the construction of retention areas, which aim at holding back water in upstream and middle stream stretches of a river system, side channels aim at increasing the discharge at bottlenecks of the river course. By creating side channels, the cross-section of a river is widened and more room for rivers is created. At the same time, the discharge capacity increases. This leads to reduced water levels at the location and slightly above of a new side channel. For example, the side channel in the Fortmond pilot project area leads to a reduction of the water level in the river of 8 cm up to 5 km upstream of the project area.

Side channels and lowering of floodplains are flood alleviation measures are also meant to improve the ecological functioning of rivers. They should redevelop the natural space for river systems and improve the situation of former river courses. They should also create a wider shore zone – the important transition between dry and wet soil. The lowering of floodplains is carried out particularly in the Netherlands, because the floodplains were heavily silted up in the past 100 years due to the building of dikes. Potential conflicts appeared in relation to shipping as a result of a reduction in discharge in the main channels, which could affect navigation in normal discharge situations. Too high discharge in the side channel could cause erosion. Too low discharges could cause sedimentation. Consequently, the improvement of the design of side channels was crucial to increase acceptance for these measures and to make them sustainable.

Different options for design, construction details and operation and maintenance aspects are presented in the following sub-chapters. The experiences gained from planning and implementing the SDF pilot projects in Emmericher Ward, Bislich-Vahnum (Germany), Bemmelse Waard and Hondsbroeksche Pleij (the Netherlands), as well as experiences obtained in SDF from Gameren and Vreugderijkerwaard (the Netherlands) are reviewed. Theoretical observations conclude the sub-chapters.

2.2.1 Concepts and mode of operation for side channels

The approach is to create new or to redevelop former parallel channels of the river. Depending on the design and the goals for an individual measure, the water flows regularly or occasionally in the side channel. The river discharge is divided between the channels either by controlled weirs or inlet works. Consequently, the division is not managed but simply regulated by the layout of overflows and the discharge in the side channel depends on the water level in the main river.

In the German stretch of the lower River Rhine at two pilot locations within SDF, flowing side channels are planned. The concept is innovative for this part of the Rhine River. Along the Upper Rhine, some projects have been implemented that aim at reconnecting existing gullies. Here, no experiences exist in digging new side channels.

Nevertheless, for the implementation of the EU Water Framework Directive, side channels play an important role. Especially in the northern part of the Upper Rhine and the northern part of the Lower Rhine, side channels are characteristic elements of the natural river.

In the Netherlands, floodplain rehabilitation projects have been developed and implemented since the 1980s as a result of more emphasis on green politics. According to different publications, e.g. the Storch Plan (De Bruin *et al*. 1987) and the WWF's Living Rivers concept (anon., 1993), side channels should be part of rehabilitation schemes. In addition, the call for more space for the river after the Rhine floods of 1993 and 1995 led to the reintroduction of side channels. The creation of side channels means a new approach in river engineering, as side channels have caused many flooding events in the past (Havinga & Smits 2000).

Proper river management demands have to be addressed when designing side channels.
- In the past, side channels have also been closed to prevent ice dams.
- Measures to combat eroding banks and growing vegetation in side channels in relation to ensuring discharge.
- Various administrative bodies are involved (responsible for floodplain management or river management). They have to be coordinated with respect to their conflicting interests.
- Costs for the inevitable dredging or preventative works (e.g. local normalisation). It should be clear who will bear the costs.

Related design and management topics are:
- Side channel discharge.
- Aggradations of the main channel (fairway) and the side channel.
- Bank stability.
- Vegetation development.
- Maintenance and ice-clogging.

In dealing with side channels, three phases can be distinguished. The first phase (1995-1999) was characterised by political pressure to implement floodplain rehabilitation projects. Hardly any ecological or hydro-morphologic design criteria were available. Boundary conditions were limited aggradations of the fairway and no raising of flood levels. Not much attention was given to managing vegetation succession, erosion of banks and silting up of the side channels. The principle seemed to be “we will wait and see what happens with side channels”. During this phase, many desk studies were carried out and local designs were prepared, but without much consideration for the site characteristics.

In the second phase, side channels were constructed and experience was gained (1997-present). A third phase dedicated to proper design and sustainable management of side channels should be implemented shortly, also considering the many plans in the various national Room for the River flood protection programmes with side channels. These programmes are mainly intended to increase the level of flood protection. However, they also have the objective of increasing ecological values in the floodplain. This phase may be characterised by systematic monitoring of morphologic developments and vegetation succession (using high-tech methods), evaluation of the situation, carrying out preventative measures and using 2D morphologic models to predict future developments.

The creation of secondary channels in the Dutch riverine delta started in 1994 with the reopening of a series of groynes along the River Waal (the major branch of the River Rhine in the Netherlands), the main shipping route between Germany and Mainport Rotterdam. Two main reasons exist to develop and/or create secondary channels along the Rhine rivers in the Netherlands. Firstly, to reduce water levels during flood peaks and secondly, to create habitats in shallow waters which are of great importance as fish spawning areas. The slow-flowing waters might even fall dry for a long period during the year.
The main fear of civil engineers in the free-flowing River Waal with 160,000 freight vessels per year in 2002 was that the secondary channel would cause sedimentation in the navigation channel. The discharge of the secondary channels in Gameren (large channels plus one of the periodical short channels) is on average about 2%. Critical locations of erosions and sedimentation were detected using WAQUA models.
Stream velocities in all secondary channels vary very much through time and space. High velocities occurred in the case of contraction elements (e.g. a bridge) and lower velocities exist along the wider parts. A special phenomenon was recognised at low river discharges. In this case, ship incluced currents may cause a change in the flow direction. No hinder due to stream patterns was recognised at the meeting points of the navigation channel and the mouths of the secondary channels in the River Waal.

In the case of monitoring work in the Gameren floodplain, only small effects could be seen on the water discharge capacity of the river. The sedimentation in the secondary channels and the vegetation succession did not yet lower the discharge capacity. This result is partly due to the missing information of the Digital Terrain Model t0 before the start of the excavation activities.

Morphological changes were difficult to prove because of the interference of certain effects, e.g. the movement of sand riffles/dunes on the river bed and certain disturbance from the excavation of the channels themselves. Sedimentation was predicted to take place in the main channel parallel to the Gameren floodplain and this was turned out to be the case. The erosion, as well as sedimentation rates, were larger in the first years following construction but later a regional equilibrium was established (Figure 2.62, 2.63, 2.64).

Figure 2.62: The Gameren Floodplain along the River Waal with the new dike alignment (in 1995)

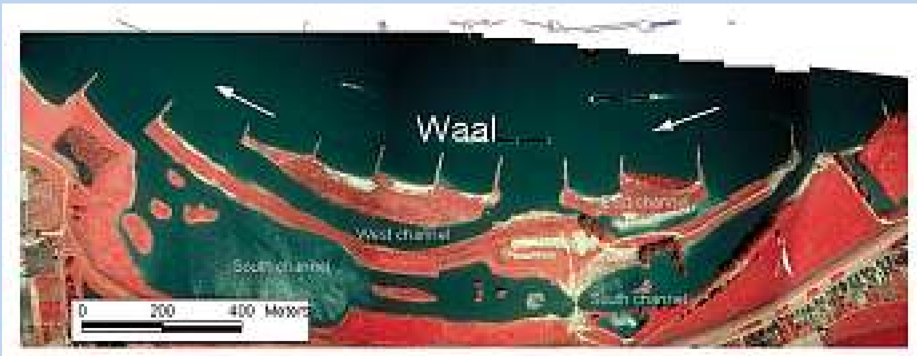


Figure 2.63: The Gameren Floodplain after the construction of the side channels (in 2000)

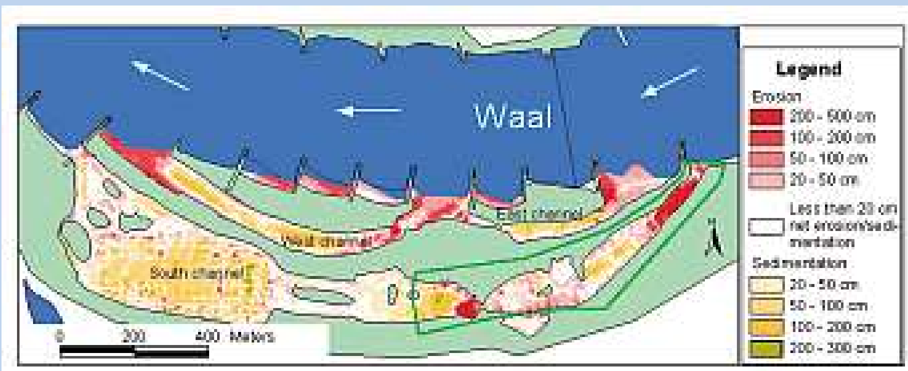


Figure 2.64: Sedimentation and Erosion rates based on monitoring between 12/1996 and 10/2002 (within the green line: 12/1998 and 10/2002)

Box 2.10.: Side channel in Gameren (NL): technical (morphological) aspects

Figure 2.65: Fortmond: Excavation of the side channel

Goals of the side channels at Fortmond and Bemmelse Waard

The main goal for developing side channels and lowering floodplains at Fortmond is nature development. The second goal and also an important precondition is increase of flood protection. The project will result in a decrease of the critical flood level between 6 and 8 cm, referred to the assigned design flood discharge of 16,000 m^3/s, at Lobith.

GIS analysis has been used to determine the most suitable places to excavate the floodplain and side channels. The side channels are located where they generate the maximum effects for lowering the water level (according to the hydraulic model used). The floodplain level determines the type of nature e.g. willow forests, natural grasslands or marshlands. Some old sand pits are also being integrated into the system of side channels.

In the first instance, the objective of the side channel at Bemmelse Waard is nature development (part of the national ecological network). A second consideration is protection, i.e. lowering the high water level (16,000 m^3/s at Lobith) by 6 cm. To achieve these objectives, the floodplain of the River Waal near Bemmel will be lowered and a side channel will be constructed. In addition, the brick factory site will be streamlined to reduce hydraulic resistance.

The Vreugderijkerwaard is one of the floodplains along the River IJssel, an area of around 130 hectares to the north-west of Zwolle. The area consists of relatively low river embankment alongside the IJssel, and low-lying floodplains alongside the dike. In 1996, after the most important farmer in that area decided to sell his land to the DLG (Dienst Landelijk Gebied), the project was developed. The plan was to develop dynamic, river-borne nature by digging a side channel, which is connected downstream and upstream to the River IJssel. The side channel would flow constantly and the new channel would follow the old morphologic patterns as much as possible. In order to prevent problems of navigation along the River IJssel and a too strong silting up in the side channels, an artificial narrowing by means of a regulated intake was constructed. The inlet structure also serves as a bridge to reach the remaining private houses in the area. In addition to cars, the bridge is also used by local cattle to get across the new channel.

This measure was initiated as a nature development project but also contributes to a flood peak reduction in the river and therefore serves two objectives: room for nature as well as room for the river. Through the inlet regulation, 1.5% of the water of the River IJssel can flow into the side channel at low water. In the case of floods, the water can flow over the inlet work.

The work started in 1999 and the project was completed in 2002. The final design criteria were the effects on nature improvement, the lowering of the water level, landscape quality, clay extraction and costs. About 450,000 m^3 of soil were excavated to develop the channel.

Excavated soil volume was placed in a temporary soil depot. Soil (about 10,000 m^3 a week) was transported by ships and 2 ships per day were filled with soil material. In the new designed floodplain, pools were created in order to ensure the survival of fish and amphibians. The course of the newly created secondary channel followed the lower-lying parts of the floodplain. The slopes vary between 1:2 and 1:100 in wide bank zones.

Since 2002, the area has developed very well and has already attracted many water birds. The management of the area is carried out by an NGO: Natuurmonumenten. Cows graze the area in order to keep the roughness of the vegetation at a certain level. The area is attractive as a nearby recreational area for the inhabitants of Zwolle.

Another action is planned within the Room for the River programme, the Westenholte dike relocation that is well-suited to the Vreugderijkerwaard project. It is a dike relocation of 500 m inland, which will lower the high water level by 15 cm. The project study will run between 2006 and 2009. The implementation period is expected to be 2010-2014.

Figure 2.66: Development of a side channel in the Vreugderijkerwaard/River IJssel (2000, spring 2002, autumn 2002)

Figure 2.67: Wooden pile foundations of the culverts (inlet works)

Figure 2.68: Design of the culverts

Box 2.11:Side channels at Vreugderijkerwaard (NL)

2.2.2 Design and technical layout of side channels

Alignments of the side channels

The decision regarding the alignment of a new side channel is based mainly on the historical river bed situation, present land use, hydraulic effects and natural as well as geotechnical conditions. In the case of Emmericher Ward, two different alternatives for the alignment of the side channel were designed and compared in a feasibility study: the foreland alternative and the riverbank alternative. Criteria like availability of space, hydraulic effects, nature conservation, etc. were considered. Consequently, the result of the comparison cannot simply be transferred to other situations, although the general approach may be.

The new side channel is designed with a width of between 20 and 50 metres, flooding on an average of 270 days per year and with a maximum flow rate between 0.5 m/s and 1.5 m/s, depending on the water level in the river. The foreland alternative involves breaking the summer dike ring at two locations 3 km apart. The foreland is therefore flooded even at moderately high water levels. The drainage ditch should be left to be formed by the floodwater forces. The height of the upstream overflow threshold must therefore be taken into account in the calculations. Downstream, the aim is to produce an inclination up to the level of the terrain.

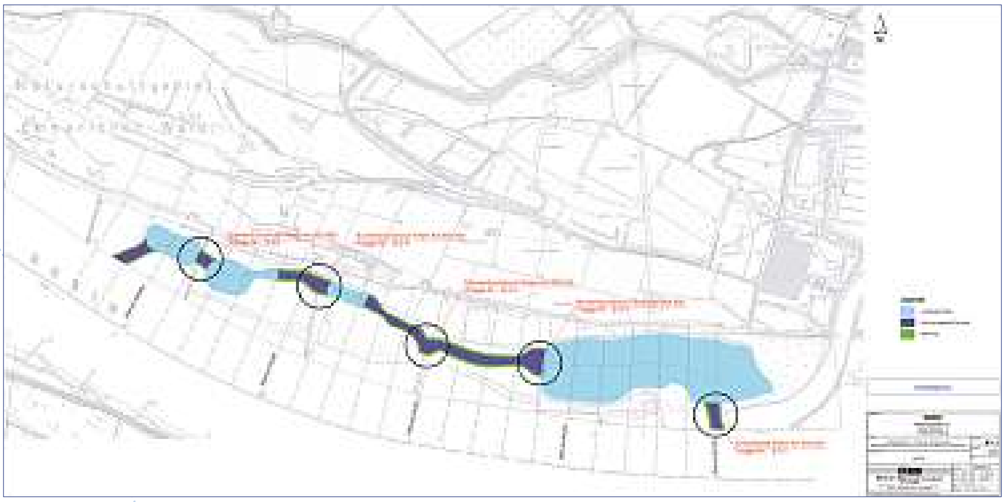


Figure 2.69: General plan of the riverbank alternative; BCE Consulting Engineers, Cologne, August 2007

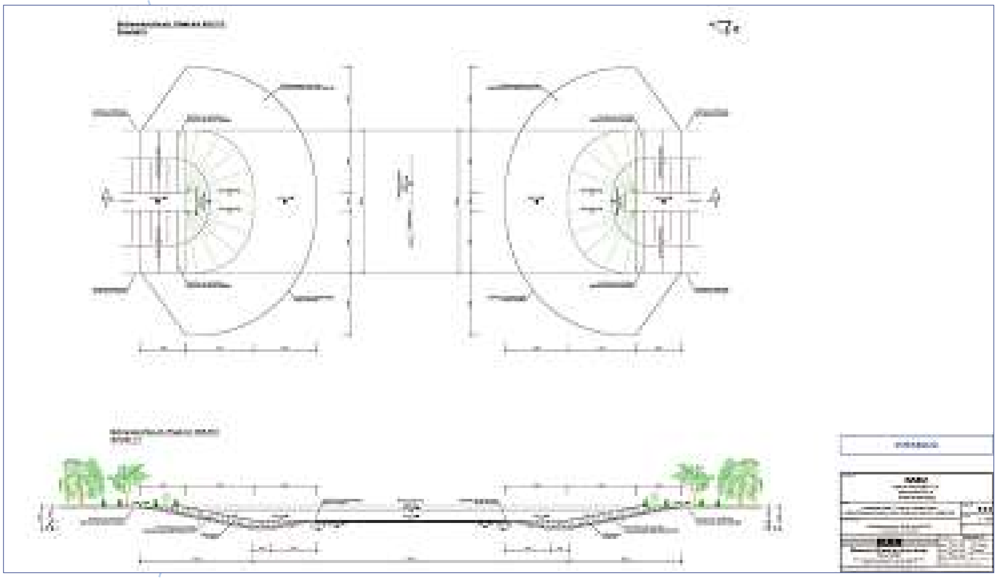


Figure 2.70: Draft plan of the groyne interruption; BCE Consulting Engineers, Cologne, August 2007

When the foreland alternative was discussed with farmers, fundamental objections were voiced. Most of the land is public land, with some land still is private hands. The private landowners disagreed with the opening of the summer dike ring, even though the land concerned is already flooded by opening a dike gate during the winter flood risk period. The landowners would not consider selling the land either. Consequently, the alternative is unlikely to be implemented at present. It has therefore been decided not to proceed with the expensive planning study.

In the riverbank alternative, the interrupting of four successive groynes at their base creates a bypass that follows an existing depth contour (Figure 2.69). Upstream, a former excavation site is involved. The channel created should be permanently flooded when mean water minus 1 m is reached. Natural, dynamic gravel bars and banks will separate the bypass from the channel. The existing groynes close to the riverbank will be interrupted over a distance of 30 m to 70 m (Figure 2.69 and 2.70). The new bed will be approximately 2.50 m deeper than the old groyne crest. The rock armour will be used to secure the connecting points to the remaining groyne. An existing channel between the groynes will be used. This requires only local dredging operations.

Design of the side channel in Fortmond

The design in Fortmond was derived from the planned nature development targets (Overijssel Nature Area Plan). The river manager made it clear, however, that any increase in the unevenness of the river bed as a result of the nature development would have to be compensated (with water or by lowering the surface level) to prevent any negative impact on the design discharge level (MHW). To prevent the nature from developing in such way as to have a marked negative effect (increased roughness) on the discharge capacity, the specific requirements that those types of vegetation impose on the environment in which they grow were considered in the design. The design also anticipated the situation when the vegetation is fully grown. The plan therefore considered different soil types in combination with the length of time that various surfaces will remain dry. For example, if part of the floodplain remains dry for 60 to 100 days every year and there is no vegetation, it is likely that softwood lowland riparian forest will grow. On the other hand, if the design is based on the floodplain remaining dry for 30 days, for example, it is likely that sedge-type vegetation will take root. Using these factors, a vegetation plan was drawn up.

These types of vegetation are entered in the computer model to calculate the effects of the measures (Figure 2.71). To design the channels in the floodplain, experts identify the locations where the current is fastest at high water. It is possible to estimate what effect constructing channels of a certain size in these tide ways will have – together with the roughness of the future vegetation – on the design discharge level. Naturally, it is also essential that the river's principal functions (safety, economy) will not be jeopardised. Nature is difficult to predict, however, which means that once the area has been developed, it has to be closely monitored. This is because nature can be adjusted when it is still in its infancy, but this becomes increasingly difficult as it matures. It is therefore essential to monitor the situation and to draw up an effective plan for managing the various functions in the area. It is also essential to take account of the local sedimentation. A silt trap has been planned for the western channel in Fortmond in the dike ramp just behind the structural works.

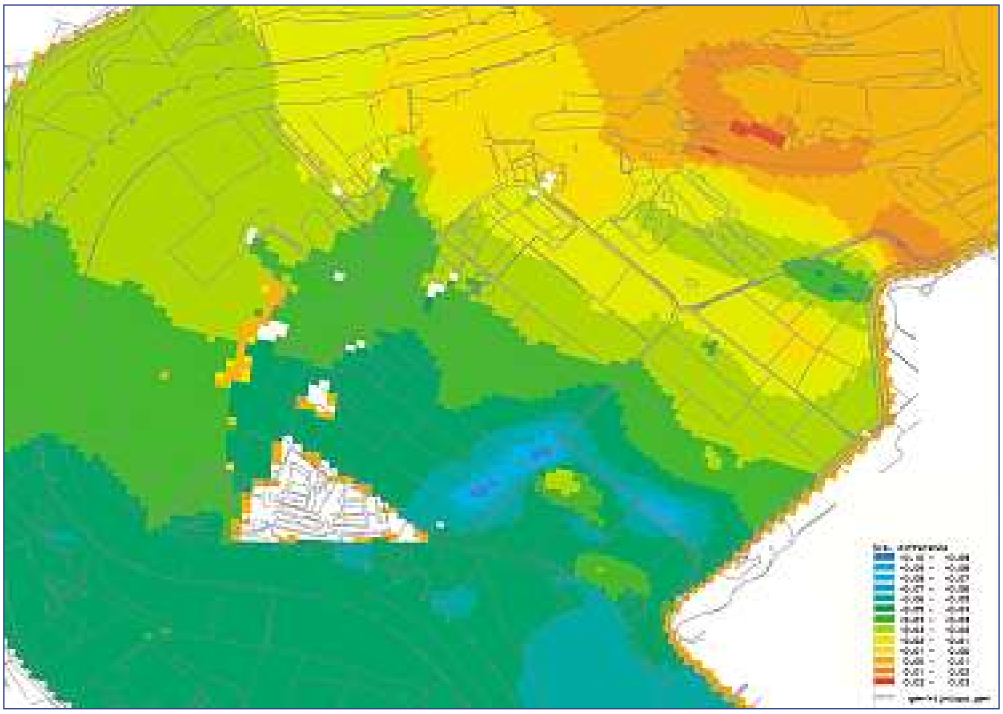


Figure 2.71: Effect of the Fortmond development plan on the water level. Differences in water level are indicated in blocks of 1 cm, starting at a decrease of the water level of 10 cm (blue) to an increase of the water level of 2 cm (red).

Combining a side channel with floodplain lowering at Bemmelse Waard

In the example of Bemmelse Waard, the goal was to improve flood protection. In this case, the planned solution is the result of a combination of measures: to achieve the required safety the river foreland will be lowered and a channel will be dug. As a result, ceramic clay and sand will be extracted. The size of the project area is approx. 400 ha. The floodplain will be lowered at the locations where the peak discharge occurs during floods. At these locations, ponds and low banks will be created. The ponds will be connected to a side channel with a length of 1,450 m and a width between 75 and 300 m. The banks of the side channel will be shallow with a smooth gradient. Alongside the banks, new riparian vegetation may develop. The excavation of the side channel will expose part of the historical pattern of the river. In total, more then 2 million m³ of sand and clay will be excavated. The side channel is not connected to the mainstream for two reasons:

- High costs involved in connecting the side channel because of the presence of polluted soil.
- Minimal hydraulic benefits if the side channel is connected.

The side channel and the River Waal are separated by the summer dike with a height of 12.5 m + NAP[2]. The water level of the River Waal at this section varies between 5.4 m + NAP and 13.5 m + NAP. This means that on average the floodplain will be flooded two days a year. Therefore, the floodplain of the Bemmelse Waard may be characterised as a low dynamic floodplain. The location of the side channel is based on:

- Present buildings and the brick factory.
- Preservation of as many existing nature values as possible.
- Achieving maximum hydraulic benefits.
- Connecting existing ponds (former sand and clay pits).
- Historical pattern of the river.

[2] NAP =Nieuw Amsterdams Peil (mean sea level)

In the main, the channel will be excavated using a suction dredger. The slopes of the excavations determine the future nature development. In the Bemmelse Waard, the following factors have been taken into account.

- The average water level in the Bemmelse Waard is 8 m + NAP. Up to around 2 m under this level, light can penetrate. This is the most interesting part of the channel for nature development. Therefore, the inclination of the slope will be as shallow as possible (1:10 to 1:15). The inclination under 6 m + NAP is 1:3 to 1:4. The slope has been chosen to optimise the excavation of sand.
- The wind direction in the Bemmelse Waard is mainly westward. The wind transports seeds. To prevent willows, etc. from developing on locations where it is not desirable for hydraulic reasons, the banks in the wind direction (westward) will be steeper than banks in other directions. The westward-oriented banks will have a slope of 1:5. Consequently, any seeds washed ashore will have a relatively small area in which to develop.

By optimising and combining these factors, sustainable development is possible, while taking account of both flood alleviation and nature development.

Discharge control for side channels

The division of discharges is managed by controlled weirs, inlet works or self controlled by overflows or fixed weirs at the upper cross-section of the side channel. In the example of Bislich-Vahnum, existing former excavation sites will be connected to a new side channel flowing alongside. Basic specifications for dimensioning the channel are determined by the German Federal Water and Navigation Administration (WSV) in the interests of maintaining the Rhine as a waterway. According to these specifications, no more than 2% of the discharge in the main channel may be diverted into the side channel. In the case of discharges below mean water level, the flow rate must not exceed 2 m^3/s. The lowering of the water level in the main channel must remain below 1 cm. These requirements have been met by constructing a culvert in the inflow area. Table 2.2 provides an overview of the discharge through the side channel as a function of the discharge in the River Rhine.
The following structural measures and technical elements have been developed as part of the draft design plan:

- Inlet sill with intake control to control and to limit the discharge.
- Shaping the riverbank of an existing excavation site.
- Cutting a channel through existing grassland and temporary bodies of water.
- Constructing new culverts through a transverse jetty and an agricultural access road.
- Three culverts will be created, two of which will initially remain closed. Option to increase the flow rate on the basis of initial experience.
- Removing a further transverse jetty with a NATO road.
- Siphoning of a purification plant drain.
- Installing a current protection system for a gravel loading harbour.

Table 2.2: Splitting of discharge by the inlet sill and proportion of Rhine discharge when a culvert is open.

No.	Load scheme	Rhine discharge [m³/s]	Discharge through culvert [m³/s]	Discharge at inlet sill [m³/s]	Total discharge [m³/s]	Proportion of Rhine discharge [%]
1	AMW 90	2,050	2.00	0.00	2.00	9
2	AMW 90 +0.07 ≈ MW	2,090[1]	1.89	0.95	2.84	13
3	MW	2,160[1]	1.13	5.23	6.36	29
4	MHW	4,850	0.38	46.28	46.66	96

[1] Discharge: estimated from the present Q-W relations at the Wesel level with the Q-W relations at the inlet sill

AMW 90	Average Medium Water Level 90
AMW 90 + 0.07 m	Average Medium Water Level 90 +0.7 m
MW	Medium Water Level
MHW	Average High Water Level

2.2.3 Maintenance of side channels

One critical issue of side channels is to secure minimum water levels for navigation in the main channels, to reduce sedimentation and erosion in the side channels and to limited negative effects of ice (see above). To manage all these processes, the combination of measures was evaluated and taken into consideration in the SDF pilot projects.

Control and maintenance principles for side channels

Up to now, side channels have been designed without much attention being given to proper design principles with regard to their sustainability. As it is a natural that one of two branching channels will eventually silt up, measures have to be taken to increase the lifespan of side channels. In natural rivers, new channels are created and old channels are abandoned by the physics of meandering and braiding.

In theory, a side channel will be stable if the proper amount of sediment reflecting the sediment transport capacity of the channel discharge is conveyed through the channel. In river engineering terms, sediment offered to the side channel is dealt with via the intake and the sediment transported according to transport capacity, which is related to hydraulic parameters (primarily velocity) and the grain diameter of the transported sediment. In turn, the channel's profile and alignment determine the hydraulic parameters. As the banks of the side channel are usually not protected, lateral sediment inflow may also be expected during moderate flows and also during floods. As a result, it will be hard to achieve a side channel that is in equilibrium. Nevertheless, if the stability of side channels is to be taken seriously, experience in designing irrigation channels may be useful. In Ghimire (2003), design principles for stable side channels are discussed. It appears that three control principles have to be addressed: sediment control by measures at the intake, hydraulic control and cross-section control (Figure 2.72).

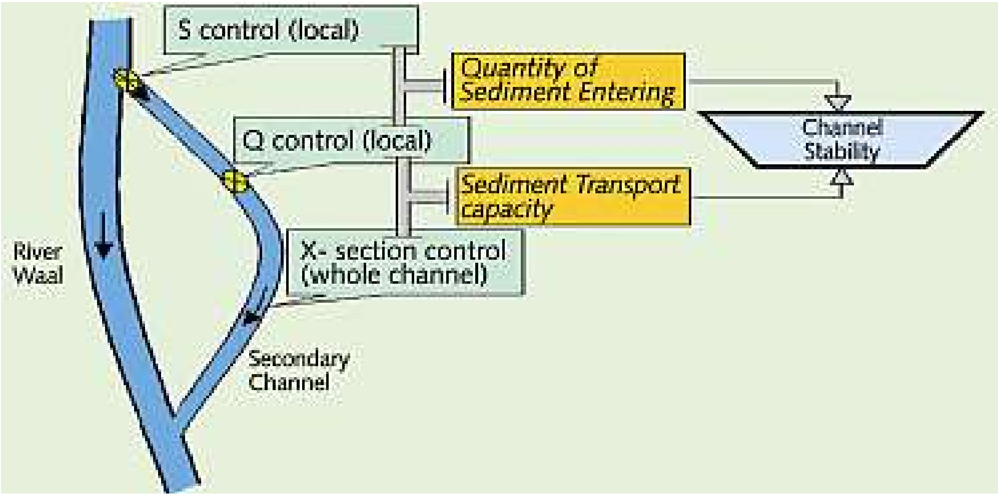


Figure 2.72: Three control principles: sediment control, hydraulic control, cross-section control

Sediment control
Sediment control is important for the sustainability of side channels and the natural processes that can develop. In the early nineties, the only demand on the side channel related to morphology was the accepted reduction of the sailing depth in the main channel, so that the overall draught of ships was not endangered. At that time, the accuracy of sounding devices was about 2 dm, so this was chosen as a suitable criterion. This leads to a maximum withdrawal by the side channels of about 3% of the mean discharge. Though this criterion seems to prevent severe shoaling of the fairway, it does not prevent aggradations of the side channel. The first step of sediment control is to avoid a great deal of sediment from entering the side channel. This can be achieved by adapting the intake of the side channel. In literature many solutions are given. They can be divided into preventive measures and curative measures.
Preventive measures are:

- Careful selection of the intake (preferably at the end of an outer bend).
- Alignment of the intake (angle of diversion).
- Sediment excluding methods. Here, a wide range of measures are available: raised entrance sill, submerged vanes, skimming wall, deflectors, guide wall, under sluice, vortex excluder, barrage regulation.

Discharge control
As indicated above, the water discharge through the side channel must be limited to prevent shoaling in the main channel, which may limit fairway dimensions. Discharge control can be achieved by building a sill (movable or not) somewhere in the channel. In the Netherlands, the sill can be made of coarse gravel, sheet piling and is sometimes incorporated in the foundation of a bridge crossing the channel. If a sediment intake structure is planned, the discharge may have to be limited to prevent erosion.

Cross-section control
The third control principle for side channels is cross-section control. To prevent erosion and sedimentation, a uniform channel profile is required, which often conflicts with ecological and landscape demands. In practice, the channel lay-out will show constrictions and wider reaches, with varying depths. Maintenance is then required to maintain a minimum flow profile. In the channel, a deeper part can function as a sandpit.

Combination of measures to distribute discharge, sediment and ice
In the example of Hondsbroeksche Pleij dike relocation, floodplain lowering and the creation of a side channel in the floodplain are combined with an inlet work to control the distribution of the discharge. The solutions are influenced by the special situation resulting from the location near the bifurcation of the Rhine River into the Lower Rhine and the IJssel.

Unless the correct layout is selected, providing more room for the rivers at and close to the point where the river splits (i.e. at IJsselkop) may have a major effect on the distribution of water, sediment, and ice. The equilibrium that has existed at this location from as far back as 1775 is extremely sensitive to local interference.

Suitable well-tested mathematical calculation models are available to study the flow of water. In using such models, an expert river management understanding of the prototype is indispensable. The potential effect on the distribution of sediment is more difficult to determine. Mathematical calculation models are not entirely reliable in this field, and constructing and calibrating them also requires a large number of exact measurements from the prototype. Such measurements are only available, however, to a limited extent. Physical models are more reliable but are expensive, and they also require measurements from the prototype. In the past, the way ice was transported by the river at this point was determined empirically. However, the fact that there has been no ice cover on the river since 1964 means that very little data is available to construct models. The problem of ensuring a stable distribution of water, sediment, and ice is therefore not an easy one to investigate and requires a great deal of historical river management knowledge.

In areas where rivers are not influenced by tides, there are two primary factors that determine water levels. Firstly, there is the downstream hydraulic resistance of the river until it reaches the sea. This is determined by the width of the river, its depth, and the roughness of its bed. The greater the resistance in a particular stretch, the greater the fall over that stretch. Reducing the resistance of a stretch of river produces a small fall over that stretch, and a drop in the water level upstream. The second factor is the discharge in the river. An increase in the discharge in a branch of a river produces a high water level throughout the length of that branch. When the design discharge level (MHW) is almost reached, the upper reaches of the IJssel rise by approximately 7 cm for every 50 m^3/s increase in the river's discharge. The Lower Rhine rises approximately 3.5 cm per 50 m^3/s. Changes in the discharge therefore affect the water level throughout the whole branch of the river, while a change in resistance has an effect only on the stretch of river concerned and immediately upstream.

If the hydraulic resistance at the entrance to the IJssel is reduced by installing a bypass, the fall there will be reduced and the water level in the IJssel at the point where it and the Lower Rhine diverge (IJsselkop) will drop. Because the situation in the Lower Rhine will initially remain unchanged, the water level in this branch of the river will remain the same. However, the water levels of the two branches of the river at the point where they divide do not necessarily need to be the same. In order to keep the levels the same at IJsselkop, more water will need to flow into the IJssel and perhaps less into the Lower Rhine. Changing the resistance in or near the entrance to a river branch leads to a redistribution of the discharge. This causes a change in water levels over the full length of both river branches.

The way sediment and ice are distributed depends on the distribution of the water and above all on the local geometry at the point where the river divides. Changes in the way the stream is directed in the summer bed of the river, e.g. by means of groynes, summer dikes, and dikes directly along the waterway, have a major influence. Changes in the distribution of sediment at the entrance to a river may lead to the development of sandbanks, which may impede navigation. Changes in the supply of sediment to a river branch eventually lead to a change in the form of the river bed over its entire length. If ice is unequally distributed and transported, the river may become blocked due to the development of ice dams. These may lead to the water backing up until it reaches a dangerous level. In the past, this has led to the bursting of numerous dikes in the Netherlands. In the second half of nineteenth century, significant improvements were made to the way ice is controlled in Dutch rivers by constructing groynes. Since then, there have been no disasters due to the development of ice dams. High summer dikes were constructed at and near IJsselkop in 1775 so as to manage sediment and ice. The method was determined empirically on the spot. The dike at Hondsbroeksche Pleij that is to be relocated is one of these former high summer dikes and is important for the proper management of sediment and ice. Changes to it therefore need to be planned very carefully.

Experience with side channels in the Gameren floodplain

The flood alleviation project at Gameren was one of the first side channel projects constructed in the Netherlands. It was completed in 1999 and consists of three side channels. The largest side channel flows permanently while the eastern and the western side channels flow only at higher discharges.
On the aerial photograph (Box 2.10), many locations can be distinguished where severe erosion is starting: at the entrances of the channels attacking groynes, downstream of the bridge (equipped with sheet piling for hydraulic control), where erosion travels to the levee. Through field visits and monitoring campaigns, the following experiences have been gained.

- The 2 dm aggradations of the main channel criteria have been met. The simple principle has therefore proven useful.
- Strong erosion is visible at locations where defences end, e.g. in the upstream part of the large side channel. In general micro-vortices occur in the flow at transition zones, leading to bank or floodplain erosion. Consequently, these transitions need to be dealt with carefully.
- An alternative to defences is regular sediment supply. However, this requires continuous monitoring.
- The rudimentary design, used in the first and second phases of designing and building side channels, did not take account of proper defences of the roots of groynes. Consequently, a number of these structures are severely eroded and need to be repaired.
- As the alluvial banks of the side channels are unprotected, bank erosion occurs. Together with the abundant supply of sediment from the main channel, this will result within a decade to a far less pronounced channel profile. The final stage seems to be a depression in the floodplain, in which willows and hawthorn will develop. This must be prevented in view of the original objectives of the side channels: greater ecological values and flood alleviation (requiring discharge profile).
- It appears that after 15 to 20 years, large-scale maintenance will be required. It is unclear which authority is responsible for the problem and who will take action or bear the costs.

Box 2.12: Experiences with side channels in Gamaren floodplain

2.3 Aspects regarding the construction phase for retention measures

The construction phase of infrastructure measures can be very relevant for the environmental impact and consequently for the sustainability of structures. This is especially important for structures in floodplains due to the highly fragile aquatic ecosystems. In the SDF project, all planned and completed measures for the sustainable development of floodplains also tackle aspects of sustainability in the construction phase.

2.3.1 Construction material logistics

In most projects that develop retention volume or side channels, a substantial part of the work is to excavate soil in the floodplains, either sand, gravel or clay. A recurring question is how to deal with large amounts of soil and how to use the excavated material to best effect.

The physical and chemical quality of the soil varies considerably, so it is important to consider the options carefully. This involves reducing the risk of uncertainties for the excavation phase and increasing the benefit of measures.

A soil survey can be conducted in advance to assess the quality and the quantities of the different types of soil. In practice, however, a survey often only gives an approximation of the actual situation. Customers often have very specific demands in terms of soil quality, particularly in the case of clay intended for use in ceramics. It is also difficult to say precisely

how much there is. For example, some soil types only occur in thin strata and are therefore difficult to excavate separately without becoming mixed with other material. This limits the accuracy of estimations used for tendering. If the data is not entirely accurate, this often has financial repercussions.
Large volumes of soil are produced when side channels are constructed. Part of the excavated soil, due to its quality, has limited market value, e.g. clay that cannot be used for ceramics. If all material is offered on the market at the same time, considerable price reductions result. In the Fortmond SDF pilot project, the Dutch DLG commissioned a study in advance to determine the financial value and the potential market for the soil to reduce both financial and practical risks.

As a result of cooperation within the SDF partnership, the **Emscher** and **Lohrwardt** projects considered an exchange of excavation material. The soil that had to be excavated (more than 1 million m³) in Dortmund-Mengede (**Emscher pilot project**) was earmarked as dike construction material for the relocation of the **Lohrwardt** dike if it proved suitable for that purpose. For qualification of the soil quantities needed for building the Haffen dike, the appropriate soil/physical requirements were made available. Furthermore, a logistics concept was developed for the transportation of the soil from Dortmund-Mengede to Rees–Haffen. In the end, once the investigations had been carried out and the results assessed, the project could not be implemented due to time constraints.
However, the survey demonstrates the potential with regard to cost saving, minimising transport routes, avoiding environmental impacts resulting from transportation of soil, etc. by advanced management. In general, the close cooperation of project managers in large-scale water management projects with a demand for or surplus of soil may lead to a more cost-effective performance. Consequently, it would be helpful to put working structures in place that support such cooperation.

To manage the risks and uncertainties related associated with soil management, DLG opted for a design and construct procedure in **Fortmond** (see chapter 5.2). In addition, DLG has had the soil certified (BRL 9335), which will make it easier for the contractor to sell it without having to conduct extensive sample testing. Only random samples will need to be taken in situ to verify the specified quality.

Example for soil certificates

The BRL 9335 Dutch quality system uses statistics. The soil quality can be predicted by taking a random sample and testing it. The number of control samples is steadily increased if the results of later samples differ from those obtained from the first sample. This system is accepted in Dutch soil policy and is recognised by the competent authority, which means that certified soil can be used anywhere in the Netherlands. Soil which does not meet the BRL standards has to be inspected before it can be land filled or processed. The soil also has to be inspected for the risk of dispersion of the substances with which the soil is contaminated. Concentration of contaminated soil and covering it with a layer of clean material is often sufficient. This can be proved using model calculations.

Box.2.13: Example for soil certificates

Transport by trucks or by boat

Construction activities in floodplains often means that transport of building material is also possible by boat. Truck transport often affects people living in the immediate vicinity. In **Fortmond**, the River IJssel flows right through the heart of the project site, and in order to accede to residents' wishes and to minimise the inconvenience caused, the soil is transported by boat. However, that also makes it more difficult to use the soil locally. The break-even point in the choice between transport by boat and transport by trucks lies at approximately 40 kilometres distance between the excavation site and the dumping site.

Figure 2.73 Fortmond: transport by boat

At **Emscher** floodplain development sites, large quantities of soil will be excavated. The Ellinghausen floodplain may easily be reached from public roads without going through settlements, so transport is no problem. For the Mengede floodplain, solutions have to be worked out for transporting the excavated soil to the motorway or to a dump for soil deposits. Transport by ship or conveyor belt is not possible, so a temporary route for lorries will be developed using a former railway track close to the excavation site. The route will avoid settlements or other roads and following the construction phase, it will be converted into a cycle track.

Soil management at the retention area Kirschgartshausen

In the case of the Kirschgartshausen dike relocation, a focus is being placed on optimising and minimising mass movements and transport for ecological and economical reasons. A total of 250,000 m³ are required for the construction of the new dike. In the area of the channel for drainage of the remaining water, 38,000 m³ will be excavated for the activities relating to the landside water management and the relocation of the dike. About 25,000 m³ of gravel/sand from the main channel and the activities for groundwater management can be used for the construction of the dike. On the other hand, the material from the old dike, the cohesive soil covering layers and the top soil from the channels for drainage of the remaining water have only a limited use as materials for the new dike.

Most of the material for constructing the dike must be delivered by truck via the public road system. This presents no problem as the B44 road and the A6 motorway close by. In spite of its location by the Rhine, water transport did not prove to be economical. 14,000 m³ of the material delivered via the roads will be extracted from the nature conservation area, which is 25 km away from this location. For nature conservation reasons, a flat water zone and drainage channels along both sides of the river for taking up of the seepage water have been created. This has resulted in a surplus of gravel and sand. The nature conservation project could be financed only by linking this measure to the demand for gravel and sand in Kirschgartshausen.

The top soil and the cohesive covering layer material from the channels for drainage of the remaining water along the sides of the river will be used for increasing the height of natural ridges in the future floodplains. This increases the location's variety and improves the chances for developing a floodplain forest rich in species.

Remaining soil quantities that cannot be used for other purposes, e.g. from dike sections to be dismantled in the context of dike relocations, will be used nearby for the construction of a hill where wild animals can roam safely. A total of up to 80,000 m³ of unpolluted material

Figure 2.74: Hill for animals (cross-section)

will be required for this purpose. The hill shown in Figure 2.74 will be higher than the Rhine's water level even during floods and will therefore provide a space to which animals can retreat.

2.3.2 Construction roads and roads of steel plates

Temporary roads used for construction sites in floodplains should have minimum ecological impact and should not cost much. As result of cooperation within the SDF project, a Dutch technique to build temporary roads was transferred to German sites and used successfully.
In the Netherlands, steel plates are frequently used to construct temporary roads and to protect existing structures from heavy axle loads. The steel plates are usually hired from specialist companies for the duration of a project. In Germany, this type of road is less known. Based on the experiences gained by the Dutch planners in the course of the SDF project, the German engineers who have worked on the SDF project applied the Dutch solution to the German projects. It was too late for the Ingelheim Polder project as the invitations to bid had already been completed.
At two other projects in Rhineland-Palatinate, namely at an earthwork site in Montabaur and at a dike construction site in Bingen, the Dutch experiences could be implemented. Due to the fast and problem-free construction and dismantling of the temporary roads and due to the protection of the affected soil, cost savings could be made. A problem may be the transport of the steel plates, because German construction companies normally do not have the required amount of plates. Consequently, they have to rent them and transport them from the owner (in the Netherlands) to the project site.
In Fortmond, a temporary road is used to transport sand and clay from the excavation site to the river, where the sand and clay is loaded onto a vessel for transport to other projects. The main reason for a temporary road is to cause no inconvenience to the daily traffic. The second reason is that the normal tar road is not damaged by the heavy transport (dumpers). Separating daily traffic from sand and clay transport is also safer, minimising the risk of traffic accidents.

Figure 2.75: Construction of a temporary road, Fortmond

The temporary road first consisted of a layer of rubble stone covered with a layer of tar. This construction was chosen by the contractor because of the low maintenance aspects. Since this construction appeared to be not strong enough on the weak underground in the floodplain, it was strengthened with steel plates. This is a strong and flexible way of making a temporary road. A disadvantage is the maintenance of steel plate roads. The plates have to be put in place frequently with a shovel.

At the construction sites of **Ingelheim** Polder, the network of agricultural paths could be used in most cases for the construction traffic. New and shorter construction road sections are usually built in a conventional way using mineral construction materials in the German projects. These types of construction roads are generally preferred along the dikes. This is because they can be covered with earth after completion of the construction work and new seed can be sown, which means they can serve as a strip of land protecting the dikes with a permanent substrata. Based on the experiences gained by Dutch colleagues in the course of the SDF project, the *SGD Süd* will also consider the use of steel plates (which cost less) for future projects.

Box 2.14: Temporary roads, infrastructure pipes and recreational use at the Emscher

Temporary roads, infrastructure pipes and recreational use at the Emscher

The need for flood prevention and room for the rivers was often underestimated in the past. Especially in Germany after the 2nd World War, the reconstruction of towns and industries played a leading role in politics.

Consequently, regional plans since the 1960s required spatial planners to organise infrastructure very close to rivers and to bundle public utilities and man-made straightened river banks.

Today we find rivers like the Emscher – due to its linear structure – as a main axes for infrastructure (such as pipelines, communication cables, energy cables, long-distance heating systems, gas mains, etc.), often located under the maintenance paths of the Emschergenossenschaft. For widening the river bed and developing retention areas, these infrastructure elements have now to be removed from their present location to the new floodplain border. For both Emscher floodplains, about EUR 10 million will be required to relocate the infrastructure in advance of the floodplain construction work.

New paths will be constructed for leisure and recreation around the floodplains, and the outlet buildings can be used as bridges across the Emscher. At every outlet building, there is a maintenance building with technical equipment and an observation platform for the general public. A temporary road that used to be a former railway track close to the excavation site will be rebuilt and used as a cycle track after the construction phase.

Lessons learned
Klaus Markgraf Maué (NABU Naturstation Kraneburg) stated the following.

The planning of the Bislich Vahnum and Emmericherward projects benefited from Dutch experiences regarding the design and construction of side channels. Based on the Dutch examples, we have taken into account the following important aspects in the design.

- 2% of the River Rhine discharge in a side channel has no substantial impact on the fairway.
- Inlet structure with adjustable cross-section to control the discharge at the upstream end. Contruction of additional culverts which can be closed at low discharges that might be critical for navigation (Vreugderijkerwaard example).
- Construction of a bridges or roads on top of the inlet structures to cross the side channel. The tip-over guardrail construction prevent obstruction during high floods (Gameren example).
- Construction of side channels to compensate for the increased roughness of a planned floodplain forest.

3

3 Nature development and the environment

Nature development has become an integral part of EU policies. Broad strategies have been set for the development as well as for the protection of the environment. Without any doubt, nature has been favoured by this special and international attention as a cross-border phenomenon. This applies particularly to river-related nature. The restoration and development of nature and landscape is to a greater or lesser extent an objective of all pilot projects in the SDF project, although their primary focus is on reducing flood risks. Within the SDF project, there are four distinct types of projects in terms of the relationship between nature development and measures to reduce flood risks.

1. Projects in which nature development (and landscape development) is the driving force and which incorporate protection against the risk of flooding as a secondary objective (these projects include Bislich-Vahnum, Emmericher Ward).
2. Projects that were originally dedicated to nature development but in which progressive insight caused safety to become a secondary, or even a primary, objective. This category covers all projects in the Netherlands in the Nature development in the rivers area programme (Heesseltsche Uiterwaarden, Rijnwaarden, Bemmelse Waarden, Fortmond, Lexkesveer) and the Emscher project in Germany.
3. Projects whose original intention was to reduce the risk of flooding, but which eventually incorporated the objective of nature and landscape development (Ingelheim, Kirschgartshausen, Hondsbroeksche Pleij, Lohrwardt).
4. Projects that are primarily concerned with safety, but will also create new nature and landscape because of the requirement to compensate for nature that is lost.

Because of this distinction, the partners deal differently with the objectives of nature and landscape development and other environmental factors involved. The differences are addressed in various sections of this chapter.

Different instruments were chosen in SDF to enforce nature development. At the beginning of projects, there are different concepts of landscape development, visions of nature development and associated reference images (see sub-chapter 3.1.1). Since the concept of ecological flooding applied in several German projects is a new experience to most Dutch partners, the implementation and its effects on nature development are described in sub-chapter 3.1.2 as well as the lessons learned. Along the German Lower Rhine and along the Dutch river branches, the excavation of side channels and the lowering of floodplains are measures commonly used to lower high water levels, but the measures are also necessary for the purposes of nature development (see sub-chapter 3.1.3).

On completion of a project, the management and maintenance phase begins. Since the measures taken are intended to be sustainable, it is important to organise the management and regulate the land use in such a way as not to jeopardise the original objectives.

In such an intensively used area as the Rhine River basin, multifunctional land use is of great relevance. In this context, the experiences of German partners gained with the concepts of eco-account as a tool for compensation has a certain potential significance for Dutch projects (see sub-chapter 3.2.1).

There have been frequent discussions within the SDF project about vegetation management as it developed and/or should be developed in the projects (see sub-chapter 3.2.2). Central questions to be addressed are: the type and extent of vegetation from the nature viewpoint, reducing flood risks, and determining the parties responsible, also for implementing the management in a certain area. Various management concepts, each with their own significance, have emerged (see sub-chapter 3.2.3). In sub-chapter 3.2.4, the focus was on the description of the lessons learned from Dutch experiences, with grazers as nature managers. A concept was adopted and implemented at Ingelheim Polder.

All pilot projects in the SDF project involve nature and landscape qualities and other environmental factors that have to be respected according to European legislation, which is considered in brief in sub-chapter 2.3.

Finally, the sustainability of the measures implemented as part of the SDF project are discussed in sub-chapter 2.4.

3.1 Measures for nature development

3.1.1 Landscape development concepts and reference images

Plans for the restoration and development of nature and landscape qualities are often based on long-term visions, landscape development concepts and reference images.

A landscape development concept is an interdisciplinary planning tool for the development of a multifunctional landscape. As a broad planning approach, it supports sustainability as a guiding principle and landscape qualities with regard to landscape development and the sustainable usage, as well as ecological and aesthetic appreciation.

In connection with the development of the retention polder in Ingelheim and the dike relocation in Kirschgartshausen, landscape development concepts were properly considered in order to support landscape development combined with the dike relocation and building processes. For the work in the Emscher Valley, an overall reference image was developed. By way of comparison, at Lexkesveer and Bemmelse Waard along the Lower Rhine, nature development was the guiding principle of project implementation.

Development concepts, including reference images, are of major importance in developing nature. The project examples in SDF clearly show how nature development was elaborated in the light of these concepts. A reference image was often shown to explain how the project area might look like after reconstruction. Objective criteria show if the intended nature development can, in fact, be achieved. With regard to both flood protection and nature development, the landscape is considered to be a leading principle when designing floodplains. Most design aspects can be related to three fundamental values of significant importance that may also be considered as highly sustainable criteria.

1. Future value: how flexible is the design, can it be adapted to the future when necessary?
2. Practical value: what river-related functions can be distinguished and what role can they play?
3. Experience value: what relevance does the floodplain have for the people living in the area?

Landscape-related design aspects focus specially on:
- The flow direction of the river.
- The topography within floodplains.
- Natural aspects of floodplains.
- High dynamic nature.
- Cultural aspects.
- The use of floodplains.
- Historical hydro-morphological backgrounds.

In relation to these aspects, visibility is the leading force in the design process resulting in the following measurements.

1. Present agricultural landscapes are redesigned in many projects and former typical natural floodplains are partly rehabilitated.
2. The reconnection of river and floodplains provides space for morphological and hydraulic processes.
3. Side channels are excavated or partly redeveloped by tracing and visualising old gully patterns.
4. The reconnection of floodplains and the landside of the dikes by brook connections.
5. Management adapted to natural processes (process nature), cultural heritage (structure nature) and use of floodplains (products, appreciation, recreational facilities).

Landscape criteria are of major importance in defining reference images. Depending on given situations in the floodplains, choices can be made leading to workable projects. Criteria, reference images and alternatives are the basis for discussions with stakeholders and providing information to the public.

The design of a model within the planning process defines the planning aims, serves as orientation during the project phase, and may lead to a basic agreement process for the involved parties. But before planning for the future development of an area, the historical development has to be taken into account.

Landscape development in the Rhine floodplains (Upper Rhine)

After the Rhine floodplains had been cleared in the Middle Ages, they were used mainly for agricultural purposes. The floodplain forests had been largely devastated and had taken on a bush character. Closed floodplain forests only existed in residual areas. A comparison of the landscape of the Rhine floodplains over the last 200 years shows considerable changes. Even before the Rhine correction, the Rhine had shifted eastwards by approximately 1.5 km between 1780 and 1840 in the area near Offendorf - Grauelsbaum. As a result, valuable farmland was lost. The Rhine correction narrowed the river bed (which used to be over one kilometre wide) to a width of 250 m, thereby gaining land on both sides of the Rhine. Today's floodplain forest was sown and planted on the newly gained land.

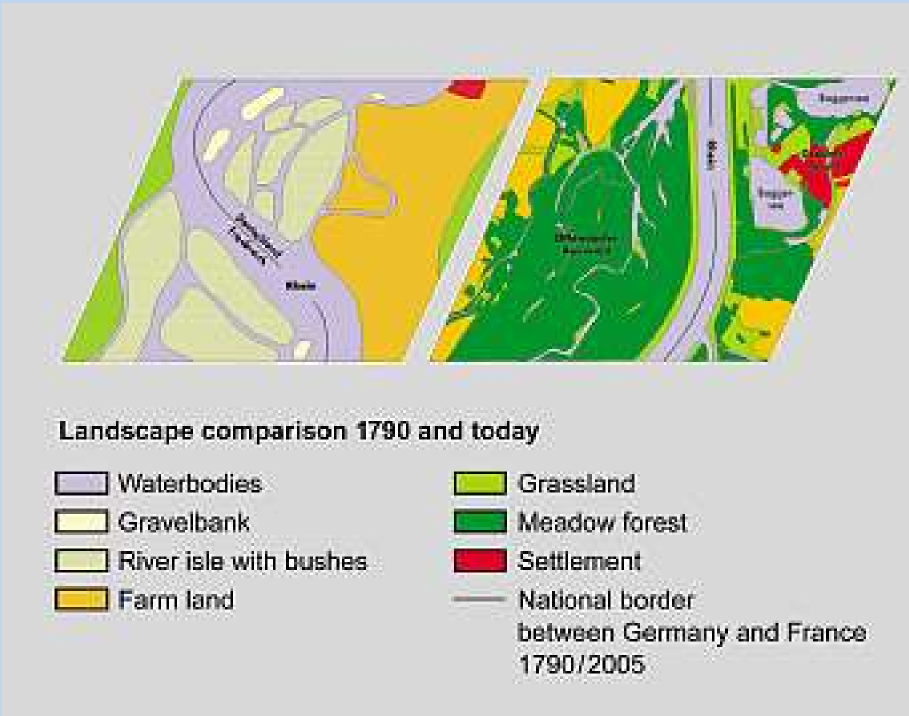


Figure 3.1: Landscape comparison 1790 and today

Development of the floodplain forest after the straightening of the Rhine
The straightening of the Rhine had already been started over 200 years ago and took many decades. During the straightening, a 1-2 km wide ground strip in the Rhine floodplains served as a correction area. In 1850, there was no floodplain forest as we know it today. Low shrubs and bushes grew on the islands and along the shore of the Rhine. The wood from the bushes and the bushes themselves served as raw materials for large bundles of brushwood (fascines, which were used for stabilising or fixing riverbanks, in this case with local woods and brushes), which were required in large quantities for securing the dam and the shore. Furthermore, the correction area was used as pasture land for domestic animals.

Figure 3.2: Use of the land in the case of the Upper Rhine during the straightening

150 years of planted forests
In 1850 at the start of the Rhine correction, there were no oaks, elms, ashes, maples, birches or beeches in the correction area. These valuable species of floodplain trees were all planted or sown into the drained river bed areas of the Rhine. The widely spreading bushes of the correction area were converted to floodplain forests in 1850 and developed in a sustained manner. After decades, poplars, ashes, oaks, maples and elms grew in this area from 1850 up until 1910 and they were between 10 and 20 meters high. Further development and care has meant that floodplain forests now reach heights of 30 meters.

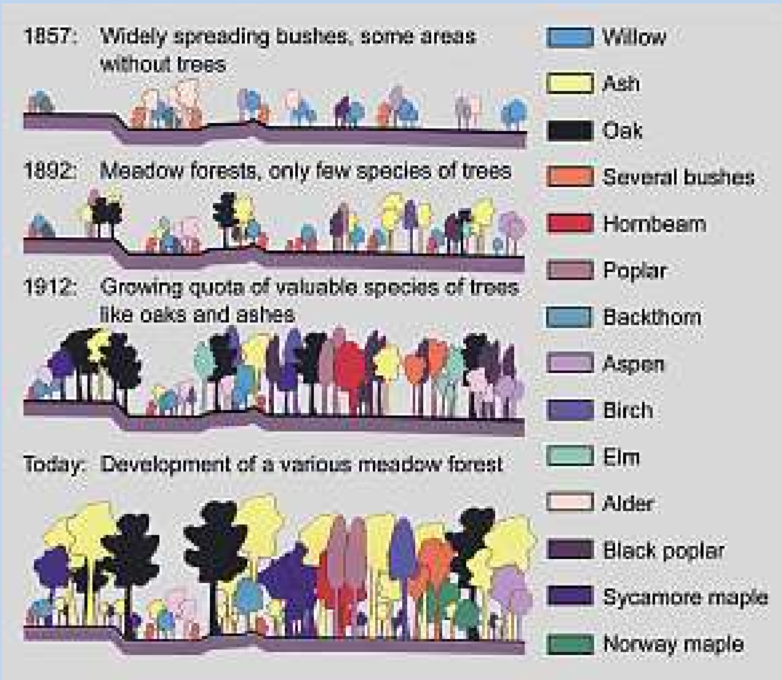


Figure 3.3: Development of the floodplain forest on the Upper Rhine from the straightening up until the present

Box 3.1: Landscape development in the Rhine floodplains (Upper Rhine)

Nature development concepts in the Netherlands
Projects in the Dutch floodplains along the Lower Rhine are still largely based on the original ideas set out in the Stork Plan (Plan Ooievaar) in 1987 and the detailing and additional ideas in documents such as the World Wildlife Fund's Living Rivers (Levende Rivieren) plan. Broadly speaking, these plans suggest that nature development along the rivers should be a predominantly natural process in line with the dynamics of the river. The link between the floodplain and the river must be restored. Large chains of robust nature areas must be created, where human intervention during the management phase is kept to a minimum.
Appropriate interventions include constructing side channels and excavating clay along the contours so that floodplains are lowered, while at the same time reinforcing differences in elevation within the floodplain. The aim of this type of measure is to restore historical landscapes and highlight cultural and historical landmarks again. Since implementing a plan like this also has to be financed, not only during construction but also in the management phase, there is a distinct economic component to the project. The principal sources of financing will be profitable sand and clay recovery and optimal exploitation of possibilities for commercially interesting recreational activities.

Box 3.2: Nature development concepts in the Netherlands

In the landscape development concept with regard to relocation of the Kirschgartshausen dike, three basic alternatives of landscape development were investigated and evaluated.

- Development of green land.
- Development of a floodplain forest.
- Natural succession.

The development of floodplain forests is mainly preferred in the new floodplain area Kirschgartshausen. The establishment of the population in the areas previously used for intensive farming requires substantial input, but the subsequent care will be extensive. In the lower lying areas, floodplains with soft wood, trees will develop. The medium and higher ground levels are the locations for the hard wood floodplain. In the sense of a sustainable use of the land in the area of the floodplains, the development of floodplain forests is especially valuable for the following reasons:

- It results in the creation of types of living space, which are to be protected and developed in accordance with the FFH guideline, and whose populations are endangered.
- It results in the creation of living spaces for a multitude of rare, endangered animal species, and to some extent plant species.
- It results in the creation of a useful supplement to the floodplain forests by the adjoining *Lampertheimer Altrhein.*
- It achieves a meaningful increase in the quality of the landscape in the densely populated area Rhein-Neckar (recreation in the close vicinity).
- It establishes a forest, with all its benefits, in an area where there are not many forests.

The new floodplain area is not covered entirely by small forests as that would hamper the runoff of flood water and contradict the aim of a floodplain landscape rich in structures. Areas at a relatively higher level are being developed as meadows. Areas with natural depressions will be deepened to allow them to carry water periodically. The result will be a varied landscape of floodplain forest, floodplain meadows, canebrake, and periodic waters, which resembles a park area and which is in line with the model. It will also be valuable from the recreation viewpoint and for nature conservation.


Figure 3.4: Example of a floodplain forest


Figure 3.5: Example of a floodplain meadow


Figure 3.6: Example of periodic waters with canebrake area

Advantages of dike relocation for Lampertheim
The town of Lampertheim in Hesse has been closely involved in the Kirschgartshausen project during the planning phase and supported it in many ways. In connection with the dike relocation, the following advantages are expected for the Lampertheim district.

- Improvement of the limnology situation in the Lampertheim Altrhein as a result of the supply of fresh water.
- Improved drainage in the southern part of Lampertheim due to the construction of the pumping station at *Holländergraben.*
- Eco-account areas in the new floodplain area.

At water levels exceeding the medium level in the Rhine, the *Lampertheim Altrhein* will in future be supplied with fresh water rich in oxygen and low in nutrients from the Rhine via the central channel in the new floodplain area. This will improve the limnology situation of the heavily eutrophicated and silted up Altrhein. Weed will be reduced and the fish population will be boosted.

During high water levels in the Rhine, the southern districts of Lampertheim are drained via *Holländergraben*. Large areas were water logged in the past at extreme water levels in the Rhine due to seepage on the landside of the dike. This situation worsened as a result of the relocation of the dike. The construction and operation of the *Holländergraben* pumping station is solving this problem.

Within the new floodplain area, high-quality floodplain biotopes are being developed in the Lampertheim district. Within the context of the eco-account (compare chapter 3.2.4), this creates possibilities for the compensation of interventions in accordance with nature conservation laws, without having to claim farmland from local agriculture.

Box 3.3: Advantages of dike relocation for Lampertheim

In comparison, the development concept for the Ingelheim Polder project has been established on the basis of the area size. About 20 ha of the 162 ha polder area was developed into an ecological flooding area. One of the main aspects for the development of the area was the management concept decision. In future, the ecological flooding area will be stocked with cattle.

The main goal of the development concept is to keep the fields, which were used intensively in the past, open for pioneer species and for bird species adapted to this temporary food and living space.

In order to achieve this goal, the animal population is five cattle per hectare/100 ha. This still leaves a great deal of space for nature in these areas and still allows some areas to be kept open. However, the animal population is about six times higher than in the wilderness concept (see chapter 3.2.2) of the SDF pilot projects.

A potential expansion of the grazing space in the area of the Ingelheim Rhine floodplains at a later date to an area of some hundred hectares would require a conceptual change (e.g. reduction of the large cattle unit/100 ha) for the development of the areas.

In the framework of the development concept, it was possible to take compensation measures for the changes in nature and landscape into account. In the planning and construction phase already compensation and substitute measures were implemented, such as the opening of the *Alte Sandlach*, as well as the ecological flooding. In addition the following compensation and substitute measures were taken.

- Development of extensively used grassland with loosening of the soil surface in the protected dike zone area. Sowing of types of grasses suitable for the area by using autochthonous material (20% Graminis flos seed/Heudrusch procedure) in an area of 59,860 m² and development of extensively used grassland at medium to dry locations on the polder dikes and the slopes of the inlet and outlet structure.
- Development of extensively used grassland at wet locations by loosening the soil surface and sowing suitable local grass types (20% Graminis flos seed/Heudrusch procedure) in an area of a total of about 5,600 m² and development of extensively used grasslands at wet locations near the inlet and outlet structure.
- Development of grassland bushes. Loose planting of bushes in groups in a strip of about 400 m² along the south edge of the stilling basin.
- Planting of a row of trees on the extensively used grassland by means of planting of 25 willows along the walkway and development of extensively used grassland in an area of about 2,500 m² along the agricultural road extending in north-south direction west of the *Im Mörs* ecological flooding area.
- Guided succession of the stilling basin and development of vegetation of alternating low and high wetness, as well as submerged water vegetation in the stilling basin of a size of about 1,100 m² by means of guided succession.
- Development of two trenches with reeds and fostering of the biotope connection over the flooding trench east of the inlet and outlet structure by means of an open culvert in the main Rhine dike.
- Development of trenches with reeds and ruderal growth in an area of about 3,700 m² near the flooding trench at the inlet and outlet structure and the *Neuer Graben* at the east side polder dike. Development of an area with reed and canebrake of about 500 m² in the area of the flooding trench at the inlet and outlet structure.

Figure 3.7: Sowing of the new dikes by means of the Heudrusch procedure

Figure 3.8: Improvement of the environment for the stork

The River **Emscher** today is still confined in a narrow, densely populated corridor. As a result of industrial changes, it lost its natural course with meanders, etc., as well as the space to redevelop a natural river. Consequently, an alternative reference image was worked out to enable the river to regain ecological structures.

For the project at the Emscher floodplain area, a reference image for vegetation and fauna was developed. In the preparation phase of the Emscher restoration planning, the Emschergenossenschaft together with the competent authorities defined the reference condition for the River Emscher *(lehmgeprägter Fluss des Tieflands* i.e. a lowland river characterised by clay deposits*)*. Though it is more or less geared to a status that existed more than 150 years ago, it is obvious that due to industrial changes the original conditions can never be regained. The Emscher will therefore adopt what may be termed as 'received nature'.

For the locations of the floodplains, a leading idea was to try to achieve a historical meander width (200 to 300 m) by designing the floodplains similar to structures created in the former Emscher Valley. The solution was therefore chosen to work with only one outlet building for each floodplain and to let the Emscher flow through the basins, streaming into the new wetlands and having the opportunity to change its bed even after smaller flood events.

The flood prevention aims for the two floodplains are different. The upstream floodplain, Ellinghausen, will be constructed to store the water at regular intervals even from smaller flood events (≥ every 5 years) to reach a more constant discharge with lower peaks downstream. This prevents the Emscher bed, flora and fauna from being damaged too often. However, it is also effective in the case of larger events (up to a frequency of 100 years).

The second floodplain, Mengede, is located about 5 km downstream of Ellinghausen and is mainly constructed for large flood events. The aim is to reduce the discharge to 70 m^3/s and to store the remainder up to an event with a frequency of 100 years. With regard to the safety level, it may be possible to combine the two floodplains as storage for events up to a frequency of 200 years.

The concept for the ecological restoration is based on the idea of widening the river bed wherever possible to create ecological hot spots. It is hoped that the Mengede and Ellinghausen floodplains will become such hot spots. The river bed within the basins will be profiled to allow regular overflow. This will form new wetlands and connect the river to biotopes in the neighbourhood. The planned growth of plants and trees in the river bed increases the risk and level of floods. Consequently, the ecological hot spots should have a positive effect with respect to flood prevention.

Differences in heights of the basin surface will lead to a variety of flora and fauna. Grooves, depressions and small ridges will result in more and less wet spaces after flooding. In combination with groundwater seepage at the bottom of the dike embankment, fen and moor structures will be initiated. Planting will be done only to initiate general structures. Most of the vegetation will grow spontaneously. The aim is to create an open landscape with max. 50% woods in the basins, the other 50% should be covered by typical wetland plants, such as reed. After the construction phase, the basins will be left to natural succession and the river will be allowed to form new structures and to find a new bed, etc. (within the basin structures).

The nature development focus of the **Lexkesveer** project consists of the development of both seepage marshes and brook marshes. For these developments, excavation of the forelands is required to a certain extent. These marshes are to be developed in direct relation to the underground and superficial water bodies existing in the glacial hills. This lateral hydrological and ecological relation between the Rhine river system and the large glacial hills is unique in the Netherlands. The development of these goals is structured by sustainable criteria.

- Redevelopment of the lateral hydrological relation between glacial hills and river forelands:
  - Seepage water:
    The glacial hills consist of large and very old groundwater bodies. A certain hydraulic pressure exists in the river forelands (due to the difference in height between the hills and the river). However, this pressure is weak due to pumping activities for drinking water. The aim is to redevelop the former existing seepage processes in the river forelands by excavating a layer of clay in order to reach the Pleistocene sand layers. In doing so, a unique hydrological system will be brought back to life.
  - Brook water:
    In addition to the deep underground water bodies, there are also superficial water bodies, draining their water to various brooks that drain to the river foreland and on to the river. The project aims to conserve this clean brook water in the river forelands, instead of loosing it directly to the River Rhine.

- Development of nature goals in accordance with existing hydrological processes:
  - Vegetation depending on seepage water:
    The seepage water originating from the glacial hills brings clean and high quality water to the surface. This water is the basis for vegetation depending on seepage water *(Scirpus Sylvaticus)*.
  - Brook-water-related vegetation:
    The new developed brook marshes will be fed with clean brook water originating from the glacial hills. These brook areas will provide a basis for the development of biotopes for special Alderbrook vegetations *(Alnus)*.

- Contributing to characteristic landscape structures:
  - The river forelands include older gully patterns at the feet of the glacial hills, where the River Rhine flowed in ancient times. The seepage marshes are designed along these patterns.
  - A drainage ditch drains the downstream agricultural land after high water periods. The excavations for the seepage marshes are designed in connection with this drainage ditch (which, however, prevents clean water being drained during summer periods). In doing so, the ditch is incorporated in a natural design and has a natural character.

Figure 3.9: Situation in early 19th century

Figure 3.10: Current situation

Figure 3.11: Planned Mengede floodplain

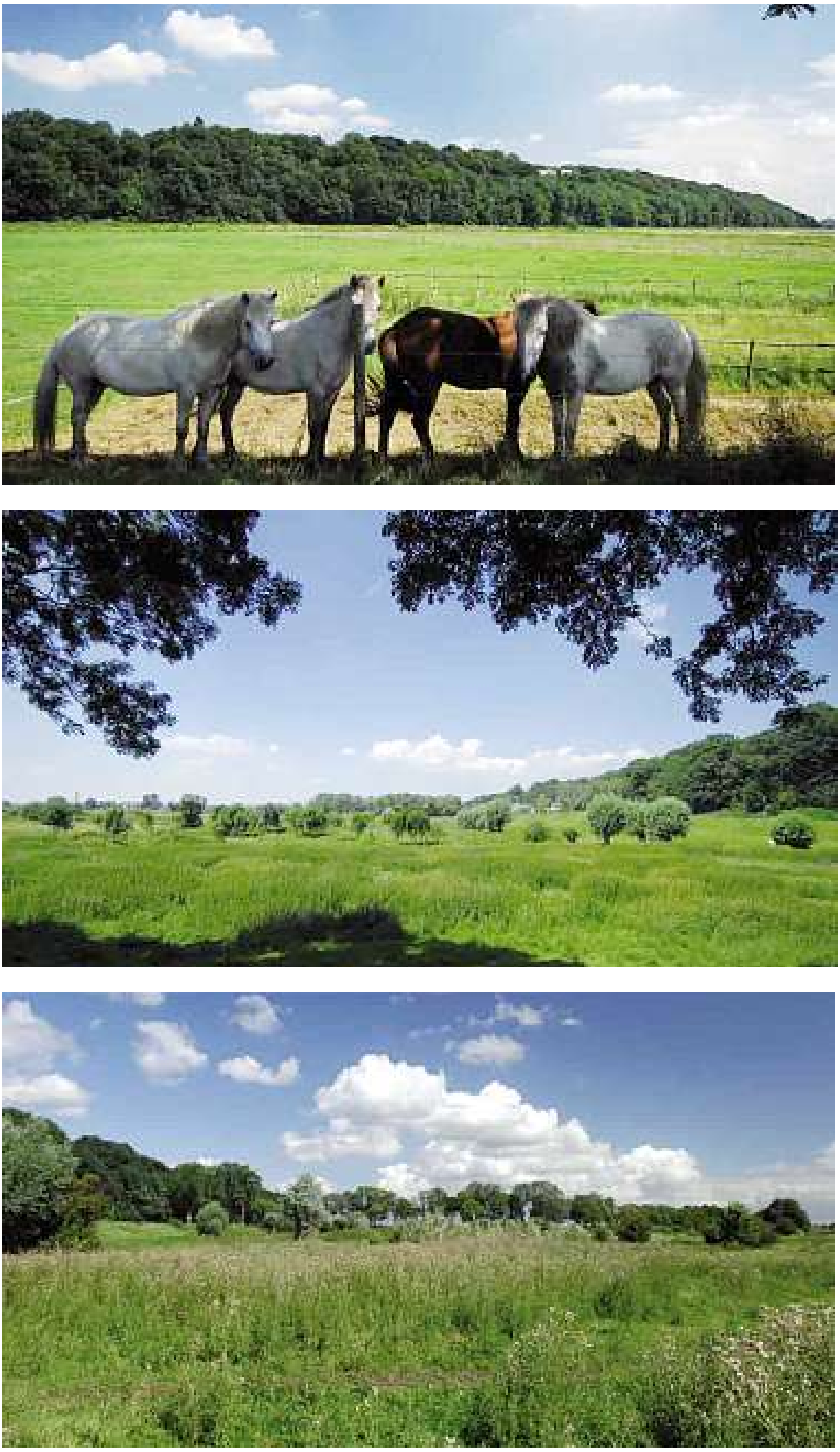


Figure 3.12: Lexkesveer: Marshes to be developed

In comparison to most other SDF pilot projects, the side channel of the Bemmelse Waard is not connected to the main stream. Because of the relatively high summer dike, the floodplain will be flooded only two days a year. Consequently, the floodplain can be characterised as a low dynamic river area. The present nature will be conserved and developed by connecting the water pools and creating shallow, smooth graded banks. Together with cattle grazing as maintenance, a related nature development area will be developed with different habitats ranging from wet to dry. The Ambtswaard and the eastern part of the area will be maintained as floodplain bird area. These areas will not be maintained by cattle but by local farmers. This will increase the diversity of the area.

Conclusions and lessons learned

Experiences in the Dutch and German projects of the SDF project have shown that the use of overarching long-term visions for nature and landscape restoration and development of and working with reference images provide a clear focus for devising outline plans and then converting them into specific measures. Using reference images also provides a clearer picture of the requirements in terms of future management and maintenance. Furthermore, they can also be helpful in communications with the local population and interest groups since they provide a clearer picture of what is going to happen and how a particular area will look in a number of years time. At the very least, it makes the debate about what needs to be done and about objections to the plans far more specific.

In addition, developing concepts have other advantages that might be considered when preparing and implementing new projects:

- Development concepts are helpful to structuring:
  SDF pilot projects make clear that development concepts are helpful to structuring projects. The goal of each project is to develop nature. However, no two projects are identical and in each case the development concept has to be specified for the project in question. Criteria are available to check if the development concept will be successful. Moreover choices have to be made.

- The following projects have been structured on the basis of development concepts:
  - For the Kirschgartshausen project, the concept of the development of areas of grassland, softwood and hardwood, depending on the topography, has been chosen.
  - The Ingelheim concept highlights an adapted form of the new wilderness concept.
  - The Emscher reference image is geared to the historical situation.
  - On the right bank of the Rhine, the Lexkesveer concept highlights the restoration of the hydrological relation between bordering glacial hills and the floodplains and on the left bank of the Rhine, extensive grazing patterns must result in higher diversity in vegetation and improve habitat quality for birds.

All projects show that in the light of these leading structures, the projects can be successfully implemented and executed. The leading structures furthermore offered a basis for further elaboration of the projects.

- Development concepts are helpful in communication:
  Projects with a clear structure can be explained more easily. Development concepts offer this structure and are helpful and often crucial in communicating and informing stakeholders and the public. In the Emscher project, for instance, the implementation of characteristic landscape elements such as the restoration of historical meanders was easy to understand, even though the original conditions may not have been reconstructed in full. In Lexkesveer, it was clear that creating hydrological conditions will lead to significantly more diversity in nature. Furthermore, based on the concept of extensive grazing patterns, local landowners agreed to participate in the nature management of the Lexkesveer project.

- <u>Development concepts are helpful in transferring knowledge:</u>
  Within the SDF project, transfer of concepts took place with regard to the new wilderness concept. This concept is a nature managing concept (see chapter 3.2.3) which has been successfully implemented in the Netherlands, e.g. at the Millingerwaard, and is now being studied in Germany and implemented in an adapted form, e.g. at Ingelheim.

3.1.2 Ecological flooding

Ecological flooding is the artificial flooding of a certain area (floodplain) that, in an ideal situation, demonstrates the same pattern as natural flooding. It is a method to restore old floodplains, to improve nature values and to ensure improved flood control by preparing the flora and fauna for high water events. Compared to flooding in case of retention, ecological flooding occurs more often, during shorter periods and with lower water levels. To bring about ecological flooding, smaller Rhine discharges will also be allowed to flood the designated areas (simulating smaller and larger natural events). During small events (about 190 days in one year), Rhine water floods only small channels and low-lying areas.

By using ecological flooding, the retention area is prepared for a flood situation but at the same time, flora and fauna in the retention area are affected by this measure. The species and biotopes of the intensively used farmland, which are not typical of the floodplains, will be replaced by species and biotopes typical of the floodplains. In future, the areas can no longer be used as farmland due to the damages caused by the flood events. Fruit trees are not very flood-tolerant and cannot adapt to the changed conditions, even if repeated smaller flood events occur.

Without this method, the retention in the case of floods would influence the nature in the retention area very intensively and negatively, so that ecological flooding is obligatory from a professional point of view. Additionally, the natural flood situations along the Rhine would not be sufficient to ensure a flora and fauna situation similar to that of a natural floodplain situation.
The natural floodplain fauna is benefiting a great deal from ecological flooding as the nourishment supply is better. This is valid not only for fish species and macrobenthos, but also for small mammals and amphibians. The fauna composition develops into more floodplain-specific species.

The goals of the Integrated Rhine Programme (IRP) of the German Federal State of Baden-Württemberg are twofold: sustainable flood protection by increasing the flood retention area in former floodplains along the (Upper) Rhine, and restoration of the former floodplains by ecological flooding. Ecological flooding prevents reduction of damage to the tree population due to floods. The trees have been growing here for a long time without any floods occurring and are therefore sensitive to floods. By means of the ecological flooding concept, the tree population has adapted to recurring flood events and damage resulting from flood water has been limited or prevented completely.

In the SDF dike relocation projects at Kirschgartshausen, Ingelheim Polder and Lohrwardt, the framework conditions for ecological flooding were implemented and practiced to improve nature values and to prepare the flora and fauna for high water events.

Up to now, the concept of ecological flooding has been applied only in Germany. The experience gained is important for projects in the Netherlands where bypasses and green rivers are being planned.

In order to guarantee the intended development of the future floodplains into nature-oriented floodplain forests and floodplain grassland in **Kirschgartshausen**, regular ecological flooding events are required depending on the natural fluctuation of the water level in the Rhine.

So far, the future floodplain area has been protected against flooding by summer and winter dikes. But even if these dikes had been completely relocated, smaller and medium flood events could not have flooded the new flood plain area due to the topographic conditions in Kirschgartshausen. The banks of the River Rhine are relatively high. This would prevent the flooding of the new flood plain area at small floods. In order to be able to flood the new floodplain area even during smaller flood events, a channel flowing at a medium water level in the Rhine must be excavated through the river bank.

In connection with the Kirschgartshausen dike relocation, the floodplain nature is being reorganised into the following two areas.

- Previous summer polder.
- New flood plain area created by the relocated main dike.

So far, flooding of the summer polder occurred during the vegetation period at an average of only once every ten years. Of course, such rare flooding events are not sufficient for the development of natural floodplains. In this case, a part of the summer dike must be relocated and inflow possibilities must be created for the natural fluctuating water level in the Rhine by adjusting the soil surface.

Up to now, the new floodplain area behind the main Rhine dike has only been waterlogged by seepage in lower lying areas if the high water levels in Rhine persist for a longer period. In future, ecological flooding events can reach these areas via the reconstructed pumping station at the *Nachtweidgraben* or via the main Rhine dike, which will be partially lowered.

The channel through the high river bank carrying water at a medium water level, as well as the modelling of the grounds are of special importance, and not only in connection with the flooding of the nature-oriented new floodplain area. It is intended to extend this channel so that water flows through the new floodplain area and therefore ensures a continued supply of fresh water to the *Lampertheim Altrhein* at above-medium water levels in the Rhine. This is especially favourable from an ecological point of view since stagnating water has a harmful effect due to the increased consumption of oxygen. The ecological flooding events may result in a mosquito plague. Consequently, the low lying areas have been connected to the system draining the remaining water via depressions.

By way of comparison, the *Im Mörs* sub area at Ingelheim Polder was connected more frequently to the hydrologic dynamic of the River Rhine. This area, which is not connected to the drainage system of the remaining agricultural polder areas, will now be flooded every year via the ecologic flood structure. The yearly flooding is limited to a maximum of 30,000 m^3 of water. The connection from the polder to the Rhine at low and medium water levels will be established by the *Alte Sandlach* old Rhine arm (Figure 3.13 and Figure 3.14).

Figure 3.13: Alte Sandlach: existing Altrhein arm

Figure 3.14: Upper stream ground excavation of the Alte Sandlach

During ecological flooding, the two drainage trenches, the *Münzengraben* and the *Brückweggraben*, as well as the side trenches flowing into them will also be flooded. The trenches are filled through the culverts already existing in the main Rhine dike. The duration of the filling phase up to a flooding height of about 40 cm in the ecological flooding area is approx. 20 hours. This estimate is based on hydrographs. Filling the drainage trenches takes about 2.5 days. Most of the water will remain in the flooded area even if water levels are decreasing in the Rhine. It seeps into the ground and evaporates at a rate of about 1 cm/day. It can be assumed that the *Im Mörs* area is flooded about 36 days a year under normal weather conditions.

Figure 3.15: *Im Mörs* ecological flooded area in March 2007

Figure 3.16: Inlet structure ecological flooding

These theoretical approaches were confirmed on three occasions in 2007.

- The first ecological flooding of the Im Mörs area was carried out in March 2007 (Figure 3.15).
- The second flooding was carried out as a result of the 100-year flood that was very weak in Ingelheim, which reached the Upper Rhine from the Swiss catchment area in August 2007.
- A third ecological flooding took place in December 2007.

All three flood events reached the 2 to 3-year flood levels in Ingelheim, so that the ecological floodplain was completely filled in all cases. The effects on flora and fauna were recorded in the scope of the monitoring, beginning in 2008. In the case of ecological flooding with a frequency of 1.25 times a year, the formation of biotic communities typical for floodplains is stimulated. During standard operation, the 10-year flooding in the case of high water requires the reduction of the polder's pre-filling level so that enough volume is available in the case of a flood. This flooding regime is relatively close to near-natural conditions in rotations of about 10 years and/or 0.8 years in ecological flooding areas and/or within the trenches of the area results in a clear stimulation of species and biotic communities typical for floodplains.

Before the construction of the polder, high-quality species in open land areas affected by seepage were already present. The future development of these partial areas took into account the existing value-adding species and biotic communities.

In this case, special reference is made to the open land species influenced by the groundwater level. In the area in question, pressurised water occurred on a regular basis with the groundwater escaping over large areas of low lying farmland. During those occurrences of pressurised water, these areas evolved into highly interesting living spaces for waders and swimming birds, and large communities of sword leaf rush were created. Further communities to be expected are watercress and water mudwort areas, Polygonaceae river shore areas, the Phalaridetum arundinaceae, as well as the Caricetum gracilis. Further upwards there will be *Phragmites australis areas, Rumex/Poa palustris L*. and/or *poikilohydrous Alopecurus pratensis* floodplains.

In order to keep as many as possible of these special and mostly endangered species in the area, large-area plantings and/or areas with new growth (areas for the growth of new copse) were avoided. Instead, a slight excavation of parts of the former seepage areas was performed in order to keep these areas waterlogged more often over longer periods and/or wet in future. It is expected that a large portion of the existing species can be safeguarded by means of these measures. Further species typical for floodplains are expected to develop in these areas.

Suitable methods for use of the land will ensure that the former open land character is maintained. That is particularly required for open land species such as waders.

Beyond these open land areas, the development of typical floodplains groves is desired. The fruit fallows, field groves and other smaller hybrid cottonwood copse present in this area will become part of the upper hardwood floodplain due to the altitude and future flooding frequency.

At the **Lohrwardt** summer polder, inlet structures, a culvert and outlet structures have been constructed with a fish passage facilities, a control station and ecological flooding facilities.

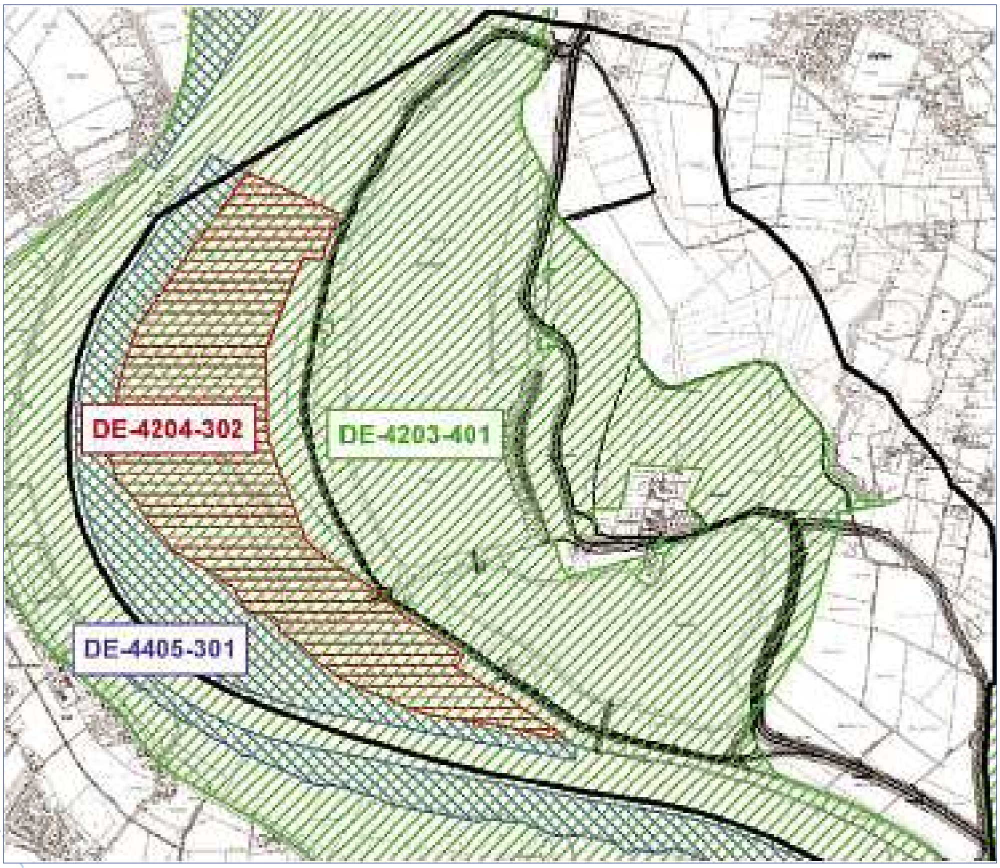


Figure 3.17: Lohrwardt Polder: Natura 2000 areas within planning area

DE-4203-401:	Bird preservation area northern Lower Rhine
DE-4204-302:	NSG Lohrwardt / Reckerfeld, Hübsche Grändort, only partial area with expansion
DE-4405-301:	Rhine fish preservation zones between Emmerich and Bad Honnef

The positive effects are: fish species and species of the Makrozoobenthos are given the opportunity to enter the flooded gravel pits and (via the outlet structure) into the Old Rhine near Rees. As a result, additional possibilities for spawning and raising are created, also for species listed in Appendix II of the FFH guideline.

Depending on the flooding, the FFH living space type 3270 (rivers with mud banks and one-year vegetation) may expand into the polder. The extensive agriculture trend increases habitat variety. The essential aim of the bird preservation area (the support and development of living space variety with its characteristic avifauna) is strengthened.

During the construction phase, impacts on the relevant Natura 2000 species are to be expected in the planning area. However, these impacts will be kept to a minimum by appropriate prevention and reduction measures. On a long-term basis, there will be an ecological gain compared to the temporary impacts. By building a summer polder, an area previously disconnected from the flooding dynamic will again be subject to influences closer to nature. This will result in the area becoming an extensive area, the habitat variety will be increased and excavated lakes will be developed with fish from the Rhine.

By allowing dynamic processes in an area previously used intensively for agriculture, the development goals of the bird preservation area are strengthened. An increase (at least for some time) of FFH living spaces is assumed.

Figure 3.17 shows the Natura 2000 areas in Lohrwardt.

Conclusions and lessons learned

In practice, the term ecological flooding is used for very different flooding concepts. These concepts have in common that ecological flooding is allowed for the purpose of achieving aims relating to the conservation of nature. Ecological flooding secures and boosts the population and development of living spaces and species adjusted to floodplains in the retention areas. In an ideal situation, the ecological flooding in a retention area imitates the flooding conditions that would prevail in natural floodplains. In this context, the location factors, frequency of floods, duration of floods, flood level and flow behaviour at flooding are of special importance. In practice, the different concepts of ecological flooding distinguish themselves mainly by the extent to which it is possible to approach the natural flooding behaviour under the conditions of a realistic retention area.

The term 'ecological flooding' is frequently distinguished from the term 'retention flooding'. Contrary to ecological flooding, retention flooding's main aim is flood protection. Retention flooding may be in conflict with ecological aims. In some retention areas, ecological flooding may also contribute to flood protection. At other locations, ecological flooding may be incompatible with the aim of the maximum retention effect.

At most of the polders on the Upper Rhine, ecological flooding is mandatory for nature conservation reasons for avoidance and reduction of interventions in the natural balance. It is effected in accordance with the model of the flooding that previously occurred naturally. In this way, nature and landscape are again involved in flooding events, which no longer occur since the building of the Rhine's main dikes and since construction of the hydroelectric power plants on the southern Upper Rhine. By opening the dikes and by means of special inlet structures, the areas are reconnected to the Rhine flood regime.

The situation on the southern Upper Rhine near the barrage is different to the situation on the northern Upper Rhine. In the south, there is a sufficiently high level of dammed water in the canalised Rhine to flood the lateral polder areas ecologically. At this location, it is also easy to halt the ecological flooding in order to drain the retention area to a considerable extent before effecting retention flooding. Almost the entire retention volume is still available for flood protection. With regard to flora and fauna, very positive experiences with ecological flooding have been gained over a long period at Altenheim Polder (which is not part of the SDF project). Information concerning these experiences can be obtained from the Baden-Württemberg authorities.

On the north side of the Upper Rhine, ecological flooding can be performed only naturally. Comparable conditions exist at the Kirschgartshausen and Ingelheim Polder SDF pilot projects. These areas can be flooded only when the Rhine's water level rises as a result of a flood. Draining the retention area is not possible at higher water levels in the Rhine.

At the Kirschgartshausen dike relocation, the demarcation of the location in connection with the natural relief would mean that the new floodplain area cannot be flooded during the frequent smaller floods. In order to avoid the limitations for the development of the corresponding floodplain, the construction of a continuous watercourse – which enables the ecological flooding of the Rhine from medium water level – is planned for Kirschgartshausen.

Besides deepening the ecological floodplain, the side arm of the Rhine, the Alte Sandlach, in Ingelheim, which had been filled with dredging sand from the Rhine in the 1950s, had to be excavated to enable the inflow of water during a 1-year flood. The amount of water flowing into the ecological floodplain is limited by means of a controlled culvert structure in order to avoid incompatibility with flooding in the case of high water.

Within the scope of the SDF project, new initiatives were taken to develop sustainable floodplains. Not only was the dike opened, an active intervention in the streaming conditions was also carried out to enable ecological flooding. This successful approach has twice been demonstrated by ecological flooding carried out in March and August 2007 on the northern Upper Rhine. The effects of the ecological flooding on flora and fauna will be recorded during future monitoring. But it can now be concluded that the establishment of the ecological floodplains has positive effects on nature and the landscape in general. More particularly, the benefits are being felt on the protected open land areas for certain species of aquatic birds, e.g. the lapwing.

Transferring the lessons learned to the Netherlands
Despite the useful and new experiences gained with ecological flooding in the German SDF pilot projects, it has not yet been applied yet in the Netherlands, at least not in the floodplains along the Rhine, Waal and IJssel rivers. The nature in these areas has already adapted to frequent flooding that occurs at high water levels.

Experiences with ecological flooding are relevant for areas that will become part of the river system as a result of measures being taken in the Room for the River (Ruimte voor de Rivier) programme. This is the case with the relocation of dikes (similar to Hondsbroeksche Pleij), the construction of new channels in areas that currently lie on the land side of dikes (for example, Noordwaard) and the construction of flood channels, as in the case of the Veessen Wapenveld Room for the River project.
In these projects, nature areas will be created or constructed with nature target types influenced by regular flooding. The frequency of flooding will vary greatly. Furthermore, it is still unclear whether a natural inlet or overflow dam or a human-operated inlet will be constructed. In these areas, it is certainly worth making use of the experience gained with ecological flooding.

3.1.3 Side channels and lowering of floodplains

The Rhine has largely been transformed as its natural course has been modified. The principle reason for this transformation had been the introduction of greater safety in riverine areas and the improvement of navigation conditions. Moreover, the decades after the World War II were dominated by the urgent need to improve agriculture in order to enlarge food production.

The general result of these developments was that existing side channels were closed and cultivated. Natural river processes in the floodplains no longer took place. High dynamic ecosystems vanished and were replaced by agricultural grasslands and maize.

The implementation of measures like the lowering of floodplains and the excavation of secondary channels started mainly as nature rehabilitation measures in the riverine area. They were intended to bring about more dynamic new nature areas instead of agricultural areas. The first side channel (one side connected downstream) was excavated in 1985 in the Duursche Waarden floodplain along the River IJssel. Evaluation of the project yielded promising results on the development of, for example, fish species, water birds and riverine habitats. Besides the effects on nature, the widening of the river bed and the lowering of floodplains are also suitable measures for decreasing flood peaks.

In the Netherlands as well as in Germany, several projects have been implemented or are planned. In the SDF floodplain projects in the Netherlands, all located on different branches of the Rhine, the floodplain level was lowered by excavation. This took place mostly in combination with the construction of a side channel and was occasionally linked to revealing the former course of the river by joining and reducing existing clay and sand pits, or in

association with providing a high water refugee for livestock.
In most cases, the SDF activities involve the planning of side channels and no experience of nature development can yet be shared. Nevertheless, nature development is the objective of most projects. The following section includes a description of the way nature development was considered during the planning at Bemmelse Waard. In this case, the technical planning was adjusted to environmental project goals. On the Lower Rhine at Emmericher Ward and Bislich-Vahnum, the feasibility of implementing side channels in nature protection areas was assessed.

In other projects, such as Ingelheim Polder, the plan had to be adjusted after the project start as measures in the ecological flooding draft plan proved to be unworkable. As a result, a side channel was opened. In addition, the example of Lexkesveer shows how sustainability criteria defined and considered at an early stage result in nature development in the floodplain. A great variety of nature, e.g. hard and softwood forests, marshes, wet and dry flower-rich grasslands, etc., is expected to develop in which all types of characteristic riverine species will occur.

Specific aspects of nature development to be dealt with in the planning phase

Specific aspects of the nature development objectives need to be taken into account as early as the planning phase of a project. That was the case, for example, at the Bemmelse Waard where the lowering of the floodplain is planned to take place at locations where the highest discharge will occur during high water (flow lines). At these locations, ponds and shallow banks will be created. The ponds will be connected to a side channel with a length of 1,450 m. The banks of the side channel will be shallow. Here, new riparian vegetation may develop. The excavation of the side channel will reveal part of the historical pattern of the river.

The slopes of the side channels, together with the future management of the area, are key factors for the future nature development. In the Bemmelse Waard, the following technical aspects have been taken into account.

1. The average water level in the Bemmelse Waard is 8 m + NAP. Light can penetrate approximately 2 m below the water surface. This is the most interesting zone for nature development. Consequently, the slope in this particular zone will be as shallow as possible (1:10 up to 1:15). The slope under 6 m + NAP is 1:3 up to 1:4 to optimise the excavation of sand.
2. The wind direction in the Bemmelse Waard is mainly westward. The wind transports seeds. To prevent willows, etc. from developing on locations where it is not desirable for hydraulic reasons, the banks in the wind direction (westward) will be steeper than banks in other directions. The westward-oriented banks will have a slope of 1:5. Consequently, any seeds washed ashore will have a relatively small area in which to develop.
3. Some parts of the Bemmelse Waard will in future be maintained by cattle. The cattle will stay in the Bemmelse Waard the whole year. To prevent cattle from drowning during high water periods, two higher areas of 14.5 m + NAP will be introduced within the project area.

This example shows how important it is to take into account the nature development objectives while planning the construction activities in the floodplain area.

Another aspect while planning engineering projects is the feasibility of the proposed nature development in the area. During the SDF activities along the Lower Rhine, for example, draft plans for the construction of side channels were prepared for the Emmericher Ward and Bislich-Vahnum. The main aspects in terms of obtaining approval of the plans have been studied and developed in detail by means of feasibility studies. The main objectives are to improve and enrich the environment of the Rhine as a habitat, to lower local high water levels and to reduce erosion of the riverbed in the main stream.

The two side channel plans share the same environmental objectives:

- Constantly flowing water in the bypass to provide a habitat for species favouring flowing water and biotic communities. The main limiting factor in this case is the Rhine's role as a waterway that does not permit water to be diverted at levels below average water level.
- Facilitating dynamic processes in the bypass, such as the movement of sediments, development of escarpments, etc. At the same time, silting processes, i.e. large-scale sedimentation, should be avoided so as to preserve a functioning system with low maintenance costs for as long as possible.

In the Bislich-Vahnum project, a limited flow rate has already been achieved at average low water level by means of a permanent inlet control structure. In the channel, taking into account the existing geomorphologic conditions, periodically flooded sections with flat river banks should alternate with steeper, faster and slower flowing sections.

In the Emmericher Ward project, dynamic transpositions are possible only to a limited extent due to the smaller size of the channel. This makes it especially important to preserve the near-natural dynamic gravel embankment located between the planned channel and the river. A flood channel is also planned for the foreland in Emmericher Ward. The intention is to cut through the summer dike ring to make an earlier flooding of the foreland possible.

Both the planned side channel and the flood channel continue to be linked to the planned riparian forest in the neighbouring dike foreland. The retaining effect of the planned forest at high water is to be compensated by the side channels combined with an accompanying forest-free strip of land. The results of a survey by the Federal Waterways Engineering and Research Institute are presented in Figure 3.18

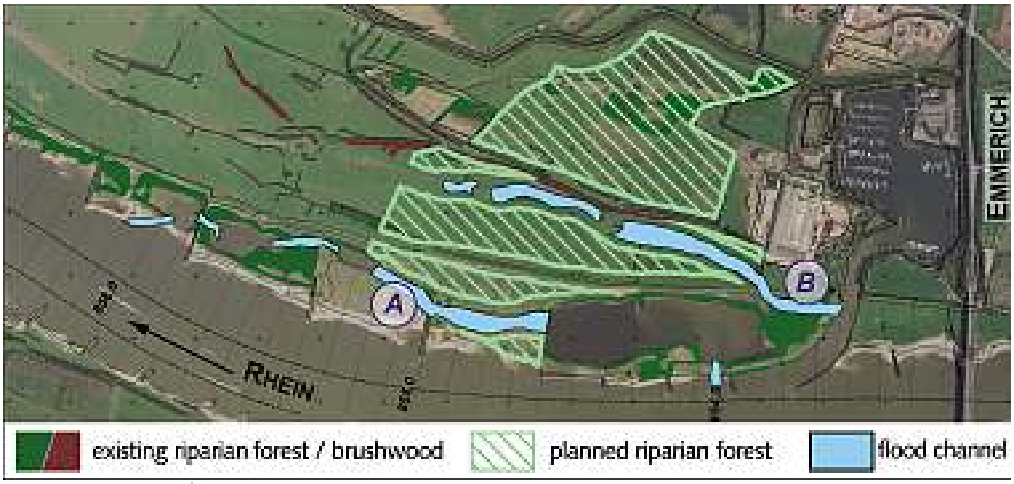


Figure 3.18: The Rhine at Emmerich with existing and planned riparian forest, planned side channel (A) and flood channel(B)

The flow rates altered as a result of the planned riparian forest and the flood channels are shown in Figure 3.19 for an average flooding event (6,381 m^3/s). The linking of the foreland on the right through flood basin B remote from the river reduces the flow rate in the river, which causes a reduction in the flow velocity in the river. In the affected section of the Rhine, in which continuous erosion has been observed over many years, this reduction in the flow velocity may be regarded as a positive development.

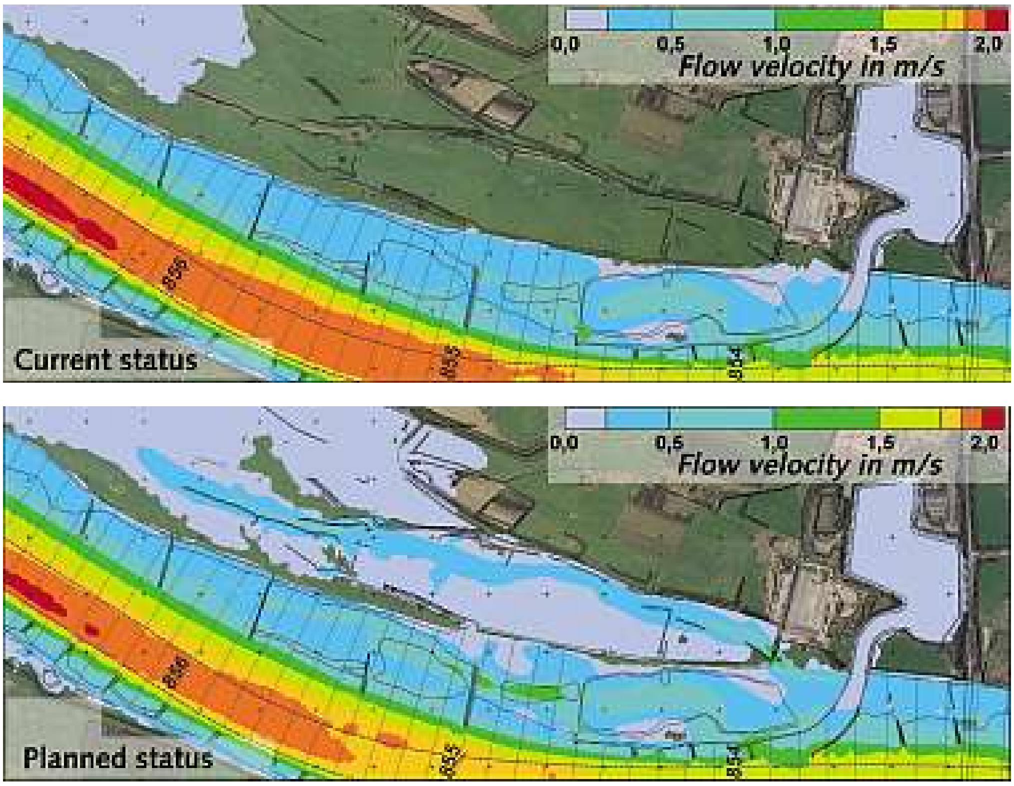


Figure 3.19: Change in flow rates due to the planned riparian forest, side channel and flood channel at average high water levels (*mittelerem Hochwasser/MHW*) (above: current status, below: planned status)

At the same time, it has become clear that the foreland is being increasingly affected by flooding, thereby increasing its function as a floodplain.

Overall, it is expected that the interests and standards of the German Federal Water and Navigation Administration can be fully incorporated into the plan. Required road connections can be preserved and pipes can be laid or siphoned. Because of the location of both plans in the EU Lower Rhine Special Protection Area and the involvement of other protected areas, the effects in terms of Natura 2000 have been thoroughly investigated and explained. In general, both plans can be expected to result in an improvement of the areas in terms of the conservation aims.

As a contribution to lowering local high water levels, side channels are elements of an inexpensive form of flood protection compatible with nature conservation and part of North Rhine-Westphalia's flood protection policy.

Specified sustainability and feasibility criteria effects construction design

The planning sometimes has to be adapted after assessing certain criteria. For example, in the Ingelheim Polder, a 2-D model had to be applied in 2003 to identify the existing options for ecological flooding of the polder after concluding that the flooding of the polder area was not that so easy. This was because the access to the open Rhine was blocked by an island. The solution was that the upstream part of the old Rhine arm (*Alte Sandlach*), which had been backfilled, had to be deepened again and the backfilled material had to be removed. This meant that there would be a connection to the river at average high water level in the Rhine. Ecological flooding can then be carried out through the Alte Sandlach towards Ingelheim Polder. Those were the results of the 2-D model calculations.

The *Alte Sandlach* is an old side arm of the Rhine, which separates an island from the actual shore. In the 1950s, the side arm was filled over a length of about 1 km with dredged material from the Rhine on the behalf of the Water and Navigation Authority. From that time on, a connection of the side arm to the regime of the Rhine took place on average only with 2-year floods. The Alte Sandlach silted up visibly and frequently dried out.

Figure 3.20: Bridge over the *Alte Sandlach* side channel, small flood in August 2007, the River Rhine is in the background

Figure 3.21: Excavated *Alte Sandlach* side channel

An initial improvement was achieved in 2003-2004 when the side arm was connected downstream to the Selz, which discharges into the Rhine at that location. Since that time, there has been a constant water level in the *Alte Sandlach* even in times of dry periods or low water.

The deepening of the backfilled upstream section of the *Alte Sandlach* was carried out in the course of the construction of the polder in 2004-2005 (Figure 3.21). Water is already flowing through the side arm at smaller flood events, and the ecological flooding of Ingelheim Polder is possible and has already taken place twice in 2007. Within two years of completion, morphological changes could be detected in the river bed. These were desirable changes that resulted in an increase in the structural variety. In the case of Ingelheim Polder, the planning and the project implementation were adjusted even after the project started.

In the case of the **Lexkesveer** project, specified sustainability criteria were defined in advance of the implementation of the project. Furthermore, the project goal (high water protection) and particularly the design of a high water gully had to be achieved according to these criteria.

Figure 3.22: Lexkesveer: overdimensioned high water gully compensates for nature development

Before describing the sustainable criteria for the project, it is important to mention further management aspects. At the beginning of the project, a decision was made to design a high water gully instead of a side channel for reasons of nature and management. This part of the river (Lower Rhine) is characterised by low dynamics during the growing season as weirs control the water level in this part of the river. Consequently, there are few possibilities for the development of organisms that are used to faster flowing water. However, a high water gully is more appropriate in a low dynamic system. In terms of management aspects, side channels easily lead to high sedimentation processes in the channel. This in turn leads to a reduction of the discharge and that is not in line with the safety goal of the project. Side channels may therefore result in a higher intervention level in the management plan, leading to a considerable increase of costs. The design of a high water gully is better suited to the Lower Rhine (*Nederrijn*) system and unlike side channels, is not subject to intensive sedimentation processes. Consequently, this measure is considered highly sustainable, with a low intervention level that contributes more effectively to nature goals with fewer disturbances of organisms.

Taking account of the nature and management aspects which led to the decision to implement a high water gully, the following sustainability criteria for the project were considered to achieve the defined goal.

- Integrated planning approach of both left and right floodplains:
  In the project, both left-side and right-side riverbanks were considered for the location of a high water gully. The flow pattern of model investigations showed that, related to river dynamics and morphology processes, the left-side riverbank would be most effective in decreasing the water level. This integrated approach is unique and has led to the most sustainable solution. Both the current orientation and the choice for a high water gully with a natural inlet above average discharge result in less sedimentation and the preservation of a long-term functioning system at low maintenance costs.
- Future value (degree of flexibility of the system):
  The high water gully can easily be enlarged in the future, both upstream and downstream, thereby enlarging the discharge if necessary.
- Compensation for nature development:
  The design of the high water gully is overdimensioned in order to compensate for additional nature development goals, such as extensively managed grasslands, reed marshes and small forest extensions.
- Contribution to nature goals related to the high water gully:
  The gully banks offer large surfaces for nature development, steep banks, as well as gentle slopes with reed vegetation. The development of a small zone of willow bushes is also possible. The surface water of the gully offers a sleeping and shelter place for geese and swans (tundra swans);
- Contribution to improving landscape structures:

  1. The high water gully is located in two flood plains separated by an access road on a dam to the ferry (Figure 3.23). This ferry dam will be excavated and replaced by a bridge construction. The combination of these two measures results in the joining of both forelands. The high water gully acts as a positive structuring element.

  2. The composition, direction and location of the gully are designed according to existing but submerged gully patterns, therefore contributing and referring to the shaping of the current landscape.

Figure 3.23: Access road separating the two floodplains

The side channel in the **Bemmelse Waard** will be constructed at such a depth that no vegetation growth is expected in the side channel. Vegetation will occur only on the banks of the side channel. Cattle will maintain this vegetation.

The sedimentation is expected to be minimal since a low dynamic floodplain is involved that will be flooded twice a year on average. The upstream part of the side channel is a deep pit of 9 m – NAP. This pit will function as a sediment trap during flooding.

The Bemmelse Waard floodplain will be monitored every five years. Monitoring items are vegetation development and sedimentation of the side channel. The data will be used to determine if the floodplain still functions according to the set hydraulic goal.

Differentiation of dynamic zones in side channels
The compromise plan for the future design of the Heesseltsche Uiterwaarden consists of three zones, based on the inundation frequency: the high dynamic zone, the low dynamic zone and the intermediate zone.

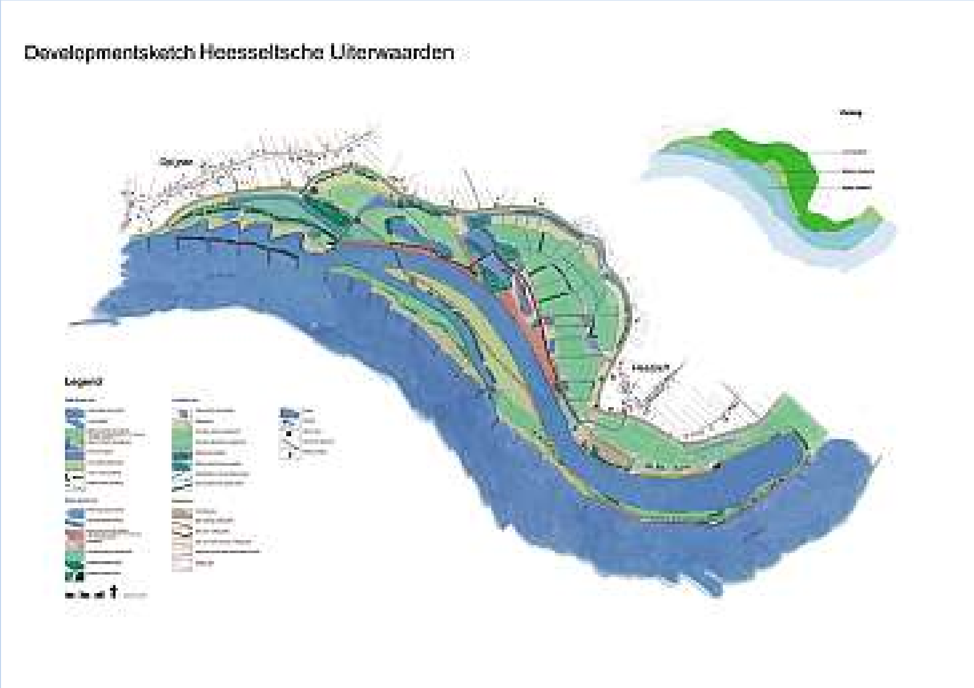


Figure 3.24: Heesseltsche Uiterwaarden compromise plan

High Dynamic Zone
The large broad secondary channel is the most important element of the high dynamic area. This channel is very important to obtain the room for the river goals. But it is also an important addition to the existing and very well functioning side channel near Opijnen.

The new channel provides a connection to the River Waal near the sand pits. To create enough discharge capacity, both sand pits will have to remain in their present state, despite the fact that is was preferable to narrow them for ecological reasons. However, the depth will be less. The pits will be filled to the level where no influence is expected on the discharge capacity.

An inlet work has to be constructed to regulate the amount of water that flows through the secondary channel. This is a maximum of 3% from the average discharge, to avoid sedimentation in the main channel of the River Waal. Consequently, the velocity of the streaming water in the secondary channel will usually be quite low. Besides the large channel a small bank channel is planned. It is located at a former channel that is mostly filled with sediment and vegetation. This channel also needs an inlet work.

Area with suppressed dynamics
The central part of the floodplains will experience less influence from the river. It consists of the large banks of the channel and an area near a new cay that will be lowered in full. The existing natural levee is being moved towards the dike in the form of a cay. This is favourable for the discharge capacity. At points where it does not affect this capacity, forest may develop.

Low dynamic area
At present, the area north of the summer dike is only inundated for approximately 10 days a year. The existing nature values are a result of this low level of river dynamics.

The area will be smaller in the future, due to the moving of the summer dike. However, the existing values and function will be maintained as far as possible. This will guarantee that the area will remain an open landscape.

Conclusions

The stakeholders accepted the zoning concept due to the fact that a variety of habitats will be developed for nature. The historic aspects of the cultural landscapes, including a brick factory and cattle grazing (by a local breed) will also be taken into consideration. The precise dimensioning (width and depth) of the side channels according to the comprise plan has to be calculated.

Maintenance will be linked to the three zones of dynamics and will be geared to safety and nature aspects. The pastures in the high and intermediate dynamic zone will be extensively grazed year round, focusing on the development of dry riverine grasslands *(Medicagini-Avenetum vegetation)*. The grazing also aims at maintaining the open landscape. In the low dynamic area, agriculture will remain, but attention will be paid to nature, particularly with regard to pastures and geese species.

The grazing will guarantee the discharge capacity with regard to vegetation roughness in the floodplain, but when sedimentation in the channels reaches a certain point, excavating may be necessary.

Box 3.4: Differentiation of dynamic zones in side channels

Conclusions and lessons learned

The project examples showed that in order to restore natural ecosystems in the floodplains, the water manager has the option of developing side channels. This development however has to meet the requirements of a safe discharge of water, ice and sediment and has to comply with navigation requirements. Consequently, side channels are limited to a maximum of discharge, velocity and distance to the dikes. Strong erosion and sedimentation processes cannot be tolerated in the case of major navigation routes like the River Rhine.

In order to contribute to a more complete ecosystem, side channels also have to comply with ecological demands. There has to be a continuous presence of shallow streaming water in one or more side gullies to permit organisms to migrate and shelter. There has to be a certain variety in flow velocity (0.3 to 0.8 m/s), the higher velocity allowing sand to move and clay-like sediments to leave. The variety in velocity will also boost the development of a more diverse pattern of vegetation and is expected to stimulate the presence of more rheophilic fish species. Water depth, sediment type, flow velocity, morphodynamics, organic matter content and soil chemistry together determine the species composition of the macro invertebrate community.

In any event, reference can be made to the following projects results. Species diversity in side channels appear to be much higher than in the main channel. This is the case for macro invertebrates, vegetation types and fish species. However, the degree of success varies between these projects and within the projects and depends on local conditions, such as flow velocity. Side channels also appear to have an important function for young fish and the large variety in steep and shallow banks attract many bird species. As far as the restoration potentials are concerned, the side channels offer suitable habitats to a wide range of species.

With regard to the above examples, no problems occurred in relation to navigation conditions and no sedimentation took place in the main channel. Sedimentation and erosion processes in the side channel took place, particularly in the first years after implementation. There were significant local impacts, although no severe problems occurred.

The projects show that there are good possibilities for constructing side channels within the limiting conditions of safety and navigation. It is recommended to aim for a great diversity of habitat types, e.g. better conditions for the development of water plants and the existence of dead wood biotopes. There is no need as yet for intensified management of sediment. However, monitoring must be continued and the challenge is to meet all these different demands and to combine ecological restoration with an increase in safety.

In addition to the effects already stated, the SDF partners experienced the following positive effects of the implementation of side channels.

- Increased dynamics in the floodplain, more variation of riverine habitats and gentle gradients along the banks.
- Spawning habitats for rheophilic and eurotypic fish species and feeding area for water birds.
- Reduction of the peaks in river discharges (cannot be controlled like the retention polders in the Upper Rhine area).
- Contribution to recreational use and attractiveness of an area.

However, negative effects may also occur, such as:

- Sedimentation problems may affect the main channel (in the Netherlands mostly a navigation route), so that after some time extra maintenance measures (i.e. excavation) must take place.
- Returning dynamics to an area also means that erosion and sedimentation processes can take place along secondary channels. In most cases, there is no apparent problem. However, if structures like winter dikes and/or bridges are eroded, the water manager will need to take action.
- The natural succession of vegetation in a dynamic floodplain will lead to the development of more bushes and floodplain forests, which might hinder the fast water discharge during floods. A balanced approach from a water and nature management point of view regarding the maintenance of these floodplains is therefore necessary.

3.2 Multifunctional land use and management concepts

3.2.1 Multifunctional land use and tools for compensation (eco-account)

In intensively used and densely populated central Europe, there are usually no unused areas along the rivers that can be made available for conflict-free flood protection. However, the introduction of flood protection measures – and particularly in the case of polder construction and the relocation of dikes – requires extensive areas. Often, the areas are competed for by flood protection considerations on the one hand and agriculture and forestry on the other. Usually, areas already used for construction can no longer be made available for flood protection.

With regard to the use of areas for flood protection, a basic distinction can be made between controlled flood retention (polder) and the relocation of a dike. In order to avoid competition between flood protection and agriculture, controlled flood retention systems are planned and implemented more often than relocations of dikes. Controlled flood retention systems are flooded only at extreme flood events and the agriculture is compensated for the resulting loss of production. In most cases, such arrangements allow the continuation of agriculture in the same manner as before. This reduces competition in areas, particularly with regard to areas lost due to construction of the new dikes.

In dike relocation areas, the agriculture conditions are changed considerably in comparison with the controlled flood retention areas. Smaller flooding events, which take place even during the vegetation period, prevent further agricultural use. In areas with low or medium flood frequencies, an agricultural alternative would be extensive cattle grazing. There are many examples of this in the Netherlands. In comparison to intensive farmland use, this extensive form of cultivation also results in an upgrading in nature conservation and in local recreation facilities.

In the **Kirschgartshausen** dike relocation area, the frequency and duration of flooding events during vegetation periods are too high for use as grazing land. However, the future situation will be favourable for the development of floodplain forests. The future forests will not only produce wood, but also will result in the development of high-quality biotopes from the nature conservation point of view. This will provide living space for many endangered species. At the same time, an attractive landscape is created, as was the case in the Netherlands where the extensive use of the pasture land created an unique landscape that also serves recreational purposes. The initial intensive care required while planting the floodplain forest may be reduced once it has been established, so that long-term use of the floodplains is ensured.

Farmers accepted the conversion of farmland into floodplain biotopes, which serve as recreation areas close to the floodplain forests. In this context, the eco-account occupied a key position (see below).

Build-up areas are usually not available for flood protection. But such areas often border the areas required for flood protection. Building sites have to be protected against rising groundwater levels and seepage. Adequate measures have to be introduced to ensure proper landside drainage conditions.
Besides the creation of attractive local recreation areas, special emphasis is placed on flood protection measures with a view to public acceptance.

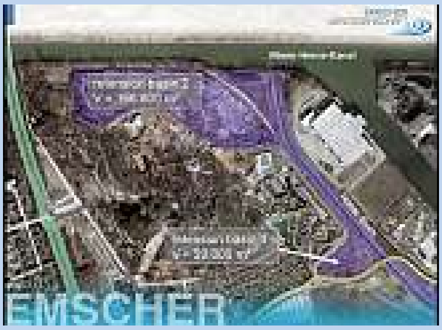
At **Ingelheim Polder**, the area was used for farming and/or extensive fruit-growing. The areas will now be used as a flood retention area, which will increase the multifunctional use of the area. The ecological flooding area will in future serve as an area for the protection of species and biotopes. The area is kept open for very special biotic communities by means of extensive cattle grazing and/or by an extensive use of the green land. This means that the periphyton developing in this area is integrated into agricultural processes. This concept of management by use is an essential component of the strategy for conservation of nature applied by the Department of the Environment of Rhineland-Palatinate.

At the same time, this reshaping of areas and this type of management result in the landscape becoming extremely interesting for the population in search of local recreation areas, as well as for tourism in Rheinhessen.

Multifunctional use at Gelsenkirchen zoo

Due to the parallel restoration of the Emscher system and the enlargement of the municipal zoo in Gelsenkirchen (located at the confluence of the *Hüller Bach* and the Emscher since 1949), the *Emschergenossenschaft* and the Municipality of Gelsenkirchen cooperated to develop a common flood prevention project to store water from the *Hüller Bach* tributary.

The construction work started in 2003 and will be completed in 2009. Three main subject areas are planned: Africa, Alaska, and Asia. To enlarge the zoo to a size of 30 hectares, a dike between the Hüller Bach and the zoo had to be removed. In the vicinity of the Hüller Bach since July 2006, the Africa World, which consists of 14 hectares for more than 300 animals (39 species), represents an African landscape and integrates a basin with a retention volume of 166,000 m³ without being apparent to visitors. An artificial shallow lake covers about 1 hectare of the Africa World. In the case of flood events, the water level of the lake rises from an overflow at the former dike. The animals may then escape to higher parts of their territory. Normally, visitors may enjoy sightseeing tours with boats on the lake and see flamingos and other animals at close range. This is an innovative solution for multifunctional land use.



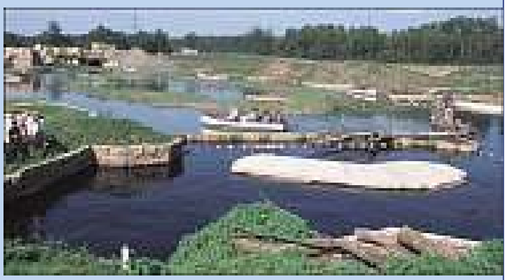


Figure 3.25: Gelsenkirchen zoo

For more information see www.zoom-erlebniswelt.de

Box 3.5: Multifunctional use at Gelsenkirchen zoo

Multifunctional economic and ecological objectives at Millingerwaard

A good example of multifunctional land use can be found at the Millingerwaard project. In this project, work has been in progress since the early 1990s to develop nature according to the ideas set out in the World Wildlife Fund's Living Rivers document. A large part of the Millingerwaard has been completed and managed for years.

New plans are currently being prepared for the remaining part of the Millingerwaard. These plans should ultimately lead to the creation of a large and robust nature area of international significance. The project is part of the transnational strategic green project *Gelderse Poort.* The majority of the existing nature within Millingerwaard has been created with carefully planned clay extraction for the brick industry. Another activity was sand extraction. These economic activities will continue to be important economic drivers of the project in the future.

While the work was being carried out, a lot of thought was given to ways of boosting the area's economy. A strong tourism sector has developed around the existing nature areas, which are open to visitors and represent a strong marketing tool. Large grazers roam freely in the area to keep the vegetation short. The size of the herd will have to be controlled, which means that at some point a number of the animals will have to be slaughtered. The meat will be sold with a special quality label.

Millingerwaard shows that economic and ecological objectives can easily be reconciled by opting for multifunctional land use.

Box 3.6: Multifunctional economic and ecological objectives at Millingerwaard

In areas with multifunctional use and an increasing demand of different uses, there has to be a guiding principle for compensation. In several federal states of **Germany** the **principles of eco-account** have been adopted. Eco-account can be described as a pool of implemented ecological valuable measures or specific areas that are available for such measures. These measures (for example the transformation of agricultural land into floodplain forest) will be credited to the eco-account. If an intervention with nature damage takes place at a later stage, the eco-account will be debited.

The basis of eco-account is that before interventions such as building activities start, the potential loss of ecological values has to be compensated and/or substituted by developing new nature at another location. If the development of nature takes place long before the building activities start, there is no loss in ecological value during the construction period. The following diagram shows the balancing of impact and compensation through the use of an eco-account.

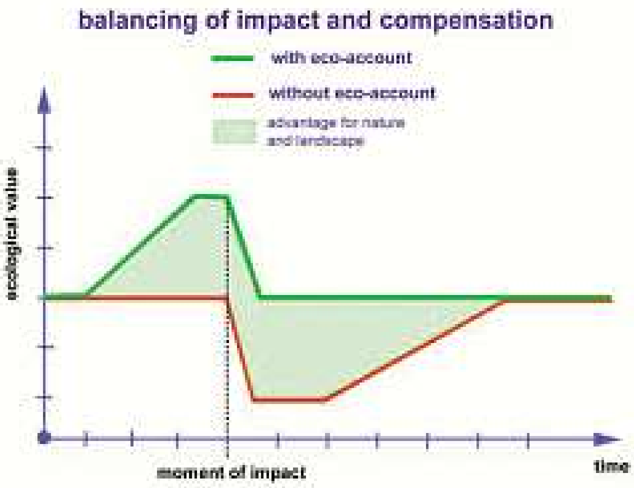


Figure 3.26: Balancing impact and compensation

In the case of the dike relocation project at **Kirschgartshausen**, very good experiences in the use of the eco-account were gained. In connection with the establishment of the availability of areas, the principle of the eco-account plays an important role. Without the eco-account, a higher resistance to the use of the leased areas, which had previously been used intensively for farming purposes, would have had to be expected. As a result of the eco-account, agriculture has the advantage that the lost areas in Kirschgartshausen will be used not only for flood protection, but that the areas which were excluded from the intended use may be used as compensation for interventions taking place elsewhere. Consequently, the loss of farming land at other locations is excluded.

At the Kirschgartshausen dike relocation, the areas shown in the illustration below (Figure 3.26) are used in accordance with the eco-account. Consequently, 15 ha of hard wood floodplain forest were already planted as compensating measures for the construction of a large multi-function stadium (SAP Arena) and the establishment of a large furniture company (IKEA). Further eco-account areas will probably be supervised by the *Nachbarschaftsverband Heidelberg-Mannheim* in Baden-Württemberg and by the municipality of Lampertheim in Hesse.

The application of the eco-account also has advantages for nature conservation as compensatory measures can be implemented prior to the interventions. For the long-term care for the eco-account areas, the individual intervening parties assigned to the areas in question will be responsible. This will relieve the owner of the areas and the water management administration.

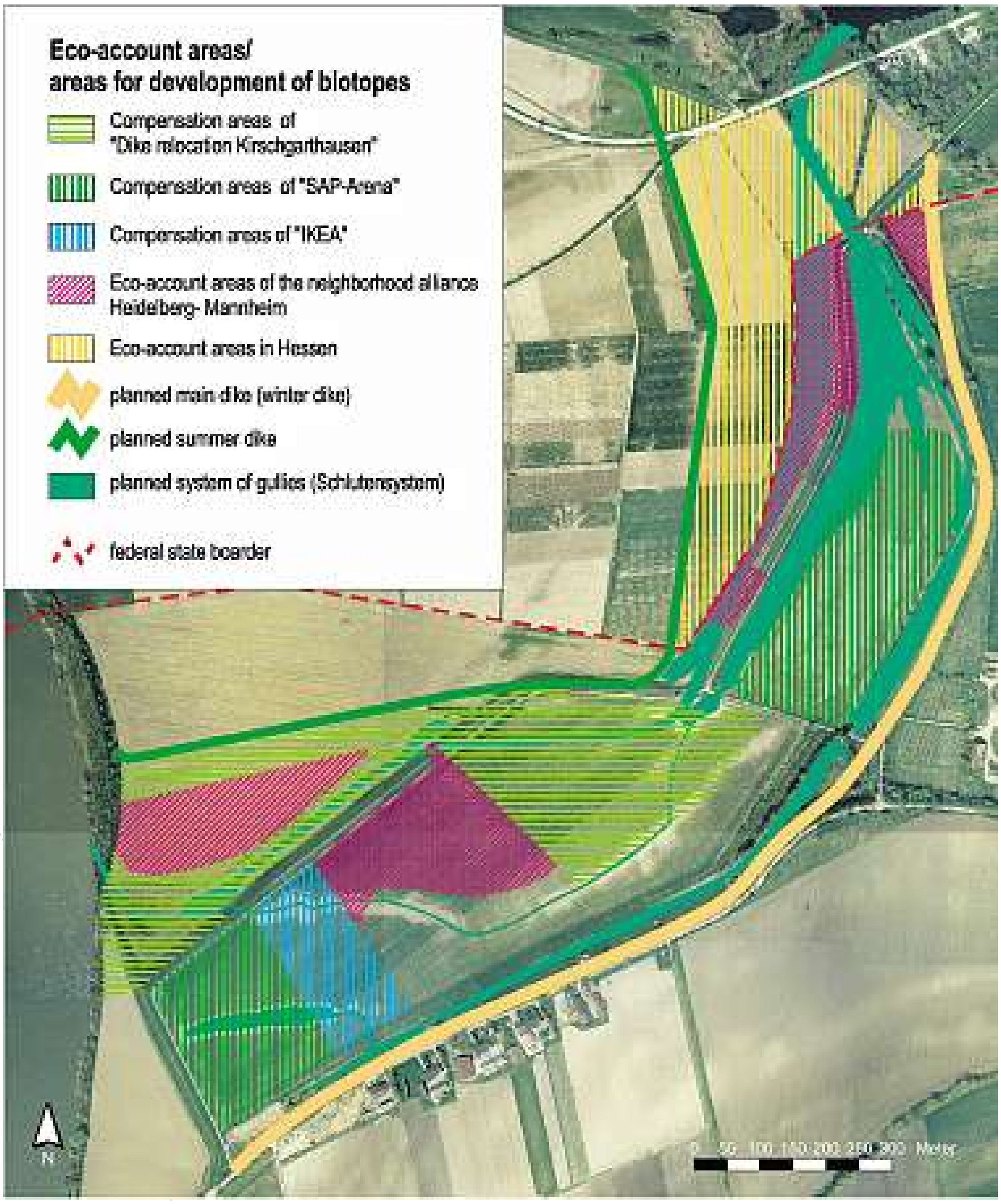


Figure 3.27: Eco-account areas in Kirschgartshausen

During the implementation of the Kirschgartshausen dike relocation, the eco-account concept proved successful for the first time in providing compensation areas for a water management project. Floodplains offer favourable conditions for the sustainable development of nature in large integrated areas and may therefore be considered high-quality compensation areas. Besides the advantages for the conservation of nature, the avoidance of conflicts with disadvantaged agricultural companies is a particular benefit. With application of the eco-account principle, the availability of areas in the planned floodplain could be simplified and accelerated.

Similar good experiences were gained at the **Ingelheim Polder** project. Within the scope of the agro-structural development design, the parties involved (agriculture, water management, nature conservation, and communities) expressed the desire that the interior of the Ingelheim Polder be used for an inter-municipal balance/eco-account. This desire was reflected in the planning of Ingelheim Polder by not including an area previously used for agriculture and upgraded by ecological flooding in the professional compensation system for the conservation of nature. The compensation for the construction of the polder was achieved by other measures. The ecological floodplain may be used by the municipalities for their professional compensation for nature conservation (e.g. in the context of their own planning of the construction supervision) in the form of participation in the costs invested by the *SGD Süd*, i.e. by the purchase of part of the eco-account.

Finally, another example is the case of the **Emscher** restoration, where agreements were reached with regard to a type of eco-account with the competent authorities. In general, all measures for the ecological development of the river system (with about 340 km of water courses) are qualified to compensate the construction and technical intervention. In the process of granting permission for the floodplains, the authorities departed somewhat from that course.

The construction of the floodplains will lead to more interventions than in other parts of the Emscher region, as the environment there has more natural resources than in the more densely populated areas downstream. The main intervention is the lowering of the groundwater level. In addition, about 8 hectares of forest will have to be removed or will be at risk of drying up. In any case, a monitoring of about 300 marked trees for 10 years on basis of a forest condition study is obligatory. Both floodplains have small water-related biotopes with endangered species very close to the basins. Due to the changing groundwater level, the biotopes are at risk of drying up. An agreement has therefore been reached with the competent authorities to have a temporary dam installed between the basins and the biotopes and to maintain the local water level during the construction phase. The biotopes will be used at a later stage as a ‘pool’ to ‘vaccinate’ the new floodplains. If the species have spread after the construction phase, the water supply into the biotopes will slowly be reduced and they will gradually dry up. The dam will then be removed and the biotopes will be integrated into the floodplains.

Very little is known in **the Netherlands** about the experiences gained in Germany with the concepts of eco-account. Nevertheless, the Netherlands does have experience with the **red for green** or **red for blue** principle. Essentially, red for green or red for blue is a particular form of public-private partnership established to finance green space or blue space by coupling plans and costs with red functions. For example, when a housing estate is being constructed, part of the profit from the sale of the houses is invested in constructing and managing green space in and around the estate. Agreements can also be made on financial compensation for nature damaged during infrastructure projects (roads, business parks, etc.).

The private partner may be a property developer, a farm, a non-agricultural company, a landowner or a nature organisation. The public partner is normally a province or a municipality. There are advantages for partnerships between public and private parties. The collaboration enables a government or semi-government body to achieve policy objectives that would otherwise be impossible to achieve or would in any case take far longer. The cooperation with and input from private parties also increases public support for policy objectives.

For the private parties in the red sector, such as property developers, a partnership is interesting because it enables them to undertake new projects that initially encountered opposition from the green sector. At the same time, they are opening up a new market segment of green housing. Meanwhile, green parties secure an entirely new source of financing for their activities in addition to the more traditional subsidies. Red for Green projects are generally ambitious. They are time-consuming and a great deal of consultation is required to reconcile apparently conflicting interests and wishes. In the first place, there has to be someone who takes the initiative to generate enthusiasm for the idea. Once the idea has been explored in more depth, some of the parties may sign a statement of intent. Further studies and discussions will then be needed to ascertain whether the project is feasible. This can ultimately lead to an actual plan and a cooperation agreement in which the stakeholders set out how the plan will be implemented. The plan will include details of how the land will be divided in the area, how the project will be financed and the actual form the cooperation will take.

The government may encourage red for green projects by providing room for them in its policy. This is in line with the landscape-oriented development strategy announced in the National Spatial Strategy (Nota Ruimte).

Conclusions and lessons learned

In densely populated central Europe, flood protection measures usually requiring large areas often result in a competition with other functions. If areas are flooded regularly, intensive agricultural use is no longer possible. Possible forms of use include pasture land and/or the development of floodplain forests in lower lying areas. The landscapes use is becoming increasingly multifunctional. In these use concepts, the following aims may be combined.

- Efficient maintenance of the areas.
- Nature development and nature conservation.
- Recreation.

The eco-account concept offers the prospect of earlier completion of new nature areas where budgets are limited. It would also greatly simplify administrative procedures for private developers that have to compensate for the damage caused to nature and the landscape by their activities. The SDF partners recommend exploring the applicability and advantages of the eco-account concepts in the Netherlands.

3.2.2 Vegetation in the floodplain – Dutch aspects

Vegetation growth in floodplains is valued differently in a river catchment. In a densely populated area as the Netherlands, the national water management approach is almost opposite to the policy in southern federal states in Germany. In a low-lying delta area, the water should be drained to the sea as quickly as possible, which means that rough and vegetation growth must not be excessive within the winter dikes. Nature development in the Netherlands is therefore not allowed to conflict with flood defence. Rijkswaterstaat limited floodplain forest development within the floodplains of the Dutch rivers to 10% of the total area. In the upper catchment of the River Rhine and/or along the tributaries, natural flood retention by floodplain forests in particular plays an important role for water managers.

In the Netherlands, an updated water policy was published in December 2000 in “A Different Approach to Water, Water Management Policy in the 21st Century”. This policy was implemented in the Room for the River Programme, in which a combination of technical measures and spatial solutions was chosen for safety and flooding. In addition to this water policy, the Ministry of Agriculture, Nature and Food Quality published the “Nature for people, people for nature” report in 2000. The report stresses the importance of robust nature areas, emphasising the size and connectivity of riverine nature areas. Particularly in the Netherlands, with a high population density, strong pressure from housing and infrastructure building activities and satisfactory cooperation between all organisations involved in water projects will be required and will contribute to better projects and a better livelihood.

The new nature areas will partly be developed according to the **new wilderness concept**. The idea is to make former floodplains with mainly grasslands more attractive to people by the creation of a more diverse nature with forest, bushes, and grasslands grazed by cows and/or horses. Nature can develop naturally, without a minimum influence of human interactions. Year-round grazing by cattle is the key instrument in managing the natural vegetation, as different grazing animals have different impacts on vegetation growth. In addition, year-round grazing impacts on vegetation development, as animals shift in grazing habits during the year. An important criterion is that the project area is sufficient, as the herds have to be large enough to be stable, and there must be a sufficient food supply for these cattle in the floodplains (chapter 3.2.4). The resulting nature areas offer visitors the possibility to encounter grazing cattle along footpaths and to roam the forests and bushes as if on an adventure trail. Examples can be found in the Millinger Waard and other floodplains.

It is likely that new nature will arise along the major rivers in the Rhine catchment in the next decennia. Instead of agricultural floodplains and fields, the amount of brushwood and/or riparian vegetation will increase. In the Netherlands, this new developed nature must be monitored and managed in certain cases. This management takes the form of grazing by cows or horses and/or cutting trees and brushwood. In certain relatively small areas, the river can maintain the balance between space and water. Erosion and sedimentation processes can create dynamic shore zones. Dynamic river management is the way in which the Dutch wish to handle rivers in future, but this means establishing clear limits so that safety and navigation are not prejudiced. Another management measure is currently being investigated: Cyclic Rejuvenation of Floodplains (CFR). CFR means that the river manager has to cut vegetation and/or lowers certain parts of floodplains in a riverine area on a regular basis in order to create pioneer zones. This is what the river can do naturally in natural river systems. However, this management is not restricted to floodplain level, it is geared towards a large stretch of river. This large-scale surface management is difficult to handle and to achieve within the Dutch riverine area at present. A method of dealing with an increase of floods in one area and compensating in another has yet to be clearly defined (see CFR box). Another risk that may be present is that the lowering of floodplains or excavation of side channels may involve the excavation of polluted soils and this might be quite costly.

The Rhine Action Programme presented a policy of technical measures of retention (polders), reconnection of floodplains and old meanders for the upper catchment of the River Rhine. In the retention areas, experience was gained with ecological flooding (chapter 3.1.2). This means water is allowed to flow into the retention areas on a regular basis so that flood-dependent riverine nature can develop and survive. Through regular flooding, natural riverine vegetation will redevelop in former agricultural areas. Due to a reconnection to the river bed, floodplain forests can recover.

One SDF example should be referred to in this context, i.e. the **Fortmond** project where **ecological cyclic management** or cyclic floodplain rejuvenation in practised, following the example of the method defined in another Interreg III B project *"Freude am Fluss"* (compare Box 3.7).

The development of large-scale river-bound nature involves the important condition that the level of flood protection is constant over the years. However, the vegetation in the river forelands will develop through the years. Therefore, the river's cross section diminishes, which leads in turn to a diminution of the discharge that can be accommodated safely. The project team plans to avoid this development by ecological cyclic management, which is intended to bring about maximum ecological quality through dynamic management.

Ecological cyclic management consists of the following steps.
1. Regular monitoring of the vegetation in the river forelands.
2. Determining possible discharge.
3. Validation of existing vegetation.
4. Evaluation of the required interventions.
5. Intervention.

Together, these steps guarantee a balance between ecological qualities and safety requirements. The river's dynamics are used to the full, as a result of which the creation of ecological valuable vegetations is possible.

This process requires not only good communication with the organisations involved and people from the surrounding area, it also requires flexible permit management. In this context, the European Natura 2000 Directives, the European Water Framework Directive, the Dutch Nature Area Plan (*natuurgebiedsplan*) and the Dutch Room for the River programme are important.

Lessons learned from the Interreg III B Freude am Fluss project

As part of the Interreg III B Freude am Fluss project, a research project was defined to develop and apply a management strategy that combines both nature and safety objectives. The overall Freude am Fluss project focuses on changes in land use via local initiatives, new market mechanisms and technical innovations. These changes in land use will generate more room for the river and the riparian vegetation, but also requires a new view on management. The Interreg III B project is carried out by French, German and Dutch governmental organisations, academic institutions and consultants.

Cyclic Floodplain Rejuvenation (CFR) is considered the system of natural processes in non-regulated rivers that is responsible for building up and breaking down morphology and vegetation. The main processes are erosion, sedimentation and vegetation succession. In natural rivers, the combined action of these processes results in cyclic rejuvenation of morphology and vegetation, and therefore in a natural regulation of the discharge capacity (Smits *et al*. 2000).

In regulated rivers like the Rhine branches, these natural processes cannot act freely because of the presence of dams, weirs, dikes and groynes, etc. As a consequence, the natural rejuvenation cycle is interrupted, and vegetation tends to develop to the climax stage (forest). The result of this development is an increase of hydraulic roughness, and subsequently an increase of the risk of flooding. (Duel *et al*. 2001; Baptist *et al*. 2004).

The basic idea of the CFR strategy is to repair the rejuvenation cycle interrupted by human interventions. Therefore, we have to understand the natural rejuvenation processes and, if possible, imitate them. In practice, this means setting back succession stages to a pioneer situation (e.g. removal of vegetation, lowering of floodplains or digging side channels).

The CFR strategy can contribute to re-establish the discharge capacity, because normally pioneer stages have a lower hydraulic roughness (RIZA, 2003). The CFR strategy will also result in more variation of succession stages, and therefore in a higher biodiversity. These are the two main reasons that the CFR strategy is a promising solution for achieving a synthesis between safety and nature. Besides, the CFR strategy also provides opportunities for sand or gravel excavations which can reduce the management costs.

In summary, applying the CFR strategy to nature restoration projects in floodplains may bring about a synthesis between safety and nature. However, many knowledge gaps still need to be filled before this new management strategy can be applied and up-scaled to entire river sections.

Box 3.7: Lessons learned from the Interreg III B *Freude am Fluss* project

3.2.3 Public or private management concepts

The choice between management by local farmers and management by nature organisations, financed by the government, depends on the frequency of flooding but also on the type of nature that should develop. In many cases, it is necessary for the acceptance of a project that local farmers participate in the future management of an area. In most cases, the implementation of a development concept and a reference image affects the decision of the management concept (chapter 3.1.1)
In **Ingelheim** for example, the success of the grazing development concept for the polder

area depends on local farmers’ readiness for implementation. Only farmers with experience in keeping cattle are suitable for an implementation of the grazing concept. The state of Rhineland-Palatinate will lay down the conditions for grazing in the *Im Mörs* ecological flooding area in a contract. The comparison of the possible management concepts for Ingelheim Polder is described in chapter 3.2.4 as well as the argumentation for the grazing concept.

- In any case, the contract stipulates the following conditions.
- Care and management.
- Demands on the grazing animals.
- Demands on the operation.
- Potential subsidies.
- Control.
- Liability.

In addition, the following aspects described in the text of the grazing development concept and included in the planning must be incorporated in the contract.

- Cattle stocking.
- Permanent fence system.
- Temporary fence system.
- Gate / access road / feeding of the animals / mobile watering place.
- Hygienic and veterinary medicine aspects.
- Tilling of flat water depressions.

The grazing must be coordinated on a yearly basis between the farmer and the Federal State of Rhineland-Palatinate in order to ensure a development in accordance with the present development concept.

Similar agreements were made at **Lohrwardt Polder**, not exclusively in the sense of management but in the sense of multifunctional use. The areas and facilities purchased by the *Deichverband* are leased and/or rented to the parties in question until they are needed by the *Deichverband* within the scope of the project, and further use by the parties is excluded. For the period after completion of the dike and/or flood protection systems along the alignment further away from the River Rhine, the Deichverband has already reached agreements with the adjoining agricultural firms for the use, care and maintenance of the future flood protection systems in accordance with the decree for protection of the dikes. The open water areas in the excavated areas and previous levee breakthroughs (*Woyen*) are used for fishery.

In the Netherlands, nature conservation and nature development were, until recently, based on the acquisition of agricultural land by the government. After completion of the works in the area, it was handed over to the State Forestry Service or an NGO, which already had an important role in the management of new and other nature areas.

Until the end of the 1990s, management by private landowners, e.g. farmers, was possible, in principle, only in existing nature areas or on agricultural land with more diverse aims for nature development. The owners could claim financial contributions from the government in order to support the measures to attain the relevant nature development aims.

Furthermore, a very important issue is and was the management of the discharge capacity of the floodplain. *Rijkswaterstaat* is responsible for the maintenance of the discharge capacity. *Rijkswaterstaat* emphasised that newly developed nature areas should be managed only by a single owner. In their opinion, maintaining the discharge capacity would be far more complex if a floodplain was managed by different organisations or private owners. Under such circumstances, the ownership boundaries in the newly developed floodplain nature area become less visible. This might lead to disagreement about the individual owner’s responsibilities for maintenance.

Since 2000, there have been several changes.

- The national government handed over a large part of the responsibilities relating to the implementation of the private nature development to the provinces.
- The efforts of the nature organisations were not subsidised, but rather the actual field results, regardless of which measures were taken.
- A possibility was created to compensate private owners for the loss of land value in designated areas when they converted from agricultural use to a nature function.
- Simultaneously, the provincial governments, in line with the general political movement, expressed an interest in the liberalisation of several markets. This included a strong preference for more private nature development and nature management, which – together with the agricultural sector in particular – was better organised than before, and so became a political goal.

Because of this shift in policy towards nature management by private landowners, it became possible and feasible for both individual farmers, or farmers organised in an agricultural NGO, to become managers of nature areas which were newly developed by themselves or even the national government. As a result, management can be effected by specialised nature organisations after land acquisition or by private land owners.

The **Lexkesveer** project is dealing with a mix of these two policies. The northern banks are to be managed by the State Forestry Service; the southern banks are to be managed by private landowners. Therefore, two separate management plans have been drawn up dealing within the same project. The management plan at the southern bank is a plan in which a private landowner and a private nature organisation will cooperate.

The management plan aims to achieve the defined nature goals on one hand, and must guarantee that landowners comply with the safety goal and accept conditions on the other. Within these conditions, landowners are free to manage their land according to their own business plan. With regard to the goal for nature development, the southern banks are divided into three major areas, each being managed separately based on an extensive grazing capacity. The ultimate goal is to bring about natural river foreland development with a great variety of vegetation types. These natural river forelands must provide optimal grassland conditions for corn crakes, swans (tundra swans) and geese species.

Nevertheless, in order to comply with the safety goal of high water protection, several conditions have been included in the management permit. These conditions are as follows.

- The amount and location of vegetation types are indicated on maps and may not be exceeded.
- A monitoring programme must be implemented aiming at mapping vegetation and sedimentation developments.
- Excessive sedimentation in the high water gully must be removed (financed by the government) if instructed by the competent authority.
- Landowners are jointly responsible for complying with the permit conditions, but one of them will be the contact person for the competent authority.
- Land owners can receive subsidies for their nature development efforts.

The advantage for the competent authority is that the management focuses on the project area as a whole, instead of isolated areas with different owners. The landowners are each responsible for the results. As the management plan covers the whole area, the plan has greater flexibility in the case of unforeseen developments. Landowners may submit (joint) proposals to the competent authority.

This policy does involve some risks.

- Management by private landowners is to be agreed strictly on a voluntarily basis. This means that at a later stage, the landowner can withdraw from the project and in the worst case, reverse the financial efforts to create an integrated project.

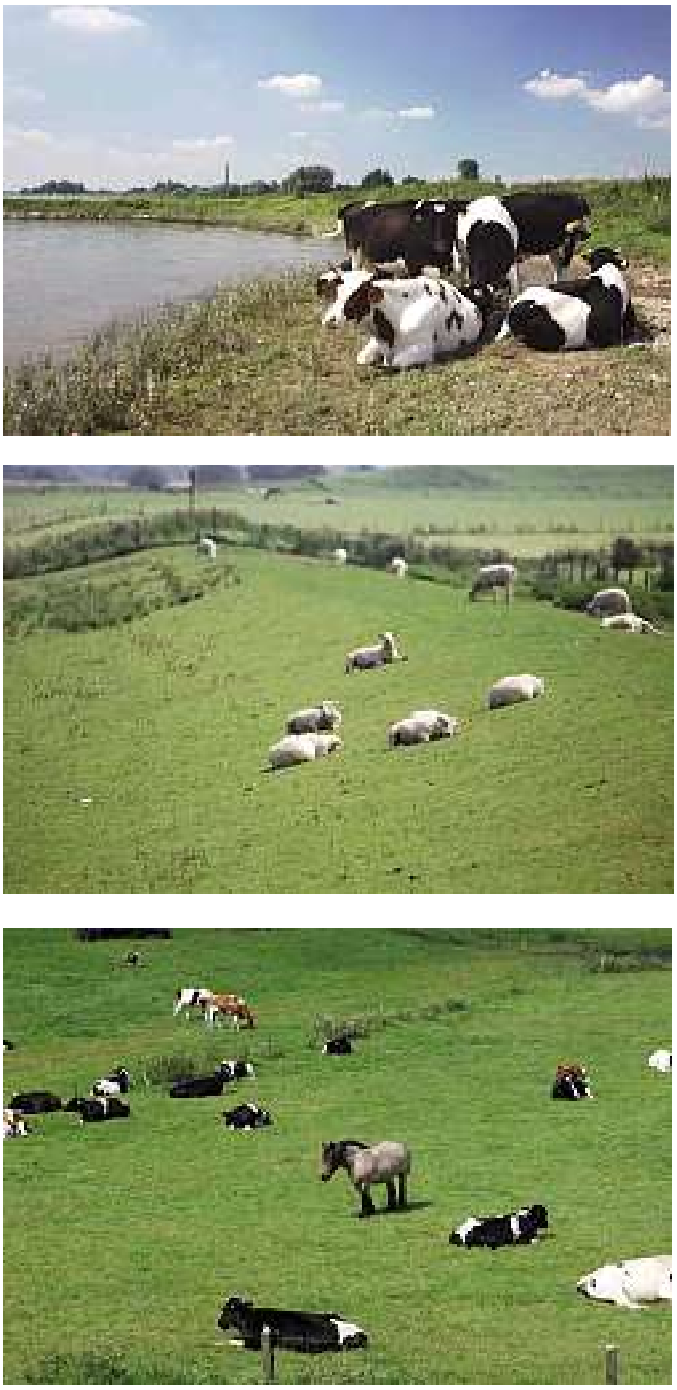


Figure 3.28: Lexkesveer: Management by private owners

- This type of management has little experience with the quality of nature to be achieved.
- Private owners do not have the same capacity and knowledge as specific nature organisations. In the case of Lexkesveer, however, a combination of a private landowner and a private nature organisation exists. With regard to new developments in respect of private nature management, more experiences will have to be gained. Evaluation of the nature quality achieved will be required, as well as an evaluation of nature management in relation to the maintenance of the high water protection level.

With regard to the **Rijnwaardense Uiterwaarden** and the **Green River**, no decision was taken during the preparations for the original plan in 2001 as to whether the management of the floodplains would be placed in the hands of public organisations, e.g. the State Forestry Service, or entrusted to private organisations, e.g. nature-related NGOs, agricultural NGOs or even individual farmers as private stakeholders.

The province drew up a map (which is revised periodically), showing which nature principle is applicable for which physical area. The area of Rijnwaarden has been defined as being mostly managed by private organisations of owners. An assumption here is that this part can be redeveloped from agricultural land to nature, while maintaining current discharge capacity. The benefits of sand and clay extraction will for a large part finance the development. In principle, the management of the area will be co-financed by the government.

The Green River area is designated to be managed by the State Forestry Service. The main reason for this lies in its relation to the National Ecological Network. Financial returns from clay and sand are insufficient to pay for the required developments, so government participation is essential. Also, in order to maintain discharge capacity, Rijkswaterstaat is insisting that new vegetation be kept short, so as to limit the physical resistance of this vegetation to the water discharge.

However, the State Forestry Service will call in the help of local farmers, presumably organised in an agricultural NGO. The State Forestry Service, partly privatised, does not consider cattle management as a core activity. Therefore, in order to maintain low vegetation cover, it will rely on the grazing of cattle by local farmers, to be laid down in a contract. Apart from these practical issues, another consideration here is the support gained from inhabitants.

Similar to the cases described above, the example of **Bemmelse Waard** summarises several aspects mentioned. In future, the main part of the Bemmelse Waard will be pastured by natural grazers, which will create an alternating, grassy, rough landscape. The agriculture land use will convert to nature. The maintenance of this area will be the responsibility of the State Forestry Service.

The Ambtswaard and the eastern part of the area will be maintained as a floodplain bird area. The function of this area remains agriculture, with certain restrictions to create a habitat for floodplain birds. A restriction is, for example, that grazing is not allowed during the breeding season. The management of these areas will be handled by local farmers. Due to restrictions, the productivity of the land will be less. For this reason, the farmers may apply for compensation.

In **Fortmond**, local farmers have had no experience until now with nature management, even though it is considered important in this project. During the dialogue sessions, inhabitants indicated that they would appreciate local cattle being used for grazing the nature areas. They referred to the MRIJ cow (which means Maas-Rijn-IJssel cow), which is a typical old Dutch breed. The State Forestry Service tried to interest farmers about 20 years ago, but they were not that interested in nature management at that time. This issue is currently on the agenda again.

In the Fortmond plan, some areas are designated for management by farmers. These are mostly areas at the borders of the project area. Initial contacts have been made with farmers concerning the possibilities of nature management. The use of nature areas is subject to strict rules. The use of cattle in the area must be constant, fences are permitted only at the area borders, and introducing fertilisers or manure is forbidden.

Conclusions and lessons learned

In considering the issue of whether public or private management should be applied, it is vital to assess possibilities as early as the planning phase, as it should be clear in advance whether land acquisition is needed or whether a contract with private partners should be concluded. The decision on whether public or private management should be applied will be determined by the following aspects.

- Policy development: depending on the political demands, there will be more or less pressure upon the project organisation to choose between the possibilities. Consequently, detailed discussions with potential partners and public organisations will be required.
- Anticipating possibilities: an assessment must be made as to whether private partners have an interest in participating in the management. They can be offered a role in this management with the result that land acquisition will not be required and therefore resulting in a reduction in project costs. It may also be possible that landowners are very willing to sell land and have no interest at all in participating in the project.
- Degree of professional nature management: an assessment must be made as to whether private partners are sufficiently professional to manage nature according to project goals. In some cases, they may cooperate with professional nature organisations in order to guarantee nature quality.
- Sustainable river management: in the Netherlands, it is considered undesirable to deal with a large number of landowners in floodplains in order to execute sustainable river management and to be able to anticipate unforeseen developments. Projects therefore emphasise that landowners should be organised and have a joint and comprehensive management plan or that there should be a unique nature organisation in order to regulate the responsibilities for compliance with the permit regulations.

3.2.4 Herds of natural grazers as nature managers

An important element of the development concepts in floodplains is the input of natural grazers. These grazers are hardened and adapted to severe weather conditions as well as to terrain roughness. Unlike domestic cattle, these natural grazers can be located in extended and rough areas. These grazers do not largely depend on human interventions but can successfully manage themselves. They live year-round in natural herds in floodplains of which they are an integrated part. They move on from one area to another, depending on existing food conditions and the need for shelter against inundations or changes in weather conditions and the periods when giving birth to calves. These natural herds consist of males, females and calves, which have a strong social interaction. The number of animals, as well as the composition of the herds, strongly depend on the type of mammal and the existing conditions and may be subject to abrupt changes. Individuals (like young individuals which have become mature) may be cast off and excluded from the herd. Other animals from different groups may be included. The fittest animals survive. These processes lead to stronger animals, are likely to prevent in-breeding and may even lead to genetic variation. These natural grazers are believed to be a key instrument in developing nature as result of their behaviour and grazing habits. They are believed to have a major influence on the landscape.

In the Netherlands, this nature management concept, sometimes called the wilderness concept, has been implemented in extended nature development areas like in the Oostvaardersplassen and in the floodplains of the Millingerwaard.

The first experiences with natural grazing processes, however, date from the 1970s.The grazing impact of different types of cattle (Galloway, Heck, Scottish Highlander), horses (Konicks, Iceland ponies) and red deer has been studied.

Natural grazing is considered a natural process, the impact of which on the ecosystems differs depending on the type of mammal and the composition and the number of herds. Grazing and grazing habits may vary strongly.

In comparison to domestic and seasonal grazing, the natural grazing processes lead to a more sustainable, wild and rough nature, without human interventions. Natural processes take place in mutual relationships. Vegetation and fauna are more adapted to the existing physical conditions, such as morphological, hydraulic and climatic processes. Interaction between these processes and vegetation and fauna are the basis of the existence of a cyclic balance.

In many floodplain projects in the Netherlands, herds of certain breeds of horses or cows are used as natural grazers. They are left free in the nature area without shepherds. Although grazers are used in some nature areas in Germany, a similar type of nature manager as in the Netherlands is not yet known. There is always the fear of spreading diseases and for potential danger for the people engaged in leisure activities in the new developed nature areas. By visiting these areas in the Netherlands, with large herds of natural grazers and by exchanging practical experiences in the presence of the local nature manager, the SDF project has provided new insights for German partners. In the coming years, the cooperation on this aspect of nature management will be intensified. In any case, the exchange of knowledge during the SDF project has already led to the implementation of a grazing concept at Ingelheim Polder.

As an example, the concept and decision-making process for the nature management of the *Im Mörs* area or ecological flooding at **Ingelheim Polder** is described below.

The development concept is determined by the presence of rare animal model species e.g. *laro-limikoles*, floodplain birds and amphibians, as well as rare plant species and communities such as sword leaf rush biotic communities, *Phalaridetum arundinaceae* and the *Caricetum gracilis.* These were significant in the preparation of the development concept. The fact that shifting would take place within the community of the species depending on the frequency of flooding and the duration of the individual floods (forecast 36 days per year) was also taken into account, and this fact had to be incorporated in the development concept.

The maintenance measures must aim to create proper living space conditions for the above target species. A rigid, impractical maintenance and cultivation of the *Im Mörs* flooding area, which would not do justice to the dynamics of the landscape, was rejected. Moreover, two variants of maintenance were developed, which provide various implementation options for the German Federal State of Rhineland-Palatinate as owner of the land. A third concept, namely the natural or guided succession, was rejected due to the development in a relatively small area and the protection of the targeted species in that area.

The developed maintenance concepts ‘cattle grazing’ and ‘mowing’ differ regarding the required maintenance. The grazing by robust cattle is suggested as the priority maintenance measure. The mowing, including the removal of the mowed grass, also presents a good alternative if the described maintenance conditions are kept. If no cattle owner can be enticed to implement the cattle grazing concept, the mowing variant should be implemented.

The mowing maintenance concept will be implemented only if extensive grazing of the *Im Mörs* ecological flooding area is not possible, e.g. because there is no suitable cattle owner available. The extensive use of the areas by mowing is aimed at developing sorrel marsh panicle floodplains and/or seasonally flooded amaranth floodplains.

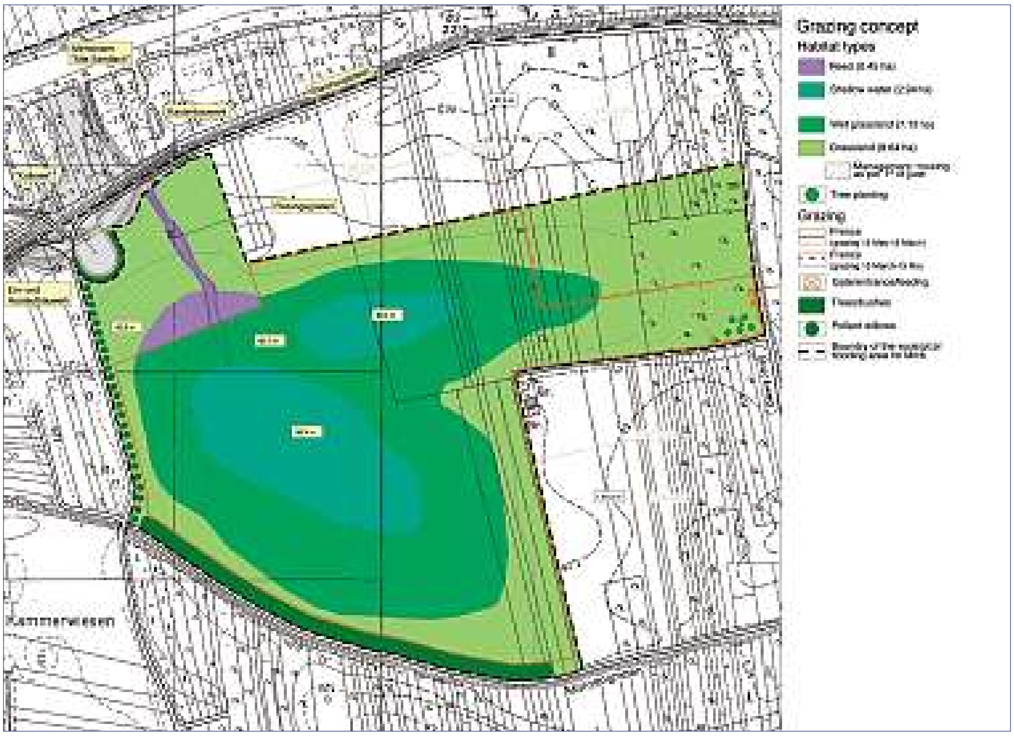


Figure 3.29: Grazing development concept at the *Im Mörs* ecological flooding area

In order to keep flat water depressions open and maintain the special cenosis of pressurized water with their very special pioneer species, maintenance measures such as the mulching or the tilling of grassland are required every three years for both maintenance concepts.

Certain maintenance requirements are specified as difficulties occurred with pioneer species. In the area of the soil excavations, the water transition areas, the water spreading areas, as well as in the area of the old Sandlach, there will be a rapid establishment of copse types. Here, measures are required to ensure that the areas are developed as provided for in the maintenance and development concept. For the open land areas, extensive cattle grazing and/or alternative mowing are provided in order to keep the areas free. In partial areas, mulching can also be used to keep the areas open in preparation for their later use.

For the development of green land communities on the former farmland in the area of the Im Mörs ecological flooding area, no seeding took place and the self-development of green plants was preferred. The advantage of this procedure is that autochthonous plant species can develop from the seed repository in the soil. However, there are problems with the pioneer species of the farmland areas with weed growth, which have a rapid and far-reaching spreading dynamic. Adjoining agricultural areas can be affected considerably by sprouting pioneer species, particularly in the first years. The sources of small-flowered thistle, in particular, which will spring up within the green land communities must be removed by mulching prior to the start of seeding.

Finally, after sharing the experiences of the Dutch SDF partners and the discussion of the development options for the area, it was decided to implement a grazing maintenance concept. Approximately 18.5 ha of the 20 ha size ecological flooding area will be used for the grazing concept (Figure 3.29). In the area of the inlet structure, an area of about 1.5 ha will be developed to serve as floodplain for medium habitats. A smaller part in the area of the feeding trench, between the inlet structure and ecological flooding area, will be developed into a canebrake area, in order to achieve an increase in the diversity of the open land.

Within the grazing area (Limosella aquatica areas, etc.), the flat-water depressions, which have an approximate size of 2.94 ha, will not have any importance as feeding areas for the grazing cattle. At prescribed cattle stocking of 0.5 large cattle units (cattle numbers per hectare)/year and a usable grazing area of about 15.76 ha, the cattle stocking may not exceed 8 cattle per hectare/year. The prescribed cattle stocking can be corrected in the accompanying area management based on the formulated goals (e.g. less than 20 % surplus fodder in autumn, upcoming spreading of bushes). The basic rule for achieving an adjusted cattle stocking is as follows. The existing biomass will be eaten up to a degree that only 10 to 20% of excess grass is left. Depending on the growth conditions differing from season to season, the yearly output of an extensive pasture fluctuates considerably; the amount of animals must also be adapted accordingly.

These possible modifications must be provided for as an option in a cultivation contract. The pasture land is divided into a large and a small pasture portion. In general, grazing on the pasture can occur on the largest portion of the pasture during the period from 15 May of every year to 15 March of the following year. During the breeding period of the floodplain birds, grazing is not allowed in that area. During that time, the cattle will be kept in the smaller fenced-off area in the east of the ecological flooding area.

Figure 3.30: Grazing Galloway cattle at Worms-Rheindürkheim

Figure 3.30 shows grazing of Galloway cattle at the lake's ditch in an area for the landside flood protection north of Worms-Rheindürkheim. A total area of about 40 ha is used for agricultural purposes in this area. The animals cope very well with the flooding situation as they can constantly retreat to higher areas within the pastureland.

Conclusions and lessons learned

Overall, encouraged by the good experiences and lessons learned with large area pasture projects in the Netherlands, which the Dutch colleagues imparted to the German partners, an extensive cattle pasture is intended for the cultivation of parts of Ingelheim Polder. This form of use of the Rhine floodplain adapted to the location presents a form of use and care very well suited to the value-adding animal and plant species and to their biocoenosis. For the protection of ground breeding species, the maximum number of animals allowed in this area must not be exceeded. In small areas, it makes sense in this connection to divide the pasture land into two or more partial areas.

In the long term, an attempt should be made to develop the pasture area to the full. It would be ideal if the grazing cattle could retreat of their own accord to higher parts of the ground south of the polder in the case of floods. That way, the grazing could be developed more economically in future. Besides the care of the area from the professional point of view for conservation of the nature, these flood protection areas could contribute to the supply of high-quality (biological) beef originating from appropriate cattle. The extensive grazing of cattle enables half-open pasture landscapes to be achieved.

If natural grazing is introduced, a process of naturalisation will commence. Herds will regaining their natural behaviour and will have to survive without help.

If the project organisation is considering introducing natural grazing as the main management, the following questions should first be answered.

- Is natural grazing possible in relation to the size of the project area?:

In the case of development of nature projects, nature goals must be determined at an early stage in relationship to the type of nature management desired. As it happens, the type of management determines the type of nature that will develop. It should be assessed at this stage whether these goals can be achieved. If it is preferred, for instance, to introduce natural grazers, the project area has to meet a minimum size condition (preferably 500 ha). In addition, if natural grazing is preferred, consideration has to be given to combining different and large management areas, as such areas are important to offer the herds sufficient possibilities for migration and food supply.

- In case of natural grazing, have veterinary and judicial aspects been considered?

Is the project management prepared for questions like: what will be done with dead animals? May they play a role in the total and coherent eco system or do existing laws demand that dead animals be taken away? How far away are intensive agricultural areas which might be infected by contagious diseases? Is public opinion prepared for this type of development, being confronted with rotting animals?
What is the extent of the desired naturalisation process and what goals have been set? Do we let animals die? Do we interfere? When do we interfere (e.g. feeding in difficult circumstances)?

- Three categories might be distinguished:

  - Do we simply want mowing machines to assist the nature manager in achieving his goals?
  - Do we want partly wild animals because they fit so nicely into a partly wild nature system?
  - Do we aim at a complete and coherent ecosystem of which the grazers are a natural element?

Is the project management prepared to judge nature development? How does the public judge the nature development? Are they prepared for this type of management? There may be different point of views: ethical (consciousness and responsibility), aesthetical (experience, attractiveness), or scientific (knowledge).

What role do natural grazers play in attaining safety, in view of high waters? Do they comply sufficiently with grazing shrubs, trees, herbs and high grasses? Should the nature management have to interfere because of undesired developments relating to high waters, despite other desired nature goals? If there is excessive development of shrubs and trees, ecological cyclic management may have to be considered.

Heck cattle in the Lippe floodplain – the nature managers

The River Lippe is a Rhine tributary that runs in the north parallel to the Emscher. The responsible water board – Lippeverband – is working in a joint administration with the Emschergenossenschaft, though the River Lippe has different natural, hydrological and organisational preconditions than the Emscher.

One main difference is the more rural character of the landscape, where the development of wetlands and retention measures can be managed in a very extensive and natural way. For this reason, at various locations between the towns of Marl and Haltern, Heck cattle *(Bos taurus taurus*) were introduced. This type of cattle were bred in the 1930s by the Heck brothers by using several robust types of cattle, resulting in animals about 1.45 m in height with impressive horns, living outside year-round and calving without human help. They may be compared to the Aurochs historical species *(Bos taurus primigenius)*.

The local project was carried out by Lippeverband and the local Recklinghausen Biological Station (an association of public and NGO nature protection organisations). It is located on a 140 hectare site on former drained agricultural land that was left to natural development and wilderness. On a 35-hectare large part of this area, the Heck cattle *(Bos taurus taurus)* were introduced to keep the growth of plants at a certain stage (to prevent the site from becoming forest). A local farmer, based on a contract with the Lippeverband, takes care of the animals.

Starting in 2003 with one bull and two cows of different origin, the herd now consists – as a result of additional purchase and reproduction – of nine animals and two calves. However, this figure needs to be reduced again this year (so as to avoid reaching more than nine animals on average). The cattle stay outside all year long and do not receive additional food (or only in the case of exceptional snow cover or emergencies). The site is fenced off and entrance is forbidden (for the safety of visitors and animals).

The expected vegetation structure has developed positively to an extensive mosaic of pioneer floodplain, ranging from grasslands, high bushes and reed beds to the first stages of floodplain forest within the last five years. Research and investigation show a significant increase in nature-like habitat adjusted species and communities. For instance, of the 151 bird species present, 65 were on the red list of endangered animals in North Rhine-Westphalia. Comparable structures can be found for butterflies or beetles that depend on wetland structures.

Figure 3.31: Warning sign – Free-roaming cattle on the Lippe floodplain

Box 3.8: Heck cattle in the Lippe floodplain – the nature managers

3.3 Experiences with nature policies in SDF pilot projects

Since the SDF activities were carried out in the framework of environmental policies (compare chapter 1.3 and Annex 1), conclusions could be drawn with regard to the European environmental policies: Environmental Impact Assessment, Natura 2000 and the Water Framework Directive.

In general, it can be stated that the lessons learned showed that all guidelines are based on the status quo of the nature-forming conditions for defensive nature conservation. This is often in conflict with the intended dynamic development of an area.

The directive on Environmental Impact Assessment of the effects of projects on the environment was introduced in 1985 and adopted in 1997. In general, the EIA procedure ensures "that environmental consequences of projects are identified and assessed before authorisation is given". Furthermore, a public participation process is obligatory (see chapter 4 and Annex 2). The Member States had to implement the directive into national law by 1999. Consequently, a great deal of experience has been gained regarding Environmental Impact Assessments in relation to water management projects along the Rhine. After consulting the EIA Directive project categories, the SDF partners considered which procedure should be followed. As part of the SDF activities, the Emscher, Heesseltsche Uiterwaarden and Rijnwaarden projects conducted an EIA. For the implementation projects in SDF, the need for an EIA was tested in advance.
An EIA must provide certain information. There are seven key areas that are required.

1. Description of the project.
2. Alternatives that have been considered.
3. Description of the environment,
   which means listing all aspects of the environment that may be affected by the development (e.g. populations, fauna, flora, air, soil, water, humans, landscape, cultural heritage, etc.).
4. Description of the significant effects on the environment.
   The word significant is crucial here as the meaning may vary and needs to be defined.
5. Mitigation
   Once section 4 has been completed, it will be obvious where the impacts will be greatest. Using this information, ways to avoid negative impacts should be developed.
6. Non-technical summary
   This means a summary that does not include jargon or complicated diagrams and will be used for the public participation process.
7. Lack of know-how/technical difficulties.

Even though it is not up to the SDF partners to assess the EIA as a tool, as it is obligatory in any case, they considered it suitable to assess impacts on species. It also provides planning reliability and ensures in most cases shorter permission-granting procedures. In addition, it encourages public participation, which was already defined as a crucial part of the project implementation by the SDF partners (compare chapter 4).

Nevertheless, in its procedure, the EIA evaluates the static situation of the nature and its landscapes, therefore providing defensive nature conservation. This is often in conflict with the goals for dynamic nature development of an area.

On one hand, the EIA can valorise a decrease of species, being in fact the result of project goals, resulting in a negative value. On the other hand, other important species might be developed. The question is how to valorise a decrease of species on one hand and an increase at the same location on the other.

In order to overcome problems referred to, policy is needed on nature development in floodplains. Choices have to be made on what species or nature types are desired. However existing policies, including EU directives, are not always in line. Another important and European nature policy is the European network of protected areas, Natura 2000, which was established to preserve species and habitats that are especially endangered in European terms.

For the special areas of conservation, all EU Member States will establish the required conservation measures to avoid the deterioration of natural habitats and the habitats of species.

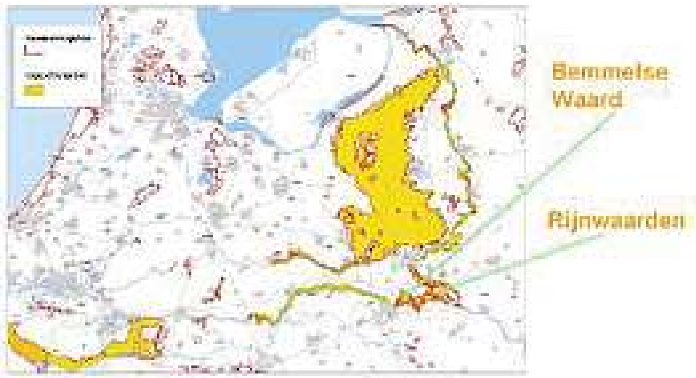


Figure 3.32: Natura 2000 areas in the Netherlands

Natura 2000 areas exists in the Bislich-Vahnum, Bemmelse Waard, Rijnwaarden, Fortmond and Lexkesveer SDF pilot projects. In general, the SDF partners consider the policy helpful in the project development and implementation, as it is useful in defining nature-related project goals. Nevertheless, they believe that the directives not always benefit the sustainable development of the areas concerned, as dynamic development is not favoured by the directives. In some cases, the existing management plans needed to be adopted to obtain the required permits. The implementation into national law is expected to smooth the process of the acceptance of the directive.

Finally, the SDF river and floodplain projects contain numerous references to the **EU Water Framework Directive (WFD).**

The aim of the EU Water Framework Directive is to achieve a “proper status" for all surface water and groundwater bodies by 2015. To this end, a comprehensive situation analysis has been completed. Action plans will be developed for the water bodies by 2009.

The SDF section of the Rhine is classified as being eligible for the "heavily modified water bodies" category. This means that the status of "good ecological potential" must be restored by 2015. This status includes irreversible changes in the body of water or the effects of priority uses to which there are no alternatives.

In general, the SDF pilot projects lead to improvements in the water bodies and therefore to developments as defined in the directive. Several projects are contributing directly to the achievement of the objectives of the Water Framework Directive. For example, side channels along the Rhine (Emmericher Ward and Bislich-Vahnum) are essential elements for achieving a "proper potential" on the Lower Rhine. The geomorphologic objective for the Lower Rhine (LUA NRW 2003) contains current branching and side channels as major elements in the near-natural flow characteristic for the present V-type flow section. In the "maximum ecological potential" for this section of the Rhine, "the extended, slowly and smoothly flooded sand and gravel banks in the main channel as in the model status … are present … on a significantly reduced area" (LUA 2005).

In Lexkesveer, the hydrological and lateral relation between glacial hills and floodplains has been brought back to life, resulting in a significant improvement, but also in very diverse water bodies like seepage marches and brook marches.

Figure 3.33: Lexkesveer: potential conflicts between maintaining existing geese and development goals

3.4 Sustainability of the SDF project

The SDF project has the word “sustainable” in the project title. The standard definition of sustainable development is the Brundtland definition:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987).

The ILA New Delhi Declaration (2002) expresses the view that:

“the objective of sustainable development involves a comprehensive and integrated approach to economic, social and political processes, which aims at the sustainable use of natural resources of the Earth and the protection of the environment on which nature and human life as well as social and economic development depend and which seeks to realize the right of all human beings to an adequate living standard on the basis of their active, free and meaningful participation in development and in the fair distribution of benefits resulting there from, with due regard to the needs and interests of future generations…”.

What can we expect from the sustainable development of floodplains or related sustainable flood protection? Two aspects are important.

a) Technically-oriented flood protection, as mainly practised so far, shows deficiencies in connection to sustainability in a holistic sense.
b) Particularly the third - and quite central - element of sustainability, ecology, must become the guiding principle of sustainable flood protection.

Measures of traditional flood protection are derived normally from a local to (at most) a regional point of view. Moreover, a river system is not regarded as a whole. This includes the risk (in the most extreme case) that measures implemented in the headwaters and upstream areas increase dangers of flooding for people living downstream.
The approach of SDF to cross-link projects along the River Rhine (from the middle of the Upper Rhine to areas near the estuary) over a wide range and across borders and to coordinate measures, justifies the ‘S’ in the name of the project. Communication, exchange and participation (core principals of sustainable development) are also pursued and implemented by the SDF Project. In addition, the demands of the EU Floods Directive, requiring solid united cooperation between upstream and downstream riparians have been met.
Furthermore, the SDF Project combines flood protection measures with nature development or at least nature-orientated improvements; two aims that have been regarded incompatible in the past. Nowadays, programmes such as Room for the River in the Netherlands, Making space for Water in the United Kingdom and *Flüsse brauchen mehr Raum* in Germany are being implemented on a broad scale.

To evaluate the requirement of sustainability, a study was carried out (Fehrenbach *et al*., 2008). It appeared that there are not many methods to evaluate sustainable river development projects. One Austrian example was found within the Mölltal project that worked with a matrix (Ömer & Strigl, 2000).

3.4.1 Set-up of the sustainability analysis

For the analysis within the SDF project, it was desirable to know whether the project could fulfil the goals and indicators of sustainability and/or sustainable development. It was not the aim to perform a comparative assessment of the several single SDF pilot projects, but rather the compliance with the overall SDF project. Common indicators, such as contribution to the greenhouse effect, contribution to gross domestic products, etc. could not or could hardly be applied. Therefore, indicators/criteria in the following categories: project-specific, ecological and socio-economic, were detailed and used in the evaluation. The evaluation was performed with a comprehensive questionnaire (Table 3.1). Criteria of a pure economical consideration were regarded as being not relevant for a detailed examination.

Project-specific Criteria
General compatibility of the project objectives with basic principles of sustainability
Compliance of the measures with the project objectives
Fulfilment of the project objectives
Ecological Criteria
Are ecological measures being implemented?
Are synergies of flood protection with nature and environment protection being used?
Is development of floodplains allowed?
Does rehabilitation take place?
Is biodiversity supported?
Success of the measures
Is the success of the measures monitored?
Is a change of land use towards more sustainability being achieved?
Handling of protected areas
Do protected areas exist?
Are there any conflicts with regard to protected areas?
Does the project lead to additional declaration of protected areas?
Are protected areas supported?
Are there any conflicts regarding the ecological area?
Socio-economical Criteria
Are there any service capacities, are they being achieved?
Is there a conflict with service capacities?
Are synergistic effects being achieved (win-win)?
Is there any planning for future uses?
Are there any conflicts due to the project?
Are there any compensatory measures and/or earning alternatives for the farmers in question?
Do further beneficial use conflicts exists in the socio-economic field?
Are there any conflicts with laws, etc.?
Do strategies for solving conflicts exist?

How are communication and interdisciplinary exchange organised?
Exchange inside the SDF project circle
Performance of public relations
Does public participation take place?
Project acceptance by the public/in politics

Table 3.1: Summary of the consulted criteria for assessing the sustainability of SDF

An exact cost-benefit analysis of the SDF project is not feasible. Taking the general compatibility of the project objectives with basic principles of sustainability into account, the overall economic benefit of the SDF project may be considered sufficiently positive.

3.4.2 Objective compliance of the project

At first, it was assessed how far the objectives of SDF and its individual projects comply with the aims of sustainability, whether the project measures are in line with these aims in a sustainable sense, and to what extent compliance with the objectives is achieved. The final question, in particular, is of special importance for the assessment, as a project can contribute to a sustainable development only if it achieves its defined aims.

As a superior aim, flood protection is placed at the centre of the overall project. The following objectives are linked to the claim of sustainability.

- Integration of flood protection with the development of nature and landscape.
- Development or rehabilitation of nature typical of floodplains in the national ecological framework requirement embedded in sustainable flood protection.
- Avoiding or limiting intervention in natural areas of high value (necessity of regular maintenance).
- Possibility of creating flood awareness among the public (increasing awareness of river riparians including all potentials and risks).

In summary, it may be stated that the objectives of a combination of sustainable flood protection and the development of floodplains with high ecological value, as well as nature and environmental protection, have a high priority in the SDF project and the individual pilot projects. This is a clear requirement for a sustainable development.

The fact that objectives have developed in an ecologically-orientated direction during the project implementation is also a positive criterion for sustainable development.

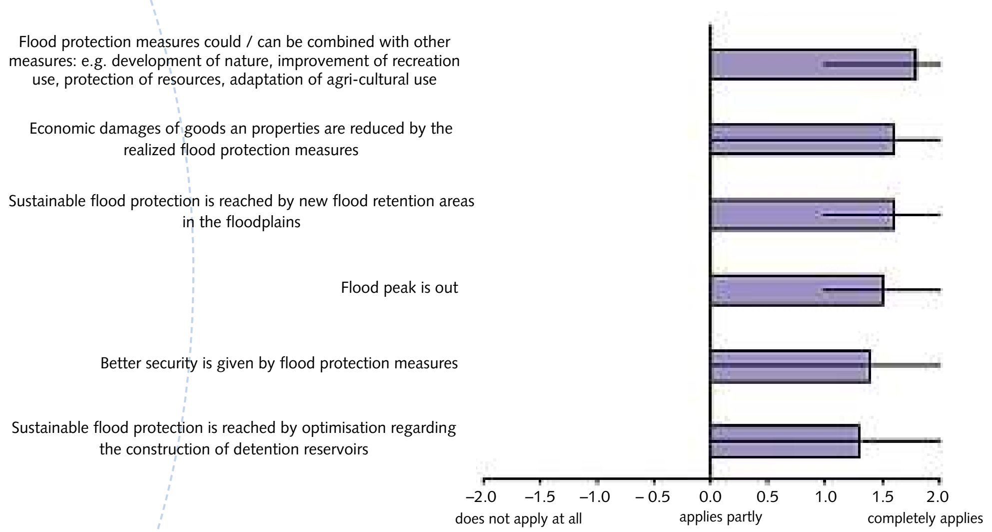


Figure 3.34: Aims and fulfilment of objectives of the overall SDF project

3.4.3 Outcomes of the Sustainability analysis

Table 3.2 presents an overview of the overall outcomes. The results showed that all people and organisations involved discussed and implemented sustainable flood alleviation measures in a broad and interdisciplinary manner. Strategic differences in measures exist due to the geographic location in a river catchment. A positive aspect was that the goals of some SDF pilot projects evolved in a more ecological direction, which means more dynamic development and flexibility.

Sustainable Development of Floodplains (((SDF)))	Criteria fulfilled **good to very good**	Criteria **partly** fulfilled	Criteria **not** fulfilled
Goals of Project fulfilled			
Project as a whole	X		
Individual Projects	X		
Fulfilment of ecological criteria			
Implementation of ecological measures	X		
Monitoring of success of implemented measures		X	
Protected areas	X		
Implemented strategies to solve conflicts		X	
Fulfilment of socio-economic criteria			
Existing potentials of use and implementation	X		
Future sustainable use of project areas	X		
Achievement and use of synergetic effects (win-win)		X	
Achievement of successful strategies in case of conflicts		X	
Internal communication and interdisciplinary knowledge exchange	X		
Public participation and acceptance among public and in politics	X		

Table 3.2: Final analysis of the fulfilment of sustainability criteria within the SDF project (2008)

3.4.4 Advices for improvement of future projects

Monitoring of implemented measures is necessary in order to evaluate the successes for flora and fauna and to help improve comparable planned measures in the future. In many floodplains agricultural use is still present. However, a change to extensive grazing (nature management) contributes to more natural conditions.

The recreational use of floodplains was not highly stimulated within the SDF project. People can enjoy parts of the area by cycling or walking. Other parts are protected areas for flora and fauna. Zoning is a useful tool here.

Public participation (and/or involvement) was applied in most projects. Consequently, the acceptance of projects was quite good. Of course, it is still not easy to find alternatives for certain stakeholders such as the farmers in floodplain rehabilitation projects. In the SDF project, the few conflicts that occurred were solved by adjustment of measures and finding compromises. This could also be seen as a good indicator for the acceptance of the project. In future projects, public participation can be applied in a more active way, as the approaches adopted in the SDF pilot projects have demonstrated their effectiveness in the planning procedure.