INTERMEUSE: The Meuse reconnected

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Preface

Belgium, France, Germany, Luxembourg and the Netherlands submitted a joint programme for prevention against flooding to the European Commission, in the light of the EC's INTERREG-IIC initiative. This programme was approved in 1997 and was given the name IRMA (Interreg-IIC Rhine Meuse Activities). Within the frame of this programme the project INTERMEUSE, part of the umbrella project IRMA/SPONGE which is managed by the Netherlands Centre for River studies (NCR), is started up by the following partners:

- RIZA Rijkswaterstaat, the Netherlands (main applicant);
- ALTERRA, Green World Research, the Netherlands;
- Institute for Nature Conservation, Flanders, Belgium;
- University of Metz, France.

The project was monitored by the ISAC representatives Prof. Dr. A. Musy and Prof. Ir. E. van Beek. Part of the work is performed by external contracted parties: Royal Haskoning (the Netherlands). Last but not least a great number of institutes, parties and persons have helped to bring the project to a good end. We like to thank them all for their efforts.

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Abstract
In the coming years decision makers are confronted with the question how to combine aims for sustainable flood protection and floodplain rehabilitation in the best possible way. Both topics deal with spatial planning aspects and dimensions of measures. On this basis an evaluation method was developed within the IRMA/SPONGE project INTERMEUSE and illustrated for (fictive) situations in the Meuse basin. The integration of flood protection and floodplain rehabilitation can be performed on two scale levels that are interrelated: global for (large parts of) a stream basin or local for a specific site. Both scale levels are elaborated within INTERMEUSE: a link with flood protection measures and/or strategies is made via changed abiotic conditions, resulting in indications on chances to link flood protection goals to ecosystem rehabilitation goals. Ecological aspects under study were spatial cohesion and habitat configuration (global level) and habitat quality (local level). Based on the results of the analyses performed an integration approach was constructed that can be used in different parts of the planning cycle: different toolboxes for the planning phase and the actual evaluation and guidelines of how to use these toolboxes in practise. The results of this first study show clearly that there is a good chance to combine floodplain rehabilitation aims with flood protection activities, both on a local and international scale. In practise, for both cases close co-operation of parties involved is an important prerequisite.

Keywords:
Integrated water management, flood plain rehabilitation, spatial cohesion, physical habitat evaluation, Meuse, planning and evaluation.

Contents

1. Introduction

1.1 Background

The natural river landscapes in NW Europe have changed drastically over the last centuries due to human activities. Normalisation and regulation of the river ensured quick run off from water, ice and sediments and at the same time enhanced navigation. Dikes were raised to protect people and goods from flooding. The remaining floodplain areas are almost completely being used by agriculture and at some places gravel, sand or clay mining has been carried out. The massive flooding events of 1993 and 1995 along the river Meuse (and Rhine) proved that the presumed safety against flooding was to be reconsidered. In the past dikes were raised after (potential) flood events, now it was clear that new strategies needed to be developed as further raising of dikes was not a solution on a long term.

The central theme of these new strategies was to give back the rivers some of the "room" they had lost in the past centuries. As if this wasn't a challenge enough, spatial designs needed to integrate riverine functions as well as possible. Space in most cases is scarce and this is especially true along and around river systems. Apart from flood protection other riverine functions claim the scarce available space, like urbanisation, industry, recreation, agriculture and nature. Therefore, so-called win-win situations need to be achieved: measures being beneficial for various river-functions. Many functions, e.g. nature, could benefit from the changes that will take place to maintain safety against flooding.

As a result of the above mentioned human activities the natural river landscape deteriorated. Natural features of river systems are the result of the dynamic abiotic processes. With the decline of natural habitat diversity the accompanying characteristic species vanished or were left in isolated scattered fragments of habitats. The last decades national and international programs were started aiming at the ecological rehabilitation of river systems. The guiding principle for this needs to be the (restoration of) natural river processes: in particular the hydro- and morphodynamics. With the expected large scale changes in spatial design of floodplain areas along NW European river systems resulting from flood protection measures, tuning of measures and aims for the ecological rehabilitation of river systems has become a prerequisite.

The elaboration of new flood protection strategies into daily practise calls not only for new technical solutions. There is also a strong need for new concepts and accompanying tools which can help the decision-makers to explore future spatial designs for floodplain areas. Both flood protection and river rehabilitation are strongly served by an integrated approach on a river basin level. Partly as space is scarce as mentioned earlier, partly as problems cannot be solved always at the particular site in question. For both flood protection and river rehabilitation it is not enough to have enough space, also a good spatial connectivity is important, even a necessity. For flood protection this coherence is even the guiding principle for future spatial arrangement. The same stands for conservation and restoration of natural assets.

Within the IRMA/SPONGE-project INTERMEUSE an attempt is made to elaborate such a concept and accompanying toolbox. The focus has been on the ecological impacts of certain flood protection strategies and measures.

1.2. Objective

The **main objective** of the project INTERMEUSE is the development and application of a methodology for the evaluation of spatial planning alternatives for river basins, with respect to the integration of flood protection and floodplain rehabilitation. The effect assessment will focus on the ecological impacts of certain flood protection strategies and measures. The Meuse basin was chosen as study area to develop the proposed evaluation methodology and to illustrate its applicability. The proposed method can be applied in both (spatial) planning and subsequent evaluation (Figure 1.1).

Another important aspect of the INTERMEUSE-project is the co-operation of scientists and spatial planners from the three involved countries. It is important to ensure the transboundary integration of spatial planning in the river basin. Therefore, institutes and authorities from the three countries through which the Meuse flows worked together in this project. This co-operation improves international co-operation and tuning of management practices and enhances the exchange of knowledge.

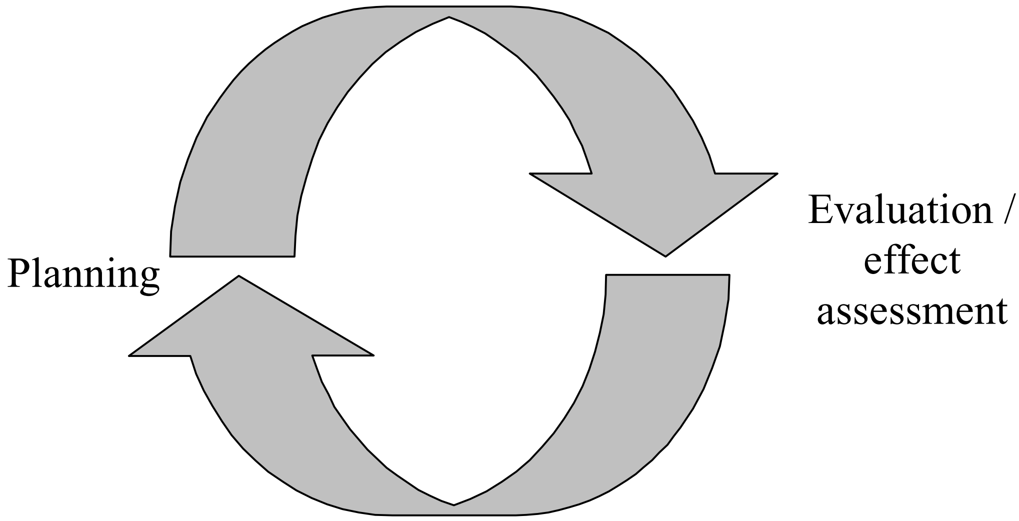

Figure 1.1. Planning cycle. The INTERMEUSE evaluation method can be incorporated in both the planning phase as the evaluation phase.

2. The INTERMEUSE-case

2.1 Outline

The basic theme with respect to the integration of flood protection and flood plain rehabilitation is*: in order to maintain safety against flooding a certain flood protection measure (or strategy) will be carried out, resulting in changes in the abiotic environment that in turn will influence biological developments and potentials*. In order to integrate the goals of both flood protection and flood plain rehabilitation knowledge on this basic theme and understanding of the interrelations is of utmost importance. This is the basis for guidelines and tools to assist decision makers, water and nature managers, spatial planners and all other parties involved in river basin management.

Integration can be dealt with on different scale levels that are interrelated. Each level has its own value in the decision making process of river management and landscaping. The scale levels and the subsequent approaches are characterised in Table 2.1, each having its own objective and requirements, specific data, toolboxes etc..

Table 2.1. Overview characteristics scale levels under study in INTERMEUSE.

Aspect	Global	Local
Study area	catchment / basin / river stretch	river bed (incl. flood plain)
- same, for INTERMEUSE	Meuse basin	pilot stretches
Flood protection function	flood protection strategies	flood protection measures
Ecological function	ecological network functioning	habitat quality
Ecological effect parameter	landscape ecological units	species (i.e. vegetation and carabid beetle communities) / biodiversity
Win-win / integration aspect	spatial aspects: spatial arrangement / cohesion	dimensions measures: interaction abiotic environment – species requirements habitats
Decision making: type of study	reconnaissance	Landscaping
Degree of detail	global / abstract	detailed / specific
Output	concept / scenario / strategy	plan / outline / design

Flood protection aims at a sustainable protection level against flooding. When studied on a *global* level mostly strategies representing certain flood protection measures are being assessed for their effects. These global studies are mostly performed on the level of catchments down to river stretches (with a length of several kilometres).
After assessing the several possibilities, the actual measures are being studied in more *detail*. In general this takes place on a more local scale (length max. a couple of kilometres) as to incorporate in the best possible way the specific local conditions.

Flood plain rehabilitation shows a similar division in approach. On a local scale the prevailing or future local conditions determine the ecological development and succession that can take place. The central item in INTERMEUSE for this scale is the analysis of ecological quality, linked to meadow vegetation communities and carabid beetle communities. Determining aspects are completeness of gradients linked to species habitat requirements and species communities. On a more global scale spatial habitat aspects like area and configuration give a good insight in the ecological potentials of a certain landscape variant. The central item in this approach is ecological network analysis of habitat configurations. Determining aspects are area and distance between habitats related to dispersion capacity of species (indicating the spatial connectivity of habitats).

In INTERMEUSE, this will be illustrated and tested for the river Meuse. The global approach will be tested on the whole Meuse basin, the more detailed local approach will be used in a selection of pilot stretches (see also Figure 2.1.):

- The section Mouzay – Lusy in the Lorraine Meuse;
- The Common Meuse;
- The section Sambeek – Cuijk in the Sand Meuse.

2.2. New concepts for flood protection

By now it is generally accepted that continuously raising of dikes as protection against flooding during high river discharges is no sustainable solution. New concepts for flood protection concentrate on the following aspects:

- Retaining water to slow down run-off to the main streambed;
- Retention of peak discharges;
- Increasing discharge capacity to ensure quick run-of of water.

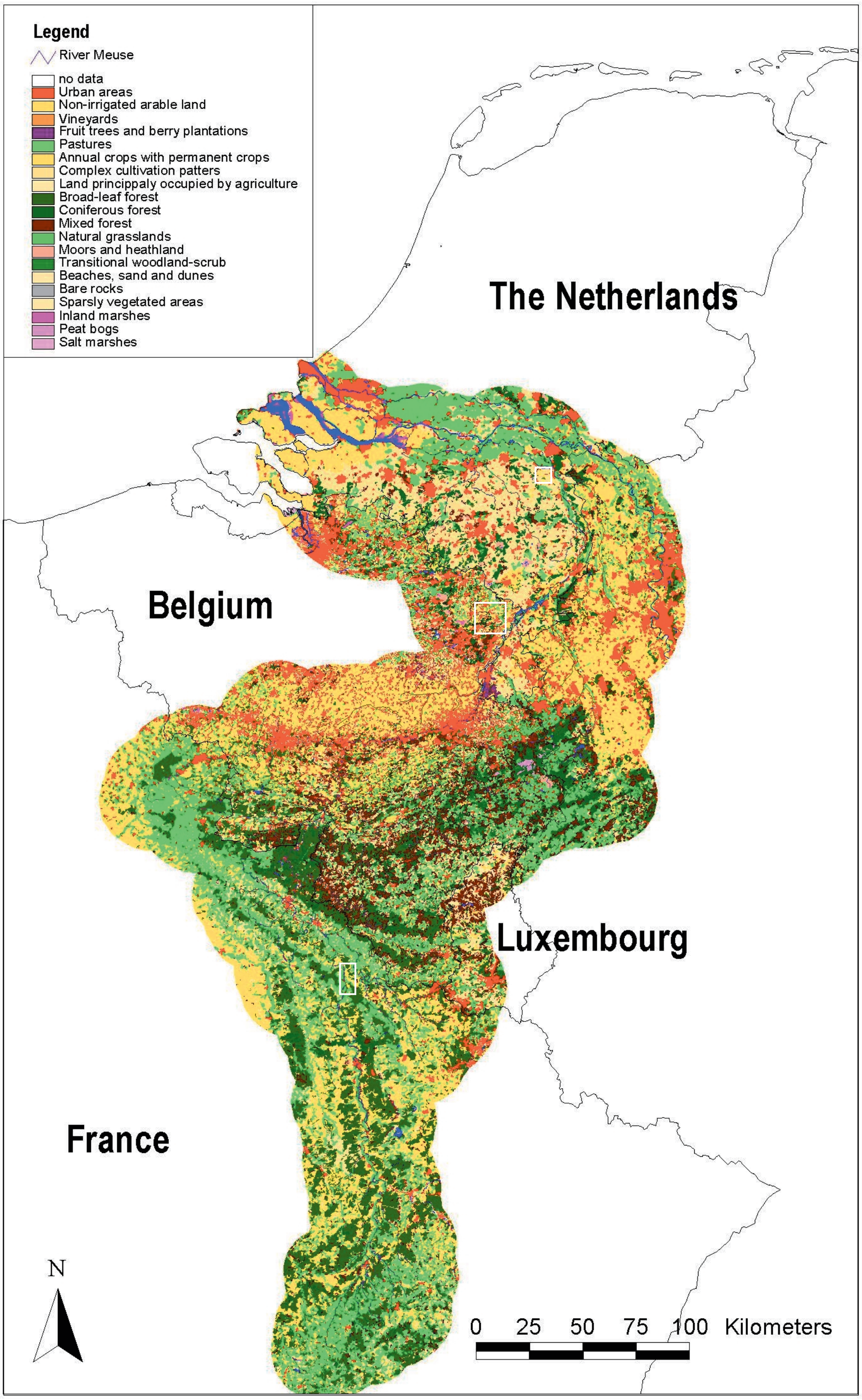

Figure 2.1. INTERMEUSE study area: Meuse basin, with pilot stretches for detailed analysis indicated in boxes. Map shows ecological land units for the present situation, based on the CORINE Land Cover map (European Commission, 1994).

In INTERMEUSE these new concepts were translated to fictive flood protection strategies, each representing a specific kind of measure and aim. The role of these strategies is to define distinct options in flood protection and to assess the effects on the ecological quality of the river system by these strategies. The strategies focus on alternatives in integrated basin management to elaborate an evaluation tool for a wide range of watershed management options.

A couple of criteria were formulated that needed to be met by the proposed flood protection strategies:

- The strategies need to be relevant for river policy and management. The interpretation in terms of different land and river management options must be clearly distinguishable.
- Impacts and effects on hydraulics and ecology of the river need to be clear in the different strategies.
- Application of a strategy or measure is in line with the characteristics (e.g. geomorphological) of a certain river stretch or local site.

This resulted in the following fictive flood protection strategies that were used in INTERMEUSE (see also Figure 2.2.):

1. **SPONGE**: set of measures implemented on the catchment level influencing the total runoff to the river from upstream areas. This implies recovery and increment of the sponge effect (storage of water) in upstream areas and the tributaries, by means of, for example, bringing the watercourse back in its natural shape or changed land use. Within INTERMEUSE this strategy was applied on the Lorraine Meuse, the Common Meuse and the Sand Meuse. The underlying measure was defined as: development of softwood forest along selected tributaries, in zones of 25 m width at both sides of the minor bed of the tributaries.

2. **RETENTION**: set of measures that control the movement of the flood wave through the river, and implemented at selected sites along the river. This implies storage of water (e.g. in reservoirs) especially during peak discharges. The main difference between SPONGE and RETENTION is that RETENTION is only effective during high discharges whereas SPONGE is effective during high and low discharges. Within INTERMEUSE this strategy was applied on the Lorraine Meuse, the Common Meuse and the Sand Meuse. The locations used correspond with existing plans or studies. The ecological objective in these areas was defined as marshland in the Lorraine Meuse and softwood forest at the sites along the Common Meuse and Sand Meuse.

3. **WINTERBED**: set of measures in the major bed of the river, e.g. floodplain enlargement and implementation of secondary channels. This means an increase of the discharge capacity and storage of water preventing (local) flood problems. WINTERBED is based on the principle of enlargement of the river cross-section, aiming at an enlargement of the discharge capacity. It should be stated that this does not imply a decrease of the peak discharges. With WINTERBED water levels will be lowered, while the discharge may stay the same or even increases in downstream direction. Measures in the major bed have specifically a local effect. Within INTERMEUSE this strategy was applied for the whole Meuse basin. The ecological objective for WINTERBED was stated to be a mixture of side channels/open water, grassland and herbaceous vegetation.

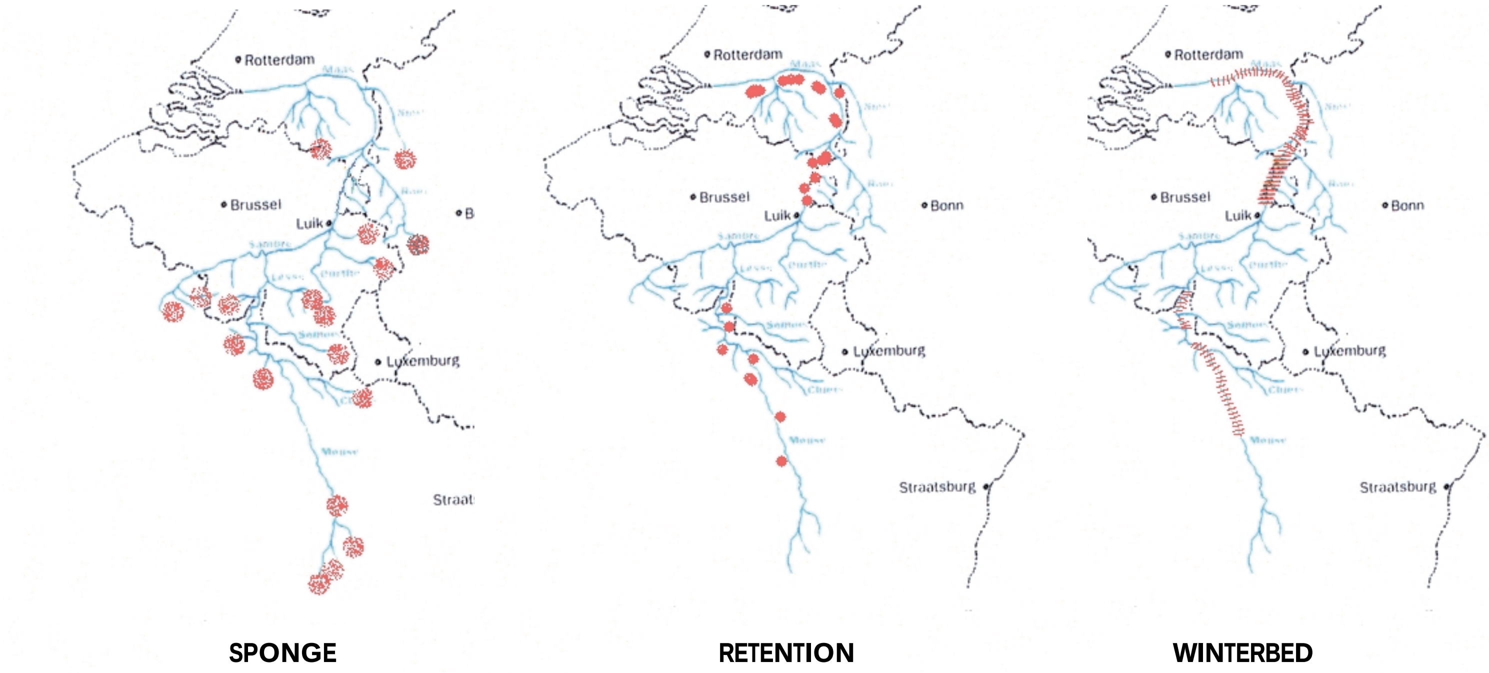

Figure 2.2. Fictive representation of the flood protection strategies used within INTERMEUSE.

2.3 Integration of flood protection and flood plain rehabilitation

The basic idea of the proposed INTERMEUSE evaluation method is the identification and quantification of key elements to incorporate floodplain rehabilitation aspects in spatial planning and integrated effect assessment. Starting point of the quantification is the identification of the "ecological minimum", the critical boundary or minimum level of habitat conditions for a potentially good ecological functioning. It is the least acceptable state for riverine nature that is still valuable to some extent, compared to a natural river ecosystem (Figure 2.3).

In Chapter 3 and 4 the proposed evaluation method will be elaborated and illustrated for the two scale levels under study (see also Table 2.1).

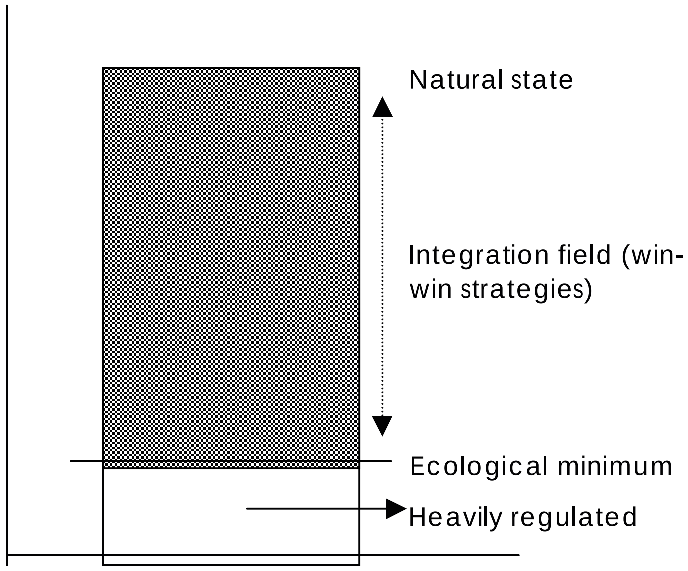

Figure 2.3. Field of integration were goals of ecological rehabilitation and other functions (in case of INTERMEUSE: flood protection) can be combined.

3. Integration on a global level

3.1 Ecological effect variables

On a global scale (e.g. river basin) focus for ecological effect assessment of flood protection activities will be on spatial configuration of habitats. As input landscape ecological data are needed. For this a landscape ecological unit typology was chosen (i.e. based on ecotopes), that is based on a combination of features of the abiotic environment and land use. As an example the resulting map for the present situation for the Meuse basin is shown in Figure 1.1. The used typology is synchronised with existing typologies used by partners within the International Rhine Commission (ICPR), the CORINE land cover project, the Habitat Directive typology and other IRMA-SPONGE projects (i.e. BIOSAFE);

3.2 Determination new abiotics

On a global scale the three proposed flood protection strategies are assessed for their potential effects on the discharge and water level duration curves. For this, data from gauges situated near the pilot stretches used for the detailed analyses were used (i.e. Stenay (Lorraine Meuse), Borgharen (Common Meuse) and Sambeek (Sand Meuse)). Due to the nature of the project the effect assessment at this scale level for the whole Meuse basin was performed in a more qualitative way. It was anticipated that the strategies all have a different effect on the discharge or water levels of the river Meuse. The contributing factors of each strategy (see Table 3.1) were globally assessed, partly by expert judgement, for their effects on the water level and discharge.

Table 3.1. Factors per flood protection strategy that were included in the analyses of the changed abiotic environment on a global scale.

SPONGE	RETENTION	WINTERBED
• increase infiltration of precipitation • change of land use • re-meandering watercourses • water level control • buffer ponds	• shape of flood wave (height and duration) • infrastructure of reservoir • storage capacity of reservoir	• roughness vegetation (land use)

The analyses resulted in the following hydrological effects to be expected from the strategies.

The **SPONGE**-strategy has the best effect by application in the upstream parts of the catchment. The peak discharge of precipitation water will be delayed and probably reduced, because water stays longer in the ground. This means for the discharge of the river, on which the area drains its water, that the peak discharge will be delayed and usually be decreased. This has an indirect effect on the water levels, that will also decrease. The SPONGE-effect will be especially noticeable during low and normal discharges, due to the storage capacity in summertime. In wintertime the storage capacity is less due to the high seasonal precipitation rate. By applying SPONGE water will be stored in the ground (also in wintertime, only less), instead of discharged straight away into a watercourse. In this way the groundwater supply is complemented. Furthermore, discharge peaks of tributaries do not coincide. By delaying a discharge peak in one tributary by applying SPONGE, the discharge peak of the Meuse can be lowered. In this way this strategy can have a large effect on the discharge and therefore on the water level.

The **RETENTION**-strategy acts much like SPONGE, but then at higher floods. As soon as a retention basin is active, the discharges are reduced and the peak water levels over the downstream stretches as well. Apart from peak attenuation, which decreases the occurrence of peak discharges, there is a second effect: an increase of occurrence of lower discharges through outflow of the reservoirs. Upstream of a reservoir, implementation of retention reservoirs has no significant effect on the occurrence of a discharge peak, the peak discharges will practically stay the same. The water level on the other hand is effected over some distance, due to the increase of the hydraulic slope ("draw-down" effect). This effect can reach for some kilometres upstream. For the Common Meuse this effect is noticeable approximately 10 kilometres upstream. For the Sand Meuse this is more: 30 to 40 kilometres upstream.

WINTERBED-measures increase the flow cross-section of flood plains. However, discharges are not influenced, only discharge capacity. In contrast to the previous strategies this strategy acts on a local level, and therefore especially is interesting for *bottleneck* situations. The maximum drop in water level can be found at the upstream side of the area where the cross-section has been enlarged. Depending on a new land use the hydraulic resistance of the major bed can increase, which has a relatively negative effect on the water level. The water level upstream will be relatively pounded up by the increased roughness over some distance. This effect on the water level is however minor compared to the effect of enlargement.

As input for the ecological rehabilitation analyses of these strategies the assessed changed abiotic environment is combined with the prescribed nature targets for each strategy (par. 2.2) and expressed in maps of landscape ecological units (as in Figure 1.1):

- SPONGE: as nature target for this strategy softwood forest was stated. Based on the preconditions set by INTERMEUSE this strategy results in an increase in total area of softwood forest by 4,128 ha, located along the selected tributaries.
- RETENTION: as nature targets a combination of marshland and wet grassland was stated for the French part of the Meuse, and softwood forest for the Dutch part. This strategy results in these parts of the Meuse in an increase in total area of marshland, wet grassland and softwood forest of resp. 70, 279 and 16,858 ha.
- WINTERBED: as nature targets a combination of open water, herbaceous grassland and grassland was stated for the whole Meuse. Over the whole Meuse this strategy results in an increase in total area of these nature types by resp. 15,146, 30,293 and 15,146 ha.

3.3 Ecological rehabilitation analysis

On the global scale the ecological rehabilitation goals and therefore the analysis focus on the spatial configuration of habitats. A number of habitats within reach of each other can form an ecological network, thus enabling species to form viable populations. This concept is based on the theory of metapopulations. For the evaluation of this ecological network functioning in the different flood protection strategies a method was developed. Key elements in this approach are:

- characteristics of a species: e.g. habitat preference, home range, dispersal capacity;
- the amount, shape and area of habitat patches in a landscape;
- connectivity of the landscape, which defines how easily species can move to other habitat patches. For example, roads can seriously hamper the connectivity between closely orientated habitat patches.

Within the developed method the network function of a strategy or landscape can be tested on the basis of a set of so-called ecological profiles. Each ecological profile represents a range of species with similar traits (dispersal capacity and area requirements) that can occur in a landscape. For the INTERMEUSE-case a set of 10 ecological profiles was selected (Table 3.2). For these species the current habitat configuration in the Meuse catchment area and the situations resulting from the defined flood protection strategies are analysed whether or not viable populations can (potentially) be sustained.

Table 3.2. Selection of ecological profiles

Habitat \ Dispersal pattern	Locale scale	Regional scale	National/European scale
Herbaceous vegetation/ grassland		Whinchat	Corncrake
Marshland	Large Marshgrasshopper	Blue throat	Bittern
Riverine forests		Medium spotted woodpecker Beaver	Black kite Otter
Open water/ secondary channels	Wolf spider	Beaver	Otter

For the analyses the LARCH[1] model (Landscape Analysis and Rules for the Configuration of Habitat) was made operational. LARCH is designed as an expert system, used for scenario analysis and policy

[1] For an in-depth description of LARCH referred is to Foppen et al., 1999; Chardon et al., 2000; Sluis & Chardon, 2001.

evaluation. The model requires a habitat map (in case of INTERMEUSE maps with landscape ecological units) and ecological standards or rules (e.g. on dispersal distance, population density etc.). LARCH standards are based on literature, empirical studies and simulations with a dynamic population model. Since the assessment is based on potentials for a habitat network of a species, actual species distribution or abundance data are not required. The results of the spatial analysis with the model LARCH in INTERMEUSE are summarised in Table 3.3, an illustration of the outcome is presented in Figure 3.1. The results showed:

WINTERBED
- The selected species indicative for herbaceous vegetation or grasslands are Whinchat and Corncrake. Under current conditions for the Corncrake the whole area forms already one network. WINTERBED results in large areas of riverine pastures. Here a key-population for Whinchat and Corncrake is possible under newly created conditions. This strategy is optimal compared to the other strategies for grassland species, by showing a large MVP (minimal viable population) for most of the riverine pastures in France and the Netherlands.
- An improvement also occurs for marshland species (except for the Bittern, that needs larger areas of wetland), resulting in large key populations in the floodplain areas of the Netherlands and France.
- Also for forest species, the WINTERBED-strategy results in local improvement of the network functioning. But the gain in habitat is generally to small to allow for considerable improvement in the populations.

RETENTION
- For the selected grassland species the RETENTION-strategy has little effect, only locally and mainly in the Netherlands.
- For marshland species RETENTION is the optimal strategy, as a results of the larger wetland area. The Bittern shows at present a rather small, but more or less stable population, mainly around large wetlands in the Netherlands, and an area in France. RETENTION results in a larger wetland area and subsequently in a new key patch for Bittern. The Large marsh grasshopper at present has a fragmented metapopulation structure, with small, local populations spread over the area, and very few key-populations. In potential the riverine grasslands can form a set of key populations and local populations, with suitable management and sufficient wet conditions.
- The RETENTION-strategy results in an improvement in a wider area for forest birds. However, the habitat proves to be still limiting, so no viable populations are possible. Nevertheless, a local population around the Beersche Overlaat still results, which is however too small to form a key population.

SPONGE
- The SPONGE-strategy shows no differences for grassland species compared to the present situation, since there is no change in relevant ecological land units.
- The SPONGE-strategy results even in a decrease of marshland species, due to loss of habitat as a result of changes in the floodplains.
- For forest species the SPONGE-strategy results in considerable improvements of the ecological network upstream in France. However, also here the habitat is still limiting, so no viable populations are possible of the selected forest species.
- The SPONGE-strategy shows best results for Otter, as indicative for side channels and open water: locally considerable wetland clusters are created. Despite the fact that the area is still too small for key-populations, it is likely that there will be a resident population.

As illustrated in Figure 3.1 for the Marsh Grasshopper, all results clearly showed the areas where improvements are required: the bottlenecks in the ecological network. For almost all species selected, the suitable habitats show clear gaps in the distribution in the stretch of the Ardennes Meuse. This is easily explained by the nature of this river stretch (hardly any flood plain, steep slopes etc).

Table 3.3 Summary of results for the LARCH analysis: strategies compared to current situation

Ecotope	*Species*	*Retention*	*Sponge*	*Winterbed*
Marshland	Bittern	+	0	0
	Blue throat	(+)	0	++
	Large marsh grasshopper	(+)	-	++
Rough growth	Whinchat	0	0	++
	Corncrake	(+)	0	++
Forest	Medium sized forest bird	(+)	(-)	0
	Otter	(+)	++	++
Side channels, open water	Otter	(+)	++	++

0: no change, - decrease, -- strong decrease, + increase, ++ increase almost everywhere, (+) localised increase

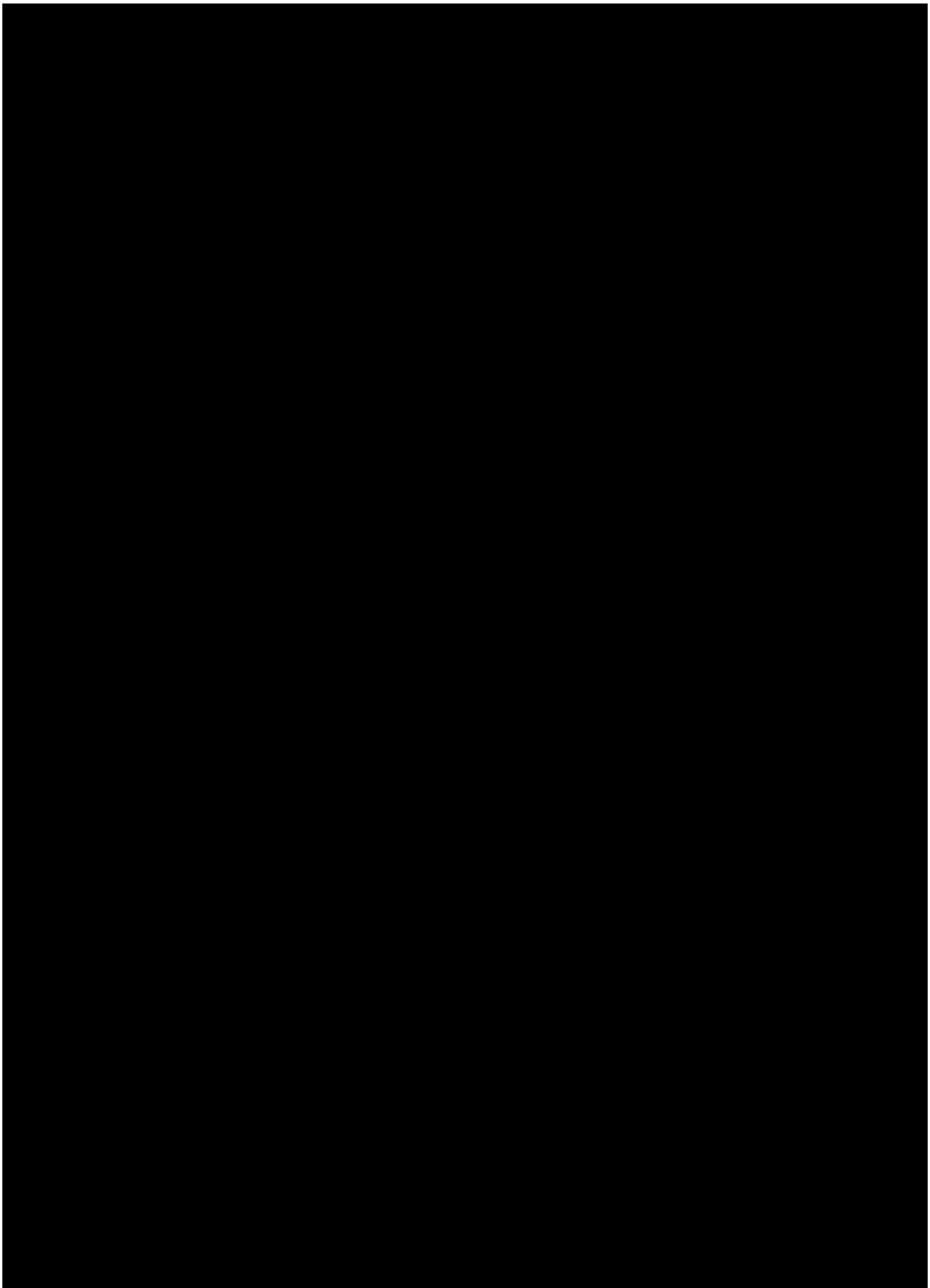

Figure3.1. Example of results of LARCH-analyses of the current situation and the three flood protection strategies for the Large marshgrasshopper.

3.4 Spatial planning

For application of the concept of ecological networks and the insights of the analyses in the planning phase, guidelines for the ecological minimum are elaborated and quantified. These "building blocks" form a useful tool for decision makers and spatial planners to incorporate in an early phase relevant information on spatial aspects of ecological rehabilitation. In this way both flood protection and floodplain rehabilitation can be integrated on an equal basis.

The ecological minimum is defined as a certain amount of habitat combined with a maximum degree of fragmentation of habitat (species that are tolerant to fragmentation are not within the focus of ecological network assessments). As this minimum still needs to have some chances on viable population development for some species groups, the area of habitat involved at this stage meets the requirements for at least one key area.

In Tables 3.4 and 3.5 indications are listed for key area size and total area needed for an ecological network supporting viable populations of species. These indications are based on autecological knowledge of large numbers of species, concerning habitat demands, area needs and dispersal capacity in search of new habitats to colonise.

Improvement of the network function of a landscape can be obtained by enlarging existing habitat patches or the creation of new habitat patches. Depending on type, size and shape these can function as key area or stepping stone or corridor. The main objective with respect to a cohesive, viable ecological network should be prevention of further fragmentation and creation of natural areas as great in size as possible.

Table 3.4. Area indications per ecotope type per species group with respect to key area potentials.

Area (ha)	Shallow water	Flats and muds	Marshland	Natural grassland	Herbaceous terrain	Natural forest
5	Insects	insects				
50	Fish		small mammals			
200		amphibians				small mammals
500				reptiles		
1000		small, medium and large birds	small birds	insects	amphibians	
1500	medium and large birds		medium and large birds			medium and large birds
5000				small birds	small birds	small birds
10000				medium birds	medium and large birds	
25000			large mammals	large birds		large mammals

3.5 Evaluation: tools and guidelines

As stated, for the evaluation of the ecological network functioning of strategies or landscape the model LARCH can be used. On the basis of the results of such an analysis the recommendations listed in the previous paragraph should be used to optimise the underlying habitat configuration by means of spatial planning or management.

Table 3.5. Indications for the area ratio between key areas and sustainable networks, with and without a key area).

Species group	Key population	Sustainable network with a key area	Sustainable network without a key area
Large birds	1	4	6
Medium birds	1	3	5
Small birds and mammals	1	1.5	2
Reptiles	1	2.5	2.5
Amphibians and butterflies	-	-	20 habitat spots

4. Integration on a local level

4.1 Ecological effect variables

On a more detailed, local scale (e.g. flood plain) focus for ecological effect assessment of flood protection activities will be on completeness of species communities in relation to local conditions, as indication for biological quality. Within INTERMEUSE meadow vegetations and carabid beetles were chosen as taxonomic groups for this aspect of ecological effect assessment and means for integration with flood protection.

4.2 Determination new abiotics

In contrast to the determination of new abiotics on a global level, here changes in flood duration and water level are computed in a quantitative way, using a hydraulic model (i.e. SOBEK). Based on the characteristics of the pilot stretches one or more strategies was elaborated. Information on type and location of measures was derived from existing studies:

- RETENTION for the section Mouzay – Lusy in the Lorraine Meuse. Data were obtained from EPAMA;
- WINTERBED for the Common Meuse, based on the preliminary design of the Maaswerken-project (incorporating widening of the main channel, supplemented at some locations with flood plain lowering;
- WINTERBED for the section Sambeek – Cuijk in the Sand Meuse: based on the most environmental friendly variant of the Maaswerken-project.

As the focus in the pilot stretches was strongly on the main bed of the river Meuse, the SPONGE strategy was not elaborated on the detailed level.

A major factor influencing ecological developments in river systems is flood duration. Both the used land ecological unit typology (chapter 3) and the distinction in species community clusters in the chosen taxonomic groups can be linked to flood duration classifications. For the computation of changes in flooded zones for these ecological relevant flood duration classes due to flood protection activities, corresponding discharges were identified to be used in the hydraulic model. An example is listed in Table 4.1 for gauge Borgharen.

Table 4.1. Summary of the information used for the computation of changes in flood duration as result of flood protection strategies. Ecologically relevant classifications are linked to hydraulic features.

classes	**typical division of inundation frequencies for river ecotopes (days of flooding per year)**	**classes meadow vegetation analysis**	**approximate corresponding discharges at Borgharen in m^3/s (in between brackets exceedence days per year)**
1	<2	0	1500 (1.5)
2	2-20	1	750 (20.9)
3	20-50	2+3	500 (50.8)
4	50-150	4+5	250 (123)
5	>150	6	50 (251)

The results of the hydraulic analyses are illustrated here for the Common Meuse pilot. The proposed WINTERBED-measures lead to an effective water level reduction over the whole range of discharges that increases with increasing discharge (see Figure 4.1). The water level reduction by the WINTERBED measures in the Common Meuse pilot is rather spectacular. Causes for the large reduction are:

- Overlapping locations where WINTERBED measures are implemented, resulting in amplification of water level reduction (by accumulation of drawdown effects);
- Relative large widening of flow profiles at lower flows due to significant width increase of the low water channel and adjoining flood plains;
- No weir regulation of the Common Meuse (in contrast to the Sand Meuse).

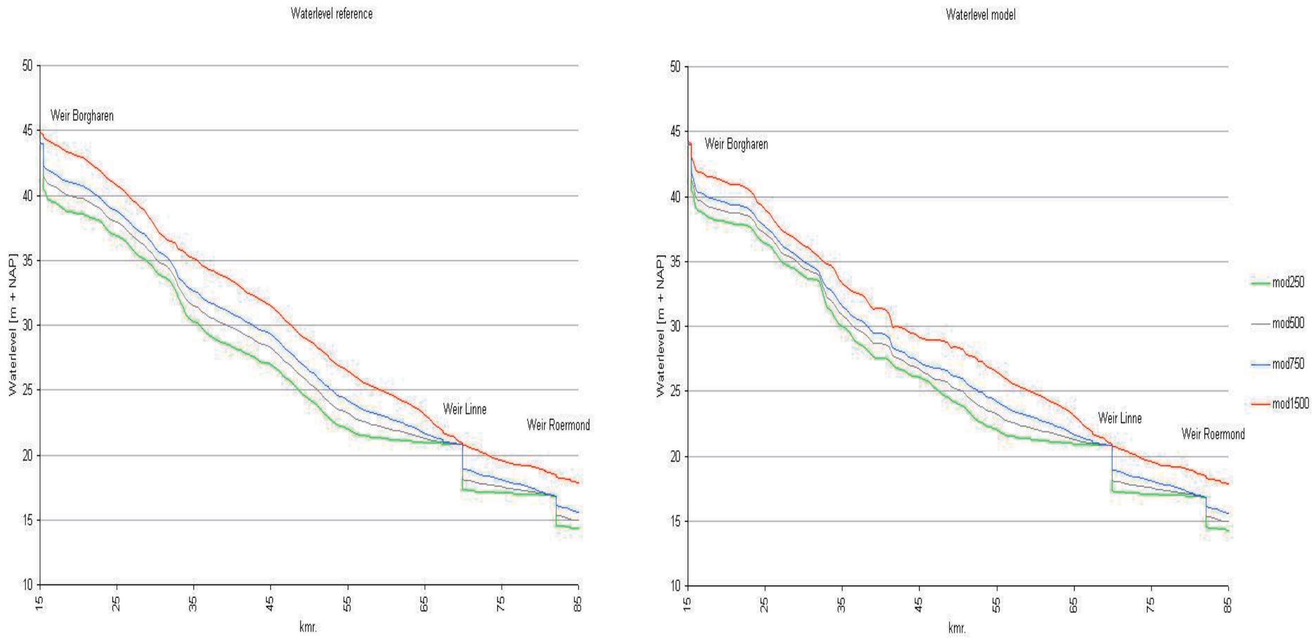

Figure 4.1 Common Meuse pilot: water level difference reference (present) and pilot situation (WINTERBED-strategy).

The results of the analyses with respect to the area of ecologically based flooded zones is presented in Table 4.2. As comparison the results of both Common Meuse (no weirs) and Sand Meuse (weirs) are shown. Inundation is influenced strongly by the water level reduction (less inundation) compared to the area which is lowered by WINTERBED measures (positive for inundation). In the Common Meuse, despite the large width increase of the main channel, this resulted in no significant increase in inundation area as floodplains are not flooded at discharges of 750 m^3/s and lower. At the discharge of 1500 m^3/s the major part of the floodplains are to be flooded in the present situation. However, in WINTERBED the water level reduction leads to smaller inundated areas. In contrast with the results for the Common Meuse pilot the Sand Meuse pilot shows a significant increase of inundated area all over the range of discharges to 750 m^3/s. As a result of the present weirs lowering of the flood plain by WINTERBED measures prevails above water level effects. At the discharge at 1500 m^3/s there is no influence of the weirs anymore, resulting in a significant reduction of the inundation area, comparable to the Common Meuse pilot.

Table 4.2 : Inundation area (ha) Common Meuse

	Common Meuse		**Sand Meuse**	
Discharge Borgharen (m^3/s)	**Inundation area present (ha)**	**Inundation area WINTERBED (ha)**	**Inundation area present (ha)**	**Inundation area WINTERBED (ha)**
50	1436	1446	794	1040
250	1564	1572	804	1057
500	1703	1733	843	1100
750	1933	1928	913	1175
1500	3558	2805	3877	2985

Apart from flood duration, changes in water depth were computed based on water level data and topographical data. The results showed rather limited changes for the WINTERBED strategy. This is due to a compensating effect mentioned earlier: at the one hand there is a significant increase in wet areas as result of the measures, at the other hand the measures lead to a water level reduction thus decreasing the inundated areas.

4.3 Ecological quality analysis

On the local scale the ecological rehabilitation goals and therefore the analysis focus on the ecological quality, and in case of INTERMEUSE is assessed for two species groups: meadow vegetation (as indicator for the winter bed) and carabid beetles (as indicator for the summer bed). Central theme for both groups is linkage of characteristic species communities to distinct habitat conditions as a whole representing the number of gradients present in a river ecosystem. By doing so, information on the abiotic environment can be translated into potentials for species diversity and based on indicator species the habitat diversity can be described. Both elements are valuable information to optimise river management.

4.3.1 Meadow vegetation

Differences in plant composition and zonation in floodplains can be largely explained by two major environmental factors: hydrological regime (mainly flood duration) and agricultural practices. Within INTERMEUSE vegetation monitoring results from the the different Meuse stretches were analysed. For this analysis 80 relevés from France, 60 relevés from Belgium and 20 relevés from the Dutch part of the Meuse were combined. Based on a phytosociological study for the grasslands of the Mouzay-Luzy pilot 13 different vegetation groups were defined after cluster analysis, ranging from hygrophilic communities to mesoxerophilic communities. These clusters were linked to the defined landscape ecological units (par. 3.1). Correlation and regression analyses between the clusters and the determining environmental factors resulted in probability assessments for the vegetation communities. With this, for each vegetation type a vegetation response map was calculated, showing the probability of occurrence of each type. These probability maps were combined to produce a new vegetation map, based on the vegetation type with the highest probability of occurrence. In Table 4.3 the results of this exercise are listed for the Mouzy-Luzy pilot stretch. With this approach potentials for meadow vegetation developments can be assessed for any given (future) situation. But, to what extent these potentials can be achieved is not only depending on the new hydrological conditions. Soil seed bank may prove to be a very important factor in this respect.

Table 4.3 Summary of the ecology quality evaluation for the Mouzy-Luzy pilot stretch on the basis of targets for meadow vegetations. Presented are the present situation and two proposed flood protection strategies analysed for this pilot stretch.

Vegetation	ha **Ecological goal**	% **Present situation**	% **Retention strategy**	% **Winterbed strategy**
Mesoxerophilic communities	100	52	11	19
Mesophilic communities	180	100	100	100
Mesohygrophilic communities	400	73	64	93
Hygrophilic communities	100	60	61	100
Aquatic and sub-aquatic vegetation	35	46	46	100
Crops	0	100	100	100

4.3.2 Carabid beetle communities

For the analysis of the carabid beetle communities a similar approach as for the meadow vegetation is used. In a field survey, data were collected in the pilot stretches on carabid fauna, vegetation and abiotic river bank characteristics. In total 20 plots were sampled resulting in 4881 carabid beetles. Based on correlations between species communities and environmental features habitat-templates ("profiles") are defined, that are grouped in three zones within the riverbank. Indicator species are identified with strong relevancy to the different habitats in the riverbed. The defined templates are linked to biotic and abiotic characteristics which enables the development of a response model that can be used for the prediction of potentials of river management activities as well as the effect assessment. Within in INTERMEUSE this was elaborated for the WINTERBED-strategy in the different pilot stretches (Table 4.4).

The correspondence analysis lead to three important variables with respect to prediction of habitat integrity: peak velocity, peak frequency and width-depth ratio. These variables can be linked to the INTERMEUSE flood protection strategies:

- the SPONGE-strategy has the strongest influence on the lowering of peak velocity;
- the RETENTION-strategy reduces peak frequency;
- the WINTERBED-strategy influences width-depth ratios.

Table 4.4. Performance of habitats in present situation and WINTERBED strategy.

	Mouzay			**Common Meuse**			**Sand Meuse**		
Habitat templet	**Goal**	**present**	**strategy**	**goal**	**present**	**strategy**	**goal**	**present**	**strategy**
Pioneer gravel bar	20ha	100%	100%	100ha	10%	100%	10ha	20%	40%
Higher open gravel bar	10ha	100%	100%	150ha	10%	70%	30ha	10%	60%
Pioneer sand bar	5ha	20%	75%	25ha	5%	90%	20ha	0%	75%
Higher vegetated bar	5ha	10%	30%	70ha	20%	80%	15ha	30%	100%
Wooded bar	5ha	10%	50%	30ha	5%	100%	50ha	10%	60%
Eroding bank	2ha	80%	100%	3ha	40%	60%	2ha	50%	50%
Steep bank	1ha	100%	100%	10ha	100%	100%	10ha	100%	100%
Levee bar	5ha	5%	40%	20ha	15%	100%	150 ha	10%	50%
Flood channel	20ha	20%	100%	120ha	10%	80%	400 ha	20%	80%

4.4 Planning phase: guidelines

4.4.1 Meadow vegetation

As stated, the main aspects with regard to the diversity of floodplain meadow communities are the hydrological gradient (mainly flooding duration) and agricultural practices (mainly grazing and level of fertilisation). So, the least acceptable state of riverine nature (ecological minimum (par. 2.3)) that allows development en persistence of sustainable meadow communities will be based on these two aspects. The elaboration of this ecological minimum is performed for the unregulated French pilot stretch. From this stretch 13 distinguished vegetation groups were clustered in four classes of meadow communities. These classes correspond to the whole hydrological gradient. Based on this the ecological minimum was defined as a minimum of 1 group per community class. Thus, a total of 4 vegetation groups representing the whole hydrological gradient should be the lowest acceptable level of ecosystem restoration. The natural baseline is achieved if all vegetation groups are present in the floodplains. Based on the French pilot stretch, this ecological minimum was quantified defining a minimum area for each community necessary to allow its preservation (Table 4.5). The connectivity with the fluvial system is an important factor for the preservation of the two wettest communities (mesohygrophilic and hygrophilic). So, spatial fragmentation in small patches of these two habitats severly hampers sustainable communities.

Table 4.5. Quantification of the ecological minimum for the different meadow communities to allow preservation.

Meadow vegetation communities	**% of total area**
Hygrophilic communities	2.5
Mesohygrophilic communities	10
Mesophilic communities	5
Mesoxerophilic communities	2.5

Compared to the rather natural French pilot stretch the other INTERMEUSE pilot stretches not always achieved this ecological minimum in the present situation. Both the Common Meuse and the Sand Meuse attained only 50 % of this minimum: only two communities out of four are sustainable in the present day situation. The ecological goal for the pilot stretches was by translating the situation of the French phytosociological results to the other stretches, assuming an extensifation of agricultural management (Table 4.6).

Table 4.6. Goals for rehabilitation of meadow vegetations, with indications of actual state for the pilot stretches.

	Mouzay		**Common Meuse**		**Sand Meuse**	
Vegetation type	**Ecological goal**	**Present**	**Ecological goal**	**Present**	**Ecological goal**	**Present**
Hygrophilic communities	100 ha	60 %	490 ha	?	495 ha	10 %
Mesohygrophilic communities	400 ha	73 %	1965 ha	?	1980 ha	1 %
Mesophilic communities	180 ha	100 %	880 ha	?	890 ha	26 %
Mesoxerophilic communities	100 ha	52 %	490 ha	100 %	495 ha	100 %
Crops	0 ha	100 %	0 ha	100 %	0 ha	100 %

In Table 4.7. the ecological minimum and natural baseline are linked to flood duration, one of the main predictors for meadow habitat integrity. All these “building blocks” form essential input for the planning process within integrated river management related to the winter bed.

Table 4.7. Relation between the defined ecological minimum and natural baseline and the relevant flood duration classes.

	Lorraine Meuse		**Common Meuse**		**Sand Meuse**	
Flood duration	**Ecological minimum**	**Natural baseline**	**Ecological minimum**	**Natural baseline**	**Ecological minimum**	**Natural baseline**
0 = < 1 week	2 ha	10 ha	140 ha	700 ha	100 ha	500 ha
1 = 1-2 weeks	18 ha	90 ha	240 ha	1200 ha	360 ha	1800 ha
2 = 2-5 weeks	40 ha	180 ha	220 ha	1000 ha	100 ha	400 ha
3 = 5-8 weeks	75 ha	370 ha	140 ha	700 ha	125 ha	600 ha
4 = 8-12 weeks	20 ha	100 ha	200 ha	1000 ha	120 ha	600 ha
5 = 12-20 weeks	8 ha	35 ha	115 ha	500 ha	95 ha	400 ha
6 = > 20 weeks		30 ha		400 ha		600 ha

Remark : Class 6 includse river bed and side channels

4.4.2 Carabid beetles

With respect to the river bed a similar approach as used for the meadow vegetation can be applied for the carabid beetle communities. As stated analysis showed that these communities are grouped in three zones within the riverbank. From the distinction of these groups an ecological minimum can be defined as a minimum available habitat within each of these gradient groups to allow sustainable populations of one of the communities. So, a minimum of 3 communities (divided over the 3 zones of the defined gradient) is necessary to achieve basic ecological integrity. Based on the analysis in INTERMEUSE this ecological minimum habitat integrity was present in 50% of the sites monitored.

The natural baseline (maximum habitat integrity) is achieved when all characteristic communities have sufficient habitat for the development of sustainable populations. Based on this the ecological goal for the pilot stretches was determined by interpretation of the landscape ecological unit mapping (see par. 3.1) and the carabid beetle sampling results (Table 4.8). The goal definition corresponds to the habitat integrity goal of the natural baseline condition and was based on reference conditions. To reach the ecological minimum in a scenario, there need to be at least three habitats that reach the goal area.

Table 4.8. Goals for rehabilitation of river bed habitats based on carabid beetle communities, with actual performance for the pilot stretches.

		Mouzay		**Common Meuse**		**Sand Meuse**	
Habitat	**Landscape ecological unit**	**goal**	**present**	**Goal**	**present**	**goal**	**present**
Pioneer gravel bar	Bf1 gravel bar	20ha	100%	100ha	10%	10ha	20%
High open bar	Bf2 sandy bank	10ha	100%	150ha	10%	30ha	10%
Pioneer sand bar	Bf5 sand bar	5ha	20%	25ha	5%	20ha	0%
High vegetated bar	Nf4 wet border	5ha	10%	70ha	20%	15ha	30%
Wooded bar	Tf1 softwood fringe	5ha	10%	30ha	5%	50ha	10%
Cut off bank	Bf4 steep bank/groin	2ha	80%	3ha	40%	2ha	50%
Steep bank	Bf4 steep bank	1ha	100%	10ha	100%	10ha	100%
Overbank levee bar	Bl5 sand bar/dune	5ha	5%	20ha	15%	150 ha	10%
Flood channel	Sf1 flood channel	20ha	20%	120ha	10%	400 ha	20%

For the implementation of these goals some guidelines can be stated. Principle element in the riverbank habitat integrity is the river dynamics and its gradient over the riverbank. A good measure for the river dynamics proves to be the bank full width and the width/depth-ratio of a river stretch. The latter is a good indication for the morphological activity in a river stretch. Within INTERMEUSE for each pilot stretch the variation in these parameters was assessed. The results are listed in Table 4.9 and form additional information for the ecological rehabilitation of the river bed and the integration with flood protection activities.

Table 4.9. Guidelines for river class types for the planning predictor variable Width/depth ratio.

Size/character class	Meuse stretch	Sinuosity	Bank full (m^3/s)	Ecological minimum W/d-ratio	Natural baseline W/d ratio
Upper middle course	Lorraine Meuse	>1.5	100-150 (<500)	10	30-50
Upper straight course	Ardennes Meuse	<1.5	250-500 (>100)	10	20-30
Lower middle course	Common Meuse	>1.2	1500 (>500)	20	50-100
Lower course	Sand Meuse	<1.2	1600 (>500)	18	>100

In Figure 4.2 the previous statements for biological integrity assessment and planning, based on carabid beetle communities as indicator for the river bed are combined. Both present situation and a the impact of a flood protection strategy (i.e. WINTERBED) compared with the ecological minimum and natural baseline for habitat integrity (in between: the win-win field for integration of flood protection and river rehabilition goals). The modelling results for the WINTERBED strategy show the positive aspects of the stronger inundation of the river banks, where in the present situation habitat integrity is very low since most banks are encroached. The gradient and habitat diversity will be more pronounced for these zones.

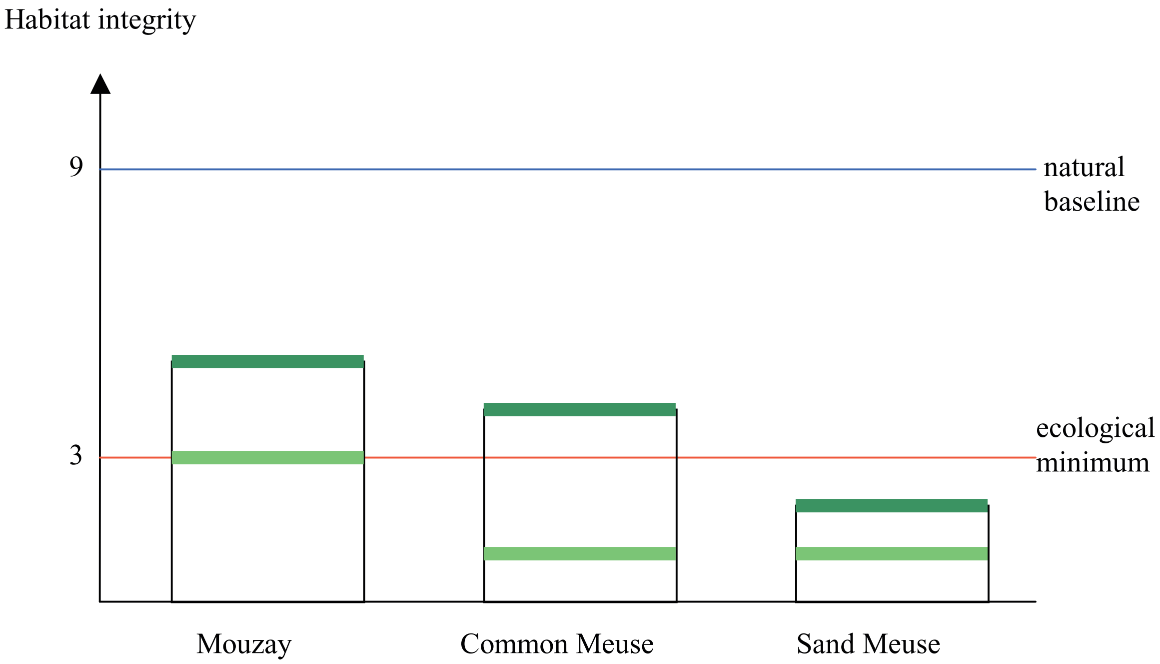

Figure 4.2. Habitat integrity in present situation ( ) and WINTERBED strategy ( ).

4.5 Evaluation

The information presented in the previous paragraphs can be used in both the planning and evaluation phase: first as guidelines and target settings, second as a reference to validate assessment results and subsequent optimalisation activities. However, one should keep in mind that some quantifications only apply on the Meuse basin or even the situations used in INTERMEUSE. The concept however, especially the introduction of the ecological minimum, natural baseline and subsequent ecological goals can be applied in river basins everywhere. Based on field data and subsequent statistical analysis relations between biological and environmental features can be established to quantify the conceptual elements.

5. Discussion

The high flood events of 1993 and 1995 called for action to maintain safety margins along the river systems like the river Meuse. Further raising of dikes proves to be no solution for the long run, and large parts of the river Meuse lack dikes so far. Based on latest insights and policy documents like the directive "Room for the Rivers" new concepts for sustainable flood protection are being developed. The main topics so far are:

- Retaining water so the run-off to the main streambed will be slowed down;
- Retention of peak discharges;
- Increasing discharge capacity so water can be run-of as quick as possible.

These topics formed the basis for the fictive flood protection strategies that were analysed within the project INTERMEUSE: resp. SPONGE, RETENTION and WINTERBED. These strategies represent conceptual approaches and are by no means blue prints for future landscaping of the river Meuse. With respect to flood protection analyses in INTERMEUSE showed that:

- SPONGE-strategy

In principle, SPONGE is very effective as the discharge may be reduced all along the downstream river stretches, thus reducing the water levels all along the downstream stretches as well. Interesting is that SPONGE is not only effective at extreme flood flows but can also be fruitful at lower flows, which may lead to a higher level of base flow, longer durations of lower flows etc. However, SPONGE-measures require a certain surface for water to be stored. Experiences elsewhere learn that water conservation or retention (like buffer ponds) should take place over a large part of a (sub)catchment in order to produce a significant effect on the total discharge. In practice this ambition level can be combined best with large-scale projects, e.g. nature development along brooks or tributary rivers or the reconstruction of the agricultural sector. The preconditions used in INTERMEUSE proved to be not enough to show large scale effects. Large-scale changes in land use within the catchment area of the Meuse are in practice not feasible. A better approach is to utilise every chance for water conservation and retention, like:

- realisation of a large number of small retention ponds e.g. using natural depressions;
- raise of weirs in tributary rivers, brooks and water courses;
- change of the dimension of brooks and water courses (shallow and wide in-stead of deep and narrow).

- RETENTION-strategy

In principle, the RETENTION-strategy acts like the SPONGE-strategy at higher floods: as soon as the retention reservoir is active, the discharges are reduced and the peak water levels all over the downstream stretches are reduced as well. The results of the analysis show considerable flow and water level reductions downstream of retention measures. In INTERMEUSE RETENTION was elaborated in different ways: for the Lorraine Meuse by construction of dams within the winter winter, for the Common Meuse and Sand Meuse by construction of "basins" outside the winter bed boundaries.

- WINTERBED-strategy

Increase of the flow cross-section of the floodplains, e.g. by lowering the major bed level, directly influences the local water level and can be very effective. However, the discharges are hardly influenced: generally some detrimental effect can be observed in the river stretches downstream of the major bed measures due to reduction of the flood wave attenuation. As a result of the local effect of WINTERBED-measures this strategy is highly effective in solving bottle-neck problems.

In general, the effect of SPONGE and RETENTION in the upstream reaches should be strived after as much as possible, as to reduce the flood peak discharges. Effective measures in the Lorraine Meuse are indispensable for reducing flood risk in the Ardennes region. The most effective local measures, especially in the Common and Sand Meuse, however still focus on increase of the major bed cross-section.

However, in view of the aim of INTERMEUSE the analysis for changed hydrodynamic conditions resulting from the proposed flood protection strategies formed a prerequisite for the ecological effect assessment and subsequent integration of flood protection and ecological river rehabilitation.

Integration of flood protection and river rehabilitation

In view of the concept of integrated river management the new flood protection concepts should focus on prevention of further deterioration of natural features as well and preferably lead to chances for rehabilitation of lost natural elements. The new EU Water Framework Directive will surely support this combination. The main objective of INTERMEUSE was to elaborate a method to support this integration. This was elaborated for two scale levels: for the whole river basin in a global way, and for specific stretches or local sites in more detail. For both scale levels results of the analysis show that flood protection measures can be beneficial for nature rehabilitation aspects as well. This is elaborated in conceptual approaches and practical guidelines.

<u>Integration on a global scale</u>

Important elements for both flood protection and river rehabilitation on the scale of a river basin are spatial aspects like size and cohesion between sites. Integration on the global level therefore focussed on the spatial aspects. The habitat configuration resulting from flood protection strategies was analysed for its ecological network functioning: the degree in which a configuration of habitat enables species to develop viable populations. The performed analyses in INTERMEUSE showed that for the development of persistent populations of species depending on typical river-bound habitats, the WINTERBED-strategy has the most obvious positive effects, especially in the Upper Meuse and in the Lower Meuse. However, since there are little possibilities to change the small winter bed in the Ardennes Meuse this stretch appears to be a natural bottleneck for the migration and dispersal of species. Regulation of the river will however enhanced this situation. The intention should be the creation of small stepping-stones wherever possible in this stretch.

In general it is stated that on the basis of the concept of ecological networks given a certain situation ecological rehabilitation of river ecosystems with respect to habitat configuration patterns should focus on enlargement of habitat prior to optimising habitat connectivity. One substantial area is better than a small number of tiny spots (a.o. due to larger impact of interference with surroundings, disturbance etc.). Application of the formulated guidelines requires knowledge on the nature targets that are to be achieved with ecological rehabilitation of river ecosystems. These can be based on existing nature values that need to be preserved and/or strengthened, or on the degree to which natural processes are still operative (or can be made operative in the process of rehabilitation). Most important processes are hydro- and morphodynamics, as these are the driving forces for habitat development and diversity. These processes embody the characteristics of a certain river(stretch). This emphasises the statement that the distinguished scale levels, each having its own value within the river management process, are strongly interrelated. The influence of river dynamical processes is the most distinct on the local scale level.

<u>Integration on a local scale</u>
As mentioned above important elements for both flood protection and river rehabilitation on a local scale (e.g. flood plain) are the river dynamical processes and the degree in which they can still influence the riverine landscape. In this respect gradients play an important role and as such are strongly linked to dimensions of management measures. In case of INTERMEUSE, this part of the analyses focussed on meadow vegetation and carabid beetles as indicators for habitat integrity for respectively winter bed and river bed. Floral and faunal communities in river systems are strongly related to river dynamical processes for the development of habitat diversity (as prerequisite for species diversity). As such there is a direct link to the type and dimensions of possible flood protection measures.

The general guideline for embedding riverine habitats in the flood protection measures, refers to the bed form and the gradients present in the river system. As river bed and winter bed are separate parts within the hydrodynamical gradient, conclusions to the impact of certain flood protection measures can differ. In natural river stretches this distinction between river bed and winter bed is of no importance. However, in regulated stretches this may lead to conflicts: favouring dynamic river bed habitats by lowering of flood plains or widening of the river bed can have negative effects on the less dynamic winter bed habitats. The decision how to decide in such matters can and will not be addressed here, as mostly other factors or functions are involved. But the presented toolboxes and guidelines can play a role in this decision making process.

With respect to the river bed analysis of the flood protection strategies used in INTERMEUSE lead to the following statements:

- SPONGE measures can best be situated adjacent to the actual river bed. Even small upstream parts of tributaries, deal with modified bank structures. Implementation of SPONGE at these sites has a positive effect on the development of natural bank forms and the desired habitat integrity. Secondly, SPONGE measures may have, to a certain level, a positive effect downstream: peak velocities nowadays are way above the natural conditions. Yet, a too strong decrease in peak fluxes would have a negative effect on the morphological processes which is necessary for the habitat integrity.

- Depending on the type of RETENTION measures the same recommendations as made for SPONGE are in place: the inclusion of riverbanks in the measures can result in an increase of habitat integrity. The effect of peak reduction should be focussed on the highest and lowest peaks. In these ranges the distortion of natural flow regime is the most pronounced. The peak frequency of the intermediate range of peak fluxes is responsible for the morphological activity and as such for the development of the characteristic river bank habitats.
- WINTERBED measures should be planned in a integrated manner: the combination of bed widening, bank lowering and flood channel restoration, restores the dynamic gradient in the riverbank zone and is therefore beneficial for the overall habitat integrity. The choice for only one of the measures (e.g. bank lowering) will resort effect in only one of the riverbank gradient zones.

For the habitat integrity of the winter bed previous statements are to some extent the same. However, based on the meadow vegetation analyses another general remark needs to be made. The integration of flood protection and river rehabilitation is a good approach in heavily regulated river stretches. As this is the case in large parts of NW-European rivers this integration can lead to multi-beneficial solutions in river management. However, in natural river stretches any change in abiotic conditions resulting from a flood protection measure can lead to serious impacts on existing natural values. This brings up the question of how combine flood protection strategies and quality preservation of natural ecosystems? In these river stretches focus is on nature preservation and less on rehabilitation. Based on the analyses for the Mouzay pilot stretch, which can be characterised as a natural river stretch, it is stated that flood protection measures should be promoted preferably in more degraded areas as rehabilitation of lost values after implementation may never result in the natural baseline which is available now.

The guidelines and toolboxes presented by INTERMEUSE can be very useful in both the planning process and evaluation. As absolute figures may not be applicable in other situations, the indicative value is important as well. In any case with the IRMA/SPONGE project INTERMEUSE, a first attempt for a new concept and guidelines and tools for implementation aiming at the combination of flood protection and flood plain rehabilitation was made. With the description of the ecological minimum and natural baseline the field of integration is made clear. The results of the analyses of the fictive flood protection strategies can be helpful in the elaboration of more concrete scenario's which will be combinations of the proposed fictive strategies. On this basis combinations can be made that incorporate the good elements of the different strategies in such a comprehensive way that the total scenario is better than the sum of the individual measures. Hopefully this can contribute to the translation of the theoretical stated win-win opportunities between flood protection and river rehabilitation into daily practise. Of course not all questions of the daily practise can be met, but together with other tools (existing and in development) the toolbox for integrated water management is getting more and more complete.

6. Conclusions and recommendations

Conclusions

- Integration of flood protection goals and river rehabilitation goals can well be established. In regulated river systems flood protection measures can have a positive effect on achieving river rehabilitation goals. In natural river stretches combinations may be less favourable as nature preservation can be a major goal.

- As flood protection strategy SPONGE and RETENTION should be implemented as much as possible in the upstream reaches of a river basin, as to reduce the flood peak discharges. WINTERBED-measures that increase discharge capacity are the most effective on a local basis.

- On a global level river rehabilitation should focus on enlargement of habitats and the creation of cohesive networks of habitats. On a local level the focus should be on the habitat diversity linked to gradients in the river system.

- Development of persistent populations of key species depending on typical river-bound habitats is served the best with the WINTERBED-strategy, especially in the Upper Meuse and in the Lower Meuse. The SPONGE-strategy especially improves the situation for wetland species. The RETENTION-strategy might improve the situation for marshland species with large home range (e.g. Bittern). Considerable areas of habitat are developed under this strategy.

- Based on the network analysis the Ardennes Meuse seems to be a natural bottle neck, due the physical characteristics of this river stretch. However, river regulation will have enhanced this situation. With the creation of stepping stones this situation can strongly be improved.

- In the current situation the Dutch meadow vegetations are poorly developed and intensively used by agriculture. Restoration of the hydrological gradient would result in an increase in moist and wet meadows. This implies a change in land use and consequently an increase of meadows biodiversity. However, the restoration of meadow vegetations in such heavily regulated river stretches might be hampered by the lack of a effective soil seed bank. This was not studied in INTERMEUSE.

- Win-win situations for flood protection and floodplain rehabilitation are theoretically possible. In practise the involved costs pose the main problem for actual implementation.

Recommendations

- The analysis in INTERMEUSE revealed that hydraulic modelling is not fully equipped for the questions resulting from the integration of flood protection and river rehabilitation. This is the result of the focus on high flood events, no interaction with ecologists on their boundary conditions, different scale levels (time and space) etc.. In the future this problem should be solved to make integrated river management applicable in daily practise.

- In this study existing data and studies were used as much as possible. Sometimes this resulted in non-compatible datasets. Due to the time and capacity in this project it was not possible to solve these problems in a proper way. In most cases pragmatic solutions were used.

- The analysis of the new abiotic situation on a global level was performed in a qualitative way, due to the lack of sufficient good data for the whole Meuse basin. However, if data are available it should be possible to perform a quantitative analysis.

- The value of the evaluation method should be tested on other river systems and with more complete data. As a concept this method is valuable anyway.

- Cooperation between institutes from different countries is very informative and illuminating. However, to increase the potentials of these co-operations commitment of stakeholders should be optimised. In many cases requests for data, information etc. were obstructed by unwilling parties of which some are stakeholders.

Glossary

Ecological network: a series of physically separated habitat patches for a population of a particular species or a set of species with similar requirements that exchanges individuals by dispersal.

Ecological profile: An ecological profile is defined by dispersal capacity and area requirements of a species. Each ecological profile represents a range of species with similar traits (dispersal capacity and area requirements) that can occur in a landscape. Viability standards for an ecological profile are derived from standards of a representative species which belongs to this ecological profile.

Ecotope: a physically limited landscape ecological unit, whose composition and development are determined by abiotic, biotic and anthropogenic aspects. Ecotopes are more or less homogeneous units on the scale of the landscape, identifiable by their similarities and differences in geomorphological and hydrological characteristics and characterised by a vegetation structure that is linked to the mentioned abiotic conditions in combination with land use.

carrying capacity: the maximum population of a species that a specific ecosystem can support indefinitely without deterioration of the character and quality of the resource, i.e., vegetation or soil.

key population: a relatively large, local population in a network, which is persistent under the condition of one immigrant per generation.

key patch: a patch with a carrying capacity large enough to sustain a key population.

local population: small population of at least one pair, in one habitat patch, or more habitat patches within the home-range of a species. A local population on its own is not large enough to be sustainable.

metapopulation: a set of populations in a habitat network, connected by inter-patch dispersal.

minimum viable population (MVP): a population with a probability of 95% to survive 100 years under the assumption of zero immigration.

viable population: a population with a probability of at least 95% to survive 100 years.

Ecological minimum: Critical boundary or minimum level of habitat conditions for a potentially good ecological functioning.