Pilot Study “Elbe River Basin”

EXECUTIVE SUMMARY

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Member of the Dresden Flood Research Center (D-FRC)

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Executive Summary for Task 21

1. Scope of the research in Task 21

1.1 Overall objectives

The pilot study for the Elbe River basin aims at a comprehensive developing and testing of the FLOODsite integrated methodologies on long-term flood risk management under the conditions of a large and transnational European river basin. The thematic scope ranges from analysis of the entire flood risk system over the formulation and evaluation of future scenarios and strategic alternatives to the DSS development and stakeholder involvement. Within this comprehensive view, emphasis is put on particular research topics like e.g. regional climate change, the influence of land-use change on the runoff generation, multi-criteria risk evaluation, as well as hydraulic investigations on flood polders. All other contributions for the integrated approach come either from a number of other FLOODsite tasks or from matching fund research projects. Due to the size of the basin, different spatial levels of investigation ensure sufficient details in five pilot areas on the one hand and required overview for the entire Elbe River basin on the other hand (see Fig. 1.1).

Figure 1.1 FLOODsite pilot site Elbe River basin with five pilot areas

The transnational Elbe River basin has been chosen because of its wide range of different issues of flooding, which are typical for Europe. It is one of the major Central European catchments covering large areas of the Czech Republic and Eastern and Northern Germany. Minor parts of the headwaters are located in Austria and Poland. The catchment area is 148,268 km² and the total length of the river is 1,091 km. Flood risks occur in upland and lowland areas. In the mountainous regions, the flooding processes are characterised by high discharge dynamic. Hazards in some cases can even be classified as flash floods, which cause high local risks in the narrow mountain valleys. The flood risks in the lowland regions are caused by plain floods of the tributaries and the Elbe River itself. Slow raising flood waves with extreme discharge can lead to very large inundation volumes. Flood-prone areas of river sections function as pathways or receptors depending on the existence and effectiveness of mitigations measures. In the larger tributaries, like the Mulde River, uplands and lowlands are additionally related as source areas (uplands) and receptor areas (lowlands).
An extreme flood event in August 2002, which resulted in damages of more than €12 Billion, highlighted shortcomings in the existing flood protection provided in the basin. Against this background, the pilot site should contribute to establish a risk-based approach considering the whole cascade of flood risk generation and a scenario-based long-term management. It is assumed that results will assist in developing future flood risk management strategies, especially with respect to flood risk management plans according to the Floods Directive.

The research being undertaken on the Elbe is a collaboration of six research institutions: Leibniz Institute of Ecological and Regional Development (IOER), the Technische Universität Dresden, the Helmholtz Centre for Environmental Research – UFZ, the Potsdam University, the Czech Technical University in Prague and the GEO Group in Prague. An intensive exchange with practitioners of flood risk management has been established on various levels to facilitate the uptake of the research results. At the local level, water and spatial planning authorities and municipalities are involved. At the national and international levels there is collaboration with the German Elbe Board and the International Commission for the Protection of the Elbe River (ICPE). Research findings are also being disseminated to the general public through public events and via the media.

1.2 Research design

Developing and testing the FLOODsite integrated methodologies within the Elbe River basin draw upon a basic framework for flood risk management which encompasses risk analysis, risk evaluation and risk reduction as part of a societal decision-making and development process (Schanze 2006, 2007a,b, et al. 2008, Ammann 2006). The overall approach accordingly considers the following topics:

A. Risk analysis
   - Description of the flood risk system
   - Coupled modelling of the flood hazard, flood vulnerability and flood risk
   - Long-term scenarios of future changes (e.g., climate change, land-use change)
B. Risk evaluation
   - Multi-criteria evaluation of flood risks
C. Risk reduction
   - Analysis of effects of physical measures and policy instruments
   - Ex-post evaluation of measures and instruments (e.g. effectiveness)
   - Ex-ante evaluation of strategic alternatives (e.g. robustness)
D. Decision-making and development process
   - Design of a scenario-based tool for strategic planning support
   - Strategy development of stakeholder
   - Risk perception of people at risk

As prerequisite for this comprehensive programme various links have been established with Tasks 1, 9, 10, 11, 12, 13, 14, 18, 29, 30 and 31 of FLOODsite. Externally, there are close co-operations with the projects VERIS-Elbe (Schanze et al. 2007a), ELLA (www.ella-interreg.org), FLOOD-ERA (Schanze et al. 2007b), Weißeritz-Regio (Wirth & Schanze 2004), and others. Data were provided by many public authorities, in particular by the Free State of Saxony, Saxony-Anhalt, the German Weather Service (DWD), the Vltava River Watershed Authority, Czech Hydrometeorological Institute, Municipality of Nové Hrady and Horní Strøpnice, CEC-Potsdam. Because of the size of the Elbe River basin, research needs to focus specific sites. Thus five pilot areas had been chosen considering the sources, pathways, receptors and consequences of the flood risk system. These sites are the headwaters of Moldawa River (Czech Republic) with the Horní Strøpnice River (Aa) and the Trebon Basin (Ab), the Elbe tributary Upper (Ba) and Lower (Bb) Mulde River (Germany) as well as the Lowland Elbe River (C; Germany) (see Fig. 1.1). Beyond the entire basin is considered in scenario planning and a scenario-based tool for strategic planning support.
2. Principal results

The summary of FLOODsite research findings in the Elbe River basin is presented considering both the pilot areas and the integrated approach of the site-specific investigations.

2.1 Horni Stropnice and Trebon Basin

Research carried out along the headwaters of the Elbe River basin concentrate on the hydrologic conditions, the ecological vulnerability as well as on recommendations for municipalities and the public. As result for the Horni Stropnice River catchment (85 km²) it can be shown that existing dams in this rural region performed well during frequent flood events (5yrs), but not during rare events (50-100yrs), like the 2002 flood. At the same time, flood detention is increasing due to land-use change from arable land to forestry since 1990. Experiments with artificial floods show a minor ecological flood vulnerability of aquatic community in the study area because of life strategies of the species and natural pattern of flood occurrence (Komínková et al., 2007). However, flood conveyance is reduced due to low bridges and congestions of sediment, garden waste and trees. Risk reduction options were developed in close cooperation with municipalities and governmental organisations.

Table 2.1 Primary retention capacity of the watershed

<table>
<thead>
<tr>
<th>Amount of retain water [m³]</th>
<th>1945</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest</td>
<td>1.343 to 2.417 million</td>
<td>1.75 to 3.15 million</td>
</tr>
<tr>
<td>Grass fields</td>
<td>0.6732 to 1.5147 million</td>
<td>0.29 to 0.65 million</td>
</tr>
<tr>
<td>Arable soil</td>
<td>0.1065 to 0.426 million</td>
<td>0.13 to 0.5 million</td>
</tr>
<tr>
<td>Total</td>
<td>2.1227 to 4.4107 million</td>
<td>2.17 to 4.3 million</td>
</tr>
</tbody>
</table>

The downstream Trebon Basin pond system of about 500 km² has originally detention function. Here, the change of land use and the detention capacity have been analysed based on historical, hydrologic, hydrogeological and LANDSAT 7 data. An ecological vulnerability analysis allowed for an assessment of the current ecological risk. Flood hazard, ecological vulnerability and risk are presented in a GIS project. A set of recommendations to improve the flood risk management were derived and discussed with local authorities and the public. (Zikmund & Kodrova 2006)

Figure 2.1 Coupled modelling of the flood risk system of the Mulde River catchment (Schanze 2007b, adapted)
2.2 Mulde River Catchment

For the Czech-German Mulde River catchment (5340 km²) a comprehensive flood risk system is described to test coupled modelling of the whole process of risk generation. This covers all methodological steps displayed in Figure 2.1. According to the features of the catchment, research regarding the mountainous Upper Mulde River focuses the hydro-meteorological processes, whereof the Lower Mulde River is subject of hydrodynamic modelling and multi-criteria risk analysis. However, both are linked by the hydrologic and hydrodynamic models and consistent scenarios.

2.2.1 Upper Mulde River Catchment

Meteorological investigations

Two meteorological drivers of the flood risk systems are investigated based on regionalised climate and climate change projections according to the IPCC scenarios: Pre-event moisture and heavy rainfall events. Research encompassed analyses of the daily climate scenario data (transient run) and the effects of climate change on design precipitation and return periods. Data are derived from the GCM base ECHAM5 (MPI-M Hamburg) for SRES scenarios A2 and B1 and the dynamical statistical downscaling using weather patterns (WETTREG). Three transient realisations (dry, mean, wet) for each station and decade between 2001-2100 were considered with mean realisation of 2041-2050 and 2091-2100.

Figure 2.2 Changed return period of hN(48h,100a) for 1951-2000, summer period (may-sep), catchments "Zwickauer Mulde" and "Freiberger Mulde" (Bernhofer et al. 2007)

Results indicate temperature and precipitation changes in the Mulde River catchment with higher precipitation changes in the lowlands in summer. Extreme precipitation (> 50 mm) is not covered by climate projections (like 2002) which may change the probability density functions. Historical 100a return period will probably be 65a (1d), 85a (2d), 97a (3d)… by the end of the 21st century. As an example Figure 2.2 shows the reduction in return period for a precipitation event with 48 hours duration and an actual return period of 100 years (reference period 1951-2000). Changes in pre-event moisture and snow melt floods are possible what should be investigated in further works. (Bernhofer et al. 2007)

Macro-scale modelling the influence of land-use and climate change on the rainfall-runoff process

The aim of the study is (i) to assess land-use parameters of different model approaches, (ii) to analyse the effect of realistic land-use scenarios, and (iii) to simulate the impacts of climate change on the soil-water budget. As far as modelling the infiltration is concerned, BOOK90-LFW was applied.
Results confirm that adopted land use could be an efficient means of flood detention providing additional storage (see Fig. 2.3) and transferring runoff into slower pathways. However, these effects are limited to events of lower recurrence probability, site-specific and not static. There is a considerable lack of data for model parameterisation particularly with respect to short-term vegetation changes and their long-term effects on soil properties. The corresponding investigations on false chronosequences circumstantiate that e.g. for afforestation an increased conductivity and a higher portion of coarse/middle pores can be observed. This causes an increased infiltration and soil water retention potential especially for the top soil layer (Tab. 2.2). Compared to the vegetation parameters these soil effects are generally not simulated in rainfall-runoff models concerning land-use scenarios.

Table 2.2  Pore distribution [Vol%], related field capacity (mm) and unsaturated hydraulic conductivity [mm d\(^{-1}\)] in the top layers (30 cm)

<table>
<thead>
<tr>
<th>Land-use</th>
<th>Horizon</th>
<th>Pore diameter [µm]</th>
<th>Field Capacity [mm]</th>
<th>Hydraulic Conductivity [mm d(^{-1})] at pF 2,5</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>&gt; 50</td>
<td>50 - 10</td>
<td>10 – 0,2</td>
</tr>
<tr>
<td>Arable land</td>
<td>Ap</td>
<td>6</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Young afforestation</td>
<td>Ah</td>
<td>6</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Old afforestation</td>
<td>Ah</td>
<td>5</td>
<td>14</td>
<td>10</td>
</tr>
</tbody>
</table>

Existing assessment tools are scale-specific in accordance to their data requirements. In this respect one can distinguish point (site) models, expert systems and spatially distributed meso-scale rainfall-runoff models. A combination of such tools appears to be adequate. (Wahren et al. 2007a, b)

Meso-scale hydrologic modelling

The rainfall-runoff model PREVAH has been set up for one part of the Upper Mulde River catchment and verified after comprehensive data analysis. A reservoir module was developed and implemented in the model system. The remaining parts of the catchment were calculated with the already running WASIM-ETH model. Following the meteorological investigations, rainfall series were used to analyse flood characteristics under possible future climatic conditions. Results of reanalysis show no significant change of the hydrologic characteristics compared to the average hydrologic characteristics of the last 90 years. Instead, future climate change projections indicate a decrease of the discharge. This would mean that the future flood hazard could be totally covered by the currently planned........
structural measures of the Saxon Flood Protection Concepts. Therefore, flood hydrographs were derived applying the mean standardised hydrographs (DYCK 1979) as input for the subsequent hydraulic modelling and flood risk analysis. (Lennartz et al. 2007)

Figure 2.4 Flood hydrographs for return periods 200 and 500 years for gauge Wechselburg (Zwickauer Mulde, left) and gauge Erlln (Freiberger Mulde; right) (Lennartz et al., 2007)

2.2.2 Lower Mulde River Catchment

For the Lower Mulde a complete risk analysis and assessment have been carried out. This compromises (i) a hydrodynamic modelling of inundation depth (ii) a vulnerability analysis and damage evaluation and (iii) a multi-criteria evaluation and mapping of these social, economic and environmental flood damages and risks.

Hydrodynamic modelling

Using a quasi 2D-hydrodynamic modelling (HEC-RAS) water stages of different recurrence intervals (1:10, 1:25, 1:50, 1:100, 1:200, 1:500) were calculated for the Vereinigte Mulde River for two waterway construction scenarios. Inundation depth was calculated for the whole Lower Mulde and mapped for a grid with a spatial resolution of a 10m.

Figure 2.5 Flooded areas and water depths at a stretch between Eilenburg and Löbnitz of the Vereinigte Mulde river (state 2, HQ50)
Inundation depth is calculated for two states of the flood protection system at the Mulde River: State 1 is calculated for the state of protection in 2002 before the flood occurred. State 2 considers all measures planned in the flood protection concept for the Mulde. As an example in Figure 2.5 flooded areas and water depths are shown for a stretch between Eilenburg and Löbnitz for status 2 and HQ30. For this recurrence interval polder Mörtitz and polder Löbnitz are activated. Both polders are artificial water courses (diked grassland) which are flooded by discharges larger then HQ25. Inlets and outlets are controlled hydraulic structures. Outside the settlement areas large dike stretches were moved backwards. Compared with state 1 the inundated area for state 2 is clearly enlarged. The activated polders lead to an increase of the cross sectional area and hence to lower water levels compared to state 1. These inundation data are used as a basis for the vulnerability analysis and multi-criteria evaluation of flood risk.

**Vulnerability analysis and multi-criteria risk evaluation**

For the analysis of the current and future flood vulnerability and risks, the GIS-based multi-criteria assessment and mapping approach of Task 10 has been tested at the Lower Mulde River. The method allows for (i) considering flood risks in monetary and non-monetary terms, (ii) mapping of thematic flood risks (Fig. 2.6), and (iii) derivation of multiple flood risks including different weights for the thematic risks (Fig. 2.7). Two multi-criteria decision rules, a *disjunctive approach* and an *additive weighting approach*, are used for the assessment and mapping. Both, the risk calculation and mapping of single criteria as well as the multi-criteria analysis are supported by a software tool (FloodCalc). A GIS dataset of economic as well as of social and environmental risk criteria has been built up for the pilot area. Moreover, the method is used to display the risk reduction effects of the regional Flood Protection Concepts of the Free State of Saxony.

![Figure 2.6](image-url) Economic (top left), environmental (top right) and social (population, down left; social hot spots, down right) risks (Meyer et al. 2007)
While it is crucial for flood risk management to identify social hot spots, further findings from the sociological work in FLOODsite reveal that social vulnerability – as something related to local communities, social groups, households and individuals – is not restricted to certain socio-economic or socio-demographic criteria. Findings from Task 11 in the Lower Mulde River Catchment show by evidence that

- vulnerability is highly context- and event-specific;
- there is no single variable which explains the vulnerability of specific groups coherently and for all the disaster phases;
- no specific group is per se highly (or little) vulnerable;
- the same group may be vulnerable in certain phases – anticipation, resistance and coping, recovery and reconstruction – and not vulnerable in others;
- the same group may be vulnerable in relation to certain aspects – e.g. preparedness, risk awareness, capacity to receive help during the event, flood impact – and not vulnerable in relation to others;
- some relations are not linear, it is rather extreme groups (e.g. the very young and the very old) which in certain respects turn out to be more vulnerable than the other groups “in-between”.

![Figure 2.7 Multiple flood risk weighting economic risk (0.33), environmental risk (0.33), social (population; 0.20) and hot spots (social hot spots; 0.13) risks (Meyer et al. 2007)](image)

**Risk awareness and preparedness**

In several locations of the Lower Mulde River Catchment questionnaire surveys and in-depth interviews with residents were conducted to better understand risk awareness and social behaviour before, during and after the 2002 flood (Kuhlicke & Steinführer 2006; Steinführer & Kuhlicke 2007).

![Figure 2.8 Perceived preparedness for an extreme flood by research location](image)
As for risk awareness, there is a need to question some desirable but rarely existing causal relationships: There is no automatism between being aware of the risk of flooding and actual behaviour – a crucial issue from the perspective of the European Floods Directive, since assumptions that preparedness is a direct result of awareness are widespread. This finding holds for further supposed relations, such as feeling informed and being prepared, too. Hence, there are no direct, immediate, and univocal links between perceptions, opinions, and attitudes on the one hand and actual behaviour on the other. Although from a social-science perspective this finding is not surprising, it is necessary to stress it.

Figure 2.9 “Flood protection [...] is rather costintensive. How much should the following actors contribute to the costs?” (mean values)

Yet, there is a significant rise in subjective preparedness. In contrast with 2002, the residents feel better prepared for a disastrous event. But two restrictions need to be made: firstly, the majority of the residents still feel “not prepared” (all mean values below 3; Fig. 2.8), secondly, this result contrasts with the perception of a very low degree of community preparedness. Moreover, also a rise in the actual application of preparatory measures can be reported. But the majority still do not apply any measure and among those mentioned, insurance and minor adaptations in the buildings prevail. A final focus was on the evaluation of public measures. The residents at risk were asked who in their minds should bear the costs for flood risk protection. The result (Fig. 2.9) clearly points to clear distinction between personal and collective responsibility and its delegation to authorities.

The issue of private and public mitigation measures is a crucial one in the context of flood risk management, since this paradigm carries with it a shift in responsibilities. It expects the residents at risk to take active part in these efforts. Yet, the empirical findings underline that recent developments in the policy sector are not shared (or even understood) by the people at risk. While the demand that individuals should take responsibility and adopt private precautionary measures seems relatively well established within the scientific community and among flood-risk managers the research results show that among the residents at risk traditional assumptions about flood protection, both its structure (technical defence) and the responsible bodies (public authorities) dominate.

Thus a gap of knowledge between the scientific community and the policy makers on the one hand, and the local population on the other, is apparent. Probably even more important, there exists also a gap in the attribution of meaning to private preparatory measures since the residents at risk have their own clear comprehension about responsibilities for flood protection which, in their point of view needs to be borne by public authorities (similarly for the U.K.: Brown and Damery, 2002, 423). These findings underline that flood risk management also requires new partnerships and synergies, otherwise placing greater responsibility on private shoulders is likely to be ineffective.

2.3 Lowland Elbe River

For large rivers like the Elbe, risk reduction through flood polders is one major option. A flood polder is a detention basin which reduces river peak flood flows through temporary water storage. Effects and side-effects of the operation of the proposed flood polder Axien/Mauken (storage capacity 40 million
m³) at the Lowland Elbe were analysed. Research encompasses hydrodynamic modelling using a 1D and coupled 1D-2D approach to simulate the flood hazard and particularly the peak discharge of the downstream Elbe River under different scenarios and control alternatives.

Results show that during large floods the utilisation of the flood polder significantly reduces the Elbe River peak discharges. However, the magnitude of the attenuation depends on the steepness of the flood hydrograph and the applied control strategy with well-timed gate operations (Förster et al., accepted; Chatterjee et al., under review). Utilisation of flood polders can lead to environmentally harmful situations in the storage basin. One major problem is the depletion of dissolved oxygen concentrations due to the strong oxygen demand imposed by organic material in the water body and at the bottom. Based on the hydrodynamic model set-up, water quality was simulated focusing on the oxygen balance of the flood polder. In addition, flood vulnerability of and risk for the rural land use within the flood polder were determined as basis for ex-ante evaluation of the alternatives (Förster et al., under review). In the context of a close co-operation with the regional water authorities, recommendations were derived for the future operation strategy depending on flood characteristics and land-use development within the flood polder.

Figure 2.10 Simulated peak discharge reduction (approx. 310 m³/s), water level reduction (approx. 19 cm) and water levels in flood polder basins for the August 2002 flood event

2.4 Elbe River Basin

Initial resources of FLOODsite did not allow for inclusion of the Elbe River and its entire basin. Based on the German Federal Research Programme RIMAX, the matching fund VERIS-Elbe project is being realised (Schanze et al. 2007). The project deals with change and management of risks due to extreme flood events in large river basins. It thus scientifically addresses long-term flood risk management in a comparable, partly complementary and more detailed way as the FLOODsite Elbe River pilot study may do. Major links between both projects refer to (i) the development and testing of a specific scenario planning approach, (ii) the design of a scenario-based strategic planning support tool, and (iii) investigations on the decision-making and development process.

Scenario planning approach

Research on development, analysis and ex-ante evaluation of futures of the flood risk system under FLOODsite Task 14 is also linked with the Elbe River pilot study. Together with the VERIS-Elbe project a specific scenario planning approach has been elaborated for large river basin. It consists on the following steps: (i) Definition of the flood risk system and set up of coupled models, (ii)
formulation and operationalisation of storylines for the composition of scenarios and of guiding principles for the composition of strategic alternatives, (iii) combination of scenarios with strategic alternatives to derive alternative futures, (iv) ex-ante analysis of these futures with the coupled models, and (v) evaluation of the futures with regard to effectiveness, efficiency, robustness etc. of strategic alternatives. Figure 2.11 presents an overview of the storylines. Ex-ante analysis and evaluation of futures will be finished within the next months. To improve the evaluation of the strategic alternatives, a case study for testing the methodology for ex-post evaluation of physical measures and policy instruments (FLOODsite Task 12) has been carried out in the Elbe River pilot study.

Figure 2.11 Storylines for the Elbe River catchment (Luther & Schanze 2007)

**Scenario-based tool for strategic planning support**

Multiple dimensions of a comprehensive analysis and simulation of the flood risk system is a huge challenge for decision makers. FLOODsite Task 18 therefore intends to enhance prerequisites for technological decision support. This includes the design of a scenario-based tool for long-term flood risk management of the Elbe River basin. Figure 2.12 presents two screenshots of the draft tool. On the left hand side, interactive selection of strategic alternatives can be seen. On the right hand side one map will display relevant measures and instruments (left map) and one map will show the resulting water levels and flood risks (right map; currently with dummy data). The entire tool will be available in August 2008.

Figure 2.12  Two screenshots of the draft scenario-based tool for long-term flood risk management for the Elbe River basin (Petroschka et al., in prep.)
Decision-making and development process

Applicability of the integrated methodology and effective risk reduction mainly depend on the people responsible for the formulation and implementation of flood risk management strategies (Schanze 2006, Hutter 2006). The so-called stakeholders are often addressed in research but their requirements are not always met. The FLOODsite Elbe River basin pilot study therefore includes research on strategic planning in flood risk management practice. Hereby a close link is established with FLOODsite Task 13 which investigates planning strategies on a generic level and within case studies. Despite one of these case studies deals with local actors of flood risk management in the Elbe River basin (Hutter & Schanze 2008), additional work is carried out at the pilot site with respect to national and transnational tasks of flood risk reduction. After first consultations with the most important institutions like the International Commission for the Protection of the Elbe River (ICPE) and the German Elbe Board there will be a series of workshops for the adjustment of the scenarios and strategic alternatives, their ex-ante analysis and evaluation as well as their usability in the context of the scenario-based tool. The workshops focus on officials and experts with different affiliations, but similar cognitive orientations. Since the preparatory research for building up the comprehensive approach needed a lot of effort, all workshops are now scheduled for the last year of FLOODsite. However, the model-based and partly web-based approach will ensure sufficient flexibility in the collaboration with the actors involved.

3. Relevance to practice

The impact of results from the Elbe River basin pilot study on the flood risk management practice is of course difficult to anticipate especially from the scientific point of view. However, there are some aspects that may indicate the relevance of research findings:

- Researchers from FLOODsite were invited by the ICPE and the German Elbe Board to present the research objectives and the entire approach. This already shows a principle interest on the scientific endeavour to comprehensively deal with the flood risk system of the large basin and its management in the long term.
- Preliminary results will now provide the opportunity to discuss in more details the applicability of the results from the integrated methodology. In this respect the scenario planning approach together with the coupled models can be seen as a rather new level of evidence base for decision making in the basin.
- Since the matter is rather complex for both researcher and experts from flood risk management practice the scenario-based tool will allow for a stepwise exploration of the findings. The use of the English language in the tool which is needed for its European accessibility should most probably be amended by a German version. Unfortunately this will not be possible with current funds.
- In addition, there are a number of direct applicable outcomes such as climate change projections, flood hazard determination for extreme events, vulnerability and risk maps, recommendations for the flood polder operation, evaluations of measures and instruments, and so forth.

All in all, results from FLOODsite together with the VERIS-Elbe project can be seen as a significant step toward the implementation of a flood risk management plan for the Elbe River basin. Based on this, the basin may even become a pilot case for a good long-term flood risk management practice.

Knowledge and empirical examples from the study finally contribute to the knowledge-base and workshop material of the FLOODmaster university master course at the Technische Universität Dresden.
4. Innovations and remaining gaps in knowledge

Despite major emphasis of the pilot study is put on understanding and supporting real-world flood risk management in the Elbe River basin, there are a number of innovative scientific outcomes from the pilot study. Firstly, this counts for the further development and operationalisation of a comprehensive approach of flood risk management with a long-term perspective. Several issues on the emergent level of integration could be identified, in some cases even partly solved. This for instance counts for the interfaces between the models. Furthermore, a weather generator for the regionalisation of climate change projections has been elaborated and successfully applied. And last but not least the adjustment of the scenario-based tool will end up with decision support which is much closer to the real challenges of practical flood risk management then this has been before.

However, it can be said that the interface between technological knowledge and evidence base on the one hand and the decision making and development process of responsible actors and the people affected on the other hand seems still to need further research efforts. Dynamic change of the flood risk system additionally requests for more long-term surveys on the applicability of a strategic planning approach especially on the regional and national level. And finally beyond the formulation of future strategies, success factors and according instruments for better implementation in terms of good governance should be seen as crucial for flood risk reduction.

5. References


