Managing Adaptive REsponses to changing flood risk,

The Hannover Flood Risk Management Study

City of Hannover in collaboration with the partners of the MARE project

FV 130104

Summary

This case study report describes the process by which the City of Hannover is developing a flood risk management strategy and a flood risk management plan that satisfies the requirements of the EU Flood Directive. The strategy is being developed so that it will cover all aspects of flooding, but the immediate priority is to develop a plan for the management of flooding from the Rivers Ihme and Leine which have been identified as presenting a significant risk of flooding by the State of Lower Saxony, which is responsible for carrying out the Preliminary Flood Risk Assessment.

List of stakeholders

Ref. No.	Stakeholder					Interest																									
						Regulators										Planning bodies										Knowledge development					
		Developers		Long term ownership		Wild life		Heritage		Environment		Water quality		Water quantity		Emergency plannning		Strategy planners		Development control		Building control		Road/Transport		Initiators		Create state of the art knowledge		knowledge maintenance	
		A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
	Public authorities and water utility organisations																														
	State of Lower Saxony																														
1	NLWKN	X	X			X	X					X	X	X	X	X										X					
	Hannover Region																														
2	Water Body	X				X	X					X	X	X	X											X					
	City of Hannover																														
3	Highways Division	X												X	X	X		X	X	X	X					X					
4	Planning Division	X																X		X		X									
5	Department of Greenspaces	X																X	X	X	X										
6	Sewage Division	X										X	X	X	X	X	X	X	X	X	X					X					
	Knowledge institutions																														
7	Leibniz University of Hannover	X																X		X		X								X	
8	TU Hamburg-Harburg	X																X		X										X	

Contents

1 Introduction

1.1 Backgound

The River Leine flows from south to north through Hannover, giving rise to flood risk for the adjacent urban areas and their residents.

Although the city administration has only limited legal responsibility for the implementation of flood protection measures, it nevertheless attaches the highest priority to managing flood risk to minimise its impact on the urban area and its communities.

The city administration has developed a considerable of technical expertise and management capacity in many aspects of risk management and has developed a strategic approach to improving Hannover's flood protection and has been putting it into practice since 2006. This approach has included the design and construction of flood risk reduction and protection measures costing around EUR 30 million. These are largely technical flood protection measures at priority locations that have a high level of risk.

Part way through this process, the, the European Flood Directive (2007/60/EC) was published in 2007. This directive specifies the basis for assessing the risk of flooding and drawing up flood risk management plans. The directive has been enshrined in national law, and the responsibility for its implementation, and therefore the responsibility for preparing FRM (Flood Risk Management) plans in the federal state of Lower Saxony, rests with the state rather than with the city administration. This responsibility is discharged by the NLWKN (Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency).

The state administration's work on flood risk management plans has resulted in the publications of flood risk maps at a scale of 1:25,000, which lacks the precision needed to meet the requirements of municipalities. Furthermore, the approach adopted by the state administration currently takes no account of the impacts of climate change when drawing up FRM plans, and will not be doing so until the statutorily required routine review of the plans takes place in 2020.

This, from the city's point of view, is inadequate. With this in mind, the City of Hannover commissioned a study of the impacts of climate change within the city, and has developed a municipal strategy for dealing with climate change.

1.2 Drivers

The basic requirements of the Flood Directive, are:

- To complete the preliminary flood risk assessment in accordance with Article 5 of the Directive by December 2011
- To produce flood risk maps in accordance with Article 7 of the Directive by December 2013
- To complete and publish flood risk management plans in accordance with Articles 9 and 10 of the Directive by December 2015

In addition the City of Hannover has several other drivers behind its development of an exemplary flood risk management plan within the framework of the MARE project. These are:

- To improve the management of risk from all types of flooding and reduce the level of flood risk within Hannover

- To increase the scale at which flood risk can be mapped within the city to 1.5,000.
- To develop a practicable catalogue of measures for the implementation of the flood risk management plan within the city
- To consider climate change and its impacts at the municipal level in the preparation of the flood risk management plan.
- To gather knowledge and experience about adaptive measures and about flood risk management planning so as to improve the capacity to review and comment on the work carried out by the state administration.

The approach has been developed through the MARE transnational partnership which has provided a platform for sharing knowledge and experience within an environment of action learning, the benefits of which have been recognised by NLWKN.

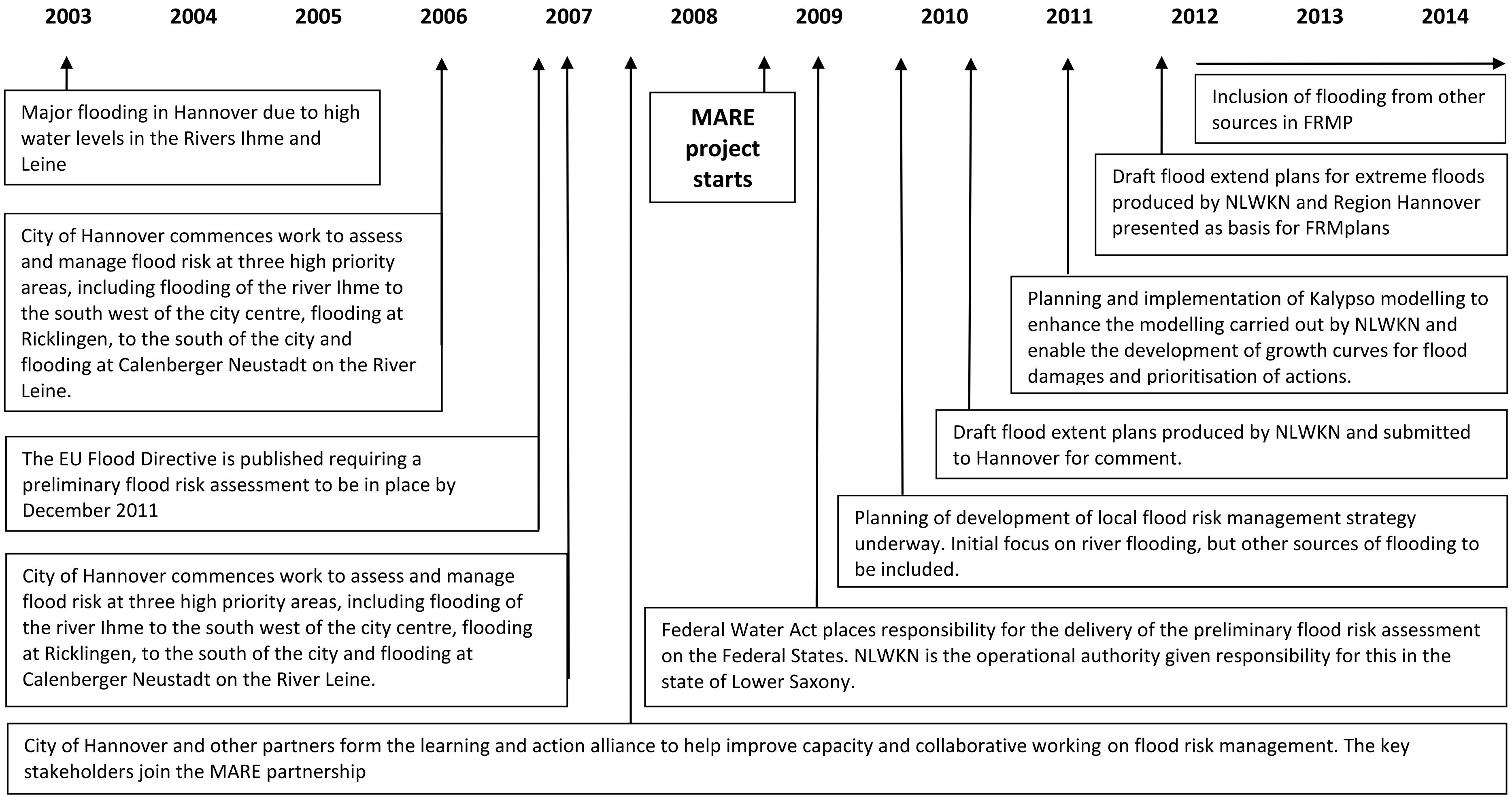
1.3 Regulations, procedures and standards

The EU Floods Directive forms the basis of the work being carried out in Hannover. This requires that flood risk management plans for areas with significant flood risk have to be prepared and published by 22 December 2015. This directive has been enshrined in national law by way of the Federal Water Resources Act (*Wasserhaushaltsgesetz/WHG*), which identifies that the responsibility for preparing the FRM plans in Germany lies with the federal states. In order to achieve a largely consistent implementation of the Flood Directive throughout Germany, representatives of all federal states and from the federal government level have drawn up recommendations implementation within the framework of the "Flood Protection and Hydrology" subcommittee of what is known as the LAWA (Bund/**L**änder-**A**rbeitsgemeinschaft **Wa**sser)/German Working Group of the Federal States on Water Issues)

As things currently stand in Lower Saxony in terms of the implementation, there are no provisions on the part of the state administration for any direct involvement of the municipalities in the process of drawing up the plans. This means that there is no formal opportunity for municipal authorities to influence the state administration's approach or detailed methods. The completed risk and hazard maps merely indicate so-called search and action areas of significant flood risk within which the state administration considers it sensible for municipalities to consider to take further action. It is then up to the municipalities to provide the state administration with proposals as to measures for managing these risks so that the latter is then in a position to provide the EU with a progress report on implementation. The municipalities are not currently under any statutory obligation to become involved except to provide feedback.

1.4 Timeline and flow diagram

The timeline and flow diagram for the production of the flood risk management plan are shown in Figure 1


2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Major flooding in Hannover due to high water levels in the Rivers Ihme and Leine
MARE project starts
Inclusion of flooding from other sources in FRMP
Draft flood extend plans for extreme floods produced by NLWKN and Region Hannover presented as basis for FRMplans
City of Hannover commences work to assess and manage flood risk at three high priority areas, including flooding of the river Ihme to the south west of the city centre, flooding at Ricklingen, to the south of the city and flooding at Calenberger Neustadt on the River Leine.
Planning and implementation of Kalypso modelling to enhance the modelling carried out by NLWKN and enable the development of growth curves for flood damages and prioritisation of actions.
Draft flood extent plans produced by NLWKN and submitted to Hannover for comment.
The EU Flood Directive is published requiring a preliminary flood risk assessment to be in place by December 2011
Planning of development of local flood risk management strategy underway. Initial focus on river flooding, but other sources of flooding to be included.
City of Hannover commences work to assess and manage flood risk at three high priority areas, including flooding of the river Ihme to the south west of the city centre, flooding at Ricklingen, to the south of the city and flooding at Calenberger Neustadt on the River Leine.
Federal Water Act places responsibility for the delivery of the preliminary flood risk assessment on the Federal States. NLWKN is the operational authority given responsibility for this in the state of Lower Saxony.
City of Hannover and other partners form the learning and action alliance to help improve capacity and collaborative working on flood risk management. The key stakeholders join the MARE partnership

2 Details

2.1 Stakeholder analysis

2.1.1 Schedule of stakeholders and responsibilities

2.1.2 Key stakeholders

2.1.2.1 Federal state of Lower Saxony

As lead water authority, the federal state of Lower Saxony is responsible for drawing up the FRM plans, which it does through NLWKN (Ref. no. 1) which is responsible for implementation. Analysis and assessment and decisions regarding the scope and content of the work are carried out by the NLWKN without the participation of the municipalities or of associations. The NLWKN puts together the fundaments for the risk and hazard plans; but, in individual cases, account is taken of additional data or analysis voluntarily provided by the municipalities on their own initiative.

The NLWKN draws up the risk and hazard maps at its own cost, indicates so-called local search areas for flood protection measures in the municipalities and in turn makes these maps available to the municipalities.

2.1.2.2 Hannover Region

The Hannover Region (Ref. no. 2) has two functions, one of which is formally as lower tier water authority and the other as regional planning authority for the municipalities which lie within the Region.

The Hannover Region is not involved by the state side in the preparation of the FRM plans by the NLWKN and therefore has no direct tasks in this respect. However, it makes an indirect contribution towards the drawing up of the risk and hazard maps because the so-called flood zones determined by the Hannover Region correspond to the HQ_{100} measurements identified on the maps produced by NLWKN and reference is therefore made to them. However, the Hannover Region has a direct interest in how flood risk is managed as it has a responsibility for disaster control and civil protection within its territory.

Because it has responsibilities as a lower tier flood authority and for civil protection, the Hannover Region is involved in the work of the LAA (Learning & Action Alliance) in rder to help coordinate the work of developing flood risk management strategy and the flood risk management plan.

2.1.2.3 City of Hannover

Although the City of Hannover is not directly involved in the preparation of the flood risk maps by NLWKN, there are at least four different departments within the city administration which are affected and whose actions have to be internally integrated and externally aligned with other stakeholder organisations.

The Civil Engineering (*Tiefbau*) department (Ref. No. 3) bears responsibility for the River Leine and, within the framework oft he MARE project, for the city's flood protection planning; it coordinates those involved, both within and outside of the city.

The Urban Planning (*Stadtplanung*) department (Ref. no. 4) is responsible for the city's urban development, provides data for the FRM planning, takes account of the results thereof and coordinates the planning activities.

The Green Spaces (*Grünfächen*) department (Ref. no. 5) is responsible for the development and care of the green areas in the urban area. All of the areas at risk from flooding contain green areas which would be affected, so the Environment department likewise provides data and has to help in the implementation of the directive's requirements.

The Municipal Drainage and Water Treatment (*Stadtentwässerung*) department (Ref. no. 6) operates the city's drainage system and is responsible for the secondary waters. It likewise provides data for the FRM planning and implements the results.

At its own expense the city administration has integrated and aligned the data bases for the FRM planning and made them available to the state administration. One example in this respect is that an airborne laser scan was carried out in order to gain more precise terrain data for the urban area. The state administration had previously used the FRM planning with a 12.5 m grid, but the laser scan enabled grid reduction to 1.0 m and thus makes for vastly improved results.

2.1.2.4 Knowledge institutions

Capacity building played a major part in the development of the strategy for flood risk management and the flood risk management plan. Within the MARE framework a Learning and Action Alliance was formed by the City of Hannover, the Hannover Region, the State of Lower Saxony and two universities, the Leibniz University Hannover (Ref. no. 7) which through the faculties of Architecture and Landscape has contributed its knowledge to the FRM planning process, and the Technical University of Hamburg-Harburg (Ref. No. 8)which amongst other things has carried out, hydrological calculations.

2.1.3 How the LAA is organised

The coordination of the activities of the LAA was organised by the Hannover city administration's Civil Engineering (*Tiefbau*) department (Ref. no. 3). Information was exchanged and the results discussed as part of regular LAA meetings. The information and results were exchanged in both directions so that all parties involved not only supplied but also received information and data for their own work.

The universities have provided their cooperation and services free of charge within the framework of the MARE project.

There are no plans for a formal cooperation in the preparation of the state administration's FRM planning. There is, however, participation on the part of the Lower Water Authority and the municipalities which can then make comments and statements following the state administration's completion of the FRM plans. The sphere of science is not involved in this respect.

The FRM planning process within the framework of the MARE project involves the participation of the upper and lower water authorities, various of the City of Hannover administration departments, Leibniz University Hannover and the Technical University of Hamburg-Harburg. The cooperation of the stakeholders within the framework of the LAA has been organized and coordinated by the Hannover city administration's Civil Engineering (*Tiefbau*) department (Ref. no. 3. Information was exchanged and the results discussed as part of regular LAA meetings. The information and results were exchanged in both directions so that all parties involved not only supplied but also received information and data for their own work.

2.2 Diagnostic study

2.2.1 The analytical process

In line with the time frames specified by the EU Flood Directive and Federal law, the state administration initially determined the management units within which the FRM planning process is to take place. A preliminary assessment of the flood risk within these management units was completed by the state administration towards the end of 2011.

This assessment came to the blanket conclusion that the entire urban area of Hannover is subject to a significant risk of river flooding . However, to date, it has not been possible to differentiate between the different types of flooding within the area of significant risk. Nor has it been possible to identify the likelihood of flooding or the levels of risk from other sources of flooding at different locations within the city. Furthermore, this is not likely to happen within the foreseeable future. The only maps that have been made available by the state as part of the preliminary flood risk assessment are for the HQ_{100} and extreme HQ scenarios along the main rivers. Maps for a low HQ scenario have not yet been commenced.

Against this background the City of Hannover has, through the MARE project has collaborated with the Technical University of Hamburg-Harburg to carry out a more detailed analysis and assessment of flood risks along the rivers using a computer software tool Kalypso (Annex 1). The analysis was carried out for the HQ1, 5, 10, 20, 50, 100 scenarios and for the extreme scenario. This means that the results of the analysis could be linked to the state mapping through the HQ_{100} and extreme scenarios and that a more detailed understanding of the likelihood of flooding and the level of risk due to the rivers in the urban area are available.

The information for the production of the risk maps was drawn from the city's own databases (building blocks and uses, population figures, land utilization, industrial facilities and other relevant uses). This has enabled the production of risk and hazard maps which provide the views from a number of perspectives and which are sufficiently detailed and accurate to encourage the participation of the relevant stakeholders.

This more detailed analysis has helped to identify where the weak spots in the current defences lie. A total of 27 risk zones have been identified in the urban area, which would not have been possible by sticking to the letter of the law and simply using the state administration's data.

Within the framework of the MARE project, specific proposals for measures and action to be taken for the individual risk zones have been developed, with account being taken of the approaches developed from the Climate Proofing Toolbox (CPT).

Key elements from the CPT in this respect are, for example:

- the stakeholder analysis, (who does what and why?) to identify who should be involved
- the "tipping-point" approach, to identify the weak spots, and
- the consideration of synergies with other construction projects..

A substantial difference in comparison with the state administration's work also lies in:

- the inclusion of surface water flooding caused by torrential and prolonged heavy rainfall and its impacts on the urban area, and
- taking account of climate change.

2.2.2 The role of municipalities

The City of Hannover has been driven by its integrating role in the management of the built, natural and water environments within the city boundaries. The way in which the urban area can be planned and managed as a whole is of vital importance. It is therefore important to identify those areas which are to regarded as critical in respect of possible uses. As part of the planning and management process it is vital to know:

- which areas are regularly submerged by water,
- where water leads to significant infrastructural constraints,
- how much financial damage these can cause, and not least
- what practical coordination of measures are needed for preventing damage to the health and life of the people living there.

Taking into account the fact that the data to be expected from the state of Lower Saxony for the urban area are (a) too imprecise and (b) therefore unusable, the City of Hannover administration decided to make its own efforts with the intention of drawing up a flood risk management plan within the framework of the MARE project. This is linked with the hope that the plan is suitable for serving as basis for taking decisions on investments and municipal strategies.

Therefore, the plan sets out to be beneficial to and to facilitate the strategic and daily work of the individual affected authorities, from planning right through to disaster response. Ultimately the approach taken will lead to more integrated planning and management of built, natural and water environments within the City of Hannover. This can only occur through the participations of all the relevant departments and specialist disciplines, which from the perspective of flood risk management includes Urban Planning, Sewage and Water Treatment, Civil Engineering, Environment and the Fire Service as a minimum.

In Hannover, the pooling of this cross-disciplinary knowledge has made it possible to develop a flood risk management strategy a and produce a flood risk management plan which provides an example for other municipalities.

2.2.3 Detailed flood risk and hazard maps for river flooding

The City of Hannover has drawn up flood risk and hazard maps for the entire urban area, lying within the flood plains of the rivers Leine and Ihme.

As an example, Fig. 2 shows a section of the hazard map for an HQ_{100} event; the hazard maps for the other HQ calculations are stored in the GIS system. The data from the airborne laser scan voluntarily performed by the City of Hannover enabled a vastly improved resolution of the maps in comparison with the state administration’s base data.

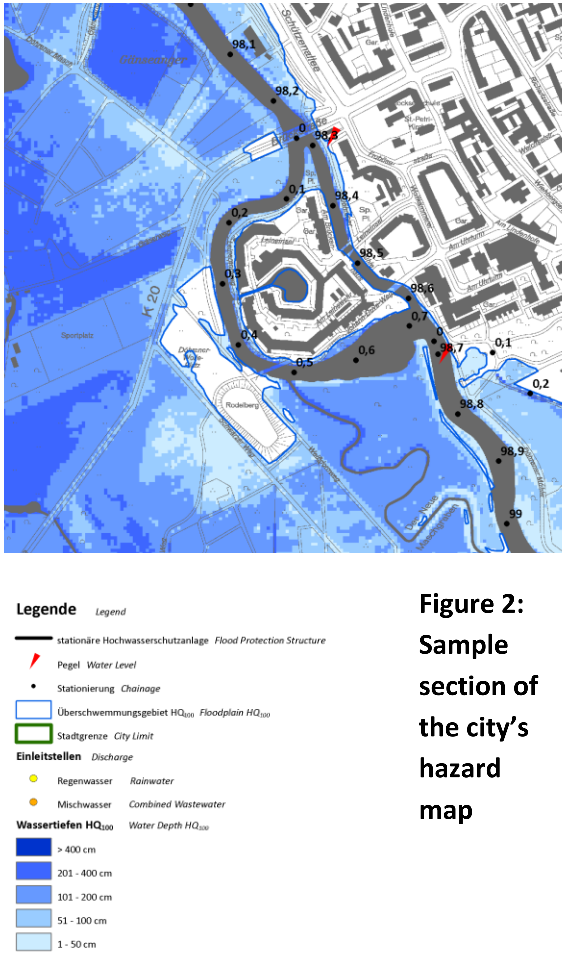


Figure 2: Sample section of the city's hazard map

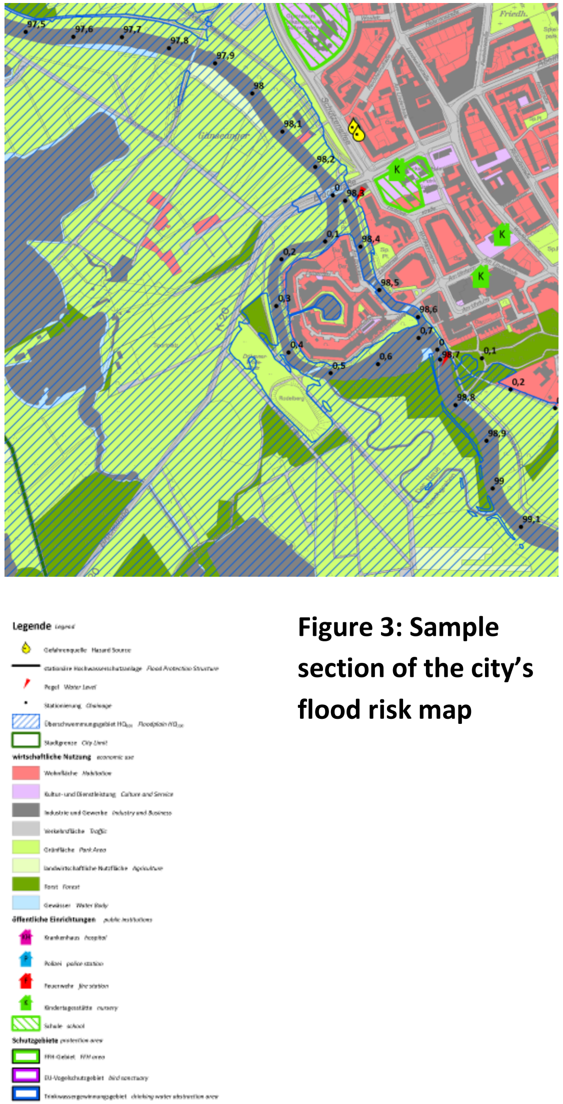


Figure 3: Sample section of the city's flood risk map

The risk-relevant data on land utilization, population figures, etc. were collated using an approach aligned with the state administration's method. However, the sub-classification of the land usage is in some cases more detailed than that of the state administration. Figure 3 shows a sample section of the city's risk map.

2.2.4 Enhancement of current flood risk and hazard maps to include other sources of flooding

According to the state administration's interpretation, the FRM plans primarily concern river-induced flooding. Where Hannover is concerned, the state administration is drawing up the FRM plan for the area around the River Leine. However, the city's water system includes streams of which no account is taken. Furthermore, no account whatsoever is taken of the aspect of surface water flooding caused by high intensity or prolonged heavy rainfall which can have a significant effect within the city. The impact of climate change is not intended to be included in the state administration's maps until the regular revision process for 2020.

The limited scope of the preliminary flood risk assessment can lead to a distorted perspective of flood risk and this in turn can lead to the selection of unsuitable risk treatment options. This from the perspective of municipal planning, is an unsatisfactory state of affairs.

During the course of the MARE project the city administration has developed a strategy for handling climate change in which water plays a key role. Strategies about how and when to adapt to climate change have been developed for all aspects of water within the city, not just for river flooding.

In this respect the development of a flood risk management strategy by the MARE project team (LAA) and the city's working group for adaptation to climate change have been mutually beneficial. For example surface water flooding is now starting to be included because areas were identified where the sewerage system could not carry the flows caused by intense rainfall. It is planned to carry out further investigations to identify and develop and implement appropriate surface water management measures to reduce the likelihood of surface water flooding, for example from runoff from saturated green space caused by prolonged heavy rainfall. In addition, the capacity of the city administration to investigate the need for and to design and implement sewer system enhancement is to be improved.

By using the tipping point approach, it has been possible to take account of the impacts of climate and for each of the 27 risk zones to identify the point in time where the level of risk needs to be addressed.

In addition to enhancing the information on the likelihood of flooding, the maps are also being enhanced by increasing the detail about the consequences of flooding:

- The classification of the land usage is much more detailed with green spaces being further sub-classified into green areas, arable land and woodland.
- Public buildings are further classified into schools, kindergartens, hospitals, police stations etc.,
- Protected zones and reserves are identified as FHH areas, bird sanctuaries and drinking water abstraction areas etc.
- The city's flood risk maps itemize the state's blanket depiction of commercial and industrial sites to identify among other things; petrol stations, companies/plants using materials/substances hazardous to water, (such as, for example, in paper processing, paint shops, etc.), relay stations operated by energy providers, telecommunication operations, etc., as potential hazards.
- Lastly, cultural assets within the city level have been included alongside the cultural monuments. These include museums, archives, historically important quarters and green spaces.

2.2.5 Socio-economic impact assessments

The Flood Directive provides no guidance about the assessment of socio-economic impacts arising from flood events. Furthermore, the state administration decided not to address this when it drew up its flood risk and hazard maps, nor has it provided the municipalities with any recommendations or guidance towards describing and assessing such impacts.

The team working on the flood risk management plan used a variety of approaches and data sources were used to develop a methodology for assessing the socio-economic impacts. Because of the experimental nature of the approach and the lack of firm data, there is a high degree of uncertainty in the results of the analysis, and the outcome must be viewed as an approximation. However, the outputs of the analysis helped to rank the consequences of flooding and hence helped to prioritise the need to take action. It was important to differentiate between the consequences of flooding on different land uses, (green spaces, missed use, transport routes etc.), building status (occupied and unoccupied) and vehicles within the flood area, and so these were taken as basis for the analysis. Damage functions were identified from relevant literature (e.g. Schadensfunktion nach Björnsen Ingenieure 2004, Hochwasseraktionsplan Werre, Land- und Forstwirtschaft nach DVWK 1985, Schadenermittlung from Günther und Schmidtke 1988), data from Dr. Thomas Hirschhäuser, Schadensfunktion für Gewerbe der IKSE Elbe and Ingenieurbüro Hydrotec / Sönnichsen). From these it was possible to determine the overall damage cost the city would sustain in an HQ_{100} flood scenario, though, because of the uncertainty, the absolute value of damages remains in question.

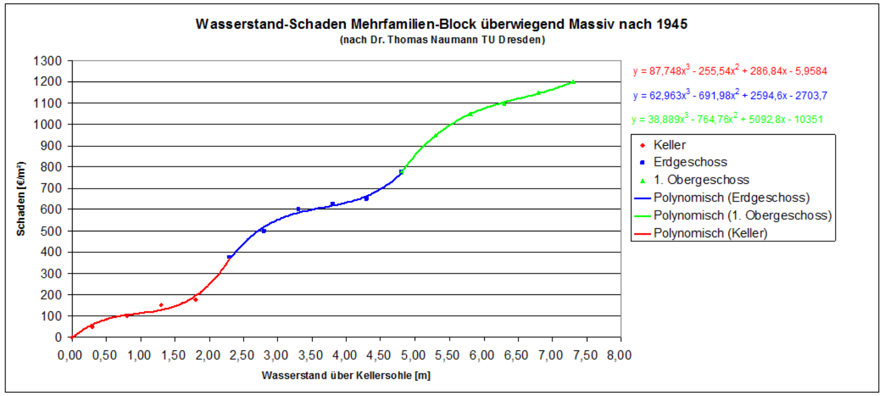


Figure 4: Damage function for blocks of flats

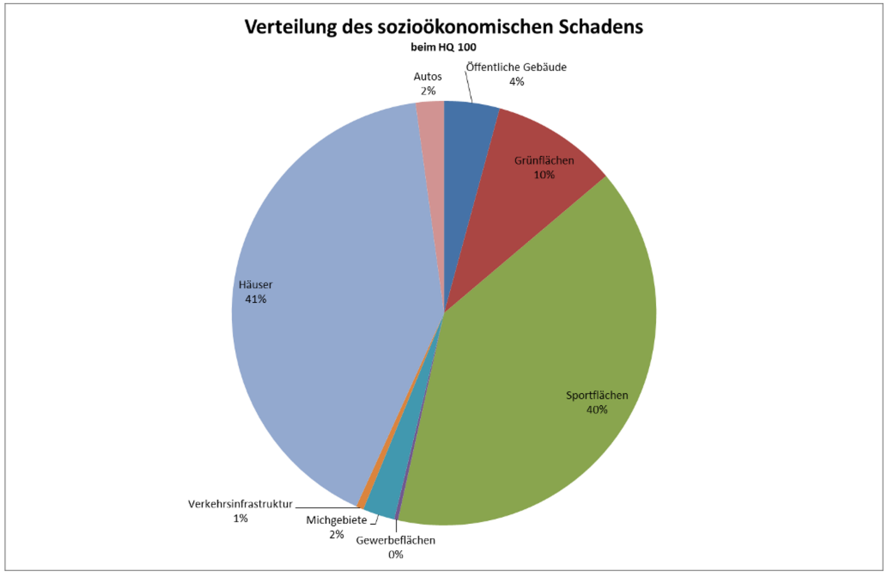


Figure 5: Distribution of the socio-economic damage (own calculations)

The uncertainty is caused by the need to use a general damage function across the whole of the flooded area as in Figure 4, but such damage functions fail to take account of different types of building construction, the length of time spent in alternative accommodation, which can vary because of a number of factors or to the value of the contents. Thus in reality, the costs associated with an individual property may differ significantly from the damage function and because the damage function cannot cover every eventuality, the actual cost will tend to be higher.

Once the damage functions had been determined they were used to calculate the socio-economic impacts of an HQ_{100} flood event in Hannover. Figure 5 shows the distribution of costs among the different parameters (land uses, building types, vehicle etc.). An interesting aspect in the calculation of the socio-economic impacts lay in the fact that, at 40 percent of the total damage, the proportion of the damage to sports grounds (land drainage systems, changing facilities etc.) in Hannover is in the same order of magnitude as the damage to buildings. This is because a large number of the city's sports facilities are situated in the green areas close to the River Leine. This had not previously been recognised. This has lead to a reassessment of the use of sports grounds as retention areas in the event of a flood.

2.3 Problem definition

The processes described in Section 2.3 have identified 27 risk zones where adaptive responses to the risk of river flooding are required. In order to prioritise these zones and develop a plan for managing the flood risk, it is necessary to compare and contrast the likelihood and consequence of flooding within each zone. This has been done by compiling and tabulating basic information describing and quantifying the likelihood and consequence of the flooding within each risk zone. This information includes the length of the weak spot, height of the floodwater at the weak spot, water level at which flooding commences, the number of local residents affected and the impact on infrastructure and facilities. Figure 6 shows how this information can be visually represented.

Figure 6: Example of risk zone analysis

2.4 Development of strategy

In Germany, risk treatment options fall into the categories contained within the Flood Risk Management loop illustrated in Figure 7. Structural and non structural options can be used to ***alleviate*** and ***avoid*** risk, and if the capacity of those is exceeded to take ***action*** and provide ***assistance*** during and after a flood event and to raise ***awareness*** about flooding and flood risk. Together these options provide a portfolio of measures to reduce the level of flood risk, by reducing the likelihood of flooding and/or the consequences. It is the role of the municipalities to **analyse**, **assess** and select a combination of options appropriate to the circumstances of each problem area. One of the options to be considered is the ***acceptance*** of the current level of risk, which leads to a no action approach. The impact of this approach can be compared with that of the other options as part of the assessment process.

Figure 7: Flood precautions and management loop

Key to terms

VORSORGE	PREVENTION
Flächenvorsorge	face care
Bauvorsorge	building precautions
Risikovorsorge	risk provision
Informationsvorsorge	information provision
Verhaltensvorsorge	preventive behaviour
Natürlicher Wasserrückhalt	Natural water retention
Technischer Hochwasserschutz	Technical Flood Protection
Vorbereitung Gefahrenabwehr und Katastrophenschutz	preparation security and civil protection
HOCHWASSEREREIGNIS	FLOOD EVENT
BEWÄLTIGUNG	MANAGEMENT
Abwehr	defense
Hilfe für die Betroffenen	Help for the affected
Aufbauhilfe	reconstruction aid
Wiederaufbau	reconstruction

2.4.1 Selection of options

Although the focus has been on the river flooding, it is recognised that flooding from other sources can occur within the flood plain. It is also recognised that some measures taken to alleviate river flooding can have impacts on the drainage of the flood plain. These include locking of drainage systems and entrapment of surface water behind defences when river levels are elevated. This means that it has been necessary to identify and engage with all the relevant stakeholders to make a preliminary assessment to determine the measures which are applicable and those which no longer need to be considered.

The stakeholder analysis (Who does what and why) in Annex 3 of the Local Strategy, provides a check list to help identify the responsibilities of the different organisations/ departments that should be involved in the planning. Design and management of the different measures and which problems are the responsibility of land and property owners.

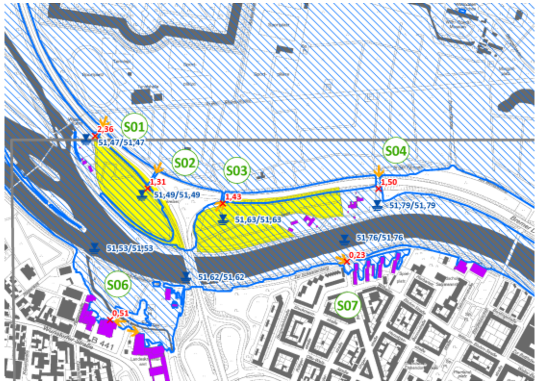
Two tables / structures were developed for this purpose within the framework of a transnational workshop; these can be used for the further processing of the FRM plans. Oneof the tables (Table 1) shows the assignment of individual measures and action areas to the different parts (MARE 1, 2 and 3) of the MARE toolbox.

Table 2 summarises the main results and lines of action for the weak spots (risk zones). 27 of these tables were produced in Hannover, one for each weak spot.

Table 1: Assignment of individual measures to the MARE toolbox

Theme 2: Alleviation and avoidance - Non structural measures (This table associates the sdifferent non structural measures with the inland and coastal sources, pathways and receptors. The number 1 denotes the need to apply MARE 1. MARE 2 is relevant to the cells shaded green. The number 3 indicates the need to consider the impact of MARE 3 on serviceability and/or structural performance)				**Inland Sources/Pathways/Receptors**																															**Coastal water categories**			
				Rural and urban areas														**Artificial water bodies**					**Streams and ponds**								**Rivers and lakes**							
Topics					**Surface water and soil**				**Groundwater**			**Drainage infrastructure**											**Small Stream[2]**			**Large Stream[3]**			**Ponds**			**Lakes**						
Level 1	**Level 2**	**Level 3**	**Level 4**	**Exceedence pathways**	**Rural green space**	**Green space at urban fringe**	**Green space within urban area**	**Developed urban surface**	**Artificial superficial deposits**	**Natural superficial deposits**	**Bedrock**	**Combined sewer**	**Surface water sewer**	**Foul sewer**	**SUDS/Source control**	**Pipe drain**	**Open Drain**	**Drainage channel**	**Canal**	**Reservoirs**	**Lakes**	**Ponds**	**Open**	**Piped/culverted**	**Built over**	**Open**	**Piped/culverted**	**Built over**	**Ponds with outlets**	**Ponds without outlets**	**River[1]**	**Lakes with outlets**	**Lakes without outlets (oxbow)**	**Salt lakes (inland seas)**	**Open sea**	**Estuaries**	**Deltas**	**Fjords and inlets**
	Strategy and master planning	Regulation			1	1	1	1	1	1	1	1	1	1	1	1	1																					
		Support	Guidance		1	1	1	1	1	1	1	1	1	1	1	1	1																					
			Experience		1	1	1	1	1	1	1	1	1	1	1	1	1																					
		Land use zoning, ordinances and maps			1	1	1	1	1	1	1	1	1	1	1	1	1																					
	Development control	Regulation			1	1	1	1	1	1	1	1	1	1	1	1	1																					
		Support	Guidance		1	1	1	1	1	1	1	1	1	1	1	1	1																					
			Experience		1	1	1	1	1	1	1	1	1	1	1	1	1																					
	Building control	Regulation					1	1	1	1	1	1	1	1	1	1	1																					
		Support	Guidance				1	1	1	1	1	1	1	1	1	1	1																					
			Experience				1	1	1	1	1	1	1	1	1	1	1																					
	Water management	Regulation		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
		Support	Guidance	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
			Experience	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Promoting/requiring flood risk adapted land use			1,3	1,3	1,3	1,3	1,3																														
	Promoting/requiring water sensitive urban design			1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Promoting/requiring resilient and resistant infrastructure			1,3			1,3	1,3				1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3	1,3
Non structural measures	Promoting/requiring resilient	Dry proofing						1,3																														

Table 2 Part 1: Assessment of measures/weak spots (extract from the table, the complete table can be found in the annex)

Affected area	**Westschnellweg** (trunk road B6) is located on an embankment and therefore basically constitutes a barrier to the flooding of the River Leine. At two points (S01 and S02) on Westschnellweg, however, there are underpasses which enable an inflow of flood waters in the Grosser Garten/Georgengarten area
Abbreviation: **S01**	  The hazards triggered by S01 are linked with the areas S02, S03, S04 and S05 and need to be considered jointly when developing lines of action to be taken.

Affected flood protection factors	**Human health** (local residents affected in an HQ_{100} flood event)	**Environment** (IPPC installations, etc.)	**Cultural heritage** (cultural monuments protected by state law)	**Economic activities**
	3,200	**-**	**X**	**-**

Hydraulic data	**Flood area** (HQ100) [km²]	**Median flood level** (HQ100) [m]	**Max. water depth** at the inflow point/line before/after the foreshore excavations on the River Ihme (HQ100) [m]	**Level in Herrenhausen** in the event of overflow [m]	**Length** of the inflow/defence line (HQ100) [m]
	1.88	**1.45**	**2.35/2.35**	**- insert formation -**	**< 10**

Table 2 Part 2: Assessment of measures/weak spots (stakeholder involvement)

Completion assistance:

A - Advisor
D – Decision maker

Stakeholders					Interest																									
					Regulators										Planning bodies										Knowledge development					
	Long term ownership		Developers		Wild life		Heritage		Environment		Water quality		Water quantity		Emergency planning		Strategy planners		Development planners		Building control		Road/ Transport		Initiators		Create state of the art		knowledge maintenance	
	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D	A	D
Public																														
Fed. government																														
Federal state		x		x																			x	x						
Region																														
Municipality		x		x									x	x	x	x	x	x	x	x	x	x	x	x					x	
Water board																														
Private																														
Science			x																										x	
Other																														

The information summarised in Figure 5, and Tables 1 and 2 is then used to quantify the costs and benefits of the different options for each of the risk zones in sufficient detail to prioritise the need for action and to develop a detailed programme for design and selection of options at each location as described in the case study for the Calenberger Neustadt district located on the banks of the River Leine.

2.5 Managing climate change and uncertainty

2.5.1 Climate change

In Hannover, the cornerstones of an urban strategy for adaptation to climate change were developed parallel to and in conjunction with the development of the flood risk management strategy. Whilst Hannover has adopted strategies to mitigate climate change by reducing CO_2 emissions, the city administration recognises that it has to be able to adapt to all the different impacts that can be reasonably anticipated. In this respect, flood risk management is just one of several areas of activity for which the city administration has responsibilities, and so a coordinated approach is being taken to minimise costs and maximise benefits.

The adaptation strategy (see publication 0933/2012) is focussed on eight actions, with the topic of water featuring prominently. The spheres of action are as follows:

Action 1: Flood protection
Action 2: Rainwater management
Action 3: Preventative soil and groundwater protection
Action 4: Greening of roofs
Action 5: Climate-adapted vegetation
Action 6: Climate-adapted urban planning and climate-adjusted construction
Action 7: Specific climate adjustment maps
Action 8: Public relations work

The difference between the approach to flood risk management taken by the state authorities and that taken by Hannover lies in the fact that Hannover takes account of climate change and the state authorities currently do not. Climate change has been integrated into the flood risk management process through the tipping-point method. This has allowed the identification of when in the future flood protection measures in risk areas are likely to fail. This has enabled the development of an implementation plan that achieves a an acceptable balance between levels of expenditure and the level of risk throughout the city.

This has been achieved through adaptive responses in which technical protective measures are to be designed in such a way that they can "grow with" climate change and that settlement structures in high risk areas can be converted so that the damage caused by flooding can be kept to a minimum.

2.5.2 Uncertainty

Climate change is just one of many areas of uncertainty that affect flood risk management. Others areas of uncertainty include:

- the relationship between the depth, duration and frequency of rainfall,
- the absorptive capacity of the earth's surface,
- extreme river flows,
- recorded data on flooding and
- the modelling of the hydrological processes.

This means that it is not realistic to expect accurate results from the modelling.

One way to manage this uncertainty is to allow for it in the design of the risk treatment options, which means that those options which include plenty of spare capacity at little or no additional cost should be favoured. This approach is consistent with the achievement of multiple benefits by integrating flood risk management with other aspects of the built natural and water environment.

3 Review

3.1 Learning points

3.1.1 Stakeholder participation

Practice has shown that the implementation of EU Flood Directive by the state administration alone is not practical. It is not sufficient just to consult municipalities on specific aspects relating to the areas of high significance identified by the state administration. The inclusion of municipalities in the identification of the areas of high significance would improve the process and also improve the understanding of flooding and flood risk within the state.

It is important to raise the awareness of and involve all the relevant specialist disciplines and stakeholder institutions in order to align and integrate actions and to manage flood risk along all other relevant aspects of the built and natural environments to best effect by ensuring an ongoing dialogue.

The processes developed and enhanced in the MARE project have made it possible to appropriately involve a large number of experts at the municipal, regional and state scales to address climate and other change drivers in adaptive flood risk management and planning. The interest that has been generated in this approach given rise to requests from a wind range of disciplines and organisations for more information and lectures/presentations on the topic of flood protection.

The awareness raising was made possible by the cooperation of all stakeholders and the intensive exchange of information between them. However, the question as to whether or not this will continue after the MARE project's completion remains to be answered.

Practical experience has also shown that such collaborations work when there is clear benefit to the partners. In Hannover, the state administration only became fully involved when it became clear that the City of Hannover had the data, technical competencies and local understanding which changed the state's understanding of flood risks and its initial findings. As a result of the willingness of the City to share its data and knowledge with the state, the limits of the new flood zone (HQ_{100}) were more accurately identified and in places the maps which had already been created were revised.

In practice, the involvement of the Hannover Region administration did not at first prove to be easy. This was partially due to the Region's hybrid status and partly because it was not assigned any specific task in the state administration's preparation of FRM plans. The Hannover Region is responsible for the regional planning and at the same time for the lower tier water authority, but it has no responsibilities of its own for waters or territory as these are devolved to the municipalities within the region, and its involvement in the implementation of flood alleviation and avoidance measures is therefore limited. However as an emergency management authority, it is required to take action and provide assistance during and after flood events and hence it has an interest in flooding and flood risk management and is a partner in the development of a portfolio of appropriate risk treatment measures.

3.1.2 Methodology provided by the national state bodies

Experiences show that the technical approaches used by the state administration for drawing up FRM plans are good as far as they go. However, it would be beneficial to make improvements to the process and some of the outputs, namely:

- the involvement of the municipalities,
- the degree of detail provided by the flood risk and hazard maps made available, and
- the recommendation of methods for depicting the socio-economic impacts of flood events.

However, the elimination of these shortcomings with the objective of producing a FRM plan which is manageable at the municipal level will require a considerable outlay on the part of the municipalities. Small municipalities which do not have their own specialists are do not have the capacity to do this unless they have considerable financial resources for using the services of external experts.

The conclusion to be drawn is that by designating areas of significant flood risk the state bodies are placing municipalities in a difficult position because they currently do not offer them any financial or specialist assistance towards remedying potentially arising risks and hazards.

A checklist has been developed and provides an aid for the municipality to help in the description of the areas of significant risk and individual danger points. However, there is a lack of technical and non-technical guidance about how to go about minimizing hazards and there are no guidelines about the circumstances in which zero-action solutions can be tolerated.

As a result of the work carried out by the MARE team in Hannover, the state's checklist has been enhanced by adding key elements of the Climate Proofing Toolbox (CPT) including:

- hydraulic data for describing the problem areas,
- the stakeholder analysis,
- references to other projects in the search area so as to develop synergies and to help identify alternative measures.

This has been discussed with the state authorities and met with a positive response. However, it remains to be seen whether the aforementioned additions will be taken on board and therefore automatically offered to other municipalities.

3.1.3 Developing risk "zones"

The development of risk zones and the description of risk were the subjects of controversial debate.

"Risk" has historically been defined as the product of the probability and the consequences of an occurrence, although more recently this defined as the level of risk. In the case of the Flood Directive this means the probability of a flood (HQ low, HQ_{100} and HQ extreme) and the negative impacts thereof, in other words the resultant damage.

The cartographic depiction by the state administration is based on the various flood scenarios, confined to indicating the boundaries of the affected areas for each probability and the land usage within those boundaries. A classification into high, medium or low risk zones has not been undertaken, although the currently available data should enable a classification based on the frequency of flooding (the more frequent the flooding, the higher the risk) and the flood depth (the greater the damage, the higher the risk) to be undertaken. This would provide the municipalities, with a point of reference for the determination of priorities for action.

Within Hannover, the use of the Tipping Point approach coupled with the more detailed analysis of flood frequency has further enhanced this approach to grading priorities, by identifying the current level of protection against flooding and by identifying the frequency of events that cause sudden expansion of the flood risk areas or sudden increases in depth of flooding

Depending on the results, it is then possible to assess whether individual measures are adequate at that point, whether the point in question interacts with other points or even if flooding can be accepted at that point.

The definition of risk zones thus helps in the first place to establish consciousness that certain facilities or land usages are at risk of flooding. However, it is not until the tipping-point method is applied that the municipality is given a concrete evidence to help the process of prioritisation.

3.2 Conclusions

The review of the flood extent maps produced by the State of Lower Saxony for the Preliminary Flood Risk Assessment revealed that the scale at which they were produced was not sufficient for the purposes of developing detailed flood risk and hazard maps and for the development of a prioritised flood risk management plan.

There is a need to increase the horizontal and vertical resolution of the mapping to identify where the flooding takes place and the depth of flooding.

It is also important to consider land use and the importance and vulnerability of buildings and infrastructure, including cultural heritage such as museums, libraries, churches and art galleries which are important to the social fabric of the city.

There is also a need to produce maps for a greater number of event probabilities so that current and future local tipping points can be identified and the damages quantified. This will enable the prioritisation of each local flood zone and the development of a flood risk management plan which deals with problems in order of priority. However, the impacts of actions taken in one flood zone can have an impact of adjacent zones which may cross administrative boundaries. This means that problems cannot be viewed in isolation.

The Preliminary Flood Risk Assessment and the maps produced by the state can be seen very much as a first pass assessment. It is clear that a more detailed assessment using tipping point approaches like MARE 2 and MARE 3 and described in this case study is required at local level. Local authorities are in the position to coordinate this work as it involves the cooperation of the many disciplines that they cover. They also have the legitimacy for decision making through the political process. However, there is a need to build capacity and to resource the assessment process and the development of the subsequent flood risk management plan. Some aspects of the development of capacity and the sourcing of resources may best be achieved at regional or state scale, but that is a matter of detail.

Although the focus of this case study has been on river flooding, the conclusions are equally relevant to other sources of inland flooding.

3.3 Recommendations

Local authorities should recognise their vital role in the analysis of flood risk and the development and implementation of Flood Risk Management Plans. However, individual local authorities may not have the resources to manage this process, so they may wish to work collaboratively with other local authorities and stakeholders, including at regional scale to develop capacity and prioritise, develop and resource actions.

Although the analytical process as described in MARE 2 and MARE 3 is very much within the domain of the water management community, prioritisation of what is important and the development of cost effective solutions which have multiplebenefits should be community lead. This requires the involvement of a wide range of disciplines and the engagement of communities as described in MARE 1.