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National Flood Damage Evaluation Methods
A Review of Applied Methods in England, the Netherlands, the Czech Republic and Germany

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SUMMARY

This Report is the first deliverable of FLOODsite task 9, which is on flood damage evaluation methods. It summarises both the outcome of a literature survey on flood damage evaluation methods in selected EU countries and the major results of complementary expert interviews. The overall objective is to identify the methodological diversity regarding the practical application of flood damage evaluation methods in EU countries, which are known to have a leading position in this field. The results of this report are an important prerequisite for the major deliverable of task 9, which aims, among others, at proposing harmonised state-of-the-art methods and principles for flood damage analysis in EU countries.

The report shows that the four countries, England, the Netherlands, the Czech Republic and Germany, which feature very different histories of flood protection policy and different institutional settings, use sophisticated methods of flood damage evaluation. These in principle follow the same idea, namely trying to put economic values to elements of flood risk in order to estimate the benefits of flood protection measures in terms of prevented flood damage. In detail, though, the methods exhibit many different approaches. The major differences in flood damage evaluation methods relate to the damage categories considered, the degree of detail, the scale of analysis, the application of basic evaluation principles (e.g., replacement cost versus depreciated cost), and the application or non-application of results in benefit-cost and risk analyses. This diversity of flood damage evaluation methods, even in riparian states which share a major river, indicates that there is still a lack in transboundary cooperation in flood policy decision making in the EU.

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CONTENTS

Tables

Figures

1. Introduction

This Report is the first deliverable of task 9 in FLOOD*site*. It summarises both the outcome of a literature survey on flood damage evaluation methods in selected EU countries and the major results of complementary expert interviews. The overall objective is to identify the methodological diversity regarding the practical application of flood damage evaluation methods in EU countries, which are known to have a leading position in this field. The selected countries for the study are England and the Netherlands, which both have a long tradition of flood damage analysis, as well as the Czech Republic and Germany, which started much later with the practical application of flood damage evaluation. The results of this report are an important prerequisite for the major deliverable of task 9, which aims, among others, at proposing harmonised state-of-the-art methods and principles for flood damage analysis in EU countries.

Following a thorough literature survey nine interviews with national experts, who are responsible for the application of flood damage evaluation in their country, were carried out between October 2004 and June 2005: three interviews in England, one in the Netherlands, one in the Czech Republic and one interview in each of the German federal states of North Rhine-Westphalia, Schleswig-Holstein, Saxony, and Saxony-Anhalt. The following country reports summarise the major findings of the interviews and the literature survey. Each report follows – although not strictly – the same structure. In the beginning a short overview of the existing and applied approaches of flood damage evaluation is given. After that the objectives of damage evaluation are described and the damage categories considered are listed. The main part is the description of the methods used for damage evaluation. Finally, the implementation in benefit-cost analysis – if existing – is explained and comments on shortcomings, uncertainties and further improvements of the methods are given. We start with the country report for England, because flood damage analyses have a long tradition there and, in addition to this, England (and Wales) hold an authority and leadership position in this field. The next country discussed is the Netherlands. Since large regions of this coastal country are positioned below sea level, flood protection policy has a long tradition there. Although flood protection in the Netherlands has always been based on high safety standards, great efforts have been made to develop a new and standardised damage evaluation approach. The Czech Republic can be regarded as a leading EU accession country, which actively started with the practical application of flood damage analysis after the floods in 1997 and 2002. Finally, the country report on Germany summarises the different methods used in four selected federal states.

2. Methods of Flood Damage Evaluation in England

Sources of information:

- Interview with Edmund Penning-Rowsell, FHRC, Enfield, 15.3.2005 (referred to as *Penning-Rowsell 2005* in the following text)
- Interview with Jon Wicks, Halcrow Group, Swindon, 16.3.2005 (*Wicks 2005*)
- Interview with David Richardson, Kevin Andrews (DEFRA) & Bill Watts (Environment Agency), London, 17.3.2005 (*Richardson et al 2005*)
- Published and unpublished literature as listed in the reference list of chapter 7.1

2.1 Existing approaches on different spatial scales

In England (and Wales) there is a long history of developing and applying methods of flood damage evaluation. Since the 1970s a well developed system of methods for evaluating flood risks and damages on different spatial levels evolved, which is in the process of continuous improvement (Hall et al. 2003c). E.g., the research project RASP (Risk Assessment for Flood and Coastal Defence for Strategic Planning; DEFRA & EA 2003a; www.rasp-project.net) is currently trying to develop a consistent, tiered methodology for flood risk assessment.

The following listing can only give a rough overview of the methods used for damage evaluation on the different spatial scales:

- On the **national level** the *National Appraisal of Assets at Risk* (NAAR) was carried out for England and Wales (DEFRA 2001). This method has been further improved by the RASP high level method (Hall et al. 2003a; Sayers et al 2002). This improved method has been used for the *National Flood Risk Assessm*ent (NaFRA), a follow-up of NAAR, and was also applied for *Foresight Future Flooding* (Office of Science and Technology 2004; Hall et al. 2003b). The latter study aims at an evaluation of the development of flood risks in the next 100 years in the context of different future development scenarios.
- On the **regional level** damage evaluation is carried out for *Catchment Flood Management Plans* (CFMP; EA 2004) and *Shoreline Management Plans* (SMP). While there are already numerous SMP, CFMP are still in a pilot phase and only a few CFMP exist at present. Halcrow Group developed the ArcView-based Software MDSF (Modelling and Decision Support Framework; www.mdsf.co.uk; DEFRA et al. 2004a,b) mainly for CFMP to provide a unified approach for the evaluation of economic and social impacts of flooding.
- On an **intermediate level** between CFMP and detailed project appraisals two projects on the Thames River are to be mentioned which are both not yet completely finished: The Lower Thames Strategy Study (EA 2005) and the Thames Estuary 2100 Study.
- On the **local level** pre-feasibility and feasibility studies have to be carried out for each scheme for which governmental funding (grant aid) is requested. The DEFRA guidance for the procedures of these project appraisals are laid down in the *Flood and Coastal Defence Project Appraisal Guidance*-series (FCDPAG) of which the third part *Economic Appraisal* (DEFRA 1999) is the one mainly dealing with flood damage.
- **In almost all levels** standard damage data developed by the *Flood Hazard Research Centre* (FHRC, Middlesex University) is used for damage evaluation. This data has been published since 1977 starting with the *Blue Manual* (Penning-Rowsell & Chatterton 1977) mostly dealing with direct, tangible damage. The *Red Manual* (Parker et al. 1987) added more data on indirect losses and the *Yellow Manual* (Penning-Rowsell et al. 1992) focused on coastal erosion and flooding. The newest and updated version of these manuals is the *Multi-Coloured Manual* (MCM; Penning-Rowsell et al. 2003). FHRC also developed a FORTRAN-based software for the calculation of damages called ESTDAM, which is not GIS-based. ESTDAM is used for example within the Lower Thames study, but it is not – as one interview partner mentioned (Wicks 2005) – a standard in England for the calculation of damage as is the depth-damage data from the

MCM. For example within the MDSF software-package another software for the calculation of damages, called *Damage Calculator,* is used.

2.2 Objective of damage evaluation

Nearly all expenditure for flood defence in England comes directly or indirectly from central government funding (grant aid; Green 2003). The *Department for Environment, Food and Rural Affairs* (DEFRA) has the overall policy responsibility for flood defence in England, whereas the *Environment Agency* (EA) has the operational responsibility (Hall et al. 2003c). Both DEFRA and EA have the aim to get the most efficient use of these public investments (DEFRA 1999), and therefore it is mandatory to carry out project appraisals to evaluate the most efficient flood defence scheme to receive grant aid. The economic efficiency is measured in terms of the benefit-cost ratio which is a significant criterion for decision making in flood protection, though guidance encourages appraisers to ensure that non-costed impacts are also taken fully into account.

There are also standards of protection for different "land use bands" given by DEFRA (1999), but these are only indicative standards with a proposed range of service standard. That means that only if the option with the best benefit-cost ratio provides a lower protection than the lower boundary of the indicative standard range, the next option with a higher protection level might be chosen.

DEFRA's prioritisation system for filtering projects for more detailed appraisals also considers other factors other than the pure monetary benefit-cost ratio. In the context of a multi-criteria score system the number of people affected and the habitat area protected are also taken into account (see Penning-Rowsell et al. 2003). But it can be summarized that the benefits of flood protection derived from damage evaluation play the most important role for decision making.

Therefore a hierarchical system of damage and risk analysis has been developed over the last years to provide decision support for management levels at different spatial scales (see Hall et al. 2003, Penning-Rowsell et al. 2003). The assessment on the national level like NAAR, NaFRA and FORESIGHT is used to provide a monitoring of risks and financial needs and to support long-term expenditure planning and allocation of financial resources. CFMP and SMP provide decision support on a catchment level and, when they are fully developed, will have a role in prioritising areas for project development. Pre-feasibility studies aim at the sub-catchment level and try to identify the need for further, more detailed investigations. Eventually, on the local level, different scheme options are compared in feasibility studies in order to identify the best flood defence option or policy.

2.3 Damage categories considered

The damage categories or categories of valuables considered in four selected approaches are shown in Table 2.1.
The MCM provides methods for the quantification of many damage categories in monetary terms, not only for direct tangible damage, but also for indirect and some intangible losses. However, as was mentioned in one of the interviews (Wicks 2005), the focus of project appraisal often lies on direct tangible damage, although MCM and the FCDPAG3 are giving guidance for a whole range of damage categories. That means that if a scheme can be justified only by direct tangible benefits, other evaluation methods like the assessment of intangibles are not carried out because of the greater effort required for such examinations.
Nevertheless, there was just recently a supplementary note on the FCDPAG3 concerning a simplified incorporation of health impacts into economic appraisals in monetary terms (DEFRA 2004). The approximate average value of 200 British Pounds per year and household was derived from a detailed survey and it was recommended to use this average value in further studies (DEFRA & EA 2004).

Jon Wicks from Halcrow also mentioned in the interview that a simple method for the estimation of loss of life has been developed for the Thames Estuary Study. Furthermore, there is a research project funded by DEFRA and EA (2003c), which attempts to develop a method for the estimation of flood risks to people (including flood deaths). This is not implemented yet but it is intended to incorporate a methodology into future guidance (Richardson 2005).

At all spatial levels there are also examples for the use of the *Social Flood Vulnerabilty Index* (SFVI) as a measure for the coping capacity of the flood affected population. This index was developed by FHRC for CFMP at first (Tapsell et al. 2002) including indicators for vulnerable groups and persons like elderly people, lone parents as well as persons with pre-existing health and financial deprivation problems.

Table 2.1: Damage categories considered (England)

Damage category	***Macro: NAAR, NaFRA***	***Meso: MDSF***	***Meso/Micro: Lower Thames***	***Micro: MCM, FCDPAG3***
Direct, tangible Damages				
Residential Buildings	M	M	M	M
Household inventory	M	M	M	M
Vehicles/cars				
Non-residential buildings, fixture & fittings, movable equipment	M	M	M	M
Inventories	M	M	M	M
Livestock				
Infrastructure				
Streets				
Railways				
Ground Values	Agricultural Land			
Indirect Losses				
Loss of Value Added				M
Agricultural Production	M	M		M
Emergency costs			M	M
Traffic Disruption	M		M	M
Further:			Flood Warning (Benefits)	Surrogate costs: house renting, drying out process
Intangible Losses				
People	Q	Q		(under development)
Health				M
Environmental losses			Q	M
Recreational Losses				M
Cultural goods				
Toxification				
Further::	SFVI (Social Flood Vulnerability Index)	SFVI		SFVI

M = in monetary terms, Q = other quantitative units, D = descriptive, qualitative assessment

Although a large number of damage categories are considered, direct damage to infrastructure like streets and railway lines are not included. Only losses due to traffic disruption are estimated and there is also some consideration of highway repair costs in the emergency response allowance (Richardson

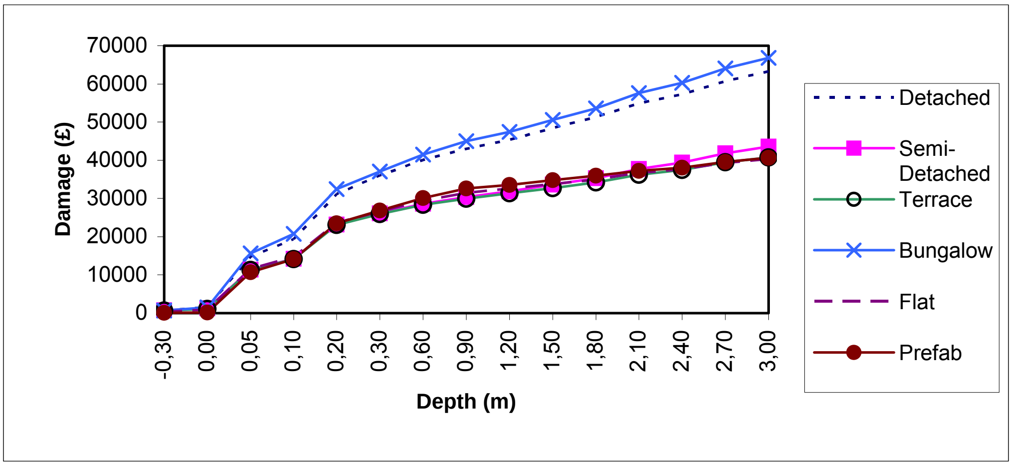
2005). Damage to cars or other motor vehicles is also not included. Richardson mentions the difficulty estimating damage rates for cars due to their mobility. For example the amount of damage sustained in a supermarket car park would be highly dependent on the time of day and day of the week when the flood struck as well as the warning time provided. According to Richardson, it is usually assumed that most damage to easily moveable property, such as cars, can be avoided by good flood warning and precautionary road closures hence the emphasis on evaluating delays and diversions. Assuming such damages as a benefit of both warning and alleviation schemes would be double counting.

2.4 Description of methods used for damage evaluation

As already mentioned above, the damage data of the Multi-Coloured Manual (MCM) builds the basis for damage evaluation at almost all levels, particularly regarding the damages to residential and non-residential properties.

The procedure for the derivation of these **damage functions** is the following. Regarding residential properties, at first a classification is carried out on type, age and social status. After that a typical inventory is compiled for each of these altogether 100 types. The depreciated value of the complete building structure inclusive its inventories is then determined according to replacement costs and market prices. On the basis of the assessment of loss adjusters the susceptibility of these assets to inundation depth is then assessed and finally absolute depth-damage functions are derived. Moreover, long and short flood durations are differentiated. Fig. 2.1 shows the damage functions for different types of houses.

Figure 2.1: Absolute damage functions for different residential house types (sector mean)



Source: Penning-Rowsell et al. 2003

Regarding non-residential properties, the classification of properties for large scale studies is taken from the focus database, a national property database. To derive damage functions for these different types of properties, interviews were carried out at a large number of firms to estimate, firstly, the approximate value of assets at risk in the different sectors and, secondly, the susceptibility of the respective properties. Unlike the damage functions for residential properties, these damage functions do not reflect absolute damages *per property* but *per square meter* of commercial property of a certain sector. At the detailed level of scheme appraisal it is recommended that further investigations of the damage potential for particular industrial or commercial properties is undertaken where these are likely to be significant in the overall evaluation.

This standard depth-damage data is used for damage evaluation on all spatial levels. However, the full level of detail, i.e. differentiation of this depth-damage data is not always used. It depends on the scale and the objective of a study and how detailed land use information is evaluated.

Regarding **land use data** for properties for large scale studies at national, regional or catchment scale, two important secondary sources exist in the UK: The AddressPoint database, which contains the location of every property, and the Focus database for non-residential properties, which includes information about the type of property (for example, residential, high street shop, etc) and its rateable value. Merging these two sources *Halcrow* created a database which includes all properties within floodplains in England and Wales (*National Property Dataset*). For each property category an average ground floor area is assumed (DEFRA et al. 2004b).

Within detailed project appraisals the whole level of detail of the standard damage data from FHRC is used. That means that in addition to the secondary land use data mentioned above it is necessary to carry out field surveys to evaluate the type and age of residential properties or the ground floor area of non-residential properties. Furthermore the threshold level, i.e. the water level at which water runs into the building, is estimated for every property in order to be able to determine inundation depth as exactly as possible. The social class of residential properties, however, is not determined by field surveys but from census data, where the distribution of households over four social classes is given for every enumeration district (approx. 150 households).

Within pre-feasibility studies and CFMP, however, no field surveys are carried out, i.e. only the above mentioned secondary sources are used to identify the land use. Correspondingly, only a sector average damage function can be used for all residential properties. Regarding non-residential properties, at least damage functions for a two-digit land use code can be used. According to Mr. Wicks, however, average ground floor areas for buildings have to be used. For the determination of the elevation of properties a Digital Terrain Model (LIDAR) may be used.

At the national level, at least regarding the NAAR (DEFRA 2001) no depth-damage functions are applied, because only inundation areas but no inundation depths are evaluated in this study. For the loss estimation so called "weighted average annual damages" are used. This average damage for properties is based on the assumption of an average depth of flooding for a range of return periods derived from empirical flood data (see Penning-Rowsell et al. 2003). While in the NAAR only a differentiation between residential and non-residential property is made, the newer NaFRA based on the RASP high level method (Sayers et al. 2002) is implementing the standard damage data (sector averages) of the *Multi-Coloured Manual* at the same level of detail as in CFMP. This becomes possible because the National Property Database is now available, which allows at least to distinguish between different types of non-residential properties.

While the evaluation of direct tangible damage builds the core of most damage evaluation studies, methods for the assessment of indirect or intangible losses are also described in the MCM and in the FCDPAG3 (DEFRA 1999).
The costs of emergency services during floods as an indirect loss are analysed by FHRC (Penning-Rowsell et al. 2003). As a result of the analysis of the losses of the autumn 2000 floods the MCM recommends a multiplier of 1.107 for emergency costs on top of property damages.
The methods for the evaluation of losses due to road and railway traffic disruption described in the MCM are quite extensive. Therefore, it is recommended only to include these losses in appraisals if main roads or railways are affected. The calculation is mainly based on the costs of delay when alternative routes have to be used.

The **indirect losses** for non-residential properties can be calculated as the loss of value added during the flood. Indeed, as it is mentioned in the FCDPAG3 (DEFRA 1999) and in the MCM (Penning-Rowsell et al. 2003) these losses are financial rather than economic, which means that there do occur losses for the affected firms but mostly not for the national economy, because nearly all production losses can be transferred to other firms. Therefore, in FCDPAG3, it is recommended to carry out such evaluations only for special circumstances, e.g. if a loss of production to other countries is likely to occur.

For the evaluation of agricultural losses the FCDPAG3 (DEFRA 1999) describes a method which considers the changes in agricultural net product. According to Richardson, this method is currently under review.

As indirect costs for residential properties the MCM (Penning-Rowsell et al. 2003) mentions the loss of own accommodation opportunities and it is recommended to use average costs of renting an equivalent home for about one month to estimate this kind of damage. Furthermore, moisture problems in buildings are listed as an indirect damage, which can be monetised by means of average costs for dehumidification.

Regarding **intangible losses**, health effects have recently been incorporated in the project appraisal process. As mentioned above, an average value per household and year of 200 British Pounds is used as a basis for the calculation of the benefits of avoiding these impacts (DEFRA 2004).

One interview partner mentioned that recreational losses could only occur in a few cases as a consequence of coastal erosion (Penning-Rowsell 2005). For the evaluation of these losses it is necessary to evaluate the number of visits per year and the value of enjoyment per visit. The latter can be derived through Contingent Valuation techniques or, if only a rough estimation is required, standard values from the MCM (Penning-Rowsell et al. 2003) can be used.

There are also methods described in the MCM and FCDPAG3 for the monetary assessment of environmental losses (non-use values). The value of these sites or goods can be estimated through replacement cost, relocation costs, costs for local protection or, if a more detailed approach is required, Contingent Valuation techniques can be used. Nevertheless, it is pointed out that such a monetary valuation is only necessary if it is likely that a significant part of all losses arise from environmental losses. If not evaluated in monetary terms, environmental consequences are nevertheless taken into account in non-monetary terms by means of environmental assessment and as part of DEFRA's prioritisation system for flood defence measures (see chapter 2.2).

Another major criterion in this prioritisation system is the number of people or households at risk. The estimation of the number of flood-affected persons is therefore an integral part of, e.g., the MDSF. However, up to now no standardised methods for the estimation of casualties due to flooding exist. As mentioned by Wicks, a rough estimation will be part of the Thames Estuary study, which is based on variables like the rise rate of inundation, the mobility of people and the effects of flood warning. Representatives of DEFRA and FHRC said that a research project dealing with this "Risk to Life"-issue is currently in process (DEFRA & EA 2003c) and, as noted above, the results will be incorporated in future guidance.

2.5 Integration in benefit-cost analysis

At all spatial levels damage evaluation is used as a part of a benefit-cost analysis. Therefore, it is not sufficient to calculate the expected damages for just one inundation scenario but for all possible floods with the whole range of probabilities of occurrence. By evaluating the damages for at least three inundation scenarios of different probabilities a loss-probability curve can be derived, showing the total risk as the area under the curve (annual average damage). For each scheme the estimated changes of the loss probability curve and consequently the risk reduction or benefit against the "do nothing" option is calculated (annual average benefit). As the whole life of a scheme has to be taken into account, future benefits have to be discounted to come to the present value of benefits which could be finally compared with the costs of each scheme (see DEFRA 1999).

2.6 Shortcomings, Uncertainties, Improvements & Comments

Even though the methodology of risk and damage analysis is quite sophisticated in England and Wales, the interview partners were also asked about shortcomings of the existing methods and major sources for uncertainties within the results. Considering damage evaluation it was stated that the accuracy of digital elevation data was a problem but has been improved recently, so that it is now easier to estimate property thresholds and inundation depth (Wicks 2005). Regarding the standard damage data from FHRC some interview partners noted that the non-residential depth-damage data, which was restructured and simplified in the MCM (Penning-Rowsell et al. 2003) still needs further substantiation by more survey data (Penning-Rowsell 2005, Wicks 2005). It was also mentioned that it might be necessary to update the depth-damage data more frequently due to the changes in value of properties over time (Penning-Rowsell 2005). Although a lot of research is done about the integration of intangibles in England it was also stated that further improvements should be made in this area (Penning-Rowsell 2005).

As a great disadvantage of the common approach of benefit assessment it was noted that it could lead to preferential treatment of rich people (Richardson et al. 2005). As poorer people possess less expensive properties the benefit of protecting them from floods, according to the strict benefit-cost approach, is comparably low. In view of this, weighted factors are now included, as advocated by the Treasury (HM Treasury, 2003) for different social groups in appraisals to reflect socio-economic equity (DEFRA 2004). The result is that for most appraisals involving residential property, the use of average loss values for property types across all social groups is recommended (Richardson 2005).

Another shortcoming may be the omission of direct damages regarding traffic infrastructure and cars. Ex-post analyses of the Elbe 2002 flood show that in particular damage to public infrastructure can be one of the most important damage categories (IKSE 2004).
Pertaining to the assessment of flood risks in the long run it was mentioned that major sources of uncertainties exist as regards crucial future development variables like impacts of climate change, policy changes, patterns of economic development, and land use changes (Richardson et al. 2005).
Agreed precautionary approaches to climate change are included in current guidance and kept under review as further research results become available and likely development patterns are taken into account in larger scale studies but there is ongoing work to consider other areas of uncertainty (Richardson 2005).

Last but not least one interview partner said that until now no comparison of the results of the methods used on different levels has been executed in order to test or demonstrate their degree of accuracy (Penning-Rowsell 2005). However, a comparison of ex-ante with ex-post damage analysis results of the autumn 2000 floods has been done, revealing that ex-ante analyses are leading to quite good results.

References for this country study are listed in chapter 7.1.

3. Methods of Flood Damage Evaluation in the Netherlands

Sources of information:
- Interview with Stephanie Holterman from Rijkswaterstaat, Delft, 17.2.2005 (*Holterman 2005*)
- Published and unpublished literature as listed in the reference list of chapter 7.2

3.1 Existing approaches on different spatial scales

In the Netherlands (NL) flood protection today is still very much based on high safety standards. Nevertheless, as benefit-cost aspects gained in importance over the last years, a standard method for flood damage evaluation in all 53 Dutch dike ring areas has been developed. The development of this method is carried out by *HKV consultants* and *TNO Bouw* and supervised by the Highway and Hydraulic Engineering Department of the Department of Public Works (Rijkswaterstaat) for the Ministry of Transport, Public Works and Water Management. The newest version is called "Standard Method 2004 – Damages and Casualties caused by Flooding" (Kok et al. 2004; Kok et al. 2002) and it is part of the *Flood Management System* (Hoogwater Informatie Systeem; HIS). There also exists standardised software for this method called HIS-SSM (Schade en Slachtoffers Module; Huizinga et al. 2002).

3.2 Objective of damage evaluation

Up to now there are four different safety standards for the 53 dike rings in the NL defined by law (with return periods of 1250, 2000, 4000 and 10000 years). The decision as to which safety standard is provided for which dike ring depends on the type of threat (coastal or river flooding) and on the value of the assets which are located and protected in each dike ring. There was only a rough estimation of values of elements at risk in the 1960s when safety standards were fixed by the *Delta Commission* (Holterman 2005). Only for one dike ring area was a benefit-cost analysis carried out.

With the development of the HIS and the Standard Method a new scientific basis for the estimation of the risk within each dike ring is provided. Up to now the results of the HIS (and HIS-SSM) are mainly used for the information of decision makers on the national and regional level, for example to show where the most severe damage could occur, or as a decision support in land use planning. In the longer run the results are also intended to be a basis for benefit-cost oriented planning of flood defence measures (Holterman 2005).

3.3 Damage categories considered

The damage categories or categories of valuables considered in the standard method are shown in Table 3.1. The standard method considers quite a lot of asset categories (see also Tab. 3.3). For most of them a differentiation is made between direct damage, primary indirect damage (which are called *direct damage through business interruption* in the context of the standard method) and secondary indirect damages (losses occurring outside the dike ring area). As the only intangible category the standard method tries to give an estimation of the number of casualties (see Jonkman et al. 2004; Jonkman & Vrijling 2005).

Table 3.1: Damage categories considered in the Netherlands

Damage category	***Standard Method***
Direct, tangible Damages	
Residential Buildings	M
Household inventory	M
Vehicles/cars	M
Non-residential buildings	M
Fixture & fittings, movable equipment, inventories	M
Livestock	M
Infrastructure	
Streets	M
Railways	M
Other:	
Airports	M
Other urban area infrastructure	M
Ground Values	
Other:	
Recreation	M
Indirect Losses	
Loss of Value Added	M (primary, secondary)
Agricultural Production	M
Emergency costs	
Traffic Disruption	M
Other:	
Intangible Losses	
People (Casualties)	Q
Health	
Environmental losses	
Recreational Losses	
Cultural goods	
Toxification	

M = in monetary terms, Q = other quantitative units, D = descriptive, qualitative assessment

3.4 Description of methods used for damage evaluation

As an input for the Standard Method inundation characteristics derived from representative dike breach scenarios are used. For each of these scenarios an aggregate failure probability is calculated by software like PC-Ring. The inundation characteristics are calculated by a hydrodynamic model for a 100m grid. Especially inundation depth is needed for the damage evaluation. In case of residential buildings impacts of velocity and waves are also considered. Regarding casualties, three different inundation characteristics are taken into account: velocity, rise rate and inundation depth.

The amount of tangible damage for each grid cell is calculated by the formula

$$S = \sum_{i=1}^{n} \alpha_i n_i S_i$$

with n_i = number of units in category i
S_i = maximum damage per unit in category i
α_i = damage factor category i

That means the three essential parts of the damage evaluation of the standard method are: firstly, the gathering of land use information, secondly the estimation of maximum damage amounts (or maximum *damage potential* or *value*) per unit of each category and thirdly the derivation of (depth-) damage functions.

- **Land use data**: There is a differentiation in the level of detail between the damage categories considered (see Tab. 3.3). Some land use categories which are more or less extensively used like agricultural land etc. are included in land use units, i.e. in square meters based on CBS land use data. Linear infrastructure elements, like streets and railways are indicated in metres based on data from other official sources. Regarding households and firms a more detailed approach is followed: household property is evaluated per dwelling. Due to the use of commercial land use data (*Bridgis*) five dwelling types can be distinguished. Regarding companies, the number of employees in each economic sector is used to approximate the intensity of economic land use. In this context *Dunn & Bradstreet* data is applied. All land use information gathered is transformed in the same 100m grid used within the inundation simulation.
- **Maximum damage amounts**: For each of these damage categories a maximum damage amount (i.e. the total value) for the particular unit is given, based on surveys and estimations of Briene et al. (2002; see Tab. 3.3). Basis for the calculation are prices of the year 2000. There is no regional differentiation made, although Briene et al. (2002) are specifying the range of the values.
  For example, for the estimation of dwelling damage, median market values are used, adjusted by the approximate ground value. The value of average contents per dwelling of 70.000 EUR was derived in a study by www.ineas.nl, an insurance company. The amount of capital assets is calculated by the amount of depreciation over a certain period in each sector, using current replacement values. For agriculture the production value per hectare of grass- and farmland is applied as well as the market value of inventories, stables and machinery. Regarding infrastructure the value of investments on assets (e.g. streets, railways, and other forms of public infrastructure) is taken. The current value of cars per household is calculated on the basis of market values for new cars, assuming a linear depreciation. In contrast to all other damage categories a correction factor is applied to consider the fact that not all cars would be damaged in case of flooding (Briene et al. 2002). However, it is not explicitly described how this correction factor is derived.
  Indirect maximum damage amounts through business interruption are evaluated on the basis of gross value added. For the secondary indirect losses outside the respective dike ring area a multiplier on this value is derived by regional input-output tables for each economic sector. For national trunk roads and railways there is also an estimation of losses due to traffic disruption.
- **Damage functions**: Altogether eleven damage functions are derived from a study by Vrouwenfelder (1997). The categorisation is shown in table 3.2. Basis for the development of the functions are both damage data and expert judgement (Holterman 2005). There is only a small damage database in the NL due to the fact that flooding does not occur very frequently. The damage functions are mostly depth-damage functions. Only the damage factor for dwellings additionally takes into account a critical velocity of inundation and the impact of waves caused by storms (Kok et al. 2004).

Table 3.2: Categorisation of damage functions in the Standard Method

1: Damage function ‘Agriculture, recreation and airports’
2: Damage function ‘Pumping stations’
3: Damage function ‘Vehicles’
4: Damage function ‘Roads and railways’
5: Damage function ‘Gas and water mains’
6: Damage function ‘Electricity and communication systems’
7: Damage function ‘Companies’
8: Damage function ‘Single-family dwellings and farms’
9: Damage function ‘Low-rise dwellings’
10: Damage function ‘Intermediate dwellings’
11: Damage function ‘High-rise dwellings’

Source: Kok et al. 2005

The approach described above refers to areas with a low frequency of flooding, i.e. to dike ring areas with a high protection standard. Regarding high-frequency flooded areas, i.e. less protected areas at the upper parts of some rivers, it is expected by Kok et al. (2004) that total damage amounts will be lower due to a kind of preparedness for flooding. Until further research is carried out on this topic, it is recommended in the Standard Method to include preparedness aspects by reducing the maximum damage amount by 25%.

Table 3.3: Standard Method: damage categories, units, maximum damage amounts, damage functions used and land use data sources (for low frequency flooded areas)

	Damage category	***Unit***	***Average maximum damage amount per unit (€)***	***Associated Damage function (of Tab. 3.2)***	***Source (data file used in the standard method)***
Land use	Agriculture direct	m^2	1.50	1	CBS land use
	Agriculture indirect	m^2	1.60	1	CBS land use
	Greenhouse horticulture direct	m^2	40.10	1	CBS land use
	Greenhouse horticulture indirect	m^2	4.00	1	CBS land use
	Urban area direct	m^2	48.60	1	CBS land use
	Intensive recreation direct	m^2	10.90	1	CBS land use
	Extensive recreation direct	m^2	8.90	1	CBS land use
	Airports direct	m^2	1 197	1	CBS land use
	Airports i.b.	m^2	36	1	CBS land use
Infrastructure	National trunk roads direct	m	1 450	4	National Wegen Bestand (NWB)
	National trunk roads indirect	m	650	4	NWB
	Motorways	m	980	4	NWB
	Other roads	m	270	4	NWB
	Railways direct	m	25 150	4	Nederlandse Spoorwegen (Spoor_NS)
	Railways indirect	m	86	4	Spoor_NS
	Railways i.b.	m	151	4	Spoor_NS
Households	Low-rise dwellings	unit	172 000	9	Bridgis dwelling types
	Intermediate dwellings	unit	172 000	10	Bridgis dwelling types
	High-rise dwellings	unit	172 000	11	Bridgis dwelling types
	Single-family dwelling	unit	241 000	8	Bridgis dwelling types
	Farm	unit	402 000	8	Bridgis dwelling types
	Vehicles	unit	1 070	3	revised Bridgis people file
Companies	Mineral extraction direct	employee	1 820 000	7	Dunn & Bradstreet (D&B)
	Mineral extraction indirect	employee	116 000	7	D&B
	Mineral extraction i.b.	employee	84 000	7	D&B
	Industry direct	employee	279 000	7	D&B
	Industry indirect	employee	70 000	7	D&B
	Industry i.b.	employee	62 000	7	D&B
	Utilities direct	employee	620 000	7	D&B
	Utilities indirect	employee	163 000	7	D&B
	Utilities i.b.	employee	112 000	7	D&B
	Construction direct	employee	10 000	7	D&B
	Construction indirect	employee	26 000	7	D&B
	Construction i.b.	employee	45 000	7	D&B
	Trade, catering direct	employee	20 000	7	D&B
	Trade, catering indirect	employee	3 500	7	D&B
	Trade, catering i.b.	employee	7 500	7	D&B
	Banks, insurance direct	employee	90 000	7	D&B
	Banks, insurance indirect	employee	7 000	7	D&B
	Banks, insurance i.b.	employee	14 000	7	D&B
	Transport and communication direct	employee	75 000	6	D&B
	Transport and communication indirect	employee	6 400	6	D&B
	Transport and communication i.b.	employee	11 200	6	D&B
	Care provision, other direct	employee	20 000	7	D&B
	Care provision, other indirect	employee	6 300	7	D&B
	Care provision, other i.b.	employee	3 400	7	D&B
	Government direct	employee	60 000	7	D&B
	Government indirect	employee	2 200	7	D&B
	Government i.b.	employee	9 200	7	D&B
Other	Pumping stations	unit	747 200	2	WIS
	Purification plant	unit	10 853 000	5	WIS

Source: Kok et al. 2004

Regarding the estimation of **casualties** as a consequence of flooding, further research has been executed recently by Jonkman et al. (2004; Jonkman & Vrijling 2005), with the result that the method used in the Standard Method 2002 (Kok et al. 2002) could be improved for the current version (Kok et al. 2004). While the 2002 approach gives a rough estimation of the number of casualties based on information about the inundation characteristics depth and rise rate, the new approach refers to further empirical data and distinguishes three factors which might lead to death during a flood:

- High velocity (mostly in areas near the location of dike breach)
- High rise rate in combination with inundation depth (in areas with a high rise rate)
- Hypothermia, exhaustion, getting trapped (in the remaining areas)

Each grid cell is assigned to one of these three cases, so that there is only one function for each location. The number of residents for each grid cell is derived by means of commercial data (Geo-Marktprofiel BV). It is assumed that residents living in high-rise dwellings (>4 floors) will find shelter in the upper floors, so their number is removed from the dataset and not used for the estimation of casualties. The Standard Method also permits the inclusion of an evacuation factor, derived from a tool called *EvacuatieCalculator* developed at University of Twente.

Finally, in combination with the probabilities of the representative breach scenarios the flood risk for each grid cell can be calculated in terms of expected damages and number of casualties.

3.5 Shortcomings, Uncertainties, Improvements & Comments

The development of a Standard Method for the whole Netherlands has the advantage that there is a method which is easy to apply and provides comparable results. On the other hand this standardisation on a meso scale of course cuts down the accuracy in some respects. As it is stated in the Standard Method (Kok et al. 2004; Briene et al 2002), it is not possible, for example, to make any regional differentiation regarding the maximum damage amounts, or to make a distinction between damages caused by salt or fresh water.

Another shortcoming refers to the fact that the same depth-damage functions used for the calculation of direct damages are also used for the estimation of indirect losses. For example, regarding losses due to business interruption, inundation depth does not seem to be the most important factor. In this case, the duration of flooding might be a more important variable to be used for damage calculations.

Concerning the variability of damage potential over time Holterman stated that the maximum damage amounts are updated about every four years[1], and land use data seems to be updated periodically, too.
With regard to uncertainty in the whole HIS-process of risk analysis it was expected by Holterman that the most uncertain parts are, firstly, the estimation of breach locations and corresponding probabilities and, secondly, the calculation of the number of casualties – although some improvements have been made in this field of research.

References for this country study are listed in chapter 7.2.

[1] Further actualisation can be done by price indices (Briene et al. 2002)

4. Methods of Flood Damage Evaluation in the Czech Republic

Sources of information:

- Interview with Ladislav Satrapa and Martin Horsky from the Faculty of Civil Engeneering of the Czech Technical University in Prague, Prague 23.6.2005 (Satrapa & Horsky *2005*)
- Published and unpublished literature and presentations as listed in the reference list of chapter 7.3

4.1 Existing approaches on different spatial scales

The practical application of flood damage analysis is a relatively new element in Czech flood policy. Its application was promoted after major flood events in 1997 and 2002. Over the last years Mr Satrapa's group from the Czech Technical University (CTU) developed a system of three methods of damage evaluation with different levels of accuracy. All three methods are based on the same approach, using object-orientated land use information, an estimation of values of assets at risk per metre or cubic metre, mainly based on data from official statistics, and a kind of relative damage functions (Satrapa et al. 2005; Satrapa & Horsky 2005):

- "Method 3" is a detailed method for studies on a local scale. For this method site surveys are necessary. This method has been applied in three pilot studies, among others at Elbe River sites. It is also applied by Mr Drbal for the study of the International Commission for the Protection of the Elbe (IKSE).
- "Method 2" is a simplified version of method 3 for a regional scale. It relies mostly on secondary digital land use data. Site surveys are only necessary for special objects for which the secondary data is not sufficient.
- "Method 1" is a quick method for the national level, which relies completely on secondary data, but in other respects is more or less the same as method 2.

Furthermore, another method of damage evaluation is part of the Flood Analysis Toolbox (FAT) developed by the Danish engineering consultant DHI and the Morava Waterboard (Biza et al. 2001). It applies object-orientated (digitised) land use information and absolute damage functions which are derived from 1997 flood data. According to Satrapa, this approach is not as detailed as the methods mentioned above. The FAT also provides a tool for a complete benefit-cost analysis in order to assess flood protection measures.

4.2 Objective of damage evaluation

After the floods in 1997 and 2002 the responsible Ministry, the Ministry of Agriculture (before: Ministry of the Environment) sought to optimize flood protection policy through the integration of efficiency aspects. General rules for this new approach are formulated in the "Strategy of the flood preventive measures in CR" by the Ministry of Agriculture.

Up to the year 2008 several million Czech Crowns will be spent on flood protection measures, funded on the one hand by national budgets, but on the other hand also by the European Investment Bank. It is required by the European institution that its funds are used efficiently. Accordingly, an economic assessment of the planned policy measures has to be carried out. Currently about 400 measures are proposed by the responsible Czech Waterboards and other responsible institutions. Up to an early stage in the planning process the design of these measures is not influenced by criteria of economic efficiency, but is based mainly on water engineering expertise. A first assessment of these measures was mainly based on cost and water engineering criteria. For the second stage of the assessment, which is envisaged to be finished in November 2005, a complete benefit-cost analysis is carried out for about 300 measures. This study, undertaken by the group from CTU on behalf of the Ministry of Agriculture, applies Method 2 of damage evaluation as described above. The measures will be prioritised during this assessment and, if not efficient, rejected or refined. However, the final decision on flood protection measures does not depend exclusively on benefit-cost criteria, but on the criteria *people at risk* and *employees at risk*, too. The weighing of these criteria is left to the decision makers, i.e. there is no fixed weighing system like in DEFRA's prioritisation system in England (see chapter 2.2).

Method 1, which is the quick, more approximate method, will not be used for the assessment of single measures, but more for information about potential damage on the national level and for a justification of financial needs for flood protection. The most detailed Method 3, which is applied in three pilot areas, is used for verification and validation of the other two methods.
The results of damage and risk analysis have no explicit influence on land use planning, but are obviously considered among other aspects.

4.3 Damage categories considered

The damage categories considered in three methods are shown in Table 4.1.
The methods are mainly focussing on the evaluation of direct, tangible damage. In particular the estimation of damage to buildings is very sophisticated. All kind of building equipment (household inventories, commercial and industrial inventories, municipal equipment) is included as well as a lot of categories of technical infrastructure.

Regarding indirect losses, in particular losses to agricultural production are considered. Furthermore, consequences on the turnover of firms of other sectors are estimated (per number of employee) and flood insurance costs are assessed (at least for properties which are surveyed).
The only intangible category included in monetary terms is the flood impact on health.

Table 4.1: Damage categories considered in the Czech Republic

Damage category	*Method 1, 2 & 3*
Direct, tangible Damages	
Residential Buildings	M
Household inventory	M
Vehicles/cars	
Non-residential buildings	M
Inventories, fixture & fittings, movable equipment of non-residential properties	M
Equipment of municipal facilities	M
Livestock	
Infrastructure	M
Streets	M
Railways	M
Further:	Bridges (M) Communication infrastructure (M) Damages on water courses (M)
Ground Values	
Indirect Losses	
Loss of Value Added	M (Consequences to turnover)
Agricultural Production	M (only crops; measured in production costs)
Emergency costs	
Traffic Disruption	
Further:	M (Insurance costs)
	Loss of market positions
Intangible Losses	
People	Q (people affected)
Health	M (will be included soon) Method: statistical analysis of data from a medical insurance company 2000-2004
Environmental losses	
Recreational Losses	
Cultural goods	
Toxification	D

M = in monetary terms, Q = other quantitative units, D = descriptive, qualitative assessment

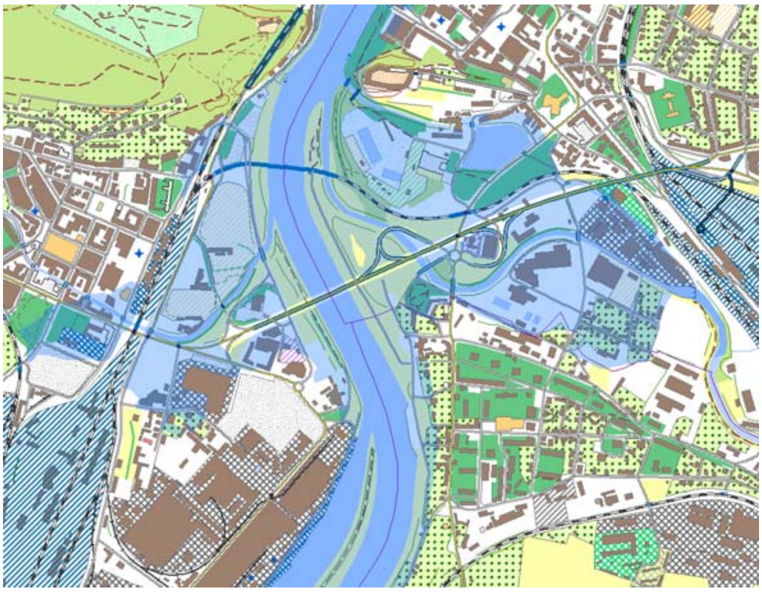
4.4 Description of methods used for damage evaluation

As mentioned above, the approach to damage calculation is more or less the same in all three methods. The main difference refers to the kind of data, especially **land use data,** used. I.e., a major distinguishing factor of the methods refers to the aspect, whether site surveys are executed or mainly secondary sources are used.

All three methods are using the following land use data sources:

- *Zabaged*, a basic digital topographic data source (see Fig. 4.1) with information on the location and size of buildings, streets, rivers etc.

Figure 4.1: Zabaged-data: example from Decin



Source: Satrapa et al. 2005

- Register of economic subjects: contains the address of each firm, its size (number of employees), branch and legal form.

- RSO address point data with the number of people and flats per address point. The small yellow dots in Fig. 4.2 each symbolise one address point.

Figure 4.2: RSO address point data: example from Decin

Source: Satrapa et al. 2005

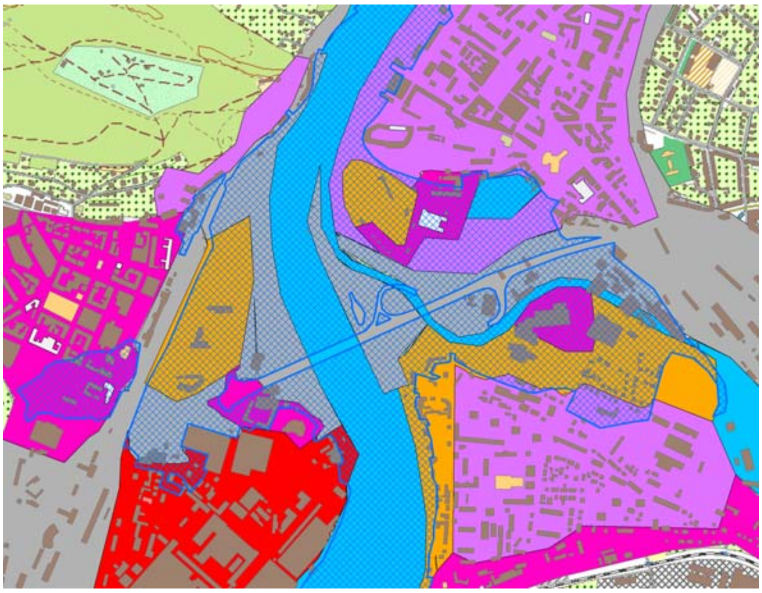
- Orthophotos (Fig. 4.3)

Figure 4.3: Orthophoto: example from Decin

Source: Satrapa et al. 2005

Method 3 additionally applies cadastral maps, providing detailed information of location and ground floor area of each property and building as well as its usage. Method 2 uses an aggregated land use data source for towns, called UPD (see Fig. 4.4), while Method 1 uses a more generalised version of UPD for whole districts.

Figure 4.4: UPD town data: example from Decin



Source: Satrapa et al. 2005

The main difference between the methods is the extent of gathering detailed object-orientated land use information by site surveys. For the pilots of method 3, complete site surveys are carried out, collecting the following additional information:

- Construction material
- Number of floors
- Height of each floor
- Height of first floor above ground
- Information about cellarage
- Age of objects
- Photo documentation

Within Method 2, site surveys are only carried out for special objects and in Method 1, they are not used at all. This is reflected in the level of detail of differentiation of land use: While Method 3 distinguishes between about 200 different types of buildings (types, subtypes and construction characteristics) in Method 1 and 2 only five different types (residential buildings, industrial buildings and halls, municipal facilities, buildings and halls) are used.

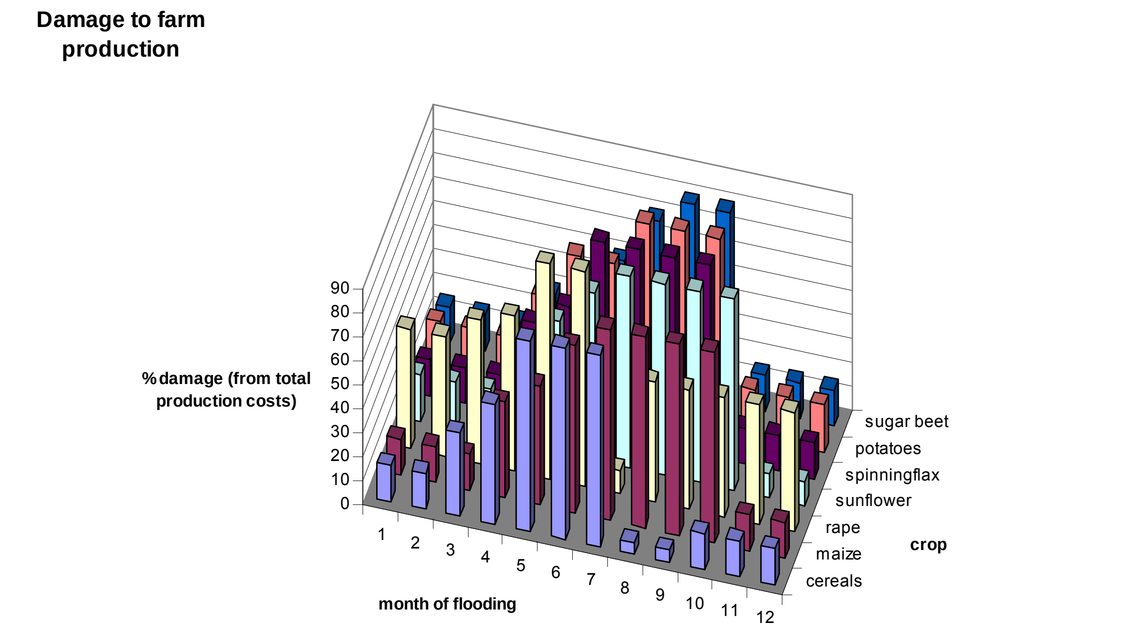
The total **value of elements at risk** is not explicitly calculated, but more or less included in the damage calculation theorem. For example, the value of buildings is estimated by construction costs (full replacement value) per cubic metre based on data on building components from JKSO (ÚRS Praha, a.s., Engineering and Consulting Company). By multiplication of the construction cost per cubic metre with the height of each floor affected and the ground floor area (based on land use data), the total value of the each floor is calculated as a basis for the damage calculation with relative damage functions. In Method 2 and 3 a lower and upper limit of value per cubic metre is used to reflect the diversity of different house types.

The costs of technical infrastructure per metre or square metre and the approximate value of household inventories per flat/property are also derived from official data (Czech Statistical Institute). The costs per square metre of equipment of municipal facilities stem from surveys.
The value of industrial inventories and stocks as well as annual turnover is derived from statistics and additional surveys.
The value of agricultural production per hectare is based on production costs for different crops published by the Czech *Institute for Agriculture Economy* (Satrapa & Horsky 2005).

For the damage calculation of buildings relative **depth-damage functions** are used, showing the damage share of total construction costs. These are mainly derived synthetically, based on the assumptions of structure components per type of building, but are also refined by experience from the last floods. While for Method 3 about 200 different damage functions have been developed for each building-subtype, Method 1 & 2 are applying only five different functions for the five main building types. As already practised in the calculations for the object values, upper and lower susceptibility limits are used for the damage functions to reflect the variety within each class. In Method 1 and 2 only inundation depth is considered as a flood characteristic for damage calculation. Method 3 also includes velocity – at least if data is available – and envisages the application of depth/velocity-damage relationships.

For household goods or other kinds of inventories or equipment no depth-damage functions are used. That means that the total value of inventories is assumed to be lost in case of flooding, but only for houses and flats affected by flooding higher than 0.7 m (Satrapa & Horsky 2005).
Regarding streets, an approximate share of damage independent from inundation depth is assumed. As far as damages to the sewerage system are concerned, only clean-up costs are considered.
Referring to agricultural production, not inundation depth but the month of occurrence of the flood is used as the main indicator to estimate the proportion of loss in production (see Fig. 4.5).

Figure 4.5: Damage to farm production according to month of flood occurrence



	1	2	3	4	5	6	7	8	9	10	11	12
cereals	15	15	35	50	80	80	80	5	5	15	15	15
maize	15	15	15	40	50	70	80	80	80	80	15	15
rape	50	50	60	65	90	90	10	50	50	50	50	50
sunflow er	20	20	20	40	55	70	80	80	80	80	10	10
spinningflax	15	15	15	40	50	80	80	80	80	15	15	15
potatoes	20	20	20	40	60	60	80	80	80	20	20	20
sugar beet	15	15	15	30	30	50	70	80	80	15	15	15

Source: Satrapa et al. 2005

Consequently, the theorem of flood damage calculation depends on three pieces of information: the damage categories affected and included, the data on damaged objects as well as the damage functions and factors to be applied. For buildings, which form the most significant damage category, the formula for the estimation of damages to an individual building floor under water reads:

$$\text{DAMAGE} = H \cdot C \cdot \%p \cdot A \quad [\text{Kč}]$$

with

- H [m] – Height of each floor of an individual building
- C [Kč/m³] – Price of a cubic metre of a building based on JKSO data (from ÚRS, a.s); (C*H = price of one square metre of a building´s ground floor area)
- A [m²] – Ground floor area of the building (GIS based)
- %p [-] – Percentage of damage to building according to damage function (source: Analysis of CTU)

Costs of health problems due to flooding are the only intangible loss category, which is estimated in monetary terms. In this regard, a statistical analysis of data from a medical insurance company for the years 2000-2004 has been carried out to determine which diseases have occurred significantly more often during or after the 2002 floods. In a second step the societal costs of these diseases will be monetised. Medical experts will be asked in a survey, which therapy is provided for each of the relevant diseases and what amount of therapy costs are likely to arise. Based on the survey results the average therapy costs will be estimated in monetary terms. The study on this subject is still on-going and will be finished by the end of 2005.

4.5 Integration in benefit-cost analysis

For every flood protection measure a complete benefit-cost analysis is carried out. Therefore, flood damages are calculated by the methods described above for three flood scenarios: the HQ 5, 20 and 100 events.[2] From the results a loss-probability curve is created. Flood risk in terms of the annual average flood damage is calculated by applying a Monte-Carlo simulation creating a synthetic series of peak flows for 10000 years and a corresponding series of flood damages. A discount rate of 3% is applied to arrive at the present value of risk.

This risk calculation is carried out for the situation *before* and *after* implementing the respective measure. By comparing the results *Risk before* and *Risk after* the benefit of each measure can be estimated. Three benefit-cost criteria are calculated as a result of the analysis (Fosumpaur et al. 2005):

- **payback period** , i.e. the time period in which the benefits will exceed the costs of the measure (costs / annual average damages).
- **relative efficiency** [-] = relation of discounted benefits to discounted costs (benefit / costs)
- **total efficiency** [$] = benefits minus costs (benefits – costs)

As described above, these efficiency-criteria will be used for the selection and prioritisation of flood protection measures.

4.6 Shortcomings, Uncertainties, Improvements & Comments

The uncertainties in the results of damage evaluation are very well integrated and documented in the methods by using minimum and maximum estimations of asset values and applying lower and upper limits of damage functions. As a result, a minimum and a maximum for the expected flood damage can be estimated for each measure considered.

Satrapa stated that results of these ex-ante flood damage calculations compared to outcomes of ex-post damage calculations for the 2002 floods showed that the ex-ante results regarding building damages and especially the damages of agricultural production were lower than the ex-post results. These deviations could of course also be due to overestimations in the ex-post analysis.
Last but not least, it was stated that for a further improvement of ex-ante damage estimation a refinement of the damage functions by empirical damage data would be helpful.

References for this country study are listed in chapter 7.3

[2] According to Satrapa, for special, detailed analyses, more events are taken into account (HQ 2, 5, 10, 20, 50, 100 and Qmax).

5. Methods of Flood Damage Evaluation in Germany

Contrary to the countries discussed above, the competencies of flood and water policy in Germany lie with the individual German federal states and not with the central government. As a consequence, given the different geographical circumstances, different levels of flood hazards and risks in each of the federal states, and also different philosophies regarding flood protection, the activities in flood protection policy and flood damage analysis vary quite significantly.

For example, there is a relatively long tradition in flood damage evaluation alongside the River Rhine in North-Rhine Westphalia. One reason for this might be the frequency and severity of floods on the River Rhine which were further fuelled in the past through intensive river regulations. Another reason refers to the enormous economic importance of the River Rhine for transportation of cargo, fishing, and the like. Since floods did not only threaten people, but also important economic activities on the Rhine, the consideration of benefits and costs of flood protection measures started relatively early in North Rhine-Westphalia. Regarding coastal protection, the state of Schleswig-Holstein is one of the leading regions considering the use of flood damage evaluation as a decisions support in flood risk management.

The federal states alongside the River Elbe – which flows through the former German Democratic Republic, some north-western states and then empties into the North Sea – were less concerned with flood protection policy. The River Elbe is much less regulated, there are larger natural flood retention areas, the river basin is flat in most of its parts and hence less flood-prone, there are less transportation activities on the river due to historical reasons (iron curtain), and the frequency of floods is much lower than in other parts of Germany. However, especially after the Elbe flood of 2002, major flood protection activities started to improve technical protection and, also, to include efficiency aspects in the decision over new measures.

In order to cope with the variety of different flood protection policies in the German federal states, four federal states were selected for expert interviews. North-Rhine Westphalia and Schleswig-Holstein were chosen to reflect the states with long traditions in flood protection policy and flood damage evaluation along the River Rhine and on the German Coast. Furthermore, Saxony and Saxony-Anhalt were included, which are two important East German riparian federal states of the River Elbe with quite different flood policy philosophies.

5.1 North Rhine-Westphalia

Sources of information:

- Interview with Mekuria Beyene from the Engineering Consultancy *ProAqua*, Aachen, 26.1.2005 (Beyene 2005)
- Published and unpublished literature as listed in the reference list in chapter 7.4

5.1.1 Existing approaches on different spatial scales

The Engineering Consultancy *ProAqua* is strongly involved in the development and application of methods of flood damage evaluation, mainly in North Rhine-Westphalia (NRW) but as well in other German federal states like Lower Saxony and Baden-Wuerttemberg. While *ProAqua* has a hydraulic engineering background, socio-economic expertise is often contributed by Mr. Pflügner (Consultancy *PlanEVAL*). The methods of damage evaluation discussed in the meeting are the following:

- On the federal state level a meso-scale damage and risk analysis was carried out for the Rhine in NRW (MURL 2000a,b) by ProAqua, PlanEVAL and the Technical University of Aachen, funded by the Ministry for the Environment, Spatial Planning and Agriculture of NRW.
- *ProAqua* was also involved in damage evaluation for the River Danube (Donau) in Baden-Wuerttemberg (ProAqua, PlanEVAL, RWTH 2001) and in Bavaria. In both cases a more detailed method of damage evaluation was applied than in NRW.
- Basically, the same method is used in the damage evaluation for the *Flood Action Plans* (Hochwasseraktionpläne) for every river of primary rank in NRW.
- Beyene is also author of a guideline for a micro-scale damage evaluation (BWK 2001)
- A very small-scale and very detailed damage evaluation was carried out by *ProAqua* for a small island in the River Rhine (Bislicher Insel).
- Not considered in the interview, as *ProAqua* was not involved in this study, but also concerning North Rhine-Westphalia is the damage evaluation study for the Rhine Atlas (IKSR 2001). Here, a large scale approach is applied for the whole River Rhine, including all floodplains in Switzerland, France, Germany and the Netherlands.

5.1.2 Objective of damage evaluation

The objectives of the studies or methods mentioned above differ quite a lot, especially regarding their spatial scale.The study for the River Rhine in NRW (MURL 2000) is not so much used a basis for the assessment of different flood protection strategies or measures. It is rather very much employed by the responsible Ministry to inform the public (as well as politicians) about the regional levels of flood risk and, thus, to reveal the benefits and the necessity of flood protection and to justify the need for funding it (Beyene 2005).

The objective of the *Flood Action Plans* is to develop and to present necessary flood protection measures for each catchment. In this context damage evaluations as part of benefit-cost analyses are applied to prioritise measures. As stated by Beyene (2005), the ratio of benefits and costs is much more important in these studies than the exact evaluation of the total amount of expected damages. The *Flood Action Plans,* which are commissioned by the district environment agencies (Staatliche Umweltämter), only formulate recommendations for the municipalities concerned. The acceptance and hence the implementation of the recommended measures varies considerably.

Regarding the study for the River Danube in Baden-Württemberg (ProAqua et al. 2001) another purpose had to be fulfilled. A planned retention basin was expected to provide benefits not only for a local area but for several municipalities downstream. Hence, the aim of the study was to evaluate these benefits quite accurately for each of these municipalities, because it was planned to calculate the respective municipalities' share of funding on the basis of the results. In addition, short abstracts of the outcomes of the flood risk analyses were produced for each municipality ("Hochwassersteckbriefe") to inform the public about their risk.

Micro-scale analyses as described in the BWK-manual "Hochwasserschadenspotenziale" (BWK 2001) have the aim of assessing the efficiency of single flood protection measures. According to Beyene (2005) the manual is not only dedicated to potential users of this method (since the few consultancies dealing with flood damage evaluation already have this knowledge) but also to the principals, who order such studies. For them it can be a kind of description of the product they are going to receive.
In the case of the very small-scale study for the Rhine-island, the objective was to evaluate compensation payments for the few households located on the island in case of flooding, because due to environmental law it was not possible to protect them properly from flooding. Here a detailed damage evaluation for every single household was carried out.

5.1.3 Damage categories considered

The damage categories or categories of valuables considered in these methods are shown in Table 5.1. All methods discussed focus mainly on the evaluation of direct, tangible damage categories, especially damage to buildings and their inventories. Nevertheless indirect losses are considered in the River Rhine study as well as in the River Danube study by potential losses of value added due to business interruption.
Intangible damage is not evaluated in monetary terms, but in quantitative or qualitative terms. E.g., the people affected are quantified in all studies. Furthermore, facilities where toxicological substances are stored are revealed in both the River Rhine and the River Danube study. The latter one also describes cultural heritage buildings which might be affected.

Table 5.1: Damage categories considered in North Rhine-Westphalia

Damage category	***River Rhine (meso)***	***River Danube, Flood Action Plans (meso/micro)***
Direct, tangible Damages		
Residential Buildings	M	M
Household inventory	M	M
Vehicles/cars	M	
Non-residential buildings	M	M
Fixture & fittings, inventories, movable equipment	M	M
Livestock		
Infrastructure		
Streets		
Railways		
Other:		
Ground Values	M	
Indirect Losses		
Loss of Value Added	M	M
Agricultural Production		
Emergency costs		
Traffic Disruption		
Intangible Losses		
People	Q	Q
Health		
Environmental losses		
Recreational Losses		
Cultural goods		D
(potential) Toxification	Q	Q

M = in monetary terms, Q = other quantitative units, D = descriptive, qualitative assessment

5.1.4 Description of methods used for damage evaluation

At least three different basic approaches can be distinguished, which have been applied in North Rhine-Westphalia and the Rhine basin: While in the Rhine Atlas (IKSR 2001) a very approximate approach is applied for the large and transboundary area under investigation, in the River Rhine study in NRW (MURL 2000) a – modified and improved – traditional meso-scale approach is used[3]. In the other studies mentioned an object-orientated damage assessment based on absolute depth-damage functions is applied.

In the Rhine Atlas (IKSR 2001) CORINE land use data is used. Only six different land use categories are derived from this data and approximate asset values are attached to each category, in the case of "industry" and "settlement" they are differentiated in mobile and fixed assets. These approximate asset values are derived from other more detailed damage evaluation studies in Germany. For each German federal state the standard values were adjusted due to differences in land use distribution. For Switzerland, France, and the Netherlands the German values were adjusted by data on purchasing power and GDP indices. For the estimation of damages six different relative depth-damage functions are used (see also Tab. 5.5 in chapter 5.3). These are derived from the German HOWAS database (see e.g. IWK 1999), a databank containing actual German flood damage data (calculated ex-post).

Regarding the River Rhine study in NRW (MURL 2000), the maximum damage potential, i.e. the total value of assets at risk is quantified on the basis of official statistics at the level of the federal state. These values are disaggregated to the research area by the use of ATKIS land use data. According to Beyene (2005) the location of the buildings within these ATKIS land use units is also digitised.
For a better spatial modelling of inhabitants and assets of the private sector (residential capital, household inventories, cars) geomarketing data (number of inhabitants & flats, purchasing power per election district) is used. In addition to this top-down approach, a bottom-up site survey of approximately 1,600 firms is carried out to evaluate their damage potential and their susceptibility. For the estimation of the expected damages relative depth-damage functions are used. A set of about ten sectoral functions is derived from the HOWAS-database, modified by expert judgement and by the results from the firm survey.

A different approach was developed for the River Danube study (ProAqua et al. 2001) and subsequently applied for the *Flood Action Plans*. Here, no assessment of the maximum damage potential is carried out, but merely an evaluation of land use. I.e., each building included in the research area is identified by the use of topographic or land register maps and also by field surveys. In this context the threshold level of each building is estimated as well.
A standardised set of absolute damage functions is used for the damage calculations. These are elaborated by Pflügner (*PlanEval*) on the basis on data of the HOWAS database. This data has been reanalysed by the University of Karlsruhe (IWK 1999) with the result that a root function is apparently the best estimation of the relationship of inundation depth and flood damages. Furthermore, damage data from an insurance company (Brandkasse Baden-Württemberg) is used to determine maximum damage amounts.
The standardised set of damage functions distinguishes different economic sectors and about ten residential building categories (by type, age, existence of basement). For some firms in the research area individual damage functions have been elaborated on the basis of field surveys. The absolute damage amounts of these functions are frequently updated considering general development of prices (Beyene 2005).

[3] Most of the meso-scale approaches in Germany are primarily based on the method developed by Klaus & Schmidtke 1990 (see also Klaus et al. 1994) within their pilot study for the Wesermarsch district at the German North Sea Coast. Since then, several further studies for other German regions or states have been carried out, adopting, varying and improving this approach (E.g. OSAM 1995, Hamann & Klug 1998, Colijn et al. 2000, Knogge & Wrobel 2000, MURL 2000, Kiese & Leineweber 2001, Meyer & Mai 2003, Elsner et al. 2003)

Within the BWK guidelines (BWK 2001) the principle steps of a micro-scale damage evaluation are described: first, Hydrology and Hydraulics; second, gathering of land use information; and third, the application of absolute damage functions (HOWAS-data is mentioned here, but a set of damage functions is not proposed). The possibility of evaluating of the total damage potential in the context of a meso-scale approach is also mentioned.
For the damage evaluation for Rhine-island very detailed damage functions were elaborated for single parts of each building. Basis for this was a detailed field survey.

Although the potential influence of other inundation characteristics, like duration and velocity is mentioned, e.g. in BWK (2001), the only inundation characteristic considered for damage evaluation in each of the methods is inundation depth.

5.1.5 Integration in benefit-cost analysis

In each of the methods and studies described above not only damages for one single event are calculated, but for a range of flooding events of different return periods (for example HQ 100, 200 and 500 in the River Rhine study; HQ 20, 50, 100 and 1000 in the River Danube study). The benefits of protection systems or measures are assessed by comparing the damages with/without protection. While the River Rhine study only considers selected events, the other studies perform a complete risk analysis, i.e., annual average damages and annual average benefits, respectively, are calculated as a basis for a benefit-cost assessment.

5.1.6 Shortcomings, Uncertainties, Improvements & Comments

As mentioned above, the methods described focus mainly on the assessment of direct, tangible damages. Beyene (2005) admitted that this may be a shortcoming, but he argued it might be sufficient to evaluate intangible damage potentials in non-monetary quantitative or descriptive terms.
Other damage influencing factors apart from inundation depth are generally not considered. Only in the work for the *Flood Action Plan* for the River Emmer are the damage reducing effects of flood warning estimated. According to this, a doubling of warning lead time has the potential to reduce damages up to 10%.
Beyene (2005) stated that the evaluation of damage for areas protected by dikes etc. is associated with quite high inaccuracies, because the estimation of breach locations and of the extent of inundation following these breaches is still highly uncertain. Based on his experience this damage accounts for only a small part compared with the damages to unprotected areas. Hence, a rough estimation seems to be sufficient for such cases.

ProAqua also developed a software for the automation of the damage evaluation process. HWSCalc is an Access-based software in which hydraulic parameters, land use data and damage functions can be implemented as input. An interlinking with a GIS (HWSMap) was planned but only internally realised. Nevertheless, an interconnection with a GIS is possible if the spatial information is stored by an ID-number. The software is not restricted to a micro-scale approach, because the units to be considered can be either objects or bigger land use units.
For Germany, the approaches developed by ProAqua and others for the Rhine basin are quite innovative. Other studies referred to this work and applied similar principles and damage functions.

References for this country study is listed in chapter 7.4

5.2 Schleswig-Holstein

Sources of information:

- Interview with Jacobus Hofstede from the Ministry of the Interior in Schleswig-Holstein and with Stefan Reese from the Department of Geography of the University of Kiel, Kiel, 20.1.2005 (*Hofstede et al. 2005*)
- Published and unpublished literature as listed in the reference list of chapter 7.4

5.2.1 Existing approaches on different spatial scales

For the coastal zones of the federal state of Schleswig-Holstein three methods were developed and applied to estimate flood damages or at least the value of the assets at risk (for a detailed description, see also Sterr et al. 2005):

1. Within the framework of the German IPCC-study for all coastal areas in Germany, the endangered values of assets at risk for the coastal areas of Schleswig-Holstein were evaluated on a macro-scale (Ebenhöh et al. 1997; Behnen 2000).
2. A more detailed, meso-scale approach was developed and carried out for all coastal lowlands of Schleswig-Holstein. The output was also an evaluation of assets at risk. That means no damage estimation was carried out. The study was commissioned by the former Ministry for Rural Areas, Spatial Planning, Agriculture and Tourism and was carried out by the Research and Technology Centre West Coast (Colijn et al. 2000; Hofstede & Hamann 2000).
3. For six cities and municipalities an additional micro-scale damage evaluation was executed, also funded by the former Ministry for Rural Areas, Spatial Planning, Agriculture and Tourism and carried out by the Research and Technology Centre West Coast (MERK; Reese et al. 2003; Reese 2003; Markau 2003).

5.2.2 Objective of damage evaluation

Regarding the three methods of flood damage evaluation or asset valuation, mainly the results of the meso-scale approach are currently used as a decision support in flood protection policy by the responsible ministry.
But first of all it has to be mentioned that a risk-based approach for the determination of adjusted safety standards of dikes is not possible at the moment, due to the legal situation. The “Landeswassergesetz”, the law for water-related issues in the state of Schleswig-Holstein, prescribes a specific protection level against all storm tides. That means an equal safety standard for all regions is required by law. A differentiation of dike heights on the basis of benefit-cost aspects is therefore not possible. Hence, this is not the goal of the current flood protection policy and it would be unlikely to be accepted by the people (Hofstede et al. 2005).

Nevertheless, the results of the meso-scale damage potential analysis provide a basis for the prioritisation of coastal protection investments: The measures to reach the required safety standard are listed in the “Generalplan Küstenschutz” (Masterplan Coastal Protection; MLR 2001). Due to budget restrictions not all measures can be realised at the same time. Therefore, a prioritisation of the individual measures is necessary (Hofstede et al. 2005). The criteria for this internal prioritisation are firstly the number of endangered inhabitants and secondly the values of the assets at risk (the maximum damage potential). According to Hofstede, the evaluation of the damage potential seems to be sufficient for such a prioritisation at the moment.

Nevertheless, a more detailed appraisal like MERK seems to be reasonable, particularly in bigger cities like Kiel, to achieve more accurate results. With MERK it also becomes possible to assess the benefits of single measures. Indeed, an area-wide application of MERK will not be realised due to the high effort and costs of carrying out this method.

Hofstede also mentioned the major uncertainties within the results of risk analysis as a main impediment to the implementation of a risk-based coastal protection policy. In particular the estimation of failure probabilities are not accurate enough at the moment to rely on its results. A differentiation of safety standards on the basis of such results could not be explained to the public, which is in any case very sceptical regarding such approaches.

The information of both the public and policy makers about the benefits of coastal protection was regarded by Hofstede as a second, maybe more important objective of the studies of damage evaluation. The presentation of values of assets protected by the defence system leads to an increased risk perception. Again, a description of the assets at risk seems to be sufficient and maybe better understood by the public than the documentation of expected damages. Therefore, a simple evaluation of the maximum damage potential is regarded to be sufficient for this purpose as well (Hofstede et al. 2005).

5.2.3 Damage categories considered

The damage categories or categories of valuables considered in the three approaches are shown in Table 5.2. In all three studies there is a focus on the evaluation of direct, tangible assets.

Table 5.2: Damage categories considered in Schleswig-Holstein

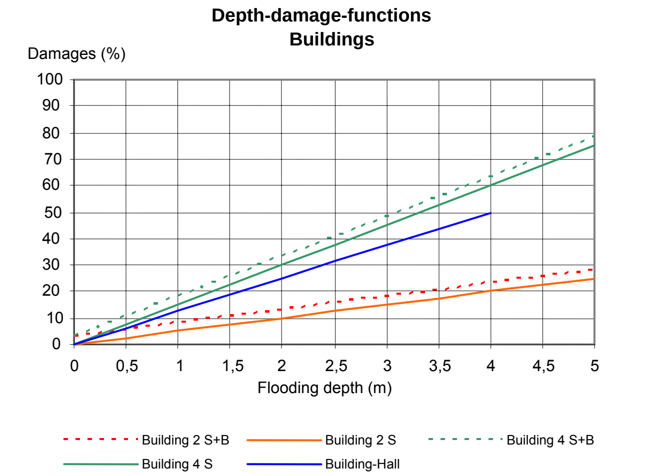
Damage category	*Macro: German IPCC*	*Meso: Coastal Lowlands*	*Micro: MERK*
Direct, tangible Damages			
Residential Buildings	M	M	M
Household inventory		M	M
Vehicles/cars		M	M
Fixed assets (Non-residential buildings, movable equipment, fixture & fittings	M	M	M
Inventories (stock assets)		M	M
Livestock		M	M
Infrastructur	M		
Streets			M
Railways			M
Further:			Windmills
Ground Values	M	M	M
Indirect Losses			
Loss of Value Added		M	M
Emergency costs			M
Traffic Disruption			
Further:			Agricultural production
Intangible Losses			
People	Q	Q	Q
Health			
Environmental goods			
Cultural goods			
Toxification			

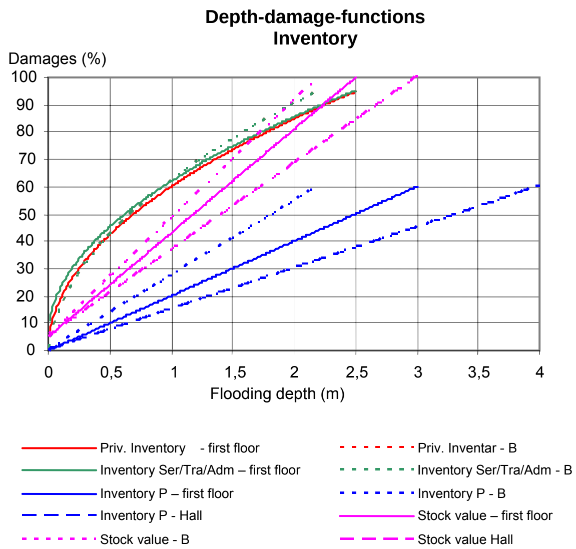
M = in monetary terms, Q = other quantitative units, D = descriptive, qualitative assessment

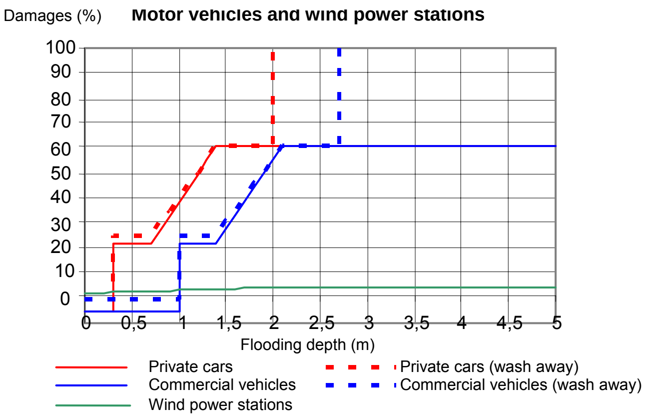
5.2.4 Description of methods used for damage evaluation

1. Macro-scale approach (German IPCC-study; Ebenhöh et al. 1997; Behnen 2000)
   Within this study all damage potentials considered are evaluated on the spatial level of municipalities. I.e., no further land use data is necessary apart from administrative borders. The main sources for the evaluation of the assets are official statistics. While, e.g., the number of inhabitants is directly available for every municipality, the value of fixed assets had to be broken down from a higher level of aggregation using the number of inhabitants or employees as a basis for disaggregation. Regarding the valuation of fixed assets (buildings, fixtures and fittings) gross values are used, i.e., not the current value but the full replacement value is used.
   The study does not execute an estimation of damages, which means only the value of assets at risk is estimated. The area at risk is defined by the five meter contour line. Only the assets located below that level are taken into account. Hereby an equal distribution of the assets within each municipality is assumed.
2. Meso-scale approach (Colijn et al. 2000; Hofstede & Hamann 2000)
   Regarding the quantification of assets at risk, the meso-scale study proceeds similarly to the macro-scale approach described above. I.e., in a first step the damage potentials are also evaluated for each municipality by the use of aggregated data from official statistics. Again, replacement values are used.
   To ensure a more detailed spatial distribution of these assets within each municipality a spatial modelling of the derived values to corresponding land use units is carried out. In the first part of the study land use data was derived by digitising landscape plans. In the second part digital land use data from the German ATKIS was used. Each category of valuables was then assigned to corresponding land use categories, e.g. residential capital to residential areas.
   Again no concrete damage calculation is carried out, i.e., only the assets at risk are evaluated, e.g. the assets lying below a certain contour line.
3. *Micro-scale Risk Evaluation of Flood-prone Coastal Lowlands* (MERK; Reese et al. 2003; Reese 2003)
   In contrast to the macro and meso approach described above, the most important asset categories are evaluated on an object level. That means not only land use units are considered but single objects like buildings. While the location, address and ground floor area is derived from small scale maps (DGK 1:5000), the use of every building is determined by field surveys.
   The value of each building is then calculated by applying "normal construction costs", which stem from an official guideline for the valuation of houses. The value of inventories and stocks is calculated on the basis of the ground floor area of each building. The specific values per square metre for residential or different non-residential building types are mostly derived from expert interviews. The number of inhabitants can be estimated for each building, too, using address-orientated official registers. Regarding the concept of valuation no clear approach is followed: both current and replacement values are used.
   Unlike the two other studies, the micro-scale study tries to estimate the damages of a set of defined inundation scenarios. Relevant for the estimation of expected damages in this context is mainly the maximum inundation depth of each scenario. The set of more than ten relative depth-damage functions for different asset categories which is used for the calculation was developed by Pflügner (Consultancy *PlanEVAL*) on the basis of the HOWAS damage database and adjusted to the regional conditions by expert judgement.
   An estimation of the risk, i.e. the calculation of annual expected damages, has been carried our in addition to the mentioned study (Reese 2003). The expected damages are only calculated for the specified scenarios and not for all possible flooding events.

Figure 5.1: Damage functions used in the MERK-study







Storey heights

Occupancy	First floor	Basement	Hall
Services/ Trade/ Administration	3.00 m	2.20 m	4.00 m
Production industries	3.00 m	2.20 m	4.00 m
Residential building	2.50 m	2.20 m	-

Functions

Building 2 S+B	Y = 5 X
Building 2 S	Y = 3 + 5 X
Building 4 S+B	Y = 3 X
Building 4 S	Y = 3 + 3 X
Building hall type	Y = 12,5 X
Priv. inventory - first floor	Y = 60 √ X
Priv. inventory B	Y = 68 √ X - 6
Fixed assets Ser/ Tra/ Adm - first floor	Y = 57 √ X + 5
Fixed assets Ser/ Tra/ Adm - B	Y = 68 √ X - 6
Fixed assets production industries – first floor	Y = 20 X
Fixed assets production industries – B	Y = 28 X
Fixed assets production industries – hall	Y = 15 X
Stock value – first floor	Y = 5 + 38 X
Stock value - B	Y = 5 + 43 X

X = Flooding depth (m)
Y = Damage (%)
S = Storey
B = Basement
Ser = Services
Tra = Trade
P = Production industries
Adm = Administration

Source: Sterr et al. (2005)

5.2.5 Shortcomings, Uncertainties, Improvements & Comments

As mentioned above, a major source for uncertainties within the whole process of risk analysis was seen in the determination of failure probabilities of the coastal defence system (Hofstede et al. 2005). The project PRODEICH (Kortenhaus & Oumeraci 2002) was mentioned as an attempt at further scientific understanding of these issues. It was expected that an application of sensitivity analyses could be a potential solution for the consideration of uncertainties regarding all parts of risk analysis.

As a shortcoming within the area of damage evaluation the disregard of intangible losses on environmental and cultural goods and the omission of indirect losses was mentioned (Hofstede et al. 2005).

Reese stated that, within FLOODsite, a simplification of the micro-scale approach used in MERK is planned as a further improvement. While the most important categories of valuables, like inhabitants and buildings, will probably be evaluated as detailed as before, less important categories will be evaluated using approximate standard values. A second concept is to generate a grid based vulnerability analysis where damage or the damage potential is determined dependent on the site density of a grid cell. This way, larger regions can be analysed without excessive effort and resources.

References fort this country study are listed in chapter 7.4

5.3 Saxony

Sources of information:

- Interview with Martin Socher (Ministry for Environment and Agriculture – SMUL, Head of Department Water Affairs) and Hans-Ulrich Sieber (Federal State Dam Administration – LTV, Head of Department Technology), Dresden, 16.12.2004
- Published and unpublished literature as listed in the reference list of chapter 7.4

5.3.1 Existing approaches and their objective

In Saxony flood damage evaluation is carried out on two different levels as a decision support for policy in terms of prioritisation of potential flood protection measures.

1. *Flood Protection Concepts*: After the 2002 flood it was decided by the responsible parties – the Ministry for Environment and Agriculture (SMUL) holding the policy responsibility and the Federal State Dam Administration (Landestalsperrenverwaltung – LTV) holding the operational responsibility – to develop "flood protection concepts" (Hochwasserschutzkonzepte – HWSK; e.g. SMUL, LTV & PGS 2004, see also Glasebach 2005) for each of the 47 rivers of primary rank. These are prepared by different engineering consultancies. In addition to a description of the 2002 flood, of other historic events, and of the actual protection status, the HWSK also include hazard maps and a damage evaluation for a 100-year event. On this basis necessary protection measures are proposed in these HWSK and also appraised and prioritised under consideration of the following criteria (Socher et al. 2005, Annex C):
   - 1a. Benefit-cost assessment, based on either benefit-cost ratio for a HQ-100 event, expected damage for a HQ-100 event, or expected annual average damage
   - 1b. Special additional potential losses (e.g. loss of life)
   - 1c. Important assets or facilities affected
   - 1d. Threats arising from the affected object (secondary damages)
   - 1e. Current level of protection
   - 1f. Improvement of retention and discharge
   - 1g. Other criteria
   - 1h. Requirements of the EU-Water framework directive

2. *Comprehensive prioritisation system for flood protection measures*: Meanwhile nearly all these HWSK are on hand and it has become necessary for the SMUL and LTV to carry out a comprehensive prioritisation for all measures proposed in the HWSK. I.e., after carrying out a prioritisation of measures within each catchment it was necessary to compare the measures of different river catchments with each other and to prioritise them from an overall perspective. Therefore, a prioritisation system has been developed ("SMS-System"; Socher et al. 2005) in which the amount of damages avoided again plays a crucial role. The damage calculations refer in urban areas to an HQ-100 event, the aspired safety standard. In more rural areas the aspired safety level is sometimes lower and hence damage calculation refers to smaller events. The criteria used in this prioritisation system are the following:
   - 2a. Cumulative expected damages (25)
   - 2b. Benefit-cost ratio (25)
   - 2c. Effects on Water Management (25)
     - i. Rentention capacity (10)
     - ii. Discharge conditions (10)
     - iii. Water ecology (5)
   - 2d. „Vulnerability" (25)
     - i. Special vulnerability (people, infrastructure, heritage sites) 10
     - ii. Potential secondary losses (e.g. hazardous substances) 10
     - iii. Special protection needs (lacking possibility of defence) 5

The assessment is carried out by a transparent 100-point-system. The number in brackets behind each criterion indicates the maximum score given to this criterion (i.e. a kind of weighing factor). The scoring within the criteria categories is defined by a classification: E.g., for a benefit-cost ratio (criterion 2b) smaller than 1, no points are given, if the ratio is between 1 and 2, 5 points are attached, a ratio between 2 and 5 results in 15 points and the maximum score (25 points) is reserved to measures attaining a benefit-cost ratio higher than 5 (Socher et al. 2005).
The method of damage evaluation is based on the damage evaluation in the HWSK. In addition it seeks to extend this approach to the estimation of damages of all possible events between the current and the aspired safety level (and not only the HQ 100 event). Furthermore, some indirect and intangible flood damages are included.

5.3.2 Damage categories considered

The damage categories or categories of valuables considered in the two approaches are shown in Table 5.3. Especially in the SMS-prioritisation focusses not only at direct tangible damage. Nevertheless it still plays an important role. Within the SMS prioritisation system tangible damage determines altogether 50% of the decision criteria, as it is considered in absolute terms (criteria 2a) as well as in a benefit-cost-ratio (criteria 2b). Unlike the damage evaluation in the HWSK, indirect losses ("mittelbare Schäden") are also included in these two criteria. According to Socher et al. (2005) production losses, losses due to traffic disruption and costs for evacuation are taken into account here.
With the vulnerability criteria 2d some intangible consequences are implemented in the decision making process (danger to life, heritage sites etc.). Contrary to the evaluation of tangible damage the assessment of intangibles is carried out in qualitative, descriptive terms. Secondary intangible losses are also considered in this context (criteria 2dii), especially in form of potential damage due to the emission or mobilisation of hazardous substances.

Table 5.3: Damage categories considered in Saxony

Damage category	***HWSK***	***SMS-prioritisation***
Direct, tangible Damages		
Residential Buildings	M	M
Household inventory	M	M
Vehicles/cars		
Non-residential buildings, fixture & fittings,	M	M
Inventories, movable equipment	M	M
Livestock	?	?
Infrastructure		
Streets	M	M
Railways	M	M
Other		
Ground Values		
Indirect Losses		
Loss of Value Added		(M)
Agricultural Production		
Emergency costs		(M)
Traffic Disruption		(M)
Intangible Losses		
People	D	D
Health		
Environmental losses		
Recreational Losses		
Cultural goods		D
Toxification		D

M = in monetary terms, Q = other quantitative units, D = descriptive, qualitative assessment

5.3.3 Description of methods used for damage evaluation and their integration in benefit-cost analysis

The essential basis for both prioritisation approaches is the evaluation of potential damages for an event at the desired protection standard (mostly the desired standard for urban areas is HQ 100[4]). The damage evaluation methods applied in both approaches is portrayed in the following sub-chapters.

a) HWSK approach
To ensure the application of an unique method for all HWSK, which are carried out by several engineering consultancies, the LTV published recommendations for the evaluation of these HQ-100 damages (LTV 2003), which have been followed in most of the HWSK.
These recommendations are orientated towards the method used in the Rhine Atlas (IKSR 2001; see chapter 5.3). The method can be divided into three steps: Firstly, gathering of land use information; secondly, application of land use specific asset values to evaluate the maximum damage potential; and thirdly, the use of depth-damage functions to calculate expected flood damages.[5] Some basic information about these three steps is described in the following.

- **Land use information**: While in the Rhine Atlas (IKSR 2001) CORINE data is used, LTV (2003) recommends using CIR biotope-type data, which provides the classification shown in Table 5.4. CIR land use information is based on data of 1993, but LTV (2003) states that a more current database was not available.
- **Asset values**: In IKSR (2001) approximate asset values are developed for each of these land use classes, in some cases differentiated in mobile and fixed assets. This is based on several other more detailed damage evaluations carried out before in Germany. For each German federal state the standard values were adjusted due to differences in land use distribution. For Switzerland, France, and the Netherlands the German values were adjusted by data on purchasing power and GDP indices. For Saxony these German standard land use specific asset values were adjusted, too (LTV 2003), whereas it was stated by an LTV member, that due to time pressure it was not possible to carry out a sophisticated adjustment process. The standard values used for Saxony are shown in Tab. 5.4.

Table 5.4: Specific asset values in Saxony

Land use category	**value of fixed assets EUR/m²**	**value of mobile assets EUR/m²**	**Total EUR/m²**
Settlement	145	40	185
Industry	207	72	279
Traffic	200	2	202
Agricultural areas	no differentiation	no differentiation	0,4
Forest	no differentiation	no differentiation	1
Other	no differentiation	no differentiation	0,01

Source: LTV 2003

[4] For more rural areas LTV (2003) recommends lower protection standards: For single buildings, periodic settlements and infrastructure of regional significance a return period of 25 years is proposed and for agricultural areas a return period of 5 years. A higher protection standard is only recommended if special objects should be protected.
[5] Of course, it is also necessary to derive the maximum inundation area and depth. This is also done in the HWSK, e.g., by the use of the one-dimensional model HEC-RAS (SMUL & PGS 2004), but this will not be explained further in this report.

- **Depth-damage functions**: The damage functions used by IKSR (2001) are adopted without any changes (Table 5.5). They are based on empirical damage data from the HOWAS database and adjusted to the CORINE land use categories.

Table 5.5: Depth-damage functions used in Saxony

Land use category	fixed assets	mobile assets	Total
Settlement	$S=2*h^2+2h$	S=11,4h+12,625	-
Industry	$S=2*h^2+2h$	S=7h+5	-
Traffic	-	-	S=10h (h<1); S=10 (h>1)
Agricultural areas	-	-	S=1
Forest	-	-	S=1
Other	-	-	S=1
S = degree of damage [%]; h = inundation depth			

Source: LTV 2003

Based on this information about land use, asset values and damage functions direct tangible damage for one specific flood event (HQ 100) is calculated for the HWSK.

b) SMS approach

Within the comprehensive SMS prioritisation approach all possible events are taken into account and indirect damage is considered as well. The cumulated damage (i.e., the total benefits of the planned measure) is calculated by the formula (Socher et al. 2005)

$$S\ (kum) = S\ (HQ\ 100) \cdot F1 \cdot F2$$

with

S (HQ 100): The direct tangible damage for the HQ-100 event derived from the HWSK by the method described above.

F1: This factor takes into account all events between the current safety standard and the desired safety standard (mostly HQ 100). The damage of the events smaller than the HQ 100 (HQ 10, 20, 50) is estimated by the relation of inundation area of the HQ 10, 20, and 50 event compared to the HQ 100 event. I.e., an equal distribution of damage within the inundation area is assumed. Each of the events mentioned above represents a range of possible events, for which a probability of occurrence (for a 100-year time span) is estimated and then multiplied by the expected damage of the representative event. The results are incorporated in the factor F1.

F2: Land use specific factor for the implementation of indirect damages. The following factors are used:

urban areas:	1.3
areas used for industry and infrastructure:	1.5
rural settlements:	1.1
agricultural areas:	1.2

These factors are approximate estimations based on previous experience (Socher et al. 2005).

Underlying the monetary damages calculated for the first two criteria of the comprehensive prioritisation system, the criteria "vulnerability" also takes some intangible and indirect damages into account:

- Threat to life
- Threat to heritage sites
- Threat to traffic, water, electricity infrastructure (⇒ indirect effects)
- Damage caused by hazardous substances (⇒ secondary effects)
- Special susceptibility due to short warning lead times

The assessment of these criteria is executed in a qualitative way by experts. For each of the three criteria of 2d a classification in 2-3 steps is possible (no – medium – high vulnerability). The assessment must be conducted by consultancies based on "individual and specific observations"

(Socher et al. 2005). There are no guidelines or benchmarks for this assessment provided by SMUL and LTV.

Within the prioritisation system not only benefits due to avoided damages are considered but also benefits due to positive effects on water management (retention, discharge, water ecology; criteria 2c). These effects are also assessed in a qualitative way.

5.3.4 Shortcomings, Uncertainties, Improvements & Comments

First of all it has to be mentioned that the methods described in LTV (2003) and Socher et al. (2005) were developed under great time pressure. Hence, it was necessary to revert to an existing method of damage evaluation (IKSR 2001), which, furthermore, can be carried out relatively quickly. Nevertheless, it has attempted not only to include avoided direct damages as a criterion in the decision making process, but also other criteria like intangible losses. As a consequence, a transparent multi-criteria system has been developed.

However, some points can be mentioned, according to which further improvements could be achieved:

- The standard asset values used for damage evaluation are only roughly adjusted for the regional conditions of Saxony.
- Since in reality these values could vary greatly dependent on local conditions, the inclusion of approaches that allow for a better differentiation of regional damage data would be reasonable. LTV (2003) recommends in this regard the comparison of SMS or HWSK results with actual flood damage data of 2002 and to derive correction factors from this comparison.
- It is not quite clear whether the standard values derived from IKSR (2001) refer to full replacement values or depreciated values. Full replacement values, which are used in some approaches to flood damage evaluation, tend to overestimate the actual damage, because reconstruction always includes improvements.
- Factor F2, which is used for the implementation of indirect effects, is based on approximate estimations. The validity of this factor should be tested in pilot studies.
- While it seems to be a good solution to include intangible losses in a non-monetary form in the prioritisation system, it might be possible to improve the assessment through standardised assessment rules. Up to now this part of the assessment is only done in a qualitative and subjective way.
- Although it is attempted to also integrate intangible losses in the prioritisation system, tangible damage with a weight of 50% in SMS altogether has still a comparatively high influence. In contrast to this the weight given to danger to life (10%, together with other intangible aspects) seems to be quite small. It should be considered to keep the weights more flexible in order to enable a better reflection of changing political preferences in the final decision process.
- While the costs of investment in protection measures are discounted, no discounting is carried out for the benefits, i.e. the damages avoided. Hence, damages in the present are set equal to damages in the future, despite the fact that financing the reconstruction of a damaged object is likely to be more costly in the present (because in the future income from interest on savings can be used as well).

References for this country study are listed in chapter 7.4

5.4 Saxony-Anhalt

Sources of information:

- Interview with Mr. Runge from the state company for flood protection and water management (Landesbetrieb für Hochwasserschutz und Wasserwirtschaft – LHW), Halle, 27.5.2005 (*Runge 2005*)
- Published and unpublished literature as listed in the reference list in chapter 7.4

5.4.1 Existing approaches on different spatial scales

In Saxony-Anhalt, damage evaluation has only recently played a role in decision-making about flood protection planning. Up to now, the availability of necessary data was not adequate (Runge 2005). Nevertheless some ex-post analyses of actual flood events were used, for example, damage data from the 1994 flood event in the Saale catchment. For the development of the *Flood Protection Concepts* of the Rivers Saale, Unstrut, Wipper and Bode these actual damages were compared with the costs of possible protection measures.

Considering ex-ante damage evaluation, there is no existing study of damage evaluation which is finished and used in practice. With an increasing quality and availability of necessary data, results of ex-ante damage analyses will also become a decision criterion for the planning of flood protection measures in Saxony-Anhalt (Runge 2005).

- In particular the “General plan for flood protection in the Elbe River basin” (Generalplan Hochwasserschutz Elbe) was mentioned in this context. The development of this plan started in September 2005 and was initiated by the LHW Saxony-Anhalt.

Other approaches are still under development, or in a pilot stage:

- In the framework of the IKSE (see also IKSE 2003) damage analyses for the Elbe are currently carried out or will be prepared by JRC, Ispra (Mrs. Gierk). The specific method used in this context is not known (Runge 2005), but it is probably the IKSR method. These damage analyses are planned to provide an information basis for the “Generalplan Elbe” which is under development.
- In the framework of the project RIS-EOS (www.risk-eos.com/) (partners *ESA, geomer* etc.) a method for damage evaluation has been developed and tested at the River Mulde in Saxony-Anhalt. The results are not yet published. RISK-EOS derives land use information from satellite data. On this basis, assets and damages are estimated. Furthermore, RISK-EOS apparently allows a real time documentation and damage estimation for hazards.
- No damage evaluation, but hazard mapping is done within the Interreg-project ELLA by *geomer*. 1:100.000 maps were developed on the basis of ATKIS-DGM-10-data with a vertical resolution of 0.5 metre for a HQ 100 and HQ extreme event. Dikes or other existing protection elements are not considered in these maps in order to reflect the hazard in case of technical failure.

5.4.2 Objective of damage evaluation

As stated above, besides the Saale catchment damage evaluation is rarely used as a decision support for flood defence planning in Saxony-Anhalt at present. The planning of defence measures is mostly orientated towards a safety standard of HQ 100 for all big rivers in the state. The required measures to reach this standard were identified after the flood in 2002 and described in the *Flood protection conception* (MLU 2003) with a planning interval reaching up to the year 2010. The prioritisation of these measures is based on hydraulic engineering expertise. I.e., benefit-cost aspects are rarely taken into account either for the design of defence measures or for their prioritisation. According to Mr. Runge (2005) one reason for this is the integration of nature conservation objectives in the planning of flood protection measures, for example in the case of dike relocation at the Elbe. These intangible aspects are not easy to assess in monetary terms. Mr. Runge does not know whether regulations for the general application of benefit-cost analyses will be enacted in the immediate future.

Mr. Runge stated that a differentiation of the safety standard on the river Elbe would not be sensible because if such a plain flood area is once flooded, inundation might possibly not be restricted to areas of a low damage potential. A benefit-cost approach might be more sensible in the Harz area (flash floods).

But it was stated that damage analyses could be a useful tool to provide information, not only for flood protection but also for civil protection (Ministry of the Interior). For example as a demonstration of the benefits and financial needs of flood protection damage analyses could be helpful as well as for the prioritisation of defence measures

5.4.3 Comments

This last report on Saxony-Anhalt points to the fact that ex-ante damage evaluation is only gradually being implemented here up to now in some actual and planned projects, but is not fully integrated in flood protection policy yet. As the main reason for this, the lack of high quality basis data was mentioned, like e.g. high-resolution terrain models and empirical damage data. Furthermore it was stated that a differentiation of the safety standard at big rivers like the Elbe would be difficult to enforce due to practical and political reasons.

Obviously, there is a strong demand for a harmonisation of flood protection standards in Germany and for the provision of relevant data and guidelines to carry out detailed flood damage evaluations and benefit-cost analyses.

References for this country study are listed in chapter 7.4

6. Conclusions

The report shows that the four countries England, the Netherlands, the Czech Republic and Germany, which feature very different histories of flood policy and different institutional settings, use sophisticated methods of flood damage evaluation. These in principle follow the same idea, namely trying to put economic values to elements at flood risk in order to estimate the benefits of flood protection measures in terms of prevented flood damage.

In detail, though, the methods exhibit a lot of different approaches. The major differences in flood damage evaluation methods relate to the damage categories considered, the degree of detail, the scale of analysis, the application of basic evaluation principles (e.g., replacement cost versus depreciated cost), and the application or non-application of results in benefit-cost and risk analyses.

This diversity of flood damage evaluation methods, even in riparian states which share a major river, indicates that there is still a lack in transboundary co-operation in flood policy decision-making in the EU. It therefore seems appropriate to strive at a harmonisation of damage evaluation methods in order to create a sound scientific basis for future co-operation in transboundary flood management and policy in the EU.

In fact, it is the major objective of task 9 of the FLOOD*site* project to prepare guidelines for the practical application of ex-ante flood damage evaluation methods for EU countries. The empirical knowledge collected for this report and the further cooperation with the practitioners interviewed in the different countries will form the solid foundation to achieve this objective.

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