Memo: Flood damage evaluation methods

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I. Background

Traditionally, flood risk management was dominated by a 'design standard philosophy', where decision makers decided upon the 'appropriate' protection level to be achieved (FLOODsite, 2007). In the Netherlands the national law defines protection levels for a number of dike rings. These protection levels are defined as the probability of exceeding a certain water level and ensure security even against extreme flood events with a frequency of occurrence ranging up to once in ten thousand years for coastal areas (Ministerie van Verkeer en Waterstaat, 2005).

Currently, a shift to more integrated flood risk management concepts can be observed which consider floods just as one of several sources of risks in a human society (Buechele, B. et al., 2006 / FLOODsite, 2007). In this context, flood risk is defined as expected flood damage for a given period of time. This shift can be observed in The Netherlands as well. Already in 1992 the Technical Advisory Committee on Water Defences (TAC) made a start on setting out a new safety approach in the research programme: "Flooding risks: a study of probabilities and consequences." (Ministerie van Verkeer en Waterstaat, 2005).

This shift implies the question, whether it is justified to spend a huge amount of tax money for flood risk reduction, while other areas of risk in society might receive much less financial support to reduce it (FLOODsite, 2007). Protection measures against flooding may no longer be properly in proportion to the consequences of flooding (Ministerie van Verkeer en Waterstaat, 2005).
Thus, the new risk approach leads to an increasing significance of flood damage evaluation (methods) for decision support in flood risk management policy. Information about flood risk, including information on expected damages are indispensable to inform the population and stakeholders about local flood risk, for planning of flood control measures and for cost-benefit analysis of these measures (Buechele, B. et al., 2006).
The EU Directive of July 2007 called "Directive on the assessment and management of floods" indicates an even growing importance of flood damage evaluations (FLOODsite 2007).[1]

Additionally, the increase of flood occurrences and their growing impacts call for a better understanding of flood damages.[2]

However, even though estimates of flood damages are an (increasingly) important part of a flood risk analysis, it received much less attention internationally as e.g. risk assessment regarding flooding probabilities.
This gets obvious by the fact that there are little reliable data on flood damage available. Only in exceptional cases up-to-date, comprehensive and reliable damage data and the respective inundation levels in the affected areas and objects will be available.

II. Classification of flood damages

Floods can have a variety of impacts, ranging from death and injury of individuals to damages on buildings, disruption of traffic and production, contamination or erosion (Merz, 2006). Damages from floods are usually divided into direct and indirect damages.
Direct damage is damage that occurs due to physical contact of flood water with human beings, properties or any objects.
Indirect damage is a damage that is induced by the direct impact, but occurs – in space or time – outside the flood event. This includes the disruption of traffic, trade or public services (Buechele, B. et al., 2006). Both types are usually further classified into tangible and intangible damage, depending on whether these damages can be assessed in monetary values (Figure 1).

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[1] The Directive requires Member States to first carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk for flooding. For these zones they would then need to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015 (Directive of the European Council and the European Parliament on the assessment and management of flood risks, PE-CONS 3618/07).

[2] Between 1998 and 2004. Europe suffered more than a 100 major damaging floods, which have caused some 700 deaths, the displacement of about half a million people and at least €25 billion in insured economic losses (European Commission)

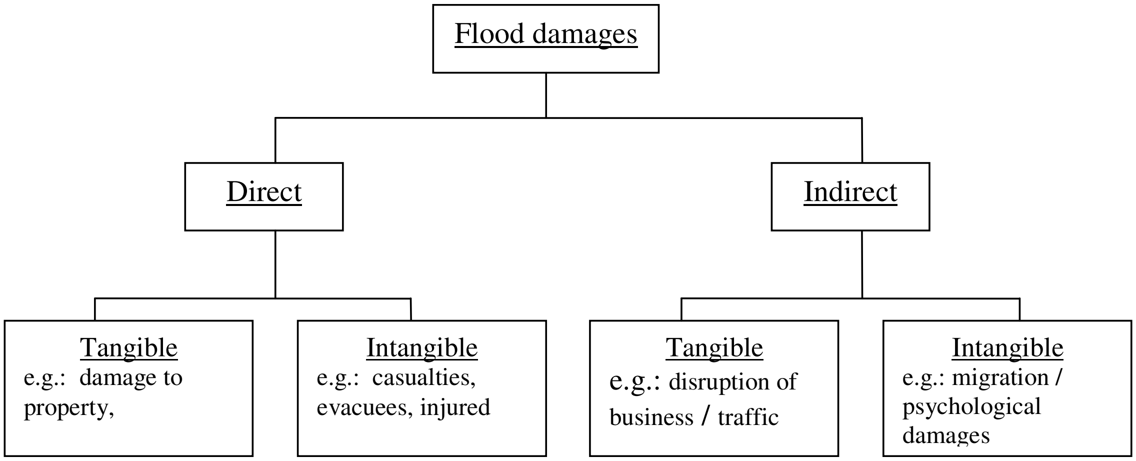

Figure 1: Classification of flood damages. (Source: Merz, 2006)

The largest part of the literature on flood damage evaluations addresses only direct tangible damages, even though it is acknowledged that direct intangible or indirect damages play an important or even dominating role in evaluating flood impacts (Buechele, B. et al., 2006).

III. Flood damage evaluation methods

An internationally accepted standard approach for flood damage evaluations is the use of so - called damage functions. These damage functions quantify the relationship between parameters influencing flood damages and the degree of damages for different land-use classes or objects such as buildings and cars. Since water depth is decisive for the occurrence of damage, most damage functions are based on this parameter (Buechele, B. et al., 2006). A pictorial depiction of a standard flood damage evaluation method is given in Figure 2.

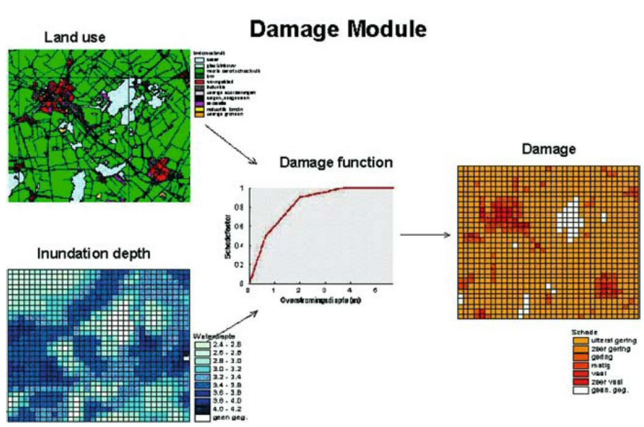

Figure 2: Standard approach for flood damage evaluations (Source: Ministerie van Verkeer en Waterstaat, 2005).

As mentioned above, often there won't be reliable data on damages available for the area under investigation. In order to still assess damages from potential floods, two assessment methods can be generally distinguished.

III.1. Transfer of historic data

Damage functions are derived from observed flood damages and temporally and spatially transferred (translated) and potentially adjusted to the area under investigation. This approach has been widely used in Germany (see V.)

III.2. Use of synthetic data

A second approach is to collect synthetic data on damages for the area under investigation. These are damages, which would occur for a potential flood with predefined parameters. These data are assessed either by experienced damage assessors or questionnaires: "How much damage would result for this element from a flood with the following parameters?" These data can be collected for single buildings or a representative object from a certain class or sector and can be used to derive damage functions.

III.3. Quality aspects of flood damage data

Most evaluation methods rely in either way on the use of historic (observed) flood damage data. This is especially the case for Germany but also for The Netherlands. In Germany, the so-called HOWAS data base (see V.1.) has been widely used, which is maintained by the 'Bayerisches Landesamt für Wasserwirtschaft'. It contains information about approximately 4000 single cases of flood damages and damage functions for different objects and land-use types.

However, using historic flood damage data involves large uncertainties, as recent studies have shown for the German HOWAS data base. These findings should hold true also for other approaches using historic damage data (Merz, 2006).

According to Buck the variance of damage values found in the HOWAS is considered that large, that the derived damage functions lack statistical significance (Buck, 2006). This variance stems from the large heterogeneity of the HOWAS data base. It contains e.g. both very frequent and very rare flooding events. Besides, the different floods showed different flow velocities and lead times. Also the duration of inundation varied. Additionally, possible contaminations of the floodwater, sediment flow and the protection measures for the respective buildings vary significantly.

The 'Institut fuer Wasserwirtschaft und Kulturtechnik' of the University of Karlsruhe came to the conclusion, that it is not possible to derive generally valid damage functions from the HOWAS. This holds especially true for damage functions of damage categories which are poorly represented in the HOWAS (IWK, 1999).

Also Merz and others refer to the uncertainties related to the HOWAS database. Merz & Gocht compare the damages calculated with the HOWAS with the observed damages for seven communities affected by a flood. Even though an optimistic and a pessimistic scenario have been developed, three out of seven cases were partly drastically below the range of dispersion (Merz, 2006). In a systematic analysis for the same seven communities Merz shows, that the coefficient of variation for the different damage categories present within the HOWAS ranges from 79% for garages up to 418% for industries. For residential buildings the coefficient of variation was around 150% (Merz, 2006).

As a result, expert bodies such as the “Deutsche Vereinigung fuer Wasserwirtschaft, Abwasser und Abfall e.V.”[3] have recommended not to use this approach any longer due to the uncertainties involved. Buck concludes that the damage functions of the HOWAS should only be used in emergency or exceptional cases (Buck, 2006). Instead, synthetic data should be derived for the area under investigation, at least for so-called “hot spots” (e.g. production facilities).

These examples show the large uncertainties involved when using generalized damage functions that are based on observed flood damage data. However, in many cases, using such generalized functions will be the only way to evaluate potential damages. Thus, it is important to indicate the uncertainties involved when using generalised damage functions.

IV. Flood damage evaluation in the Netherlands

An overview of the method of flood damage evaluation in The Netherlands is provided by Meyer & Messner (Meyer & Messner, 2005). The information of this section is mainly a summary of this overview, since many of the publications are not accessible.[4]

As discussed above, flood protection in the Netherlands is still very much based on high safety standards. However, as cost-benefit aspects gained importance with a shift to a more integrated risk approach, a ‘Standard Method’ for flood damage evaluation in all 53 dike ring areas has been developed. This method is carried out by HKV consultants and TNO Bouw and is supervised by Rijkswaterstaad. The newest version is called ‘Standard Method 2004-Damages and Casualties caused by flooding’ and is part of the Flood Management System (Hoogwater Informatie System; HIS.) With the so-called HIS-SSM (Schade en Slachtoffers Module) a standardized software for this method is available.

IV.1. Objective of damage evaluation in The Netherlands

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. These results are mainly used for informing decision makers on the national and regional level, e.g. to show where the most severe damages 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.

IV.2. Damage categories considered

The Standard Method considers quite a lot of asset categories, which are shown in Table 1. Most of the damage categories are further divided into direct damage, primary indirect damages (e.g. business interruption) and secondary indirect damages (losses occurring outside of the dike ring (Figure 3). As the only intangible category the standard method tries to give an estimation of the number of casualties.

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[3] Members of the DWA are municipalities, universities, engineering companies, public authorities and their experts. URL: http://www.dwa.de/portale/dwa_master/dwa_master.nsf/home?readform

[4] The original references can be looked up in Meyer & Messner, 2005. For a more detailed explanation of the evaluation method applied in The Netherlands refer to Meyer & Messner as well.

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

Table 1: Damage categories considered in The Netherlands (Source: Meyer & Messner)

IV.3. The Standard Method (HIS damage module)

As most other evaluation methods as well, inundation depth is needed as a main input in the Standard Method. In the case of residential buildings, impacts of velocity and waves are also considered. In respect to casualties, three different inundation characteristics are taken into account. These are velocity, rise rate and inundation depth.

Applying the Standard Method to evaluate potential damages involves mainly three essential parts:

1) Gathering of land-use data
   Information on the different land use categories and units are derived from a number of sources (Table 3), depending on the level of detail required. All land use informations collected are transformed in the same 100m grid used within the inundation simulation.
2) Estimation of maximum damage amounts per unit of each category
   For each of the damage categories a maximum damage amount for the particular unit is given (Table 3). These are based on a number of surveys and estimations provided, among others, by consultancies and insurances.
   Except for agriculture and recreation, damages are not assessed based on land use type but based on the number of units found within that land use class. Thus, grid cells with the same land use class can still show different damage values (Bruijn, K.). The maximum damage amounts are then multiplied with a damage factor of a damage function. The damage factor varies between 0 and 1, depending on the water depth (and partly on flow velocity). The total damage is derived by adding the damage of all objects.
   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. Estimated losses due to traffic interruptions for national trunk roads and railways are also included.

3) Derivation of Damage functions
Altogether, eleven damage functions are derived from a study by Vrouwenfelder in 1997 (Vrouenfelder, 1997). The different categories are presented in Figure 2. These damage functions were drawn up using both expert judgment and observed damage data. Regarding historic damage data, there is only a small damage database in The Netherlands.
As pointed out above, the damage functions applied 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.

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

Table 2: Categorisation of damage functions in the Standard Method (Source: Meyer & Messner)

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

Table 3. Standard Method: damage categories, units, maximum damage amounts, damage functions used and land use data sources (Source: Meyer & Messner)

IV.4. Discussion

The main advantage of a Standard Method for the whole Netherlands is that it is supposed to be relatively easy to apply and that it provides comparable results.

However, Meyer & Messner also point out the following shortcomings.

- The standardisation on a meso scale cuts down the accuracy in some respect. It is for example not possible to make any regional differentiation regarding the maximum damage amounts, or to make a distinction between damages caused by fresh water or salt water.
- Another shortcoming is the use of the same depth-damage function for the calculation of direct damages and the estimation of indirect losses. In contrast to direct damages, inundation depth does not seem to be the most important damage parameter in respect to losses caused by business interruption. 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 it is stated from Rijkswaterstaat that the maximum damage amounts are updated about every four years. Also land use data are updated periodically.
- Regarding uncertainties in the whole HIS-process of risk analysis, Meyer & Messner refer to the following aspects, which are based on an interview with Holtermann from Rijkswaterstaat. The most uncertain parts accordingly are the estimation of breach locations and corresponding probabilities and the calculation of the number of casualties.

In addition to these quality / uncertainty aspects mentioned by Meyer & Messner and Holterman respectively the following aspects seem to be important to me:

- A conceptual aspect is the use of replacement costs in flood damage assessment. According to Bruijn , flood damages in the HIS are assessed taking into account the replacement value for houses, capital goods and inventory (Bruijn).
  This approach seems to be problematic since the HIS represents an economic (societal) assessment of flood damages and not an individualistic. However, "using replacement costs is an overestimation of damage from a broader economic perspective, because the replacement usually involves improvements: old goods which are damaged during a flood are usually substituted by new, more productive and better performing goods. (…) the life span of the firm's capital is prolonged by reconstruction and the firm's productivity will probably improve (FLOODsite, 2007)." Thus, the depreciated value of houses, inventories and capital goods should be taken into account in an economic flood damage assessment (FLOODsite, 2007 / Buck, 2006)
- According to Holtermann, damage functions used in the Standard Method are drawn up based on both historic data and expert judgment. Regarding the use of historic data, I do not see a reason, why the uncertainties involved in using historic data, should not hold true for the Standard Method as well. In contrast, these uncertainties should be even more pronounced since there is only a small database available in The Netherlands.
- Also the use of expert judgement always involves uncertainties.
- So far, no research is available which investigates the uncertainties involved in the HIS-SSM, as it has been done by Merkel for the German HOWAS data base. As far as I have seen, uncertainties related to damage functions are not addressed neither in the HIS manual nor in flood risk studies (Ministerie van Verkeer en Waterstaat, 2005).
- It could be argued that the use of expert judgement represents a form of synthetic data which could potentially increase the accuracy of the damage functions. However, this seems doubtful due to the chosen scale, which makes no regional differentiation.

Especially regarding industrial assets, which can potentially cause major damages, this seems to involve a high degree of uncertainties.

- Concluding, assessing or estimating the accuracy of the HIS-SSM is very difficult. In my opinion, the use of the HIS damage module is less suitable to assess damages on a smaller scale due to the degree of averaging.

V. Damage Assessment in Germany

Contrary to most other countries, including the The Netherlands, the competencies of flood and water policy in Germany lie with the federal states (Bundeslaender) and not with the central government. As a consequence, there is no uniform method for flood damage assessment but flood damage analyses vary quite significantly and cannot be described in detail. Thus, the paper will only provide a description of the HOWAS data base and flood damage evaluation in Nordrhein-Westfalen and especially the Rhine Atlas.

V.1. The HOWAS data base

A common feature of most flood damage evaluations in Germany is the use of the HOWAS data base. It contains flood damage data from nine floods during 1978 and 1994, which have been collected by experts.[5] The database is divided into eight different sectors and further divided into single units. The information provided by the database is shown in Table 4.

Incident	Information about the flood incident (Date, municipality etc)	
Sector	Classified into eight economic sectors with key numbers	Number of single damage cases
	1*** Private Households	
	2*** Public infrastructure	1930
	3*** Service sector	157
	4*** Mining and building industry	630
	5*** Manufacturing industry	69
	6*** Buildings for farming, forestry and gardening	291
	7*** Agriculture, forestry and gardening (acreage)	521
	8*** Untilled areas	1
		1
	Further specified by a four digit key number e.g.:	
	12**: Single House: multi storey	
	121*: Building period until 1924, solid structure	
	1211: no cellar, no garage	90
	1214: partly with cellar, no garage	122
	1217: with cellar, no garage	64
	124*: Building period from 1949 until 1964, solid structure	87
	1247: with cellar, no garage	60
	1248: with cellar, with garage	
	2000: Public Infrastructure	
	2181: Post office	?

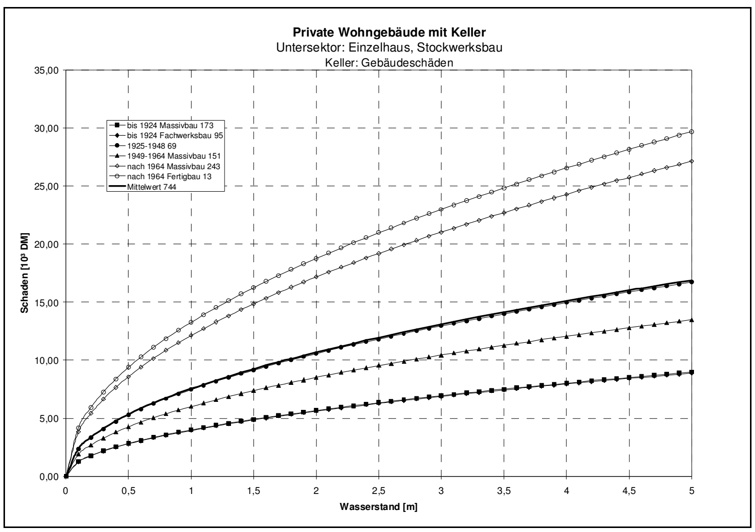
[5] An overview of the specific floods is provided in: Merz, B., Kreibich, h., Thieken, A., Schmidtke, R.: Estimation uncertainty of direct monetary flood damage to buildings. Natural Hazards and Earth System Sciences (2004) 4: 153-163.

Water depth	Inundation above the cellar / ground level
Damage	Divided into: Damages in the cellar - Building - Fixtures - Moveable inventory Damages on the structural levels - Building - Fixtures - Moveable inventory Damages on appurtenant structures

Table 4: Data sets and information available in the HOWAS data base (Derived from: Merz, 2006; Buck, 2006)

As many other approaches as well, the damage functions derived from the HOWAS are based on the parameter water depth only. Other influencing parameters are neglected (Merz, 2006). An example of a HOWAS damage function is given in Figure 2.

Figure 3: Damage function of the HOWAS data base: Private building with cellar, single house, multi storey, damage on the building structure



V.2. Damage evaluation in Nordrhein-Westfalen

Nordrhein-Westfalen, which is of interest for the ACER project, has a relatively long tradition in flood damage evaluation alongside the River Rhine. Reasons for that might be the frequency and severity of floods and the enormous economic importance of the River Rhine (Meyer & Messner, 2006).

Several studies have been carried out for flood damage assessments in Nordrhein-Westfalen, mainly concerning the River Rhine.[6] These range from small scale and very detailed evaluation to large scale approaches, such as the Rhine Atlas.

6 See Messner & Meyer for an overview.

V.3. Objective of the damage evaluations

The objectives of the damage evaluations vary significantly. While some are meant for informing the public about areas at risk (such as the Rhine Atlas), others have the aim of assessing the efficiency of single flood protections measures.

V.4. Damage categories considered

Most of the studies focus mainly on direct, tangible damages, especially buildings and their inventories. Damages due to business interruption are considered only by few studies.

V.5. Description of methods used for damage evaluations

Each of the different studies uses a different approach, which shall not be discussed in detail here. Again, a common feature of all studies is the use of information on flood damages stored in the HOWAS data base. Damage functions derived from the HOWAS are sometimes further evaluated and modified by experts, to adapt them to the regional settings.

V.5.1. The Rhine Atlas

In the face of the ACER project, the only study that shall be addressed in detail is the Rhine Atlas of the IKSR.

The assessment of damages is done in four steps (IKSR, 2001):

1. Determination of land use in the areas at flood risk, using the CORINE land cover data:
   The 44 land use categories were reclassified to 6 land use types (settlement, industry, traffic, agriculture, forest and other surfaces)
2. Determination of people affected and persons at risk in the inundated surfaces
3. Determination of assets and values on the inundated surfaces
   The total value of all goods, listed in the economic statistics from the German Laender was distributed over the six categories, distinguishing between investments in buildings and moveable assets. Since these values are only available for the German Laender, they were adapted to the other countries by applying specific factors for each of them.
4. Determination of potential damages by applying a damage function to the different goods, based on the parameter inundation depth.
   The damage functions were derived from the HOWAS as well as studies conducted in the Netherlands and expert judgement and aggregated to the six categories. Damages were assessed for cells with a cell size of 1000 square meters.

The Rhine Atlas also discusses why its results might vary from other studies. Reasons for that are:

- Other studies consider the replacement value (instead of the depreciated value), resulting in higher damages
- Interruption of production and other indirect damages are not considered
- Damages to vehicles (can make up to 2%-7% of the total damage) are not considered
- Expenses of emergency prevention, such as the deployment of the army, (can be up to several hundreds of millions) were not considered
- Damage reduction measures were not taken into account
- Damages to flood protection works (dikes, hydraulic structures) were not considered.

In respect to the River Rhine Delta, the following particularities are mentioned:

Dutch studies have determined a considerably higher damage potential in comparison to the Rhine Atlas. This is due to the fact that for settlements and the industrial sector indications are limited to direct material damage and do not take into account losses of value added and consequential damage.
Due to the high flood depth occurring in the Rhine Delta, considerable consequential damages can be expected, which do not occur to the same extent in the rest of the Rhine area. Additionally, the intensity of Dutch agriculture was not taken into account.

V.5. Discussion
Meyer & Messner mention the following shortcomings concerning the relevant studies, including the Rhine Atlas.

- A first critique is that most studies mainly focus on direct, tangible damages.
- Besides, other damage influencing factors apart from inundation depth are generally neglected.
- For areas, which are protected by a dike, high uncertainties are expected regarding the dike breach locations and the level of inundation following such an incident.

In addition, the following aspects should be taken into account, which are not mentioned by Meyer & Messner.

- As discussed above, the use of historic flood damage data involves large uncertainties (see section III.3.)

VI. The damage scanner
In the ACER project, we will make use of the so-called damage scanner, which is integrated in the Land Use Scanner.
In order to be able to evaluate damages occurring in the future, it represents a simplified damage module. In contrast to the HIS, damages are no longer assessed per object but per land use class, based on the parameter water depth. Thus, it is no longer necessary to have specific information about certain objects but the only input parameters required are a land use map and an inundation map.
The damage values for the different land use classes are derived from the HIS damage module in the following procedure (E-Mail from Karin de Bruijn, Delft Hydraulics).

1. In the HIS damage module the total damage per ha for the Netherlands was calculated corresponding with a uniform water depth in the Netherlands of 20m. The damage calculations based on 20m water depth are used as the MAXIMUM damage of each hectare.

2. Subsequently, the land use map of the ruimtescanner programme was used to calculate the AVERAGE damage (for that 20m depth) per land use type.

3. The total damage per ha for the Netherlands was calculated in the HIS damage module corresponding with a uniform water depth in the Netherlands of 0.05m, 0.1 m, 0.15m, 0.20m, 0.25m, 0.5m, 1m, 1.5m, 2m, 2.5m, 3m, 3.5m, 4m, 4.5m and 5m.

4. I calculated the average damage per land use type for a water depth of 0.05m, 0.1 m, 0.15m, 0.20m, 0.25m, 0.5m, 1m, 1.5m, 2m, 2.5m, 3m, 3.5m, 4m, 4.5m and 5m.

5. The results of step 4 have been used to derive the damage functions for the damage scanner

An overview of the maximum damage amounts for the different land use classes distinguished in the damage scanner and their respective damage functions is given in Table 5. The damage functions used are shown in Figure 4.

Table 5: Maximum damage amount per land use class

ID	Landgebruiksklasse	M€ / ha	Functie	Naam
1	wonen CSBC	9.65	1	Wonen
2	wonen GSCD	4	1	Wonen
3	wonen LW	3.9	1	Wonen
4	verblijfsrecreatie	0.11	2	Landbouw HIS
5	dagrecreatie	0.11	2	Landbouw HIS
6	werken	6.4	3	Werken
7	zeehaven	4.8	4	Zeehaven
8	natuur	0.09	2	Landbouw HIS
9	akkerbouw	0.02	2	Landbouw HIS
10	grondgebonden veeteelt	0.02	2	Landbouw HIS
11	glastuinbouw	0.7	7	glastuinbouw
12	intensieve veehouderij	0.9	8	intensieve veehouderij
13	infrastructuur	1.7	5	Infrastructuur
14	water	0	0	
15	zee	0	0	
16	bouwterrein	1.4	6	bouwterrein

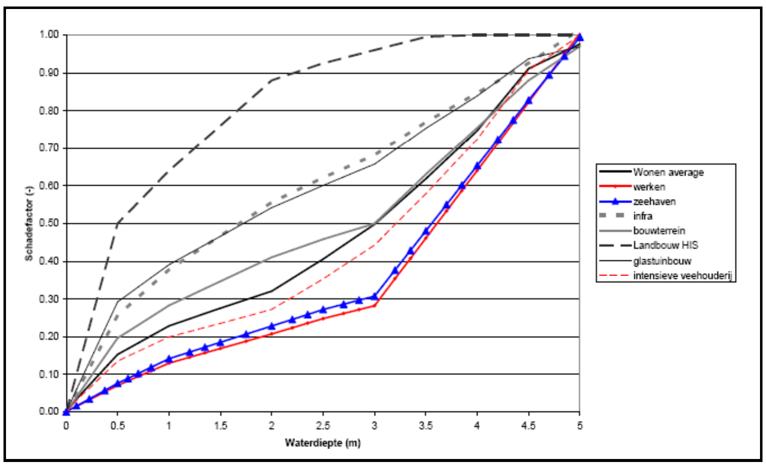


Figure 4: Damage functions used in the damage scanner

VI.1. Discussion

The following aspects should be taken into account when applying the damage scanner.

- Since the damage values and functions are derived from the HIS damage module, the quality aspects mentioned under section IV.4. should be considered for the damage scanner as well.
- The damage scanner is very simple and it is only useful for rough estimates. A main shortcoming is that it does not distinguish between damage in city centres of rural cities such as Leeuwarden and damages in 'real' cities such as Amsterdam and Rotterdam / The Hague (Bruijn).

  In the HIS damage module, the damage per grid cell can vary for one and the same type of land use. This is due to the fact that the HIS assesses damages based on specific objects, whose numbers can vary from grid cell to grid cell. In cities such as Leuwardeen there are less assets found than in city centres such as Amsterdam or Rotterdam. These differences are averaged in the land use scanner and thus no longer represented.

In order to assess the accuracy of the damage scanner in relation to the HIS damage module, de Bruijn compared the results obtained from both for two predefined scenarios for the different dike rings. The differences found range from an underestimation of damages of 28% up to an overestimation of damages of 46% (Bruijn). The largest differences are observed for small dike rings.

- The maximum damage for nature is considerably high in the damage scanner. This stems from the fact that in the HIS damage module 'nature' is not separately assessed but is a part of the land use type 'recreation'. In the HIS, the damage value for 'recreation' is specified as 90.000€/m^2. The same amount is thus specified in the damage scanner.
- Regarding the ACER project an additional challenge will be to apply the damage scanner to Germany and adjust its values.

Concluding: The damage scanner is a simplified damage assessment method, due to its averaging procedures. However, considering the scale we are looking at in the ACER project (trans-boundary river catchments), the degree of generalization in necessary and seems to be acceptable. Besides, the damage scanner is the only straight forward and feasible approach to make future projections for flood damages.

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