Damage assessment in The Netherlands

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Introduction

In the history of the Netherlands, floods have always played an important role. The system of dikes, dunes and dams is typical for the Dutch landscape and is of importance in both the spatial and administrative breakdown of the country. The fact that two-thirds of the country lies below sea level emphasizes the importance of an adequate policy against flooding.

For a large part the Netherlands are shaped by floods. A good example is the St. Elizabeth flood of 1421, which caused many towns to disappear under water and large parts of reclaimed land to be taken back by the sea. The national park The Biesbosch is a remnant of this flood. In more recent history, the flood disaster of 1953 in the provinces of Zeeland, Zuid-Holland and Brabant comes to mind. More than 1800 deaths, many injured and considerable damage have led to big changes in the Dutch water management. Flood disasters in other countries are of great influence for the Netherlands as well. From the floods in the South-East of Louisiana (US, 2005) it becomes quite clear that sometimes nature goes about her ways, with immense consequences.

The damage that occurred was enormous. As shown in the book “Damage through Flooding: Experience from New Orleans” [TU Delft & HKV, 2006] the estimated number of homes that were (partly) destroyed came to 93.000, with a corresponding damage estimate of 14 billion dollars. Damage from floods is sometimes a lot closer than thought possible, which is why it is the main topic of this paper.

In Dutch water management and more specifically in the Dutch policy on protection of our country against floods, the consequences of floods have been underexposed the last couple of years. Water-defence managers assess and design the water defences based on design conditions for water levels and waves. Dike breaches and their consequences are only recently getting more attention in the high-water protection program. This is largely due to changes in the way the safety philosophy is perceived. Besides the prevention of floods, fighting the consequences gets more and more emphasis.

In this paper a description is given on the Dutch water management in a general context. The main focus lies with the flood-risk approach, in which both probabilities of flooding and the consequences play an important role. The approach to compute risks in the Netherlands, based on probabilities and consequences is discussed. In particular we focus on the method to determine the damages and the loss of lives due to a large-scale flood from either the sea, a river or a lake.

Water management in the Netherlands

After the flood disaster of 1953 the Delta Committee was founded. The goal of this Committee was to formulate a plan which would protect the Netherlands against large-scale floods for a long period of time. This has led to the well-known Delta Works. The Delta Committee also proposed a system of safety standards (norms) with a risk approach. Based on a cost-benefit analysis (CBA) for the Western part of the Netherlands, the cost of strengthening the system of water defences was compared to the reduction of the risk due to the strengthening.

Afterwards, the Netherlands were divided into dike ring areas, each with a maximum allowed exceedance frequency of the water level. Based not only on economic grounds, but also because salt water does more damage than fresh water, and because the prediction of floods in a fluvial system is much better than those of coastal areas, the Western part of the country obtained a higher safety standard than other parts of the country.

The annual exceedance frequency of the design water level and wave conditions in the West is equal to 1/10000, while this is equal to 1/1250 per year in the upper-river area. These safety standards are not flooding probabilities[1]. The design numbers have been based on the flood risk that was deemed acceptable by the Delta Committee of 1/125.000 in the West of the Netherlands. However, with the techniques available in the sixties, it was not possible to compute the actual flooding probabilities of a dike ring. Therefore, from then on, the exceedance frequencies were used, assuming a factor 10 in residual strength of the water defences.

The safety against flooding in the Netherlands are committed by law in the Water Defence Law (1996) and the corresponding instruments. The safety standards as mentioned above are described in this law. There is also an obligation by the water-defence managers to assess the entire system based on this norm. To this end an assessment instrument and up-to-date hydraulic boundary conditions are established by the Secretary of State of the Ministry of Transport, Public Works and Water Management every five years. The method for the assessment and afterwards the improvement of insufficiently assessed water defences has proven its worth the last few years.

In the last decennia the knowledge about the computation of the actual flooding probabilities as well as the consequences have greatly increased, partly due to technological advances. There is simply more computational power, both in a probabilistic and a deterministic sense. The risk approach of the Delta Committee is ready for an update. Flooding probabilities as well as the consequences are being investigated as we speak, and are of great importance in many projects.

[1] In the case of an exceedance frequency a water level higher than the safety standard is considered. In case of the flooding probability the probability of an actual flood is considered, caused by one of various failure mechanisms.

Flood risk: probabilities and consequences

In order to say something about the safety of the Netherlands with respect to flooding, clarity is needed about the probability of a dike breach and the corresponding effects/consequences. For both aspects the Ministry of Transport, Public Works and Water Management develops computational methods and software packages, together with the Provinces, the Waterboards and consultancy firms. The flood risk can be expressed as a multiplication of the flooding probability and the consequences.

Probabilities

In order to compute the probability of a flood, the software package PC-Ring can be used. Both the hydraulic load parameters and the strength parameters are considered within this probabilistic model. An entire dike-ring area can be computed for the most important failure mechanisms, such as wave overtopping, piping and macro instability. From the results it becomes clear where the weak spots in the ring are located and which failure mechanism contributes most to the total probability of failure. For this, a considerable amount of data obtained from the water-defence managers is required. The hydraulic boundary conditions are established by the Ministry of Transport, Public Works and Water Management. The results from the PC-Ring model are the annual flooding probabilities for each section of water defence, as well as the overall failure probability for the entire dike ring. It should be noted, that the results from the project Flood Risk in the Netherlands 1 (FLORIS, 2005) are as of yet not robust for all dike-ring computations. More about this project and its follow-up (FLORIS2) can be found in the chapter The Damage method used in projects.

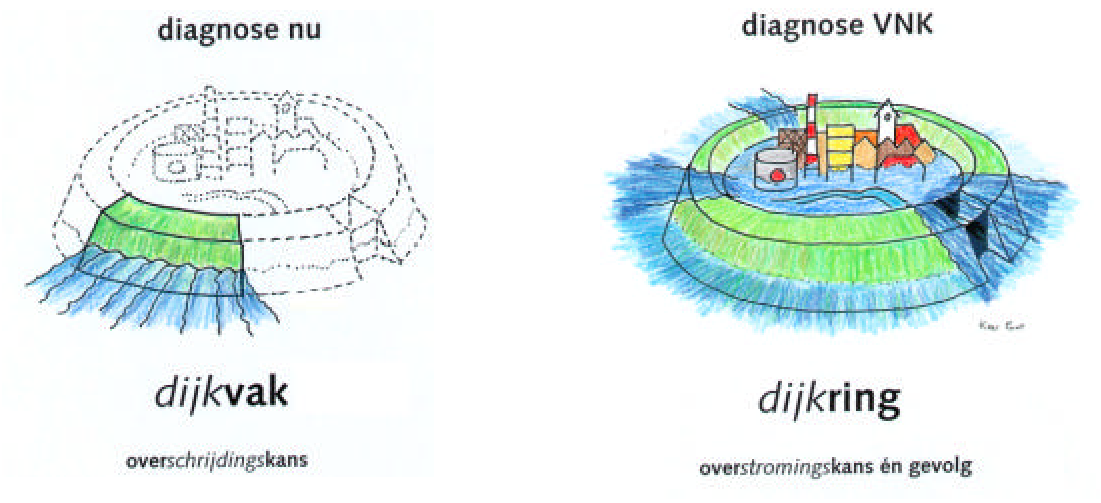

Fig. 1: Left: approach for a section of the ring, right: 'total ring approach' used in FLORIS (VNK)

Consequences

To find the flood risk, the flooding probabilities need to be multiplied by the consequences. The first step in computing the consequences is the creation of a flood-simulation model for a specific area (dike ring). In a flood-simulation model one and two-dimensional data, such as terrain height and roughness of the terrain (2D) are coupled with the water system (1D). The flood-simulation model then computes the development of a flood in time, based on the provided hydraulic boundary conditions and input about the breach location and growth.

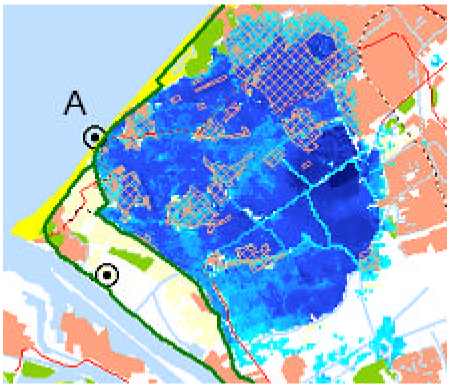

Fig. 2: Fictional example of the result of a flood simulation

The output of such a computation is, amongst others, a flooding pattern with information about the maximum water depth, the progress of the water depth in time and occurring flow velocities. It is also possible to visualize the flood by means of an animation. Especially for governors and policy makers these animations and flood maps are considered very important. They give a direct overview of what could go wrong and how a flood develops. In the discussion about dealing with the danger of floods and the preparation for an unexpected flood, these animations are often used. When making evacuation and disaster plans these data are invaluable.
Also towards the general public these maps and animations are used to create more awareness about the risks of flooding. The minister of Interior and Kingdom Relations and the Secretary of State of the Ministry of Transport, Public Works and Water Management have agreed to work towards the appearance of a national Flood Risk Map in the year 2007.

Assessment of flood damage

A flood simulation basically provides technical output, such as the before-mentioned occurring water depths and arrival times of the water. For a number of research projects this is sufficient information. With a flood simulation alone, however, nothing can be said yet about the amount of damage and losses of life. The prospect of being able to quantify the consequences, in other words express them in terms of money and numbers of casualties, becomes ever bigger.

The Ministry of Transport, Public Works and Water Management is investigating whether the safety of the Netherlands against flooding is still adequate. On both large and small scales safety studies are carried out which, together, should keep our country free of flooding. Additionally, the question arises how effective certain measures are. It has turned out that the quantification of the costs and benefits of a measure are a well-balanced way to compare and evaluate various measures.

With the aid of a cost-benefit analysis it is possible (based on economic grounds) to weigh the cost of a certain measure against its benefits. The cost, for example, are the construction and maintenance cost of a water defence. The benefits are less easy to establish, but are characterized by a reduction of the damage in case of a flood. As an example we mention the construction of a compartment dike which reduces the size of a potential flood zone. The damage in the flooded area might be larger than without the dike, but the dry area is spared, which leads to damage reduction.

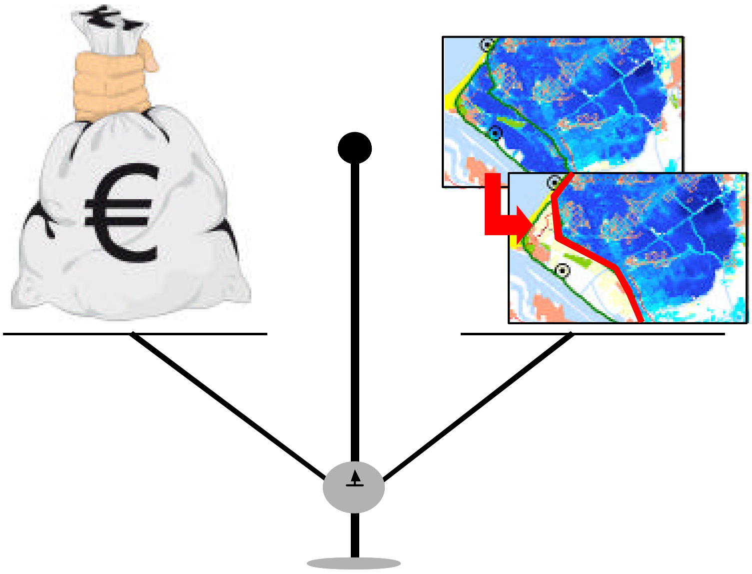

Fig. 3: Effects of measures and the costs are carefully weight against each other in a cost benefit analyses

Ultimately it is possible to determine the economically most efficient measures with this technique (CBA). Besides the CBA the common welfare, in other words the acceptance of measures, is of great importance.

From the previous it can be concluded that an instrument to assess the damage and loss of life of a large-scale flood is essential in giving hands and feet to the flood risk approach.

Introduction to the damage module (HIS SSM)

Background

The damage and casualty module (HIS SSM) is frequently used in The Netherlands to assess the expected damage and number of casualties as a result of a (large scale) flood. The module is part of the High water Information System (HIS). This information system is mainly used in the preparation phase of a flood, but it can also be used during a high-water situation. The main purpose of the system is to improve the information exchange and communication.

HIS and HIS SSM are both owned by the Ministry of Transport, Public Works and Water Management, Road and Hydraulic Engineering Division (DWW). The development of the damage module was started in 1999/2000. Besides the DWW firms such as HKV consultants, GEODAN and TNO were involved. The development of the module still continues to this day. The latest version of the damage module was released in the summer of 2006.

With permission of the DWW, the damage module is available for users. Besides the Ministry of Transport, Public Works and Water Management, it is often used by Dutch provinces, water boards and consultancy firms.

The damage module has been developed to determine the amount of damage and casualties as a result of a (large) flood. A large flood (*Fig. 4*) corresponds for example with the flooding of an entire dike-ring area. The Netherlands as a whole is divided into dike rings (*Fig. 5*). A dike ring is an area surrounded by (primary) flood defences such as dikes, dunes and hydraulic structures. For each dike ring a safety level is assigned by the Flood Defence Law.

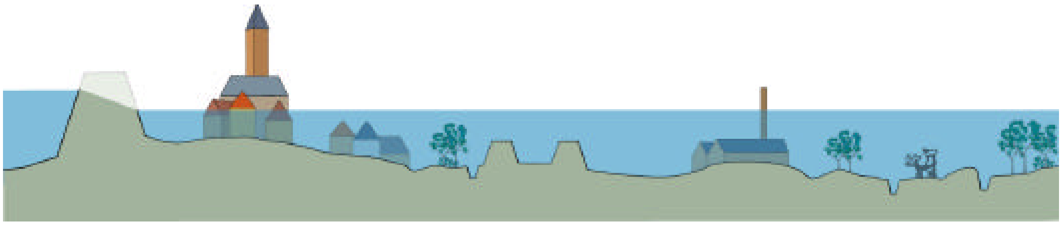

Fig. 4: Sketch ofthe impact of a large scale flood

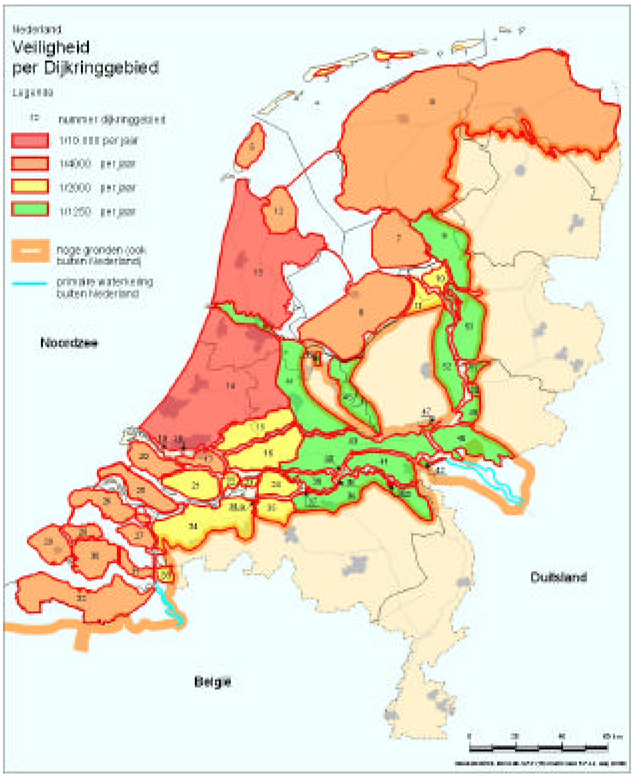

Fig. 5: Dike rings in The Netherlands

Damage

The monetary damage computed by the module is calculated in euros. Three types of damages are distinguished:

- Damage to buildings, inventories, terrain and infrastructure. For example the damage to family houses in the flooded area.
- Direct damage caused by production loss of companies in flooded areas. For example the damage to a bakery in the flooded area.

- Indirect damage, which is caused outside the flooded area, such as damaged roads that make transport of goods by road impossible, or damage to suppliers of companies in the flooded area.

Casualties and Evacuation

The module also calculates the number of people in the flooded area and casualties caused by the flood. Casualties occur due to high water depths, high water ascending rates (>0,5 m/hour) and high flow velocities (> 2m/s). The effect of evacuation on the casualties can also be calculated. Therefore the user determines the percentage of people that will be evacuated, which is then used as input for the computation.

The damage module

Fig. 6 gives a schematic overview of the damage and casualties module. The model can be described by the three main components:

- Input
- The module
- Output

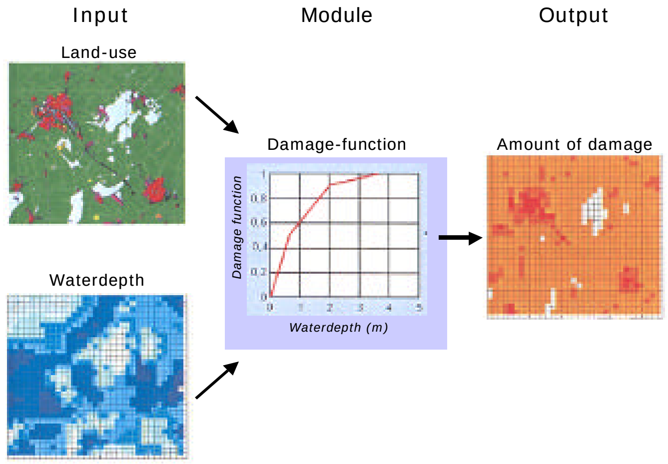

Fig. 6: The damage module

Input

The flood-damage model combines the flood pattern and the hydraulic situation (flow velocity, water level ascension rates) with a land-use model. The damage is calculated on grids with a cell size of 100 by 100 meters. When using a one or two-dimensional hydraulic model such as Sobek as flood simulation model, the results can be used directly as input for the damage module.

Module

The damage module HIS SSM contains a default damage model and dataset called the 'default method'. For a user it is possible to construct a new model, using building blocks from this 'default method'.

The HIS SSM (default) damage model consists of:

- Geographical data (eg. land use, houses and employment figures)
- Damage functions
- Damage amounts

Geographical data

The geographical data in HIS SSM is divided in different damage categories. This geographical data is available in the model as polygons (m^2), lines (m) and point (number of item) information. The geographical information is based on information available in 2005.

The damage is determined for different damage categories:

Land use:
- Agriculture
- Greenhouse farming
- Urban area
- Recreation
- Reservoirs
- Airports

Infrastructure:
- Highway
- Carriage way
- Remaining roads
- Railway

Households:
- Single-family building
- Low-rise building
- High-rise building
- Medium-rise building
- Farm houses

Business:
- Minerals
- Construction
- Trade and hotel / catering industry
- Transportation and communication
- Bank and insurance companies
- Industry
- Utility companies
- Health care
- Government

Others:
- Pumps
- Purification stations

Maximum Damage amounts

The damage in the 'default method', is mostly monetary damage. The only non-monetary damage that is calculated is the number of casualties caused by a flood. HIS

SSM calculates all types of damages mentioned before; the direct and indirect damage and the direct damage caused by business interruption.

The maximum damage amounts for direct damages to objects such as houses are the costs of rebuilding assuming the land is still available. For the maximum damage to for example inventories or cars, the replacement value is used (market value). For agriculture the damage caused by loss of crops or cattle should be added to the replacement costs. Production costs are used as direct damage value.

The direct damage caused by business interruption is the loss of profit. During a flood the production will (temporarily) stop and no products or services for the production process will be bought. The maximum indirect damages are also based on the profit loss.

The maximum damage amounts in HIS SSM are based on the 'Financial Numbers Damage caused by Floods' [NEI, 2002].

Damage Functions

The damage functions describe the relationship between hydraulic parameters and relative damage (factor). The following hydraulic parameters are used in the damage functions:

- flood depth (m)
- flow velocity (m/s)
- critical flow velocity (m/s)
- water-level ascend rate (m/hour)

An increasing flood depth, and a flow velocity larger than the critical flow velocity (or 0.25 * critical flow velocity) results in larger relative damage or even maximum damage. The presence of waves also increases the calculated relative damage.
There are 9 different damage functions available in the HIS SSM ‘default method’:

- Agriculture and recreation
- Cars
- Roads and railroads
- Electricity and communication
- Industry
- Low-rise buildings
- Medium-rise buildings
- High-rise buildings
- Single family houses or farms

The user is also able to define new damage functions.

Damage computation

The damage can now be calculated using equation 1.

$$S = \sum_{i=1}^{n} a_i n_i S_i \qquad (eq.\ 1)$$

With : n_i number of units in a category i (-)

S_i maximum damage of the category i (€/m² of €/unit)

a_i damage factor i (-)

Example of a damage computation

In our example area we have 10.000 m² of agriculture. The flood simulation shows that the waterdepth within the area is 1 meter. What is the damage?

In the graph below (Fig. 7) the damage function of agriculture is presented.
The damage factor at a water depth of 1 meter is 0.65.
The maximum damage of agriculture is 1.50 Euro/m^2.
The damage is equal to:

*10.000 * 0.65 * 1.50 = 9750 Euro*

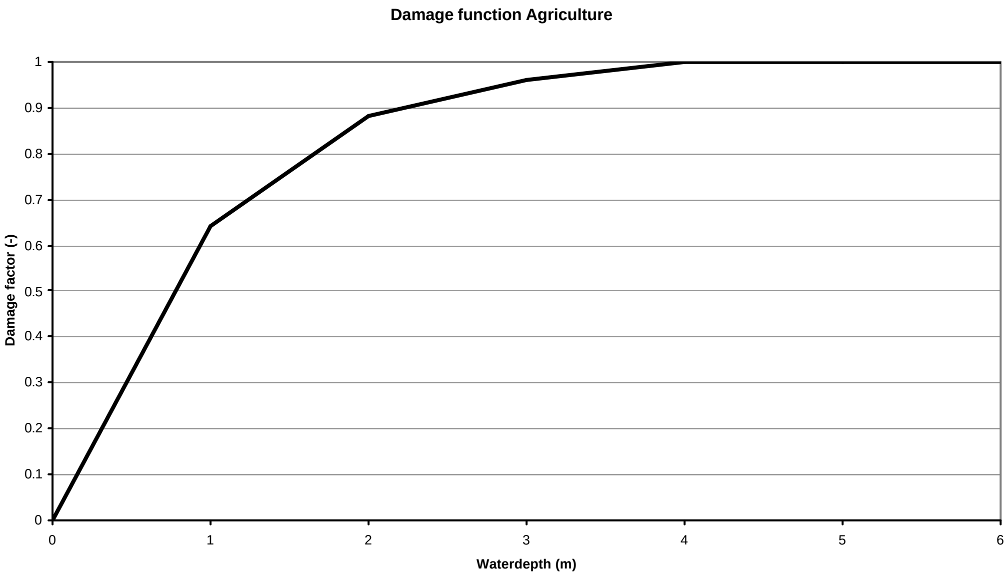

Fig. 7: Damage function agriculture

The steps shown in the example are the same steps as shown in Fig. 8 .

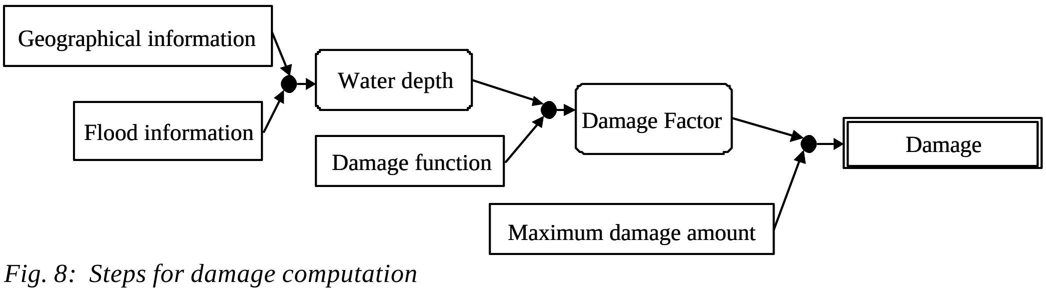

Fig. 8: Steps for damage computation

Output

Output of the damage module is the amount of damage as result of the flood for each raster cell. This information is also available in a damage table. An example of both output types are shown in Fig. 9 and Fig.10.

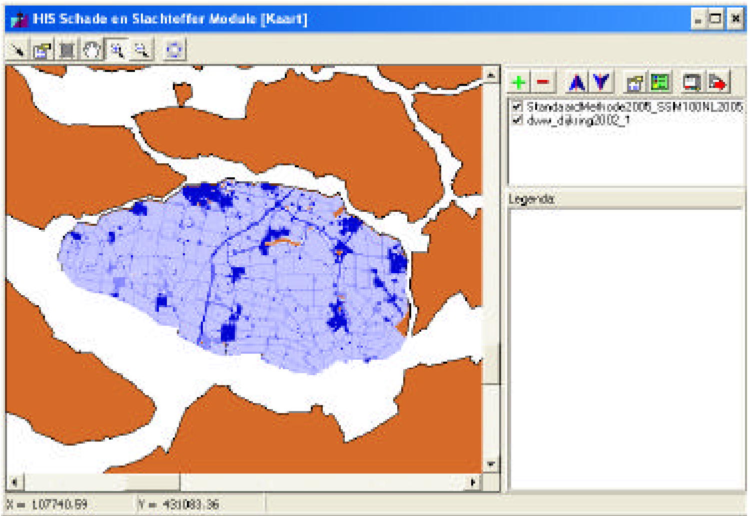

Fig. 9: Raster output of the damage module

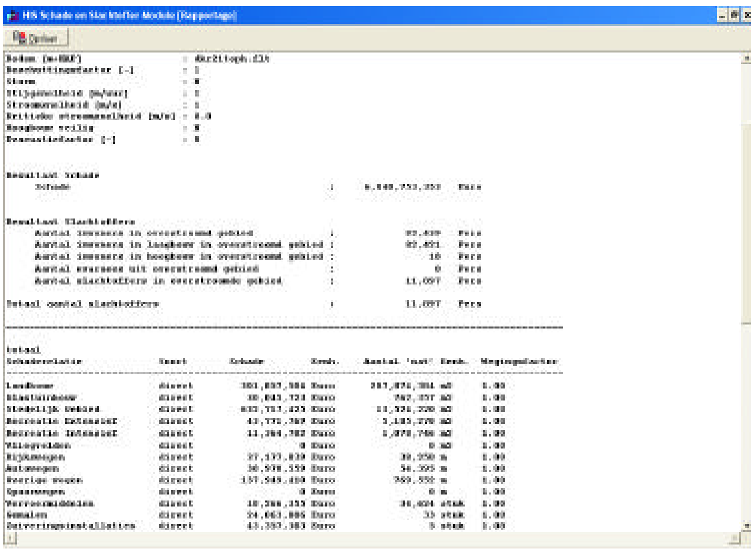

Fig. 10: Raster output of the damage module

For more information about the damage module HIS SSM we refer to the User Manual [HKV 2006] and ‘The default method 2006 beta’ [HKV, 2006].

Further development of the damage module

The damage module is used in more and more projects. Most of the time using the 'default method and model', but also user-defined models are developed. The goal of these projects is always the same; the estimation of the amount of damage and the number of casualties for a certain scenario. The Ministry of Transport, Public Works and Water Management wishes to stay in charge of the development of the module.

Development and using the damage module

The damage model is constantly being developed further. New information, new possibilities and specific questions generated in different projects result in a new version of the module about once a year. At the end of 2006 an independent panel of experts of civil engineers and financial specialists reviewed the damage module. As a result of this review different propositions for improvement of the module have been obtained. At this moment and in the near future a selection of these improvements will be carried out, for example:

- Add a new damage category for dikes
- Add new damage categories for landscapes, nature and cultural objects, preferably through economic values.
- Add the costs of evacuation, rescue operations and the cleaning of the flooded area
- Determine whether the damage for certain categories should be differentiated for different regions.

It is obvious to use the module for different projects where risk assessments are carried out. Nevertheless a few remarks should be made. At this moment there are a few limitations to the usage of the module:

- The module is developed for large-scale floods. The damage functions and damage amounts are not developed for smaller scale floods (as a result of excessive rain)
- The detail level of the module (100 by 100 meter) is not suitable for areas between the rivers and the dikes. Most of the time these areas need a more detailed model.

- Long term future developments probably ask for changes in land use, but maybe also in different categories, damage functions and damage amounts. These developments are also uncertain.

Looking in the future, changes in climate and spatial planning

As mentioned before, not only the present situation is of importance regarding water policy issues. Future developments such as changes in spatial planning, economic growth and climate change make us wonder what the impact would be in terms of flood risk. Therefore changes in probabilities and consequences are of great importance.

Large-scale building projects for houses and industry, as well as the population growth result in an increase of the economic value behind our dikes. It is important to determine this increase in order to determine the risk. The same can be said about climate change. Increasing discharges of a river as the Rhine, the rise of the sea level and the decrease of the height of our land can lead to larger floods and corresponding effects. The influences of climate change on the flood risk should be determined. Using qualitative data in these cases is simply not enough. Quantitative data is needed. The damage model can supply in this demand for quantitative results.

Projects using the damage module

The previous chapter gave a description of the content of the damage module. In the present chapter some projects in which the damage module is used, are described.

FLORIS 2

FLORIS 2 is a national project where the water boards, the provincies and the Dutch government work closely together to determine the flood risk. For each of the 53 dike rings (the new dike rings along the Meuse river are not implemented in the study) the probability of a flood is determined with the PC-RING model. Next, the flood patterns are simulated, after which the damage of these floods is calculated with the damage module. FLORIS 2 is one of the main projects for the further development of the damage module. The main goal of the FLORIS 2 project is to show the weak points in our current flood defences. Besides that FLORIS 2 inspires the discussion about a new safety standard for the Dutch dikes.

WV21

Water Safety in the 21st century is a project for the next few years and contains the following three main topics:

1. Adaptating or updating the current safety levels together with the coupled law.
   The safety level advised on by the Delta Committee is almost 50 years old. It should be looked into whether it is still useful and whether alternatives for new safety levels exist. The risk approach is an important aspect in this study. The damage module is used in this study to carry out a cost-benefit analyses.
2. Decreasing the consequences of a flood.
   This can be done in different ways. Changes in the landschape are a possibility (using compartment dikes, retention areas), but improving preparation and evacuation is also a possibility. Especially the effect of spatial changes on the consequences can be well determined using the HIS flood simulation module and the damage module. The discussion of the subject is supported by results calculated with the damage module.
3. Enlarge (public) awareness on risks.
   Just after a flood or a near flood the citizens understand the hazards of water end the required defense against it. The consequences are than quite easy to imagine for the general public. But if nothing happens for several years, the interest decreases. This is also the case for the position of this topic on the political agenda. Because of the expected climate changes and the appearing increase in risks, the Ministry of Transport, Public Works and Water Management and the Ministry of Internal affairs are providing additional funds. People should be more aware of the hazards and their own responsibility. Risk maps, including information about floods, will be produced to give the general public more information about the hazards and to

inform them on safety matters. The damage module might give input for this development.

‘The Netherlands in the future & Attention for safety’

These are two studies that aim for the future development of spatial planning and climate changes on two different time scales (50 years and 100 years ahead). It is now investigated whether the damage module can be use to determine the consequences of these changes in order to calculate the risk. Adaptation of the module is then necessary, because new land-use datasets would need to be developed, for example. This is also the case for new flood simulations.

Transnational dike-ring areas along the Niederrhein

In the collaboration structure between Nordrhein-Westfalen, the Province of Gelderland and the Ministry of Transport, Public Works and Water Management Rijkswaterstaat and the German-Dutch Workgroup High Water it has been decided to determine the flood risk for the dike rings 42 and 48 in a full co-operation project between different institutes of the two countries, Germany and The Netherlands.

Within the project different theme groups are established, and together these groups will determine the final risk. Theme group 1 concentrates on the failure mechanisms and the failure probabilities. Based on this information theme group 2 focusses on flood simulations. Next, theme group 3 determines the damages for various scenario’s. For this the damage module will be used, adjusted with German input. Cost-benefit analyses are then carried out in theme group 4. Together with all groups the risks are determined combining the probabilities and the consequences (damages).

Besides this risk computation the co-operation between the two countries and using the same methods for both countries is a main goal of the project.

Summary and conclusions

The damage module has been used for many years and in many different projects. Water safety is a very important aspect in Dutch politics, receiving lots of interest from all kinds of groups, varying from the government to the press. The wish to improve the damage module is therefore widely carried by the different parties. A large number of specialisms are involved during this development, such as civil engineers, financial experts, IT developers and experts on spatial development, landscape and nature. Besides these experts consultancy firms and (regional) governmental institutes such as the provinces and water boards are also involved in this development. We expect that the damage module will remain the model to be used to determine the damage and casualties during large scale floods.

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