Reduction of exposure to floods and reduction of flood consequences

Work package leader : Prof. dr Jeroen Aerts

Content

1 Description work package

1.1 Problem definition, aim and central research questions

Traditionally, flood risk management in the Netherlands has concentrated on flood defense. However, there is currently a trend towards a more integrated flood risk management (e.g., Büchele et al., 2006; Merz et al., 2004; FLOODsite, 2009), whereby flood risk is defined as the probability of flooding multiplied by the potential flood damage. In Europe, flood risk assessment has been given added impetus by the European Directive on Flood Risk Assessment and Management (EFD) (Directive 2007/60/EC) which entered into force in 2007, and requires Member States to assess which areas are at risk from flooding, to map flood hazards and risks, and to take adequate and coordinated measures to reduce flood risk.

The proposed research will concentrate on the potential of reducing flood damages through spatial planning measures, flood zoning and building codes. Research in Germany (Kreibich et al, 2005) and the USA (Kunreuther et al., 2009) shows the effectiveness of building codes on the implementation of flood-damage reducing measures on the household scale. If applied to large numbers of properties, their effect can be substantial.

The research activities will focus on the Rijnmond case study area (Rotterdam - Drechtsteden) and will be closely tied to the activities in WP1. In contrast to WP1, this WP will focus on developing flood damage reducing measures that can sustain a so-called "Open Rijnmond estuary adaptation strategy". Such a strategy would allow storm surges, tides and river discharges to influence the flood water levels in the area. Analogue to the situation in Hamburg (open Elbe estuary), this would require a developments of flood resistant buildings, maybe in combination with the existing levee system (WP 3), but it would also require investigating whether it is possible to combine urban (re-)-development and new properties with dike reinforcement.
This WP will assess (1) which urban planning policies in terms of zoning and building regulations are needed to combine flood defenses with urban development and (2) what risk reduction can be achieved by implementing damage reducing measures. Hence, this work package contains two projects:

- The first project (postdoc) aims at reviewing flood zoning policies for non-protected areas in the Netherlands (if existing) and also which building codes exist for flood-proofing properties. The project uses this information to analyse the Rijnmond region and to design a new “ Open Rijnmond adaptation strategy”.
- The second project is a PhD research that aims at adapting the existing flood damage models (HIS-SSM) in such a way that it can be used to assess the damage reduction and risk reduction which can be achieved with these damage-reducing measures. This involves (1) improving stage damage functions and adding stage damage functions for buildings with different degrees of flood-proofing; and (2) use the updated model for assessing the resulting flood risk for the (non-) protected parts of the Rijnmond area using the newest – probabilistic - climate scenario’s that will be derived from Theme 6 (WP3.1)

1.2 Interdisciplinarity and coherence between the projects

The first project (4.1), is predominantly an applied scientific project with a duration of 2,5 years. However, it is clearly a complex project with still many scientific challenges,. Hence we have decided to make this a postdoc project. This outcome of the project is a flood risk management strategy for an open Rijnmond Estuary which can be used in project 4.2.

The PhD project focuses on adapting the existing flood damage mode HIS-SSM in order to allow its wider application in assessments of local damage reducing measures. The project starts with investigating scientific questions on stage damage functions and the use of probabilistic scenario’s. The strategy developed in 4.1 is available for evaluation in 4.2 after 2 years, and hence can become the prime case study for the PhD research.

1.3 Stakeholders

The main stakeholders are the hotspots Large Rivers and Rotterdam-Rijnmond. They have have clearly indicated their interest in this topic. In addition, they have indicated their interest in the development of an Open Rijnmond strategy, which is also mentioned in the preparation of the Delta plan Rijnmond. Hence an important additional stakeholder is the Delta Programme.
Furthermore, insurance companies are interested in the probabilistic scenario's and the use of those scenario's for estimating flood damage distributions.

2 Project 4.1 Flood risk management through zoning and building codes for the Rijnmond area

Project leader: Prof. dr Jeroen Aerts

2.1 Problem definition, aim and central research questions

For the Rijnmond area (Rotterdam – Drechtsteden), the Delta Committee (Veerman, 2008) has recommended to investigate the possibility of a dynamic barrier system to protect the region from extreme flood events. This option is explored in WP1. Another option that has been raised by stakeholders in the region is an open Rijnmond area allowing coastal floods and river discharges to move freely through the area. Analogue to the situation in Hamburg (Elbe Estuary), this would require a reinforcement of existing embankments but also an adaptation of the urban development.

Such an "Open Rijnmond Estuary strategy" would probably require a review of existing risk zoning methods and building codes. The research will use GIS techniques to assess where new building codes and/or new spatial legislation is necessary. Furthermore, we shall assess how both new and existing properties can be made more flood proof by enforcing new building codes. An additional question is who should be responsible for developing flood risk zoning maps and building codes and what obstacles in terms of policy and legal aspects prevent such new policies. The study will therefore build on the results of WP 5.

Finally, there is the issue of the cost of such Open Rijnmond strategy. Reserving space for wider embankments requires an investment, probably by the government. New building codes also would imply additional cost for new properties as we have seen in research for the Zuidplaspolder (Dobbelsteen et al., 2008). It was found that flood proof houses would mean that housing prices increase with +/- 20%. Additional research is needed to estimate those costs and new cost curves should be developed for the different measures.

The main aims of the current postdoc proposal is to develop an Open Rijnmond Strategy through integrating flood protection measures (dikes, levees), spatial planning and building code measures. To this end, we shall address the following research questions:

1. Which risk zoning policies and building codes can be developed in the Netherlands in order to reduce the damage from floods?

2. How can innovative protection measures, building codes and risk zoning policies be combined into an integrated development strategy for the Rijnmond area that allows water to move freely and which is resilient at the same time.
3. What are the costs of such an open Rijnmond strategy and what are possible pitfalls in terms of spatial planning policies?

2.2 Approach and methodology

The research will be conducted according to the following steps:

1. Inventory of the existing (national) flood zoning policies and building codes and comparison with the results from WP 5 (project 5.4). Next, assessment of possible policies and building codes using various indicators on their potential to be implemented in the Netherlands, and in particular in the region Rijnmond.
2. Development of an “Open Rijnmond” adaptation strategy together with specialists and stakeholders, with the emphasis on measures that combine urban development with flood protection, such as combinations of embankments with urban development, new building codes to flood-proof houses in relation to risk zoning.
3. A cost estimate of the Open Rijnmond strategy including flood risk (with cost curves as used by e.g. Sprong, 2008) and information from current waterfront development projects. Here, close collaboration is sought with urban planners, TU Delft and Deltares.

2.3 Synthesis of results and the development of recommendations.Scientific deliverables and results

The research results will have considerable scientific value in the domain of flood damage mitigation and spatial planning, the methods developed and insights obtained about the feasibility of damage mitigation measures and building codes in the Region Rijnmond and about the costs involved. The scientific deliverables are:

- *Assessment of existing Dutch building codes and Dutch legislation* (using inventory of WP5)
- Overview of risk zoning strategies as a flood damage reduction measure
- A description of an *Open Rijnmond adaptation strategy* without storm surge barriers
- *Cost of the Open Rijnmond Strategy* including new insights in the cost functions for waterfront development and multi functional land use.

2.4 Integration of general research questions with hotspot-specific questions

The Hotspots “Large Rivers” and “Rotterdam-Rijnmond” have indicated their interest in this research in the existing “afstemmingsoverleg Rijnmond” (including Waterboards, Cities of Rotterdam and Dordrecht, Port Authority, etc). The interest concerns the development of an Open Rijnmond strategy as well as our proposal on flood damage modelling.

2.5 Societal deliverables and results

The proposed research will provide useful knowledge for the identified hotspot areas in forming adaptation policies, but have a broader societal relevance as well.
Given the international move towards a risk-based approach to flood risk management, probabilistic estimates of damage will be essential for making sound decisions in fields such as spatial planning, building regulations, insurance, and for re-defining spatially-variable protection standards.

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3 Project 4.2 Uncertainty assessment in flood risk modeling

project leader: Prof. dr Jeroen Aerts

3.1 Problem definition, aim and central research questions

Quite a number of flood risk and damage models have been developed and employed in, amongst others, Japan (Dutta et al., 2003), Thailand (Tang et al., 1992; Lekuthai and Vongvisessomjai, 2001) and Brazil (Nascimento et al., 2006). In Europe, several methods have been developed to assess flood damages at various scales. In the UK the 'multi-coloured manual' (Penning-Rowsell et al., 2003) forms the basis for flood risk assessments (as in Hall et al., 2005). Flood damage models generally have three components (see also Messner et al., 2007), containing information about:

- the hydrological characteristics. These are delivered by hydrological models that generate discharges and their probability. Future discharges are simulated using climate scenario's which are used as boundary conditions for a hydrological and hydrodynamic model. Recent work on this topic for the Rhine and Meuse rivers has been done by Te Linde et al (2009) and Ward et al (2008).
- The damage potential. This information can be derived from detailed databases on properties and economic assets. At a regional or national scale, land use information is often used as an indicator for potential flood damage
- Stage damage functions. These functions describe the relation between the hydrological characteristics (e.g. flood depth and velocity) and potential flood damage.

In The Netherlands, the HIS-SSM model is used to estimate potential flood damage for various scenario's. This model is based on the so called 'Standard Method' that uses stage damage functions for describing the relation between water depth and flood damage (Kok et al., 2005). Although quite some literature exists on flood damage and flood risk modelling, the uncertainty in flood risk calculations remains high in all three components. Research in progress by De Moel (2009) concentrates on the uncertainty in the second component (land use).

We propose to further elaborate on assessing uncertainty in components (1) and (3) within flood risk modelling (Apel et al, 2004):

(1) Damage reduction and stage damage functions: On a regional and national scale, these functions assume that the relation between water depth and damage is uniformly distributed, often generalizing heterogeneity in land use. For example, the land use class urban contains different objects with different damage functions. Stage damage functions also generalize the different resistance classes that can be distinguished for different building types. Hence, a review of the existing stage damage functions within the HISS SSM will be undertaken in order to address the current status of building codes and main property types. Furthermore, stage damage functions change as soon as new building codes are enforced for making properties more flood proof. Additional research is needed to construct new stage damage functions that address the effect of new building codes. Finally, another challenge is to see whether we can model stage damage functions over time assuming properties and their building codes change over time.

(2) Probability distribution of flood damages: Once we have managed to derive improved stage-damage functions, we can next try to calculate uncertainty of future damages under the assumption of a variety of climate change scenario's. One of the main limitations is that the climate change impact assessments on which the damage estimates are based, predominantly rely on a scenario based approach (see New et al., 2007). The scenario based approach is useful for exploring the potential impacts of climate change. However, it presents major problems for the assessment of adaptation options and for decision makers, since the scenarios used only represent single future pathways, and have no associated likelihood. As we would like to estimate the effectiveness of various damage reducing measures in WP 4.1, the tendency may then be to evaluate a measure to a middle of the road scenario or more conservatively, a strategy that is robust in the face of all available scenario-based information. One of the main recommendations of the Veerman Commission was, hence, the need to develop better estimates of the probability of a flood using probabilistic climate change scenarios, in order to provide improved estimates of flood risk and flood damage (New et al. (2007). Lopez et al. (2009) used a probabilistic scenario based approach to examine the effects of climate change on low flows and high flows on the rivers Thames and Exe respectively, and their impacts on water resource management.

The main ***research goal*** of the current proposal is to assess the uncertainty in flood damage modelling in the Netherlands. Firstly, we will update the existing HIS-SSM model by reviewing the stage damage functions and accommodate the model for running under future scenario's (both climate and land us scenario's). Secondly, we aim to examine methods to use probabilistic climate change scenarios to estimate flood damages and their probability distribution using the updated HIS SSM model. For this, we closely cooperate with Theme 6 (climate scenario's) and existing KvK projects on hydrological modelling

(HBV-SOBEK) for the Rhine and Meuse rivers. The method will be applied to the Rijnmond region, the same case study as used within WP 4.1

In order to achieve these main goal, we will address the following research objectives:

1. Make an inventory of the existing stage damage functions in the HIS SSM
2. Develop new stage damage functions on the basis of updated building codes
3. Derive probabilistic discharges for the rivers Rhine and Meuse from Theme 6, WP3.1
4. Generate a distribution of damages for the Rijnmond region
5. Demonstrate the effectiveness of damage reducing measures as defined under WP 4.1 assuming the probabilistic scenario's.

3.2 Approach and methodology

The research will be conducted according to the following five steps:

1. Existing stage damage functions will be assessed and compared with stage damage functions used in other models (e.g Rhine-Atlas (IKSR, 2001); Vanneuville et al. (2006) Meyer and Messner (2005); Veerbeek et al., 2009).
2. We then use new information on possible future building codes from WP4.1 and WP5 for developing new stage damage function that represent new building codes. The new functions will be implemented in the HIS SSM
3. From KvK Theme 6, WP 3.1 we will derive both probabilistic climate as well as discharge probability distributions. These will be used as input for hydrological models (HBV-SOBEK) in existing KvK projects on the Rhine and Meuse. These models produce inundation distributions, which in turn can be used as input for the HIS SSM model in order to develop flood damage probability distributions.
4. The damage distributions (both for the current and the future climate) will be used to develop loss probability curves for the full range of return periods (from annual up to >1000 years), the integral of which can be used to derive improved estimates of annualised damage and the associated uncertainty (Kunreuther, 2002; Grossi and Kunreuther, 2005).
5. The loss probability curves will be calculated using information on damage reducing measures for the region Rijnmond developed in WP4.1 (through altering the stage damage functions). In this way, we can simulate how these measures.

3.3 Scientific deliverables and results

The scientific deliverables are:

- *Paper 'Effect of building codes'*
- *Paper 'Dynamics of building codes'*
- *Paper 'Probabilistic flood damages'*
- *Paper Managing extreme flood events'*

3.4 Integration of general research questions with hotspot-specific questions

The hotspots “Grote Rivieren” and “Rotterdam – Rijnmond” have clearly indicated there is a need for research into flood damage reducing measures. This research adjusts existing flood damage models in order to improve the simulation of the effect of damage reducing measures. Furthermore, one of the main recommendations of both the Veerman Committee and AvV was the need to develop better estimates of the probability of a flood using probabilistic climate change scenarios, in order to provide improved estimates of flood risk and flood damage. To our knowledge, there have been only few studies have attempted to use probabilistic scenarios of climate change to develop probabilistic scenarios of flood risk and flood damage (New et al., 2007; Lopez et al., 2009).

3.5 Societal deliverables and results

The proposed research will provide useful knowledge for the identified Hotspots in forming adaptation policies, but have a broader societal relevance as well. Evidently, these insights are very valuable for Water managers and other decision-makers are faced with uncertainty in future scenarios. Furthermore, given the international move towards a more risk-based approach to flood management, probabilistic estimates of damage will be essential in order to make sound decisions in fields such as spatial planning, building codes, insurance, and in defining spatially variable safety standards. Finally, there is link with Theme 7 and insurers, since loss probability curves can provide valuable information to stakeholders in flood risk management, such as the insurance industry. For example, they can be used for computing insurance premiums and decisions on the extent of insurance coverage that can be provided. Moreover, loss probability curves are needed to derive the amounts of capital reserves that are required for potential damage reimbursements.

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