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RESEARCH

FLOOD MANAGEMENT IN FLANDERS WITH SPECIAL FOCUS ON NAVIGABLE WATERWAYS

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Flood management in Flanders with special focus on navigable waterways.

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1 PROBLEM ANALYSIS

1.1 The present situation regarding flood protection and erosion control.

Flanders is covered by the three major catchment basins (Yser, Scheldt and Meuse). This rather low-lying nearly flat region (2 to 150 m altitude above sea-level) with a southern hilly part where erosion of loess deposits occurs in the catchment basins of minor tributaries of the larger major rivers. Risk of flooding by rainfall due to heavy summer thunder storms for minor rivers or caused by longer lasting wet periods with gradual importance of impact along the minor rivers towards the major ones.
The tidal activity in the river Scheldt downstream Ghent is the major flood threat. Storms with northwesterly and westerly winds induce high flood water levels. The tidal rivers are characterised by salinity fluctuations and by a large amount of sediment in suspension. River valleys are densely populated and characterised by human flood protection constructions along the whole length of the rivers and along the modified navigable parts of rivers and canals.

Flanders has been facing frequent major flood events during the past decade. There have been floodings in the valleys of the rivers Meuse and Yser in December 1993, again of the Meuse in January 1995, of the Dijle basin in August 1996, in the Nete and Demer basin in September 1998 and in the Dender basin in December 1999 and January 2003. Nearly all Flemish cities historically originated along rivers and low-lying flat floodplains have become now densely populated areas. This explains why these vulnerable areas still will have to cope with the effects of flooding and damage.

In Belgium the water management has been transferred to the regions since 1985. Hence both the Walloon region, Brussels and Flanders are responsible for the water management. Within Flanders the navigable waterways are managed by the Administration of Waterways and Marine Affairs (AWZ), the non-navigable watercourses 1st category are managed by the Environmental Administration (AMINAL) and non-navigable watercourses second and third category are managed by Provinces and municipalities. The meteorological competence for the entire Belgian territory is situated at the Royal Meteorological Institute. During flood events and depending on the magnitude of the event, the crisis management is co-ordinated by a Major, the Governor of a Province or the Minister of Internal Affairs.

Informing these authorities in a truly anticipatory way is one of the key tasks of the water managers to mitigate the flood damages. Therefore, besides important defence works that have been built in the aftermath of the past flooding, Flanders is investing money in sophisticated flood forecasting systems. Especially as it is now clear that sooner or later new flooding events will challenge existing and newly designed but inadequate infrastructure.

New durable infrastructure, taking into account a gradual sea level rise of 60 cm for this century, is under construction. Permanent research on hydrological trends is done. Until now no evidence is available for significant changes of rainfall, water levels and discharges.
So Flanders has been developing a dense and automated network of hydrological measurement stations (discharge, water levels, rainfall), which are all connected to a central computer by telemetry. Data is collected in databases, hydraulic and hydrological models are available and flood warning systems are developed. Integrated flood management plans are already existing or under construction. New methods are being developed using the risk management approach.

Numerous organisations are involved in the Flemish flood management sometimes causing co-ordination problems, double work, complex decision processes, problems in implementing and planning flood preventing measures. Collaboration with neighbouring countries or regions is necessary (the Walloon region, France, the Netherlands). Flanders is strongly supporting the international river commission for the Scheldt and Meuse river basin and committed to a future elaboration of its work in the near future.

1.2. Assessment of available data, tools and legislation.

In Flanders, a dense network of hydrological measurement devices (discharge, water levels, rainfall), with a high level of automation is being developed.
Since decades, throughout Flanders, the Royal Meteorological Institute has been recording rainfall data. At the Ukkel main station, there is even an hourly time series record available since 1898. The Hydrological Information Centre has developed a dense network of 25 tipping bucket rain gauges, with measurements aggregated over a period of 15' or 1 hour. Every rain gauge is connected by teletransmission to the central hydrological database of the Hydrological Information Centre.

Water levels are monitored at more than 300 locations on all important Flemish rivers and canals, with hourly, 15' and 1' time steps. The data is coming in to the central hydrological database almost in real time condition from the monitoring station.

River discharges are recorded at some 160 locations in Flanders, with hourly or 15' time steps. Discharge data are computed via water level monitoring using a stage-discharge relationship, but more and more acoustic and ultrasonic velocity devices are put into practice.

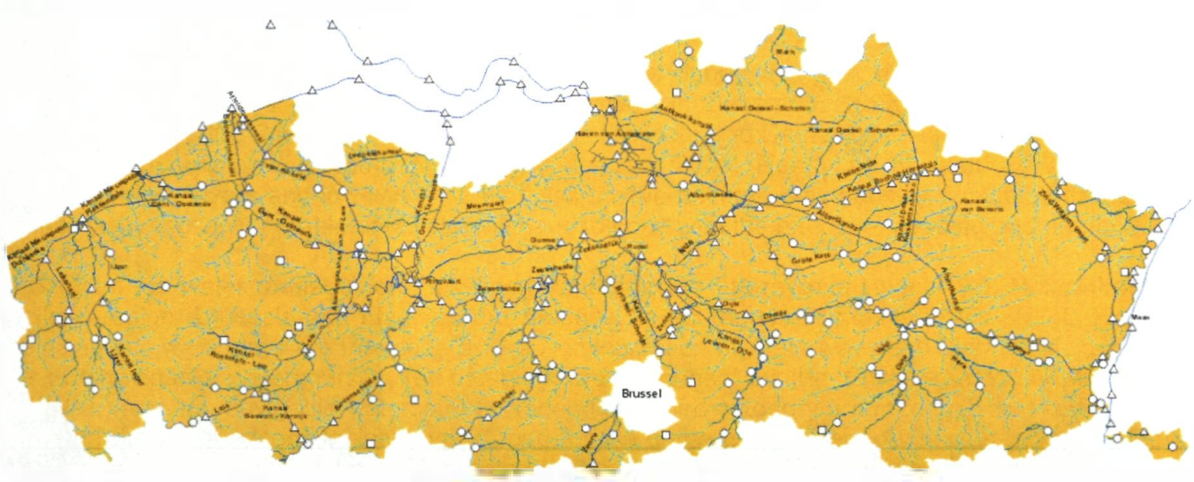

Figure 1 : Real-time measurement networks in Flanders (Δ= water level, o= water level/flow, = precipitation)

The effectiveness of the hydrological network is controlled 365 days/year. Five field personnel are in charge of daily stations maintenance. The daily fall-out does not exceed 2% of the total station figure.

Some stations have a data series record of more than 50 years, which is extremely helpful for the statistical processing of extreme high and low water events. Based on these data, two websites have been built by the Hydrological Information Centre.
http://www.lin.vlaanderen.be/awz/waterstanden/hydra provides almost real time water levels and discharges of all Flemish navigable and non navigable rivers and canals. Being refreshed each 15 minutes, this website visualises the main hydrological data of the last 10 days.

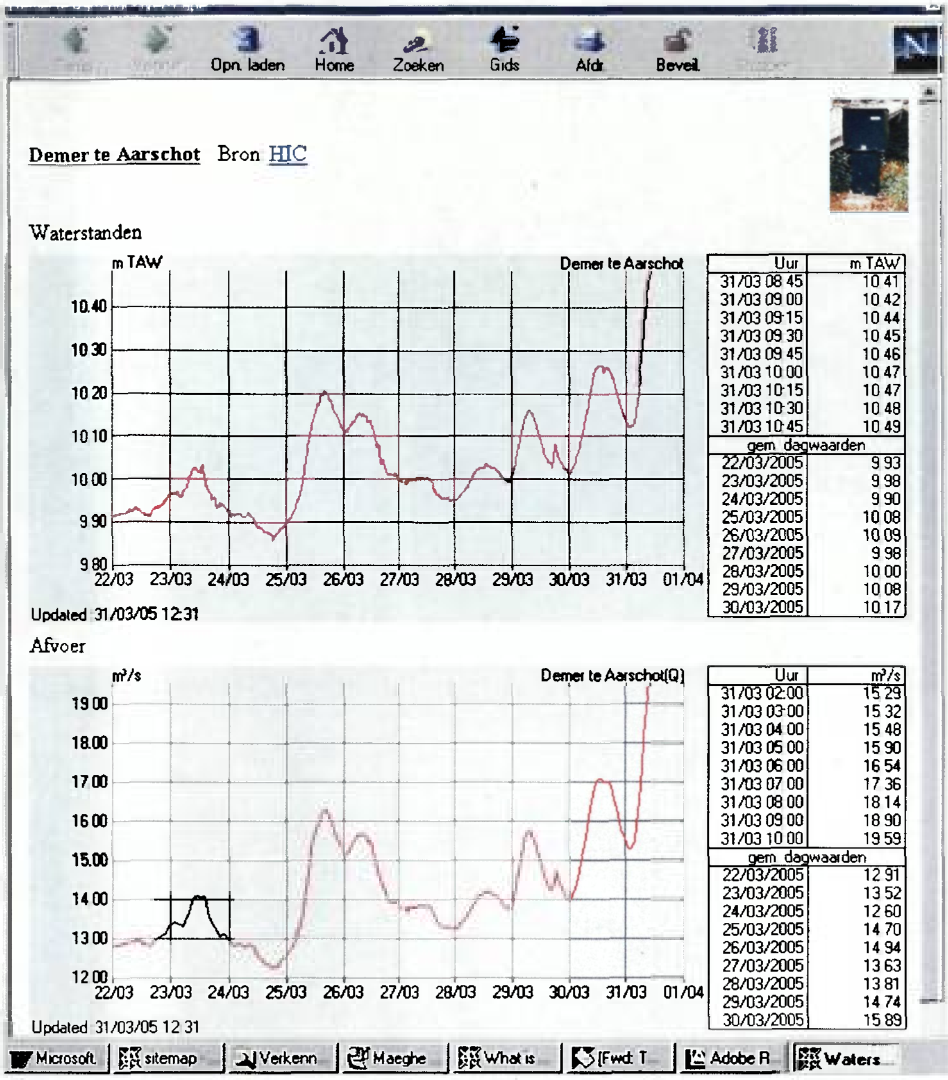

Figure 2 : Hydrological website of the Hydrological Information Centre

Nowadays, a new website is being designed to supply visitors with downloads of long time data series. This website will be accessible via login name and password.

In the framework of the Flemish water management, the Flemish authority has set up an inventory of flood prone areas which were inundated in the past and were recently inundated. The inventory resulted in two middle scale data sets : the NOG maps and the ROG maps.
The NOG map shows areas which can permanently or periodically be inundated in the absence of man-made built water protection infrastructure. This inventory is based on tracks in the soil left by former flooding (river valleys and polder areas). The NOG are covering 20% of the Flemish overall area.
The ROG maps shows regions which have been inundated in the period of 1988 to 2003. For the purpose of this inventory, the regions have been digitised from analogue maps of different sources. Almost 3% of the Flemish area is identified as recently inundated area. One third of this area is inundated more than once during the last 15 years.

Also land use maps are available for the whole area of Flanders. The land use maps are based on interpretations of two satellite images : Corine Land Cover (based on Landsat), Small Scale Land Use Map of Flanders and Brussels (for one based on Spot).

As a small and lowland area situated downstream in river basins of Scheldt and Meuse, Flanders is also strongly interested in hydrological data and predictions from the Walloon region, the Netherlands and France. Hydrological conditions in these regions are directly affecting the situation in Flanders. Within the international river commissions of Scheldt and Meuse, Flanders is putting strong emphasis on international data exchange. Nowadays, Flanders is being supplied with actual hydrological information by the Dutch and the Walloon region. But in order to produce better hydrological forecasts, Flanders is interested in more elaborated data and information exchange.

Based on all these data, numerical hydrological and hydraulic models were set up for all navigable Flemish rivers and canals. For this purpose one dimensional hydrological and hydraulic numerical model software is used to simulate flood routing in rivers and canals.

These 1D-hydrodynamical models are based on detailed topographical surveys where cross-sections of the watercourse are defined each 50-200 meter, 3D-bank lines are determined and all characteristics of structures such as bridges, sluices, gates, ... are inventoried. All results are available as time series of water levels, discharges and as inundation maps. For model building purposes the Digital Elevation Model Flanders is also available, representing the topography of Flanders at a resolution of 5 meters and a high accuracy (maximum averaged error of 7 cm). Because of detailed source data the resulting models can be used for high resolution applications (scale 1:2500). These models are used as offline models for scenario-analysis of future flood defence works and also for the drawing of flood risk and flood damage maps. The same numerical models are also re-used for setting up flood forecasting systems. Special attention hereby is needed for getting extremely stable and fast running models. Hence the hydrodynamical models are tested over large flow ranges and by applying multiple runs containing at least 50 extreme events. Also extra model-units are added in order to avoid modelled flow to drop below a critical base flow causing model instabilities.
Also two- and three dimensional hydraulic models are used for research on erosion/sedimentation processes and morphological variations on the Flemish rivers.

1.3. Appraisal of expected impact of climate change.

Based on historical measured water levels, a continuous rise of the mean sea level and the mean water level of tide influenced rivers has been detected. After the last 100 years, the detected rise appeared to be about 15 - 20 cm showing a linear shape. (figure 3)

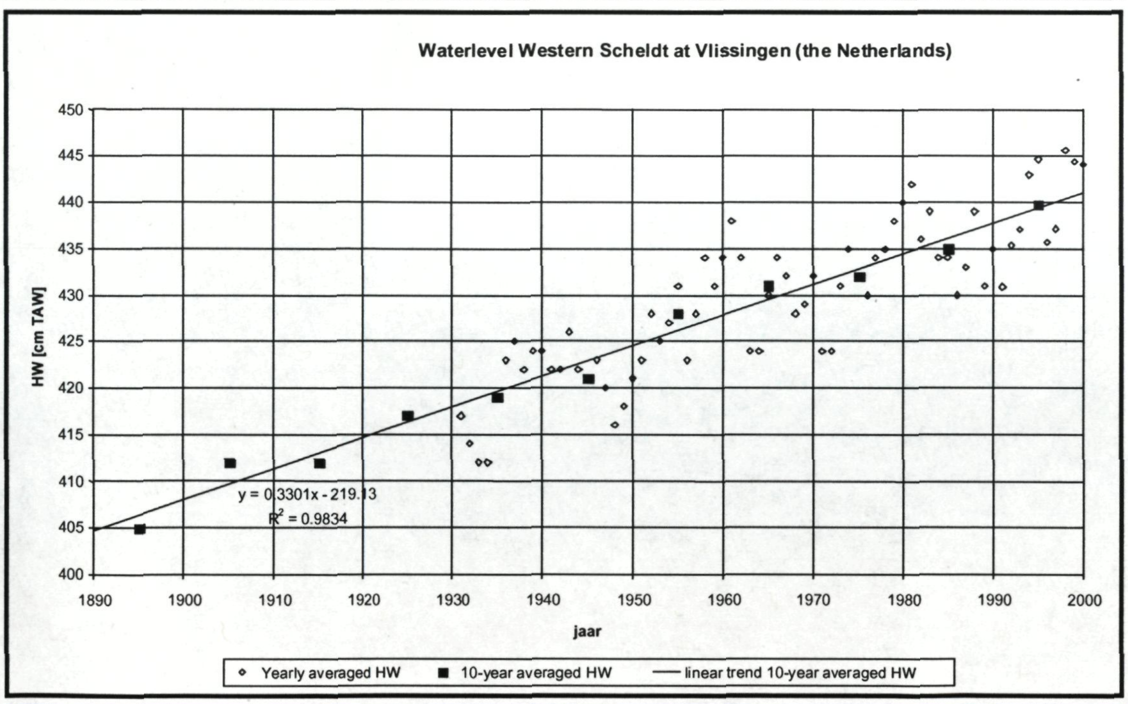

Figure 3 : Water level Western Scheldt – Vlissingen

The rise of the mean sea level is expected to grow for the next 100 years with a parabolic trend. A predicted rise of 60 cm during the next 100 years is not unrealistic.

Also, due to a possible climate change, a change in the pattern of rainfall occurrence can be expected. There will be a few additional percentages rainfall yearly. Rainfall is to be more clustered : more and longer rainy periods during winter season and more and longer dry periods during summertime.
The expected rise of the mean sea level has been taken into account in the review of the flood risk strategies for the different Flemish river catchment basins. The 'Sigmaplan', a water protection plan nowadays being actualised, is an example of such a flood risk strategy. In its actualisation the Sigmaplan takes into consideration a sea level rise of 60 cm over the next 100 years.

The effect of a possible change in the pattern of rainfall occurrence on discharges in the Flemish rivers has not yet been investigated. Research on this subject is to start in 2005. Although in Flanders the last decade (from 1993 to 2003) was very wet, with several high water events due to extreme rainfall volumes, there is up till now no statistical analysis available that could characterise these events with a significant tendency.

2. POLICY MAKING

2.1 Review of the adopted approach

Not very long ago, most public authorities and citizens still were assuming that dykes, given they were high enough, could protect against floods. But floods are a natural and unavoidable reality. What is more, 100% protection against flooding is not socially, nor economically justifiable.

Water level management in Flanders today therefore no longer aims at floods prevention at all costs, but instead seeks to limit damage. This idea can be expressed by the formula risk = probability x vulnerability. A frequently flooded meadow will not, in principle, be given extra protection, because the economic damage resulting from a flood is small. A densely populated area, however, will be given extra protection, even if it is not flooded very often: because here the level of damage is very high.

To determine the inundation risk, the Hydrological Information Centre has developed a standard method, based on international methods and adapted to the typical Flemish topography and available data sets, which can be used to define a number of economically measurable consequences of flooding. There are also a large number of factors which are much more difficult to quantify: the degradation of the aesthetic quality of landscape, for example, or people's emotional attachment to things which they lost in the flood. To take these aspects into account, a social cost-benefit analysis (SCBA) is needed. This allows the benefits of the protective measures to be weighed up against their social cost.

The great challenge for an SCBA of this kind is to quantify all the intangible effects: how is one weighing up the interests of shipping against those of the countryside or agriculture? Where is the point when the disadvantages of a flood no longer outweigh the cost of protecting an area from flooding and the resulting damage? There are various ways of weighing up these factors, each of which has its own advantages and disadvantages. The SCBA project will ultimately have to choose one of these methods in order to quantify all the effects.

In the end all the economic and social aspects will be brought together in a way the effects of the proposed measures can be analysed and the social costs and benefits of the alternatives can be weighed up against each other:

- Which combinations of measures guarantee the best cost-benefit ratio? Which implementation variants achieve the best score?
- What is the optimum level of safety, taking both costs and benefits into account?

Ultimately, a risk analysis and a social cost-benefit analysis will be carried out for every navigable waterway. With this information policymakers and water managers will be able to weigh up the economic damage against less quantifiable factors.

Based on a risk analysis this social cost-benefit analysis tries to detect a set of flood protection measures which are acceptable from an economical and social background. Water protection measures with large benefits compared to the total implementation cost will in the end be taken. In this way the policy of "space for rivers" fully supports this principle. The "space for rivers" policy aims at avoiding or minimising future increase in flood risk by avoiding inappropriate development of properties and infrastructure in flood prone areas. This policy is described in the "Water policy plan".

The social cost-benefit analysis can be used to minimise the costs of inundation, or wants to minimise the unwanted consequences of flooding. The global policy consists of several steps :

- prevention : avoiding or minimising future increase in flood risk by avoiding inappropriate development of properties and infrastructure in flood prone areas
- protection : reducing negative flood impact by structural and non-structural measures
- preparedness : providing flood forecasting and early warning, raising awareness of the population about flood hazards and risks, preparing and maintaining appropriate emergency response plans
- emergency response : implementing appropriate emergency response plans and co-ordinated civil protection response to floods (According to the magnitude of the event, the crisis management is co-ordinated by a Major, a Governor of a Province or the Minister of Internal Affairs.
- recovery and lessons learned : assisting to return to normal conditions as soon as possible, mitigating both the social and economic impacts on people, property and the environment, and reviewing and improving risk management procedures

2.2 Review of institutional setting

Within Flanders the navigable waterways are managed by the Administration of Waterways and Marine Affairs (AWZ), the non-navigable watercourses first category are managed by the Environmental Administration (AMINAL) and non-navigable watercourses second and third category are managed by Provinces and municipalities. During flood events, the crisis management is co-ordinated by a Major, a Governor of a Province or the Minister of Internal Affairs depending on the magnitude of the event. If the flooding has a mininal return period of 25 years, the event will be categorised as a official disaster, and damage will be compensated for by the federal Ministry of Internal Affairs.

2.3 Lessons learned: Evaluation of flood protection and erosion control policies

Not very long ago, most public authorities and citizens still were assuming that dykes, given they were high enough, could protect against floods. But floods are a natural and unavoidable reality. What is more, 100% protection against flooding is not socially, nor economically justifiable. Due to this change of policy, all flood protection plans are actualised nowadays, or will be actualised in the near future.
This actualisation of flood protection measures can be carried out with respect to different triggers, such as a change of major policy, the evaluation of historical floods or the need for increased effectiveness and uniformity with respect to the approach of safety standards in the flood prone area. Nowadays, Flanders has no legislation imposing regular evaluations of the actual flood management.

3 3. PLANNING AND DESIGN

3.1 Strategy

Flemish strategy concerning navigable waterways consists of :
- preparative research and determining necessary policy instruments
- modernising monitoring devices, introducing an on-line prediction system and river models
- elaborating an adequate safety standards determining method

- introducing a legislation to fix safety standards, to accept the flood management plans and to make measures possible and efficient.
- designing measures in so-called flood management plans, based on safety standards and social cost-benefit analysis (SCBA).
- integrating these plans in the framework of integral water management plans
- implementing these plans.

The first three steps are already finalised with a possibility to apply them to all rivers; the legislation has to be made; some flood management plans already exist (e.g. the Sigmaplan), are subject to modification and, of course, further implementation has to be achieved.

3.2 Safety standards

In Flanders steps are taken to introduce safety standards necessary to design measures. Till now the return period of major floods is indicative but no safety standards are included in any legislation. In the near future the level of protection against flooding will be determined on a risk based approach which asks for an estimate of the potential damage for floods with different return periods. Extensive preparative research is being performed by the Hydrological Information Centre (HIC).

To define flood related risk, some assumptions have to be made. This project focuses on flood events due to overflow and dike breaches, which is taken into account from a conceptual viewpoint. For example, flooding from sewer systems is not taken into account. The calculation of risk can be divided into 3 steps (as illustrated by figure 4):

- defining the probability and extent of flooding;
- determining the occurring damage for each return period;
- combining the damage maps in order to define an overall risk map.

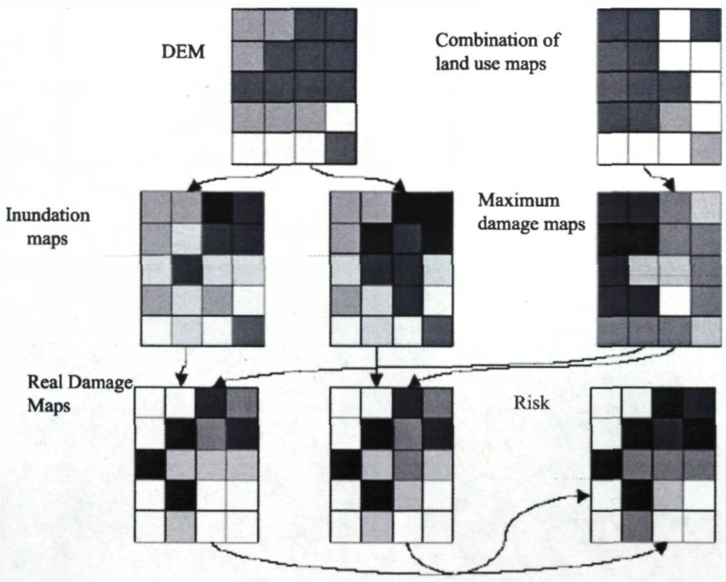

Figure 4 : General derivation scheme of risk maps

Step 1: defining the probability and extent of flooding
What is the probability for a particular area to be flooded? And what will be the extent of that flood? These are the first questions that the risk analysis project seeks to answer. Through statistical analysis of levels and flow rate figures in the past, the HIC hydrologists calculates the average period of time within which a particular maximum water level may reoccur. The higher the water level, the longer it will take on average before it occurs.

Once the highest water levels for a particular recurrence period are known, the HIC uses a computer model to produce two types of flood maps for the whole river (and for each recurrence period).

- A flood or inundation map showing the maximum water level. This map shows precisely what area may be affected by a flood.
- A flood map showing the maximum speed at which the water will rise. When the water rises quickly, it may be more difficult to evacuate people and as a result there may be casualties.

Step 2: determining the damage

What is the possible number of casualties in a particular area? What is the material damage? The HIC has developed a standard method to calculate all this.

The first step is to determine the land use in the flooded area. To do this the HIC uses satellite images which are analysed by computer and divided into various types of land use: built-up areas, agricultural land, woodland etc.

The economic damage for each class of land use is then calculated. This ultimately results in a calculation of the damage, for example for built-up areas (making a distinction between city centre building, suburban building and detached building), industrial estates, arable land, grazing land and infrastructural links (such as railway lines or motorways). Damage to vehicles and the possibility of casualties are also included in the calculation.

Damage maps are generated from inundation maps and a maximum or potential damage map. For each land use class water depth-damage relationships are defined, based on European experience (see e.g. Penning-Rowsell et al 2003), and adapted for the Flemish situation. Not only direct damage is taken into account, but the indirect damage can also be analysed. Indirect damage is e.g. permanent loss of fertile soils, production losses, cleaning costs. The monetary value of the indirect damage is expressed as a fraction of the direct damage (Griggs et al 1976), also dependent of the water depth at a specific place.

Step 3: defining the risk

Step 3 in the risk analysis process consists of working out the risk of flooding for each place on the basis of the various damage and flood maps. This risk is calculated on the basis of the probability x vulnerability formula, for all recurrence periods put together.

By 2005 the HIC will have produced flood maps for all navigable waterways in Flanders, calculated the associated damage and therefore also defined the flood risk.

The risk is calculated on the basis of the *probability x vulnerability* formula, summated over all recurrence periods. A more detailed background of the methodology and the mathematical basis is described in Vanneuville et al (2003) and examples can be found in De Maeyer et al (2003).

Most of the land use maps of the basic model are based on interpretations of satellite images: Corine Land Cover (based on Landsat), Small Scale Land Use Map of Flanders and Brussels (for one based on Spot), and an own classifications (based on IKONOS imagery). Their importance for water management based on risk methodology is described by Van de Sande (2001). The risk is refined by integrating line elements (e.g. roads and railways) and point elements (e.g. drinking water installations, historical buildings, telecommunications infrastructure, subway entries ...) into the spatial information. These line and point elements are selected for their significant difference from the environment, concerning potential damage and damage functions.

The main interest of insurance companies is the potential damage to some specific objects in an area. Objects insured by other companies are not (or only globally) taken into account in the model. Reinsurance companies are interested in a more global view using an average damage and risk. Both insurance and reinsurance companies are mainly interested in private goods that can be insured. These companies have own methodologies and they have built their own models, dealing as good as possible their questions.

A public authority, on the other hand, is interested in the damage to both public and private goods. It has not only to carry the cost for public goods but, e.g. through a disaster fund, it also has to budget money for exceptional situations where private goods are destroyed. The models of insurance companies do not answer the specific questions of public authority (nor does a model made for public authority answers the questions of the insurance companies). For that reason private (e.g. houses, industry, agricultural land ...) and public (e.g. dikes, roads, drinking water areas ...) goods are studied. The basic model is extended with line and point elements and a casualty model.

Further steps

The standard method that has been worked out by the HIC can be used to define a number of economically measurable consequences of flooding. There are also a large number of factors which are much more difficult to quantify: the degradation of the aesthetic quality of landscape, for example, or people's emotional attachment to things which are lost in the flood. To take these aspects into account, a social cost-benefit analysis (SCBA) is needed. This allows the benefits of the protective measures to be weighed up against their social cost.

The great challenge for an SCBA of this kind is to quantify all the intangible effects: how does one weigh up the interests of shipping against those of the countryside or agriculture? Where is the point when the disadvantages of a flood no longer outweigh the cost of protecting an area from flooding and the resulting damage? There are various ways of weighing up these factors, each of which has its own advantages and disadvantages. The SCBA project will ultimately have to choose one of these methods in order to quantify all the effects.

Ultimately all the economic and social aspects will be brought together so that the effects of the proposed measures can be analysed and the social costs and benefits of the alternatives can be weighed up against each other:

- Which combinations of measures guarantee the best cost-benefit ratio? Which implementation variants achieve the best score?
- What is the optimum level of safety, taking both costs and benefits into account?

For public authorities, the results of the model give a very good impression of the order of magnitude of public and private risk. This scientific base for the calculations allows spending financial resources in a more efficient and objective way (Vanneuville et al 2003).

The difference in risk between two situations (e.g. the actual state and a planned alternative) is the benefit site of the economic cost benefit analysis. The benefits, as the reduced annual damage, have to be compared with all costs to realise the alternative situation. Not only construction and maintenance costs but also the cost of execution in a pre-defined time lap (e.g. 50 or 100 years) for which the intervention is planned to be effective. The economic optimum (see figure 5) will be reached when the sum of all costs (remaining damage and cost of policy actions) is minimal (Vanneuville et al 2003). Due to the natural phenomenon of flooding and its impact on people and their property, the economic optimum is not always the policy optimum. So the number of people affected should define the social optimum, instead of monetary valuable damages (e.g. natural, historical, cultural values).

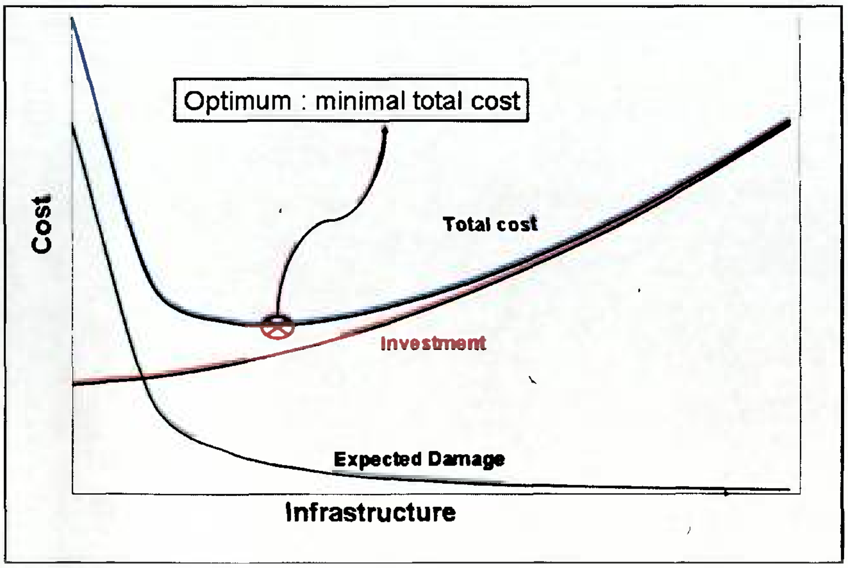

Figure 5 : Economic optimum in the cost benefit analysis.

The future
Ultimately, a risk analysis and a social cost-benefit analysis will be carried out for every navigable waterway. With this information policymakers and water managers will be able to weigh up the economic damage against less quantifiable factors.

Once this exercise has been carried out for all navigable waterways in Flanders, it will be up to those who define public policy to define the Flemish Safety Level: a single standard of protection against flooding which is equal for all navigable waterways in Flanders. Areas with the same risk of flooding (according to the probability x vulnerability formula) will, in principle, receive the same level of protection against a flood. Measures will be selected which are least costly for society. On the basis of this safety standard, the existing water management plans will then be amended.

4. IMPLEMENTATION: MANAGEMENT AND MAINTENANCE

4.1. Main characteristics of the organisation responsible for flood management and erosion control and the problems it is facing.

The organisation responsible for flood management and erosion control is the Flemish Government. There are several water managers dealing respectively with polders, small rivers, sewage systems, navigable rivers,... Even for the navigable waterways three separate organisations are active: the administration of Waterways and Marine Affairs, the NV Waterwegen en Zeekanaal, the NV de Scheepvaart.
Mean problem is the co-ordination and the collaboration between all actors which do not have all the same priorities.
All activities dealing with flood protection have to take into account elaborate legislation dealing with spatial management, environmental aspects, economical regulations, civil rights,...
Erosion control is managed by the administration Environment, Nature and Land.

4.2. Organisational setting of flood management and erosion control

The administration of Waterways and Marine Affairs co-ordinates all aspects of Integral Water Management for the Coastal Zone, the Maritime Accesses to the harbours and the inland navigable waterways. The NV Waterwegen en Zeekanaal and the NV De Scheepvaart Water are managing the inland navigable waterways. Construction and maintenance of water related infrastructure is a task of these independent parties.
The administration Environment, Nature and Land is responsible for the so-called first category rivers. The Provincial government and the communities is in charge of even smaller rivers. Water quality of all Flemish water bodies is monitored by the VMM (Vlaamse Milieu Maatschappij). Construction and maintenance of water purification installations, including the sewer systems is carried out by the NV Aquafin.

These organisations manage river and canal systems itself and all infrastructure built on these rivers. To some extent, these organisations are also managing some flood prone areas and controlled inundation areas, often in co-operation with the Nature division of the administration Environment, Nature and Land.

The daily maintenance of rivers, canals, river infrastructure, flood prone areas, controlled inundation areas,... is carried out by the local water manager.

4.3. Legislation

Recently a decree of the Flemish government for erosion control, including mitigating actions, came into existence.
A Federal law on disaster management, especially concerning flooding events with an obligatory assurance for all civilians dealing with potential disasters was developed (2003-2004).

Co-ordination between all water managers (communities, provinces, Flemish Government with organisations for navigable waterways and smaller rivers) is made more efficient by the development of a Flemish law dealing with integral Water Management. This law gave birth to the so-called CIW (Co-ordination group for integral water management) bringing together all actors within this framework. This law specifies also that for each Flemish river basin a basin management plan has to be made each 6 years, containing a detailed geographical vision and policy. This policy has to be made with all partners.

A legislation is needed for safety standards, for more efficient public works, for dangerous or failing infrastructure and for a legal basis for the water management plans.

There is a strict environmental legislation and a spatial management regulation, both putting forward restrictions and conditions for flood prevention actions.

4.4 Budget

The Flemish government provides a regular annual budget for water management and maintenance and development of the infrastructure. These funds are spent for maintenance of existing infrastructure (dykes, inundation areas, drainage structures,...), for developing new approaches and long term visions (research, planning, and implementation) such as the actualisation of the Sigmaplan for the river Scheldt, the long term vision for the development of the river Scheldt, the Meuse water management plan,...

4.5 Planning and preparation of works

The planning process and the preparation of works is best illustrated by the actual actualisation of a former flood protection plan, the Sigma Plan for the river Scheldt.
In the Netherlands, the Delta plan was developed in the aftermath the 1953 flood that struck the Zeeland province. Although at that time the flood affected Flanders too, it was only after the flood inundating the village of Ruisbroek in 1976 that a decision was taken to draw up a master plan. On February 18th 1977, the Cabinet Meeting decided to draw up the Sigma plan. The objective was to protect all low areas in the tidal part of the river Scheldt catchment basin against storm surges. A safety standard for the probability of occurrence was decided to be one percent a century. The plan had to be completed using three types of measures:

- Raising and strengthening the dikes.
- Construction and subdivision of controlled inundation areas.
- Construction of a storm surge barrier in Antwerp (Oosterweel).

At the moment, 80% of the dikes are built and 12 controlled inundation areas are in operation. The storm surge barrier was not yet built. Due to several reasons the Sigma Plan is nowadays actualised according to new insights with respect to river management:

- Space is given back to the river by installing controlled inundation areas and reduced tidal areas
- Nature development is associated with safety measures.
- Safety has to be increased significantly due to increasing tidal impact, major danger in case of west to northwester storms possibly combined with large discharges due to heavy rainfall.

The New Sigma Plan is realised by several consortia of engineering agencies together with the Flemish administration. For the Flemish part of the tidal Scheldt and all tidal tributaries, a social cost benefit analysis was made in which all measures and combinations of measures were evaluated. Calculation of damage and risk is a main input of this social cost benefit analysis (SCBA).

Another big challenge of the SCBA is to quantify all immaterial effects. How to compare the interest of shipping, agriculture, nature ...? Finally, all alternatives are brought together and compared in order to decide:

- Which combination of measurements is standing for the best cost benefit ratio and which are the best execution alternatives ?
- What is the optimal safety level, taking into account all tangible and intangible costs and benefits?

There are several reasons why this project is of great importance. From economic perspective, the Scheldt is the most important river for Flemish and Belgium economy. The implementation of a risk methodology applied on such a big area is also new to Flanders. Not only the situation in 2000 is taken into account, but also assumptions for 2100 are made. An estimation of land use and population changes is discussed as an input for the SCBA and the flood maps (and return periods) are adapted to expected sea level rising. The results of the SCBA are expected by june 2005. It takes several years of preparation, including research, intensive communication, co-ordination of all partners to get these plans accepted by the population and the government and even more years to implement the foreseen measures.

4.6 Structural and non-structural measures; Early warning and Damage Control

The Hydrological Information Centre (HIC) of the ministry of the Flemish Government is performing daily hydrological forecasts. The HIC has been given the task of forecasting the water levels and flow rates of navigable waterways in Flanders.

- On rivers for which an operational river model does not yet exist, the HIC uses empirical data: using the time-series for past years, the aim is to find the water levels and precipitation ratios that fit best to the current situation, and expected water levels are derived from these.
- On rivers for which an operational river model already exists, the model calculates the expected water levels for a period of 48 hours.

All river models will be operational not later than 2005, so that one can proceed to semi-automatic forecasts. Level forecasts will then be made systematically: even if no alarm levels have been reached, the HIC will forecast levels and flow rates for the next 48 hours.

Normally forecasts are issued once a day. During crisis situations this frequency will once again increase to five times a day. The HIC sends the information about expected water levels forecasts by mail to the River Information Services, which acts as the communication centre in the event of flooding.

Permanent quality control by experts is needed.

Parallel initiatives are developed by other divisions of the Flemish government for the non navigable rivers. Co-ordination needs to be improved. On-line data exchange with the Netherlands, France and the Walloon region is also vital for the prediction systems. Flanders supports the actual data exchange, and is willing to elaborate this process in the near future.

All hydrological forecasts are used by the River Information Services in order to inform all actors involved in the water and disaster management. Depending on the importance of the expected flooding, disaster and evacuation plans are co-ordinated and carried out by the minister, the governor or the local communal authority.

4.7 Additional requirements

As a small and lowland area situated downstream in river basins of Scheldt and Meuse, Flanders strongly appreciates the co-operative work of international river commissions, such as the International Scheldt Commission and the International Meuse Commission. Flanders supports the various action plans of these international river commissions.

5 MONITORING, RESEARCH & EVALUATION

An elaborate monitoring system exists for the Flemish region. It comprises discharge measurements, water level measurements, rainfall, sediment transport,...

Research in Flanders is performed by universities within the framework of European initiatives, scientific research centres sponsored by the government and private initiatives launched by the Flemish Government.

The most important services are provided by the Hydrological Information Centre (HIC), a subdivision of Flanders Hydraulics, Ministry of the Flemish Government.

The Hydrological Information Centre (HIC) is a research group providing for scientific support with respect to water level management on navigable waterways in Flanders. In order to achieve this, the HIC is actively co-operating with the actual managers of these waterways and with other institutions focussing on ground and surface water in Flanders. In the context of Integrated Water Management, this collaboration will still further be intensified.

The HIC is the central knowledge and information centre for navigable waterways in Flanders, which has been set up within the Flanders Hydraulics Research division. Hydrological field data are collected into a single HIC database. These data are input to several models developed to simulate flow conditions on all waterways. Since rivers are not confined by any boundaries, hydrological information is therefore important to many Flemish partners and divisions. The HIC collects all the hydrological and navigable waterways related data in Flanders into a single database called Hydra.

First of all the Hydra database is a powerful tool used by the very HIC staff. Hydra data can also freely be consulted by the public at http://hydra.lin.vlaanderen.be.

In recent years sophisticated commercial software have been allowing for quite accurate simulations of flow conditions on navigable waterways by means of HIC developed river models. These are being integrated into an overall Flemish hydrological model and are particularly suited for:

- Scenarios. What is the effect on the river's flow behaviour of all kind of events? What is the geographical impact of a flood extend given a particular high water level? A river model can simulate different conditions such as details of the floodgate, the flood zone or any other structure that can be entered into the model and visualise their effects. The HIC also uses scenarios like these to provide scientific support for flood risk strategy.
- Forecasts. If the river models are linked to the Hydra database, they can predict water levels and flow rates for the coming hours and days.

Thanks to the risk analysis project the Hydrological Information Centre (HIC) has adopted the probability x vulnerability principle to create a workable methodology. The project:

- maps the flood risk for all waterways in Flanders,
- provides for an objective flood risk calculation tool.

In this way policymakers in Flanders have been given access to substantial information in order to carry out a sound social cost-benefit analysis: Flood risks versus the cost of (total) protection. And where is absolute protection no longer socially justifiable?

The HIC, together with all water management partners, is also developing a methodology aimed at the efficient use of available surface waters volumes, especially in dry periods.

For each river the HIC draws up an inventory of water flows from and into other rivers and canals, all locations for water disposal and collection at which water is taken or released and existing treaties, for example with the Netherlands (stipulating the amount of water to be diverted into a particular river). This inventory offers a good picture of the available water quantity and the quantities that are reserved for particular purposes. In a next stage the HIC will co-operate with all water users to establish a strategy aimed at saving water consumption.

Ultimately the data will be processed by means of a general methodology into models for all navigable waterways in Flanders. The HIC can use this information in simulations to evaluate whether the proposed solutions are really feasible and the best way of implementing them.

6. CONCLUSIONS

Flanders is small, densely populated region, with enormous spatial needs, a complex legislation and administration, a huge variety of partners, river systems to be shared with neighbouring countries. Co-ordination, communication and collaboration are thus extremely important.

However, the Flemish government had been developing field measurement networks, information and data systems as well as tools to support flood management, early warning and forecasting of water levels. All Flemish partners have been joining the so-called CIW, a platform uniting and co-ordinating all administrations involved for the purpose of achieving integral water management.

Flanders Hydraulics Research is, with its subdivision Hydrological Information Centre, a focal point in Flanders for possible exchange of knowledge and experience (physical environment, water management, water quantity, engineering aspects). With respect to water quality, the VMM is the leading party.

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