Safety through informed action - that is Flood Control 2015. Since 2008, a consortium of Dutch companies and knowledge institutes, in conjunction with public bodies, have been committed in a collaborated effort to raise the information supply on all levels of water and crisis management to a higher plane. This is achieved through smart use of advanced technology and by focussing on the human dimension. No matter how accurate a water level forecast or a dike strength measurement, the decisions made in the face of an imminent flood need to be based on reliable information to prevent disasters and mitigate damages.

This book provides an overview of the results of five years of research, development and application at home and abroad: dashboards for flood risks, decreased uncertainty in computer model calculations, a Dike Strength Information System, new means of crisis communications, new (training) methodologies, an information lab for higher education, a Global Flood Observatory and more. Flood Control 2015 provides water managers, crisis teams, emergency service providers and the population with usable, practical knowledge, tools and information.
FLOOD CONTROL 2015

FIVE YEARS OF INNOVATION IN FLOOD RISK
In Flood Control 2015, technology is used as a means to enable people to better assess and respond to risky situations. From manager to citizen, people make decisions depending upon the circumstances at hand. If there is more certainty about the current situation, and if pertaining information is purposefully provided, the adverse consequences of flooding can be limited. By making smart use of the most advanced information and technology available, Flood Control 2015 makes it possible to take informed action. As illustration of the applicability and need of the Flood Control 2015 advances, ample use was made of these innovations not only within the Netherlands, but also in Indonesia and the US.

Improved flood forecasting systems or real-time monitoring of flood defences are not objectives in themselves. A characteristic feature of the Flood Consortium 2015 is that it develops knowledge and tools that are suitable for use in day-to-day practice of several professional disciplines, not only for those responsible for operational water management but also for decision-makers on different levels, crisis managers, communication advisors, news agencies and the emergency services. All of the aforementioned benefit from the yields of this program. Let us not forget about the communities within the areas at risk who will now be better equipped to help themselves and their neighbours by using this improved information and means of communication.

These innovations have a wide range of application: new or faster methods for integrating data and monitoring water levels and coastal erosion, systems forecasting dike (or levee)
strength, and interactive software (Dashboards) that streamline and present data in a well-organised fashion. Additionally, these advances in technology and means of communication have been rigorously tested through role-playing and interactive virtual (serious) games with target audiences.

Tablets and smart phones can also be utilized in the quest to reduce flood risk. Investments were also made in the future of human capital. Educational tools were developed for higher education and the first flood control professionals are actively training. You can find out more about this initiative within this book.

Flood Control 2015 is five years of integrating research, practical experiences and social needs. To me, being the Chairman of the water board Hollandse Delta, who sees the water-related responsibilities of his water board, as well as many other deltas, becoming increasingly more complex, the following could well be the greatest advancement of the program: that thanks to the agreement between diverse parties with divergent interests, innovations were brought about that we are now able to utilize in an innovative approach which is equal to the task of tackling these complex issues. Just within my own field of work, Water Boards are facing the task of having to be efficient and restrained, when executing the necessary structural dike reinforcements to ensure the Dutch flood defences are providing the required level of protection. Tools developed by Flood Control 2015 can provide assistance with this constant challenge. If we in turn provide room for implementation, this results in continued development and improvement of these tools. The Flood Control 2015 program has shown that scientific research and practical application can stimulate each other. A significant lesson (to learn) for anybody who considers the importance of flood protection.

Jan Geluk
Chairman (Dijkgraaf) of the Hollandse Delta water board and the Flood Control 2015 Feedback Committee
Contents

Introduction 7
Flood Control 2015 10
Forecasting and control 24
Dike strength and monitoring 44
Decision making 62
Smart flood control in the 21st century 84
Hendrik Balk, a modern flood adventure 92
Consortium members 100
Organisation Flood Control 2015 106
Illustrations 107
Credits 108

Flood control in practice
Education on smarter flood control in Rotterdam 18
Academic research with regard to smarter flood control 20
From early warning to early action in Jakarta 40
Test case Groot Salland 58
Training new style 76
Hurricane Risk and Safety Module for New Orleans 80
[.....]
and in all regions
the voice of the water
with its eternal calamities
is feared and heard.

Taken from *Memories of Holland* (1936) by Hendrik Marsman
Introduction

Floods caused by high river discharges, storms and tidal waves result in tremendous damage all over the world. Additionally, the consequences unfortunately also can turn into humanitarian disasters.

Flood Control 2015 lifts water safety to a higher level by ensuring the timely availability of much needed information, which directly results in increased preparedness among civilians as well as professionals.
Water safety: cause and effect
Due to the fact that many people live and work in areas that could be flooded and because the economic activity and the number of people in these areas is continuously on the rise, the impact by floods is ever increasing in both that more damage is incurred as well as the number of victims is increasing. This alone makes it imperative that we get as much grip as possible on the flood phenomenon, while knowing full well that it is impossible to completely exclude all flood probability and consequences. Safety does not solely depend on altering and managing the flow of water. Well-considered spatial planning, optimal decision-making and goal-oriented crisis management are equally important. Cause and effect need to be fully considered. Living near the water means working on all safety aspects in order to minimize the probability of flooding, as well as mitigate the wide breadth of impacts as much as possible.

Flood Control 2015
An integral approach to managing flood risks leads to optimal utilization of the available means for preventing flooding, in addition to optimizing the mitigation of the flood consequences. This insight motivated different Dutch organisations to collaborate resulting in the formation of the Flood Control 2015 consortium. The consortium formulated the following objective: cohesive development and application of new knowledge and tools to limit the probability and effects of floods. The initial research and development program was completed in 2012.

What has Flood Control 2015 yielded? This book showcases the highlights of five years of research and development. A wealth of knowledge has been gained and a wide variety of tools have been developed and disseminated. Some of the first applications have already been carried out in the Netherlands, Indonesia and United States.

Quick guide to this book
The first chapter entitled Flood Control 2015, provides background on the organisation that set out to make an effort to realize structural improvement in the flood information supply. This chapter also outlines the intended impact and scope of the program.

The following three chapters each address a program theme and describe which solutions were developed. All subdivisions of the program are passed in review: monitoring, forecasting, decision-making, training and field-trial. Each chapter opens with a summary that precedes the descriptions of projects and products presented within. Between the chapters, you will find information about the tests, the results and the applications by users.

The Flood Control program reaches completion in 2013. The chapter, Smart Flood Control in the 21e century, explains the envisaged future efforts of the consortium.

Then there is a short story about Hendrik Balk, a contemporary counterpart of Hans Brinker, who embodies the bridge between the sometimes abstract world of water management and crisis management and brings it down to human dimensions, to everyday life. In this story, you can discover how the tools of Flood Control 2015 can play a role in contemporary water management.

This is followed by profiles that provide more detailed information about the different consortium partners and the role they play in this program.

The consortium Flood Control 2015 hopes you enjoy the read!
Quick guide to this book

Chapter 1 - Flood Control 2015

Introduction

In practice: education and PhD research

Chapters 2 - 4

Introduction

Short description of projects and products

Flood control in practice

Description of projects and products

In practice: user’s comments
Smart, dry and safe

From water level measurements up to and including evacuation measures: the foundation of flood control consists of reliable, up-to-the-minute information.

The Consortium Flood Control 2015 is convinced that there is much to be gained in the field of information supply, decision-making and the cohesion between these two.

Flood control could be smarter! How? It could be smarter by making better and increased use of information technology and by improving the level of preparedness and awareness of the different parties that play an active role in crisis situations.
Program

From 2007 to 2012, the initiators of Flood Control 2015 have realized smart flood control in different ways. In research, development and education, knowledge was gained and disseminated. The program has yielded concrete solutions for water managers, crisis managers, information officials, relief and emergency care and other parties that need to be on standby when there is a flood risk.

Practice oriented

*Smart flood control* is about dealing with immediate as well as future probabilities concerning damage and victims. For example, the design of infrastructure and the layout of the landscape should also take flood risk into account. In this program, alliances were purposefully made between experienced professionals, involving the water manager in particular, to ensure that techniques, tools and knowledge of existing work methods and processes are supported and improved. Because the end-users actively integrate the Flood Control tools into their regular management of water systems, they become familiar with the tools and are optimally prepared in the case of flood risk.

Dissemination and implementation

Flood Control 2015 mainly uses publications and software to make the methods developed and the underlying knowledge accessible. The intention is for the results of the program to be used far and wide by the consortium partners of Flood Control 2015, as well as by other parties, such as district water boards, safety regions and consultants. As Flood Control 2015 considers the dissemination of knowledge of paramount importance, third parties can gain access to the methods and products at favourable conditions. The major utilizers are the national and foreign government entities responsible for water management and crisis management.
management. Flood Control 2015 is also involved in education. In cooperation with education institutes and given the denominator human capital, shape was given to the education of professionals in the field of smart flood control.

**Education**
The development of new knowledge, services and products should go hand-in-hand with educating professionals so they can use the current products as well as continue further development. In order to facilitate this, the consortium has included a Flood Control curriculum for higher education in its program.

**Flood Control-professionals**
When the consortium Flood Control 2015 was founded, there was not a single Dutch education institute that offered a program in which knowledge and experience in flood risk was integrated with forecasting and decision-making tools. The objective of the education program is to integrate the different products of Flood Control 2015 together with the gained knowledge and practical skills, and subsequently pass this on to future generations. Trained Flood Controllers are able to apply the knowledge and, where necessary, continue the development. With their research and practical projects they, in turn, provide new insights in water management and flood risk.
Institutions
Hogeschool Rotterdam has a readership City and Water and offers an education in water management. Flood Control 2015 is closely involved in the content of this readership (p.18). Besides the Hogeschool Rotterdam, three additional institutes for higher vocational education have integrated Flood Control in their education program on offer: One university and one post-academic education institute.

Consortium
The consortium Flood Control 2015 consists of three knowledge institutes, three large engineering consultancies, an international IT company, a specialized consultancy and a national cooperative researching (the monitoring of) dike strength. This composition provides a broad base of input of international knowledge and experience in all fields of flood risk. The different consortium partners are described in this book (p.100).

Cooperation
Flood Control 2015 is an example of the so-called Golden Triangle of government, knowledge institutes and the business sector. Knowledge institutes and the business sector contribute research and development. The national government provides co-financing and various authorities act as launching customer and consumers of the new technology and products. This cooperation guarantees that new techniques and products optimally match with the requirements of the water managers.

Foundation Flood Control 2015
Cooperation between consortium partners takes place under the umbrella of the Foundation Flood Control 2015. The executive board of the foundation consists of 4 people from the consortium. The foundation organizes the participant meetings with representatives of all consortium partners. For the execution of the joint development program, a compact and decisive program office was set-up. The feedback group consists of representatives of interested parties outside of the consortium. The input of the members of this feedback group contributes to maintaining proper adjustment to the developments in the daily practice of water managers. The programming committee consists of nine members; One for each consortium partner. The programming committee aligns the development ideas of the various consortium partners and it monitors and keeps a check on the proper cohesion between all developments.

The Foundation Flood Control 2015 does not execute work with regard to content. The consortium partners, often in mutual cooperation, execute everything.
Education on smarter flood control in Rotterdam

Within the consortium, Hogeschool Rotterdam was chosen as a starting point for developing an education program. The Rotterdam metropolis is a sustainable delta and port city, leading the implementation of modern technologies and, to top it off, the seat of the National Water Centre (NWC).

i-lab
At Hogeschool Rotterdam, Flood Control 2015 worked together with students and teachers on creating innovative knowledge and product development in an interactive learning environment – an innovation-lab (i-lab). This setup was chosen after consulting with the business sector, who would like to ask practical questions of the students and who, in the future, would like to employ enterprising, environmentally-aware and analytically-strong flood control professionals.

Flood Control game
In i-lab, students are challenged to independently research a question that is difficult to solve in practice and to develop a (commercial) product as a solution. The initiation point was the question how communication and decision-making between different government institutes active in the field of water management and flood risk could be improved during a flood. In answer to this question, students developed the Flood Control Game. The game is used for practical training and for education. Most of the students involved have already been employed in the water sector in the meantime.

Teaching package
A teaching package has also been developed for senior students. The package contains basic theoretical knowledge of high water/high tide, safety and risk management. In total, about one hundred students already used the package. The teaching package is largely in English, which simplifies international dissemination of Flood Control.
The knowledge and experience introduced and contributed to the Innovation Lab Flood Control provided the students with insight into the existing dilemmas in crisis communication. Based on this, and in cooperation with the people active in the field, the students were able to develop a board game. The board game provides an easily accessible way for parties to become acquainted with the communication problems that arise in the event of a flood threat.

Leander Ernst
Lecturer of Water Management
Coordinator i-lab Flood Control
Evacuation
Evacuation is one of the measures a government can take in the event of an impending flood. However, when is it the best time to make the decision to evacuate? If it is too soon, the measure is unlikely to be effective. The longer the crisis continues, citizens will increasingly decide for themselves whether to evacuate or whether to stay. A model was formulated for the different phases of the crisis. Given these phases, a methodology was developed for determining the optimal decision-making moments based on risk. This increases the probability that evacuations will progress in an orderly manner and that the inhabitants will be safely evacuated while the consequences of a flood event will be mitigated.

EvacuAid
During this research EvacuAid was developed, a tool that can estimate the effectiveness of evacuation decisions. In the calculation, several facets are taken into account such as the interaction between government, citizens, infrastructure and threat levels. The result is a percentage of the population that can be safely evacuated and an estimate of the number of victims during the evacuation. With the aid of this tool, a quick assessment can be made that could lead to working out the details of an operational evacuation plan.

In an adjoining research project, a prototype Evacuation model was developed. This model combines information about location, population density and movement in an area to be evacuated.
Evacuation often causes chaos
Decision models for flood risk

In the event of flood risk, decisions often have to be made based on complex information. Researchers have developed mathematical decision models related to the flood risks. The initial point of departure was a Markov Decision-making process, a mathematical framework for modelling decision-making processes whereby the outcome is determined partly by issues within the control of the decision-maker and partly by (uncontrollable) external influences.

The results of the model provide an indication of the best alternatives for measures, point of departure being historical data, current data and short-term expectations as well as the costs of those measures and the potential damage (property, material and victims). The model also takes ‘operational failure probabilities’ of dikes into account. These operational failure probabilities show the actual possibilities of dike failures within a certain time span, given the information available about the flood defence (structure) and the load on the structures. This research also developed and specified the concept ‘operational failure probability’.

*Uncertainty in the water level forecasts can be included in the decision-making process*
A good view of peat embankments from a distance

The Netherlands has more than 3,000 km peat embankments that protect low-lying parts of the country from being flooded. The quality of these embankments has to be kept up to standard in order to guarantee the safety of these areas. In present practice, dike inspectors assess the quality based on visual observation. This is a labour-intensive method that also carries a relatively large margin of error. In order to assess stretches of peat embankment more rapidly and more consistently, research took place into the use of remote sensing techniques and in particular, aerial photography.

Peat embankments of dubious quality were subjected to a number of techniques, such as the use of visible light, infrared and thermal energy. Deformation and irregularities in the dike were determined irrespective of the technique used to test. The irregularities concerned soil moisture and other underground processes. However, the dimensions of the deviation differed per technique applied. The conclusion is that a combined usage of the tested techniques provides a reliable picture of the weakened stretches of peat embankments.
Major floods are ravaging the globe, often leaving fatal consequences in their wake. Recent flood disasters in the US, Pakistan, Australia, Japan and Thailand were world news.

Could they have been prevented if better information had been available based on real-time information about weather and water in combination with improved forecasting? Probably not, though it is likely that the consequential loss could have been limited. The fact of the matter is that more and more people live in areas that are susceptible to flooding. This also means that more interests and larger investments have to be protected.

Flood Control 2015 has researched various possibilities for improved information supply. The results are usable, life-saving, cost-reducing methods and technologies for water and crisis management.
What if...?

We expect that water managers and crisis managers will execute appropriate measures if there is a threat of flood. The sooner they have useable information and reliable forecasting on expected water levels, wave heights and precipitation at their disposal, the sooner they can make well-founded decisions to reduce the impacts due to flooding.

Reliable information
What if there is threat of a flood? How long will the dikes (also known as levees) and dunes stand their ground? Do certain areas need to be evacuated? In times of emergency, rapid and efficient action is required. This can only occur if reliable information is available about the current and expected situation along the rivers, in the estuaries, along the coast or in a regional water system. In addition, the reliable information has to consist of the meteorological information (precipitation, wind and atmospheric pressure) as well as the hydrological information (water levels, currents and wave heights).

Systematic
Should I order bags of sand to put into position, prepare a water storage area or should I start preparations for evacuation? Modern information technology has resulted in high-speed data processing and generating very specific information. Water and crisis managers across the globe will benefit from information systems that are able to match the various kinds of data (measurements, satellite images, forecasts) and then integrate and present a well-organized overview of the data. It does not stop here however. The information systems should also quantify and reduce uncertainties so that the decision-maker is able to put the optimal measures into effect. Such a system offers solutions in crisis situations and moreover, it certainly does the same in daily water management.

Available
Flood Control 2015 offers speed, accuracy and reliability in real-time information supply about flood risks by developing new methodologies and techniques, and subsequently making this information readily available. In this way,
Flood Control 2015 meets the requirements of water managers and crisis managers in relation to information and tools that enable them to optimally execute their duties.

The tools have been developed as such that they can be rapidly and efficiently custom-made to meet the needs of the client and be tailored for a specific area or situation.
Getting a grip on flooding, in practice

“All over the world, a great number of researchers are working on improvements in forecasting the water levels in rivers and along coasts. Was there anything we at Flood Control could add or contribute to that? Certainly, and not just a little! We opted for focussing on quantifying and reducing uncertainties, being smart about the use and control offered by structures and taking suitable measures. This is the field where we developed tangible innovations and executed pilots at home and abroad. Water managers all over the globe can immediately profit from this.”  Karel Heynert, theme leader forecasting and control

1  Quantification and reduction of uncertainty
How reliable are the forecasts on river discharges, sea water levels and wave heights? In order to decrease the margin of uncertainty in model calculations and to obtain a greater degree of accuracy in forecasting, different methodologies and techniques were described and tested.

2  Real-time forecasting of coastal erosion
Where coastal defence consists of beaches and dunes, up-to-date information about coastal erosion, wave overtopping and flood probability enables managers and authorities, such as the coast guard service, to adequately respond to an acute threat while it also provides the information required to ensure well-balanced, long-term coastal management.

3  Global Flood Observatory
Why do we actually not have an online facility where the emergency services, relief organisations and water managers can actually see how a flood event is developing? The Global Flood Observatory automatically processes and combines satellite images so that everybody can stay up-to-date.

4  Optimal control of structures
Weirs, water pumping stations, reservoirs and inlets are weapons in the battle against high water. The decision models developed by Flood Control 2015 are tools to help managers make optimal use of structures to lower peak water levels.
In operational systems for hydrological forecasting, the traditional (lumped) hydrological models are slowly but surely giving way to distributed hydrological models. Existing techniques for data assimilation cannot be used any longer and have to be replaced by technologies that are able to process spatial information, distributed hydrological models and spatial uncertainties. The success of a data assimilation process depends on the degree in which uncertainties can be determined in the model data and schematisation. Under the topic Forecasting and Control, Flood Control 2015 invested substantial energy in research on and descriptions of possible improvements.

**Updating the hydrological status**
The initial condition of the hydrological system largely determines its short-term response time. It could, for instance, relate to the initial (ground) water levels and the degree of soil saturation. These are determining factors in the response of the water system in the initial hours or days of an event. For short-term forecasts, a good model representation of the response is a crucial component. The more accurate the initial condition is represented in the model, the more accurate the forecast will be. In this project, methods were developed to update the initial hydrological condition in spatially distributed models. This makes the forecasting more accurate. The techniques were tested in an application for the catchment area of the Meuse. The results are available in an open-software environment (OpenDA).

**Towards better wave forecasting**
How much of a threat are waves to a coast, a harbour or a dike? For the benefit of inland safety and navigation, accurate real-time wave forecasts are a requirement. The application of data assimilation techniques results in substantial improvement in wave forecasts for shallow water. In this project, a data assimilation technique was developed for improving the forecasts that come from the widely used SWAN wave model. Attention was paid to, and efforts were directed at, making effective use of high performance computing (HPC).
techniques to obtain operational wave forecasts. The techniques that were developed were validated in a test case for the North Sea.

**Uncertainty framework**
A flexible and scalable uncertainty framework was developed in the project. This offers guidelines for quantification, visualization and dealing with uncertainties in different types of water systems. The approach was tested in applications for larger rivers (Rhine and Meuse) and in regional water systems. Additionally, a number of applications have been worked out and described for locations abroad. This research has also resulted in the development of methods for application of the QR (quantile regression) technique for the quantification and visualization of global forecasting accuracy for locations that have measurements available.
Along the coasts, across the globe, sand and gravel beaches and dunes are the most important and most common forms of coastal defence. The effect of wind and water can lead to erosion of the beaches and dunes and at times the pace at which this occurs results in an increased flood risk. Coastal erosion can cause acute problems. During storm surges, coastal managers are aided immensely if they have an up-to-date overview of the conditions of the beaches and dunes. In cases of critical situations, such as rapid and sizeable erosion of the coast and wave overtopping, effective measures can be taken. Accurate forecasting about the condition of the coast will also form an important source of information for the development and coastal management in the long-term.

Current status of the coast
The project *Real-time Safety on Sedimentary Coasts* (RTSANCO) has yielded methods and techniques for monitoring and forecasting the erosion of a sand or gravel beach in real-time. The approach is based on the *Coastal Storm Modelling System* (COSMOS), which consists of a linked series of storm surge, wave and dune erosion models. Every effort is made to keep the models aligned with the present situation along the coast. A data assimilation technique that uses images of the beach and the breaker zone was additionally developed and applied. The images are sourced from coastally-mounted video cameras (Argus). The sub-tidal bathymetric profile within COSMOS is corrected based on these real-time images of wave patterns, in combination with near shore model predictions (XBeach) and are automatically corrected through the assimilation procedures within a software system called Beach Wizard, after which they are processed within the forecasting system.

The technique developed has been applied at three locations along the Dutch coast (Egmond, Vlugtenburg en Walcheren) and at one location on the English Isle of Jersey, where an Argus video location was set up especially for this purpose. The approach that was developed here was tested and validated. In 2012 the method was also put to the test for forecasting the morphological developments around the Zandmotor – a very sizeable sand replenishment project of roughly 20 million m³ along the Dutch coast.
Coastal erosion can have a direct impact on the infrastructure

Rip current forecaster
COSMOS predicts wave and circulation patterns for all model domains, with the highest resolution in the local model. The current predictions within this local model can also be used to forecast rip currents. In order to do this, cooperation was formed with the Egmond Lifeguards for end-user feedback and practical applications were explored.

A public website was developed where results of the real-time rip current forecaster are available with a three-day prediction horizon. In 2012, COSMOS was integrated with the generic forecasting and warning system, Delft-FEWS. This was done considering the operational deployment to reach a large user group.
To have a good overview of the progress and likely consequences of large flood events, it is of paramount importance that rapid insight and information is obtained about the potentially affected areas. In an emergency situation, the only way to get a proper overview is from the air. By presenting satellite images via an interface, everybody with an Internet connection can keep close track of flood events all over the world.

**Almost real-time**
Operational satellite sensors offer excellent possibilities for observation of floods, but in fact, only the American Dartmouth Flood Observatory (DFO) applies this facility systematically all over the world. It is done in cooperation with NASA and is based on optical satellite imagery. In order to substantially increase and institutionalize the availability of real-time flood images, Flood Control 2015, in cooperation with the DFO, developed the *Global Flood Observatory* (GFO). The GFO produces (almost) real-time images of floods all over the world in a systematic and automated manner. This is realized on the basis of freely available satellite data that is sourced from ESA and NASA.

**Translating images**
Modules were developed that can translate radar images (SAR) from ESA’s ENVISAT satellite and translate these images into the probability of flooding per pixel, including the most probable local water level. The translation algorithm is integrated in the Delft-FEWS system so it automatically assesses and merges complementary data, such as topography, freely available satellite services and data from the two NASA satellites, which are equipped with a Moderate Resolution Imaging Spectroradiometer (MODIS). The system, which was developed in 2011 and 2012, combines images from different satellites. The GFO can be used for daily or even more frequent flooding alarms.
Quality
To improve the system quality, a number of additional steps were taken. For example, an increase in the resolution of the flood images makes it possible to obtain a better view of floods in smaller rivers. Algorithms were developed that use data that will become available from ESA’s new Sentinel-satellites in 2013. The data processing and the combination of data from the different satellites was subsequently automated. Attention was paid to the technical validation of the methods and algorithms developed as well as methods for dispersing the global flood information. In order to institutionalize the GFO in the future, a lasting cooperation exists with DFO, ESA and NASA.
Weirs, water pumping stations, reservoirs and inlets for floodwater retention areas can be used to limit the consequences of floods. Optimal use of hydraulic structures could successfully contribute to achieving an extra lowering of the water levels, at relatively low cost. To ensure optimal utilization of hydraulic structures in situations with many options, decision-making models were developed and tested at Rhine branching points and in the Rhine-Meuse delta preceding and during high water.

**Decision-making models**

Which measures would yield optimal results? New and advanced decision-making models enable a water manager to make optimal use of hydraulic structures, and do it in such a way that peak water levels are reduced. The added value, as this has never been done before, is that these decision-making models also take into account the uncertainty of available (hydrological) measuring data and forecasts.

Additionally, these models are able to combine and process data from both continuous and discrete parameters, such as whether pumps are operational or not. In cooperation with the Bundesanstalt für Gewässerkunde in Germany, an application was developed for optimal utilization of emergency retention areas along the Havel River. These areas fulfil a key role in managing high water levels on the Elbe.

*At this bifurcation of the Rhine River in the Netherlands, the distribution of the water can be controlled by an hydraulic structure.*
From early warning to early action in Jakarta

All over the world, organisations are working on the prevention of flood disasters.

What information is available? What information is required and how can users best be served? In Indonesia, Flood Control 2015 joined forces with Partners for Resilience and together they developed a Dashboard Early Action for the Jakarta region.

The alliance
Partners for Resilience are a partnership between Cordaid, the Dutch Red Cross, Wetlands International, CARE Nederland and the Climate Centre of the International Red Cross. These organisations are concerned about climate change and have a strong commitment to making people in African, Asian and Central American countries less vulnerable to consequences of disasters and extreme weather conditions. The alliance has formulated a disaster climate adaptation programme. One of the activities focuses on the realization of systems that make early action possible.

The Dashboard
Prevention is better than a cure. If circumstances could lead to a disaster, it is advantageous if governments and emergency services have access to accurate and up-to-date relevant information on weather conditions and water levels. One can imagine though, that an emergency service provider would want a different kind of information compared to that which a manager might require. Another issue that is of great importance is to have all parties working on prevention to have the same vision as far as the objective is concerned so that parties are able to share information. For this reason, besides working on an analysis of the information requirements, the Partners for Resilience and Flood Control 2015 also worked on a Dashboard Early Action.

In a user-friendly way, the Dashboard clarifies what early warning information means on a strategic, tactical and operational level. Information can be configured for individual users. Information from several sources is combined in order to give the user the most complete picture possible.
The dashboard can be configured according to user requirements. This button opens a dialog box.

The user can select preferences from various types of information windows. This personal configuration is saved and is automatically shown in each session.

This example of a personal configuration shows windows from a weather satellite (a), weather forecast regarding drought and precipitation (b) and a regional map with current warnings (c). Each window is scalable.

In addition to the personal configuration, there is a pop-up window where a pre-configured screen can be selected.

The three functions of the dashboard

1. Integrating and analysing relevant early warning information from different sources.
2. Presenting early action information, which is user specific:
   - on a strategic level;
   - on a tactical level;
   - on an operational level.
3. Presentation of early action information in different time scales (year, month, week, day, hour) and alarm levels (high, medium and low).
The information supply is the same for all users. If a situation changes, all users will have the same update at their disposal. Users are also able to exchange ‘pictures’ (Dashboard views). The head office, for instance, is able to share a specific image with the regional offices so that goal-oriented measures can be arranged and agreed upon.

Moreover, the system is steered by the information requests. Disaster relief organisations, therefore, no longer need to wait until they are supplied with the information. They are able to gather the information they need in order to take action. In crisis situations, every minute counts so a gain in time is always welcome.
The Dashboard provides us with access to high quality climate and early warning knowledge in a way that is significant to us. When a disaster occurs, Red Cross volunteers are often the first relief workers at the scene to provide assistance. In most cases, however, we could save more lives and reduce the suffering if we could get into action before the disaster strikes. This is why the Red Cross has been investing in early warning systems across the globe, so that timely information about extreme weather conditions can be made available to governments, communities and households, thereby enabling people to be prepared for the worst. With the use of this Dashboard, we can effectively anticipate the risks that accompany the disasters. In the short-term, a storm warning could motivate people to start evacuating in time and seek safe shelter. Warnings on the mid-term provide an opportunity to review the disaster plans, stock-up on emergency supplies and train volunteers. Because we are able to select the information we consider pertinent to certain actions, much of the calamity and damages can be prevented. This saves lives.

Margot Steenbergen
Partners for Resilience Officer,
Philippines

Human lives are saved
DIKE STRENGTH AND MONITORING
How is the dike holding out?

Just how reliable is a dike (or levee)? Where could it possibly collapse? What is necessary to prevent collapse or at least postpone a collapse as long as possible? Anybody who holds responsibility for water safety benefits from answers to questions such as these.

For this reason, Flood Control 2015 is developing methods that determine dike strength (real-time) and forecast dike strength as accurately as possible.

State-of-the-art technology for data assimilation and monitoring are used, ranging from sensors in the dikes to remote sensing. Strength assessment and load forecasts can be integrated and presented within one system.

A system that yields forecasts on dike strength and flood risk is more than just an important source of information when flood probability increases; it is also a valuable tool in daily water management.
Keeping the water at bay

Living in a river delta means having to work on safety. By trial and error, the Dutch have learnt how water can be kept at bay. Stable dikes are of vital importance. The question is how do you know whether a dike can withstand the water?

Dikes, dikes
The Netherlands is covered with dikes. Just along the sea and the rivers alone, there are almost 1,900 km of dike, all of which are part of the primary flood defence. In regional flood defences – dikes around reclaimed land known as ‘polders’, villages and cities- the Netherlands has about 14,000 km of dikes. It protects the people, goods and property in low-lying areas. Dikes are inextricably entwined with the formation of this country and it is a product of reclamation and draining reclaimed land. Without dikes, the Netherlands would not exist. It is not without reason that the district water boards are one of the oldest state institutes of the Netherlands: a regional public body that executes the management and maintenance of dikes, amongst other things.

How strong is the dike?
For Dutch district water boards, and for all other organisations that offer flood protection, the following applies: the more that is known about the condition of the dikes, the more likely possible failures can be anticipated. This applies to both long-term (policy and management) and short-term (crisis management) activities. How strong is the dike in relation to the forces it has to face? Where are the weak spots? Is extra monitoring required?

District water boards also issue permits for (construction) activities on or near dikes and dams. In addition, district water boards execute the mandatory periodic testing of the dike system. The execution of these tasks requires up-to-date, accurate, and reliable information about the
The river Waal near Ophemert
Mapping the safety factor for piping, the actual seepage length divided by the required seepage length
strength of the dikes that is indispensable. Naturally, others also benefit from a system that can rapidly provide this information. Local authorities (zoning plans), provincial authorities (structural concept), utility companies, and the national government (supervision) each have their own tasks where it concerns environmental planning and safety. Improved information supply leads to improved policy and decision making on all levels.

Innovative dike monitoring
Dike monitoring with sensor technology makes it possible to assess and forecast the current strength of a water retaining structure by means of measurement. Smart application of the monitoring philosophy results in improved dike management, significant cost savings and achieving safety objectives more rapidly.

These monitoring systems were validated in three large validation experiments. Meanwhile, these systems have been implemented in existing dikes. These are the LiveDikes that are being or have been booted up in various locations in the Netherlands. Sensors measure or forecast the actual strength of these dikes. The Dike Data Service Centre collects the data from the LiveDikes and makes this information accessible to water managers. This enables the water managers to execute better inspections while more information becomes available, which again results in more knowledge that can be used in assessing or reinforcing dikes.

For the next few years, the objective is to further develop these monitoring systems for dikes. Research into innovative dike monitoring is largely performed in the Foundation IJkdijk program. This foundation is also part of the consortium Flood Control 2015, which guarantees intensive cooperation.

Connection
Knowledge and products of Flood Control 2015 and field-testing in the IJkdijk program fit together harmoniously. Gearing structural activities in the program to each other makes it possible for Flood Control 2015 to work on information systems in which the very latest insights in failure probabilities have been processed, making optimal use of the advantages provided by real-time dike monitoring.

Up-to-the-minute insight into the current condition of a dike yields profit. Why reinforce a dike if it is in good condition? Unnecessary dike reinforcement or maintenance results in cost savings. Why evacuate if it is unnecessary? Thanks to sensor monitoring, measures can be specifically tailored to the current state of affairs in cases of imminent calamity.

Experimental testing grounds at Groot Salland
In cooperation with water board Groot Salland, Flood Control 2015 developed an operational system that generates, integrates and presents information about the load on a dike, the strength of a dike, and the consequences of the load on the dike. Static and real-time data about the condition of a dike and the load on the dike are used to calculate its strength. This results in a forecast of failure probability of dike sections, which can subsequently be converted to the flood probability of the entire area. In conclusion, it provides the flood risk. The system defines the flood risk in terms of damage and victims (➞ p.58).
How is the dike holding out, in practice

“How within the programme, I gladly made a stand for for ‘dike strength’. Here was a perfect opportunity to modernise the ‘old-fashioned’ way we used to determine dike strength. For instance, by making better use of modern Geo-ICT. In this case, it concerned an application of 3D and real-time geo-technology as well as effective communication with decision makers, who did not have a (geo) technical background.
I challenge everybody to get on board and use the opportunity to take a leap into the 21st century!”  

Martin van der Meer, theme leader dike strength and monitoring

1 Dike strength Information System (DIS)
What kind of load is a dike able to withstand?
The foundation for sound decision-making on dike management is the strength assessment of a dike or a dike ring. Flood Control 2015 has developed and tested a calculation measurement tool that provides an accurate picture of the strength of dikes based upon remote sensing data.

2 Smart Dikes
In the Smart Dikes project, pore pressure is measured in real-time and immediate calculations are made in relation to the current dike stability and flood probability. In this way, a more precise forecast of increasing dike failure probabilities is shown as the water level rises and the longer the flood levels continue.
How can all data be optimally combined and used to determine dike strength? In a newly developed calculation module, the Dike strength Information System (DIS), Flood Control 2015 has applied height data sets (data obtained with laser altimetry) and utilizes the possibilities of modern sensor technology to obtain a reliable strength assessment of a dike ring.

**Strength maps**
To ensure that DIS connects to work processes, software and systems run by the district water boards, and that it can be used under all conditions, it was tested on the experimental testing grounds at Groot Salland. (→ p.58). One component of DIS is a graphic method for rapidly and efficiently generating a reproduction of dike strength topographic maps. These strength maps provide the manager with immediate insight into the weakest spots under certain hydraulic preconditions. The strength map can be generated for a current situation but also for any other random situation, for instance, for the benefit of a design. In the further development of DIS, the central focus is on the link to the inspections executed by the water board.

**RSDyk**
In the RSDyk project, more detailed research took place into the use of remote sensing and geophysical techniques, among others, for a dike section of the water board Groot Salland. This information is used in the charting of uncertainties in the subsurface model. The monitoring of peat dikes may also benefit from remote sensing. The actual strength of peat dikes is difficult to assess and visual monitoring methods are not always reliable, as well as being time consuming. Remote sensing can help to identify sections with potential problems. (→ p.23).

*The actual strength of a dike depends upon measures taken...*
When the water level increases, dike strength decreases. This is because the pore tension in the dike increases. It is important to monitor this tension. What is the development in dike strength in time? Will it hold or will it collapse?

**Forecasting failure probability**
In the Smart Dike project, pore pressure is measured in real-time and immediate calculations are made in relation to the current dike stability and flood probability. In this way, a more accurate forecast is made of the increase in dike failure probabilities as the water level rises. The FEWS-DAM (Dike strength Analysis Module), a calculation model for automated geotechnical analysis of dikes, is used for this purpose as it includes dike failure probabilities.

**Savings**
In the Smart Dike project, attention was also paid to working out in which cases monitoring would result in savings for the management. This showed that it would be (cost) effective to install a monitoring system in combination with monitoring for (the benefit of) dike reinforcing. This is because up-to-date dike strength information decreases the probability of failure during the implementation, as a smaller investment is required for the measures that need to be taken to prevent collapse during implementation. It was implemented in this manner in the project Modern Monitoring of dikes Eiland van Dordrecht (Island of Dordrecht).
The diagram legend shows the failure probability. The colour of the dots represents the calculated failure probability.

Clicking on one of the dots opens a new window, which shows the water level and failure probability due to piping.

The adapted dike, newly dug ditch, water level gauge, and extra water pressure meter are represented on the map.
Test case Groot Salland

Two rivers flow through the area managed by Groot Salland water board: the IJssel and the Vecht. High discharges from either of these rivers could bring substantial problems. Within Flood Control 2015, the water board has built a system in which information about the load on the dikes results in insight into the strength of the flood defences and the flood risks. How safe is it behind the dikes? Just press a button and the answer appears.

From cause to consequence
The system combines data from different sources, computer models and presentation tools. The foundation for the calculation on the strength of the dike is based upon information on load (measurements and forecasts of water levels, wind speeds and directions and waves) and about the flood defences (such as the position of the dike, what the dike body consists of, current pore tensions within the dike).

The integration of the information provides a forecast on failure probabilities of the dike sections and, finally, of the complete dike ring. The system calculates the flood risks and provides a picture of this. Uncertainties (for instance in the forecasting of water levels) have also been included. Furthermore, the consequences of a possible flood are calculated in terms of damages and victims to be expected.

Made-to-measure presentation
Up-to-the-minute information with a high level of detail is presented to a specialist. Data about cause (load) and consequence (present strength) can be combined in a presentation, consisting of graphs, tables and maps. For the benefit of decision-making and informing citizens, information can be aggregated and, in combination with field observations, it can be presented via an Internet portal. The presentation is designed to best serve the end user. The system is fully operational and it supports the daily operations of the water board.
Advantages
The added value of this system is up-to-the-minute insight into the status of the water retaining structure, at any given moment. Monitoring the dike becomes a continuous process that requires less effort than it did previously. Insight into the strength of the structure makes it possible to optimize maintenance and management. During crisis situations, the actual load is translated into the strength of the dike and a flood probability for the dike ring. The information is presented on different aggregated levels, geared to the role of the user. This current, differentiated information supply makes risk-based dike management and crisis management possible.
Measures are becoming more goal-oriented

The system offers detailed information about the current situation of the flood defences and the safety level within the dike ring. This information supports the management, policy-making and crisis management. Measures become more goal-oriented, whether it concerns dike reinforcement or a management measure during a flood threat. Because this system is able to determine the effect of a management measure on the flood probability, the water board expects that the implementation will lead to substantiated savings in dike improvement projects.

Jan Put
Department Head Implementation,
Groot Salland water board
Schematic overview of calculated dike shear

Display of the progression of water levels in the dike

A 3D schematicization of the base as important input data for the strength calculation

Residual strength of the dike is shown in colour, per location

Detailed account of the failure probabilities due to piping

Overview of the failure probability as a consequence of piping for all dike compartmentalizations in Dike ring 10 (Dijkring 10)

Dike strength modules of the Groot Salland water board
DECISION-MAKING
What are we going to do?

What is the water level? Which measures are required? What are my options? During a flood threat, everybody feels the need for having an up-to-date overview of the situation. However, a chairman of a water board has different information requirements and other options than an operational leader of a safety region or a citizen, for instance. If all parties concerned take the correct decisions and those decisions are well tuned to each other, everybody benefits. Smart flood control also means: good cooperation and clear communication.

Flood Control 2015 has developed methodologies and techniques that enable others to efficiently deal with the flood of information on offer during a flood risk.

Because the information often is highly technical in nature, it is more easily explained or interpreted in this way, which facilitates correct and timely decision-making. Much attention was paid to knowledge transfer to professionals in crisis management and to improving the skill sets of different target groups by means of training.
From information to decision

How strong is the dike? When will the highest water level be reached and which area potentially has the highest flood risk? From manager to citizen, everyone has a need for information that pertains to their perception of the environment and its corresponding dilemmas. A good understanding of the situation makes it possible to take the correct decisions. But how does made-to-measure information come into existence and how does someone make the correct decision?

**Explain and streamline**
Fifty different forecasts of water levels in the next few days, reduced dike stability and on average, 3.14 victims. What does this mean? What should I do about it? Well-founded decisions are made partly because information is effectively explained. By means of visualization, by using known characteristic numbers and mapping the effects and consequences, information links up with the user’s perception of his environment.

During a flood risk, relevant information is not only provided by specialized information systems of public organisations. Radio, television, Internet, social media are also sources of information. How does the user find his way in this abundance? The answer is: A user specific dashboard that provides all the flood information available from recognizable and reliable sources of information.

**Crisis decision-making**
How substantial is the flood probability? Can I make a comparative assessment or do I have to make a quick decision? Just how serious are the consequences? These are the questions asked in a flood risk situation and the questions that put pressure on the flood control teams involved.

Flood Control 2015 has produced new work methods to support and improve decision-making in crisis situations, examples of which are adaptive meetings, thinking in scenarios and impact analysis. Attention was also paid to the effect of information management and the degree in which crisis teams were sure of their responsibilities when it came down to performing.
Crisis training
How do you make sure that plans and tools are used effectively during a flood crisis? During the crisis there is no time to allow for taking breathers, finding plans, let alone them with full attention. Everybody has to be completely familiar with what they are supposed to do. It is a matter of regular training and practice, and preferably in a pleasant and challenging way: serious gaming!
Decision–making in practice

“‘It seriously becomes a disaster if you do not know what to do’. This is quite true. A disaster cannot be planned though, so we do not always know in advance what the best course of action is or will be. It would be more advantageous to learn to deal with the certainty of uncertainty. It also makes more sense to offer made-to-measure information than to show everything we are able to calculate. To me, that is the largest challenge of Flood Control: enabling people to determine their best course of action.”

Astrid Janssen, theme leader decision-making

1 Crisis and decision-making
   In a crisis situation, the pressure keeps building. Partners have to be consulted, decisions have to be made. The question is in which order? How fast? Crisis teams have a need for both overview as well as relevant information supply for their different roles. Methodologies and techniques to improve the performance of crisis teams are tried, tested and refined.

2 Crisis communication
   During a flood threat, everybody eagerly awaits information. Uncertainty about the situation increases the likelihood of getting the picture wrong and taking inappropriate action. Therefore it is paramount that the communication is unmistakably clear about what the situation entails, what is being taken into account and what the flood protection professionals expect from their environment.

3 Risk driven decisions
   Taking measures based on forecasts including their probability does have advantages. But what if the forecast proves to be incorrect? As measures become more drastic, it becomes more difficult to reach a decision. Fortunately, good tools are available.

4 Serious games
   A serious game is an attractive and challenging way to learn new techniques or skills and to improve performance, whether in a team or individually. Flood Control 2015 has developed serious games for different target groups.
How does decision-making take place in a crisis? The Dashboard flood risk management offers crisis teams and other users all relevant information on one screen. A survey into decision-making by managers shows that they do benefit from a measured information supply.

**Dashboard flood risk management**
One screen that contains all the information about the crisis; this is what the dashboard flood risk management is about. The dashboard offers the possibility of streamlining information and making it suitable for all users while providing everybody with the same reliable and up-to-date information. The presentation of selections from the total information supply ensures that users do not suffer information overload.

In addition to water management related information, the dashboard offers all the necessary information to obtain a good overview of the situation during the crisis. Examples are traffic images, risk maps, information about network partners, news bulletins and twitter messages. Ad-hoc information that becomes available during the crisis such as photos and video can be shared with parties involved by means of the dashboard.

The dashboard also has something to offer communities in areas where disasters occur more frequently than elsewhere, as the dashboard then becomes a means of sharing information about the crisis with each other. This has already been implemented in South-East Asia, where the dashboard is not only available on the computer but also as an App(lication) for Smartphone and Tablet PC.

**Optimal decision-making**
Research has shown that the effectiveness of managers largely depends on how sure they are of their role. In support of this, it is extremely important that the information for consideration links up with the role of the manager as a decision-maker. It is imperative that the manager only considers the information that is relevant to him. The operational leader should minimize noise and prevent information overload.
Impact analysis
An interesting fact is that not all information of managerial interest can be supplied by the operational team. This mainly applies to the known economic identifiers, which are of considerable importance for well-founded decisions. There is still room for improvement with regard to support for the regional policy teams. A tool was developed in the shape of an impact analysis, to be completed during the preparation and training phase (cold phase). Conveniently arranged tables provide an overview of the immediate effects of the various strategies under consideration so that a complete overview of the most important criteria is available during a crisis (warm phase).

Style of decision-making
Furthermore, it is important that the manager has a number of decision-making styles at this disposal for efficient decision-making in a crisis. The style of decision-making should correspond with the nature of the crisis and the time available. A one-day training was developed for regional policy teams to improve the effectiveness of decision-makers during a crisis.
Managers initially work on their environment awareness and subsequently work with given methodologies for decision-making about topics with different variables such as time pressure, uncertainty and consequences. It is important that the correct people are at the table. If a group is too large, it results in fragmentation but if the group is too small, issues might be overlooked.

Operational teams
Unlike managerial teams, members of operational teams often bring their own information to a meeting. Effective decision-making in these teams therefore mainly depends on personal assessments: which information should be shared? It is important that the chairman is certain of his role. Information coordinators filter information and provide direction. Liaisons between the safety column and water column have proven to be useful in crisis decision-making processes with regards to floods.
News coverage and conceptualization are two determining factors in the successful course of crisis management. Communication contributors and other suppliers of information have various tools at their disposal to ensure that they can inform others rapidly, keep them up-to-date and aware of what is happening.

**Improving news coverage**

In order to improve the reporting, a Communication Centre was developed. Use of a common Communication Centre ensures consistent and complete reporting. Information officers are able to draft an initial version of a report rapidly, based on a step-by-step-plan complete with building blocks for texts. This makes recurring communication more efficient and effective, for instance regularly recurring updates between authorities or recurring communications from authorities to other parties involved, such as farmers. The Communication Centre has been equipped for different kinds of disasters and for the specific user requirements of organisations.

**Independent civilian ability**

Much has been done to improve independent civilian ability to manage for themselves.

Researchers have scrutinized people’s search behaviour for information during a crisis and developed a training tool for communication staff. The most important objective of this tool is to make a complex situation understandable to the public, so that they are able to draw conclusions and determine their best course of action. The perspective of the communication officers has to be in alignment with the citizen’s point of view and communication officers become more familiar with the type of information generated by crisis teams.

**Social media**

A crisis without social media is unthinkable, but do social media have added value in crisis management? Research has shown that it would be sensible to keep a close eye on social media. If authorities viewed people’s twitters as social
During a crisis, citizens are influenced by information from social media sensors or as journalists, they could use the information as field information and eyewitness accounts. Sometimes photos and videos come to the surface that could be important for providing a broader overview in crisis management.

**Twitter monitor and Twitter generator**

Another reason to keep an eye on Twitter, for instance, is that as time progresses during a crisis, topics are singled out that have an effect on the image of the safety regions, water boards or national government. These topics need not reflect reality at all: sometimes issues start leading a life of their own. If this happens, it is important that decision makers become aware of this sooner rather than later, so quick and adequate action can be taken before the issue impacts the authority of the crisis management. People expect the government to be concerned and involved. Presence on social media counts as a measure for the level of concern. Because the stream of messages quickly becomes too vast to follow, not to mention the difficulty involved in synthesizing a general mood out of this, an extraction tool was developed that provides an indication of the messaging on social media: a Twitter monitor. Furthermore, a Twitter generator was built and during exercises, it generates messages. The crisis teams learn to deal with information via the flow of new media.
Even though we continuously gain knowledge and are able to make increasingly more accurate forecasts while developing a better understanding of the effects produced by measures, crisis procedures are often still historically determined. Most organisations base their scale up procedures on measurements instead of forecasts and, if they do scale up according to forecasts, uncertainty in the forecast is hardly taken into account. Valuable time is lost like this.

If the preparation of measures is included in the crisis procedures, it will yield time gain. That is not all it will yield, as taking adequate measures also costs less and it results in better requests for support from partners in crisis management. This offers room to opt for a less stringent scale structure, preparing for more or less drastic measures depending on circumstances with more or less preparation time or costs.

Together with the water boards, Flood Control 2015 scrutinized the existing procedures. Just showing the inherent uncertainty in information, is already taking uncertainty into account. By including this information uncertainty in a cost-benefit analysis, one can even calculate the threat level that will require measures as well as which measures this should be. In addition, a method was developed to combine the current flood forecasts, flood scenarios and strength calculations and present everything in one risk map.

Measure: mobile high-water defence
Practice makes perfect. Methods and techniques for effective flood control can be innovative and advanced, but it has to be used properly. That is why ample attention was paid to the implementation of these methods and techniques in the crisis organization and the importance of periodical use is stressed. Serious games are an excellent means of training.

Serious games can be played individually or in a team, they require relatively little time and are inexpensive. Serious games offer crisis professionals an attractive, exciting and safe practice environment and provide them with opportunities to gain insight into existing patterns, alternative procedures as well as an opportunity for testing new tools while gaining knowledge and skill.

Flood Control 2015 has developed a number of practical serious games that deepens the crisis team’s perception of the reporting and decision-making. In a game for liaisons, participants are challenged to make choices in the information supply. Players learn to work together in the field of overlap or common ground between disciplines and organizations. They learn to make better decisions despite the uncertainty in information and time-pressure. Another game concerns the cooperation between different teams in flood reporting.

*Serious games offer a safe practice environment*
What is the WMCN?
The WMCN is responsible for water level forecasts in the main water system and for timely reports about flood levels in the Dutch rivers and lakes as well as coastal (tide) flood levels. To fulfil its second task, the WMCN had a need for an adequate training environment where staff can be trained either individually or in teams and practice teamwork.

Together with Flood Control 2015, the Ministry of Waterways and Public Works has developed a training environment where historical or fictitious flood scenarios can be run virtually, down to the finest detail. Meteorological and water information are combined with events that occur within water boards, safety regions and society. The training environment is equipped with systems that are used at WMCN. The difference is that the systems are supplied with data from scenarios rather than actual measurements and forecasts. The environment is almost the same as the daily work environment.

The instructor is in control of the scenario from a central point and is able to control events that could have an influence on flood reporting: questions from society or social unrest or management measures by water boards and safety regions. The instructor can follow the action taken by the participants online and, if necessary, adjust the exercise right there and then.
Putting it to the test for the Noordwaard

The Noordwaard is being designed and prepared for dealing with extremely high discharges of the Nieuwe Merwede in a controlled manner. To this end, the area is divided into hydraulic units, varying from areas outside the dike to polders (reclaimed land) with high embankments (flood probability 1/1,000 per year). Important in relation to the flood risk in the Noordwaard, is that risky combinations of tide, high river discharge and wind are recognized in time so that livestock and goods can be brought to safety. News coverage about the water was the principal theme of the pilot project.

For participants of the local authority Werkendam, the exercise yielded more insight into the work of the WMCN. Moreover, the simulated expected water level and flood threat have contributed to and resulted in a transparent and effective disaster plan for the inhabitants of Noordwaard. The flood disaster plan ensures that all inhabitants of Noordwaard will receive timely information about what action to take preceding a possible flood event.
Joint exercise

The training environment illustrates the importance of news reports on water levels during flood risk. It shows the work methods of the WMCN during flood risk and offers other organisations such as local authorities, water boards and safety regions the possibility to adjust their work processes accordingly. It is also possible for partners and WMCN to practice together. Developments and innovations in the field of news coverage on flood risk can be practiced in advance, based on the scenarios and adjusted according to the needs of the WMCN and partners.

Stefan Nieuwenhuis
Crisis Management Consultant / Coordinator LCO
Training facilities of the Dutch Water Management Centre

Average low water in the Noordwaard polder (0.40 m + NAP)

Extremne high water in the Noordwaard polder (3.50 m + NAP)

Polder Noordwaard is a new storage area for high water on the River Rhine
With the Hurricane Risk and Safety Module, the performance of the New Orleans levee system can be forecasted under storm conditions and mitigation actions can be determined. The module is developed as a storm forecast, levee strength and decision support tool for a pilot area: New Orleans East.

A clear view on the threat
The importance of flood control solutions for New Orleans became clear after the catastrophic flooding caused by hurricane Katrina in 2005. When a major hurricane threatens to directly strike coastal communities, levee operators want to know what is going to happen, where and when so they can better decide how to respond and put the correct measures in place. To make those kinds of decisions requires accurate information at the right time.

Better decision-making
The Hurricane Risk and Safety (HRS) module integrates the forecasting of hydraulic conditions during a storm event with the forecasting of levee strength. The information is presented in a comprehensive web-based dashboard, adapted to the end-user preferences. The dashboard brings together crucial forecast and monitoring information. This facilitates optimal decision-making about possible mitigating measures, in advance and during the hurricane.
The HRS-module consists of three components:

1. **Storm forecasting module (SFM)**
   This component forecasts hydraulic load conditions for an approaching hurricane. The output exists of best estimates for maximum storm surge levels and wave conditions for an approaching storm. These parameters are subsequently used to determine potential overtopping and overflow conditions for levee sections.

2. **Levee strength module (LSM)**
   The strength module calculates the levee strength using the forecasted hydraulic load conditions and geotechnical calculation methodologies. The output of this module is a levee risk and safety map indicating the lowest safety factor of the geotechnical failure mechanisms per levee section during a storm.

3. **Dashboard/Decision support module (DSM)**
   The decision support module provides the levee operator with all relevant information and presents possible mitigating measures.
With the Hurricane and Storm Damage Risk Reduction System of New Orleans nearing completion, SLFPA East is in need of advanced solutions for efficient maintenance management. The development of the additional Levee Information Management System (LIMS) module – the Hurricane Risk and Safety Module – helps to improve decision making under storm conditions.

This product is a great effort of the project team, which helps SLFPAE in several ways. All information is presented clearly and accurately. The dashboard can pull information from different sources, which means all information on the storm event and system performance is in one place. Furthermore, storm forecasting is improved by converting the USACE Storm Atlas into a usable tool. The improved information on storm impact and levee strength helps to prioritize our actions and this tool will improve our operations over time.
Project team preparing for training session at Orleans levee district, New Orleans
SMART FLOOD CONTROL IN THE 21ST CENTURY
The Flood Control 2015 consortium is launching a new, dynamic collaboration: the International Network for Smart Flood Control (INSFC). The INSFC will continue to build on the results obtained from the Flood Control 2015 program and strives to make a global contribution to improved flood defences with Smart Flood Control. The consortium will establish a research and development centre as home base for the INSFC: the International Centre for Smart Flood Control (ICSFC). This centre will offer facilities for fundamental and applied research, as well as the necessary facilities for water managers and crisis managers to test and apply innovations in a practical setting. The ICSFC will be the first centre in the Netherlands where innovations in the field of flood risk and flood defence will be integrated with forecasting and decision-making support systems and methodologies. It will have a prominent role in the development and dissemination of water and crisis management, supported by information technology.
Centre of expertise and competence

Universities, knowledge centres, consultancies, water managers and crisis managers all play a part in the realization of innovation in flood risk. Good cooperation between all parties achieves optimal results. With the International Centre for Smart Flood Control, the consortium Flood Control 2015 would like to offer a place and a platform for this cooperation. Knowledge, methodologies and techniques, such as training modules and Apps can be disseminated via the ICSFC. The aspiration is to open a centre of expertise and competence where all interested parties are welcome to contribute and grow organically into an international Centre of Excellence in the field of information driven flood risk.

Multi-layer safety
The concept of multi-layered safety has reached maturity during the past few years in the Netherlands. It provides fertile ground for a growing realization that flood prevention and safety measures are not solely a matter of flood control (first layer). Just as important are spatial planning (second layer) and the way a flood is dealt with in disaster management (third layer). Together, these three elements are determining factors in the scope of the flood risk. This means that if a flood risk approach is the foundation of the standard flood risk, the second and third layer must also be taken into consideration.

The consortium’s objective is to develop and advance expertise for all three layers in the International Centre for Smart Flood Control.
Research and development

The ICSFC accommodates fundamental and applied research as well as the practical application of innovations. The consortium foresees various possible topics for further research and development for the benefit of flood risk:

- Quantification of uncertainty or reliability of forecasting and analyses;
- Development of methods and techniques that take uncertainties in information supply into account (decision support);
- Links between different subsystems such as water level forecasting and forecasting on structural strength (e.g.) dike strength;
- Using social media;
- Specific analysis of data and presentation of different user-specific and group-specific information.

Who does what?

The fundamental research will mainly be in the shape of doctoral research. The turnaround time of this kind of research project is approximately four years. In order to achieve fundamental developments on all fronts of smart flood control, the intention is to nominate five to ten Ph.D student research projects. The applied research will partly be executed by the doctoral students and partly by the consortium partners. Other parties are welcome to participate.
Multi-layer safety: prevention, spatial planning and crisis management
The development of tools and products is expected to mainly take place in the knowledge institutes active within the network.

The ICSFC will accommodate the application of innovative techniques. Water managers, crisis managers and other parties involved will be welcomed at the ICSFC, given explanations on state-of-the-art technology and immediately get some idea of how the techniques and methods can be applied in their own professional field. Finally, the ICSFC will serve and function as a virtual centre of excellence. Experts from the consortium can be consulted through the ICSFC, for example enabling commissioners to quickly get a team of experts together.

Not without the government
An important point of attention is financing the network and the centre. The business sector can only get sufficient return on its investment if commissioners (governments) offer sufficient room. On the one hand, the government offers possibilities in supporting innovation by means of subsidies and on the other hand, the government is a commissioner in water management and flood risk. Government organisations willing to take the part of launching customer are indispensable for the successful development of smart flood control.

Towards safer deltas
No two river basins or coastal areas are the same. Physical characteristics, use functions, population, prosperity levels and management organisations differ from delta to delta. Flood risk depends on the local situation, as the implementation of support systems will always require a commissioner-specific and location-specific approach. Nonetheless, floods everywhere are always due to interaction between water and surroundings. Discharges, waves and wind could lead to high water levels that constitute flood risk. Flood defence structures can fail and inhabitants of an area under threat are able to, or unable to, prepare for a flood. The three elements, separately and in combination, determine how serious a flood is and how serious the consequences are. The INSFC strengthens every link in the chain and forges it together: Smart Flood Control for a safer delta.

Are you interested in the developments and activities of the International Network for Smart Flood Control? For more information, please register at: info@floodcontrol.nl.
Hendrik Balk, a modern flood adventure
Hendrik Balk finds himself standing in wet, soft, sticky earth, right up to his knees, in what up until yesterday, had been the crest of the Outer Dike. The rain is mercilessly pounding his face. Icy cold water on his left, and on his right, the polder cloaked in mystery. His phone communicates only one thing – no service. It reminds him of that night in February, a long time ago.

As a boy of six, he is walking through the stormy darkness on the Strijensedijk in the direction of s’Gravendeel, holding onto his father’s hand. The fire brigade had already taken his mom and sisters to the community centre earlier. He looks back one last time and in the distance, he sees the water streaming across the dike. He can no longer see their house. Come on…. just push on a little more, we are almost safe, says father. They pass the foundry. The old blacksmith is standing in the doorway and signals them to come in. Inside it is warm. A few men are standing around the furnace, silent and unrecognisable due to fear distorting their features. The wind is howling outside. The old blacksmith asks whether our family is safe. But we nearly left Hendrik behind, father tells them, I went back and got him out of bed in the nick of time.

Woken from that nightmare in time, Hendrik looks around. The mud increasingly firms its grip on him, not a soul to be seen on this desolate dike, not a house, not a light, father has passed and no service.

We are completely in control of the situation. Almost all dikes in our management area are smart dikes. They tell us what the situation is so we know what the status of the dike is.

These are the words of Mr Meyer, the spokesman of the district water board. Because of this, we are able to make correct decisions and to keep ahead of the impending emergency situation. He is talking to Karin Bresse, a journalist covering the process of dealing with flood risk incidents for ‘Die Zeit’ and invited by the water board to be present during a flood risk situation. Is there no dike monitoring anymore?, she asks. Dike inspectors are no longer needed. We have one hundred MB digital information about the dikes, the weather, water levels and evacuation routes, says the spokesman. All this information has to be integrated and it comes together in showing complete overview of the flood threat. And then?, asks the journalist. Then we make our decisions, with additional support from the information on the Dashboard, where all the online information comes together. She finishes typing her sentence and then looks at the spokesman: But doesn’t such information often contain many uncertainties?

Well, we make the uncertainties visible and we take uncertainties into account when making scenarios.
and while determining measures. Meyer waits until she has finished typing. Ms Bresse, would you like to see our Dashboard? She nods: Yes please, I’d like to see that. She closes her laptop, gets up. I’d certainly like to see this digital reality up close.

In the clean room of the crisis centre, everything is peaceful. The operators are staring at screens along the wall. Every now and again, a colour changes somewhere on a screen and there is a soft, gentle hum that originates in the air conditioning.

All relevant information from across the region comes together here, says Meyer. The added value of our system is that the status of our dikes can be monitored in real-time. Every stretch of dike has a sensor and this sensor tells us something about the stability of the structure.

Karin points to a large screen filled with lines, dots and gauges. Above it, it reads Current Status of Dikes. She says: So, if I understand it correctly, those points there on the screen tell you what the internal condition of each dike is?

Spokesman Meyer chuckles: Yes, I suppose that is how you could say it in layman’s terms.

What about the inhabitants? If it seems like there is a danger of imminent flood, how do you inform them?

Meyer points to a screen with a map, where all the roads in the region are lit up. Evacuation routes is what it says above the map. These are the escape routes. Every household is sent targeted information on their smart phones via an evacuation App when to leave and where to go.

The journalist asks: And that is how you prevent traffic jams and panic?

Exactly, says Meyer. This is Ton, the team leader. Ton, could you show us the current status along the Schenkeldike? Operator Ton zooms in on the dike and says: That’s it, there it is. Everything is peaceful, by the looks of things and the gauges are in the green.

Meyers checks his watch: OK, that was it. Do you have any more questions Ms Bresse? Suddenly a penetrating whistle breaks the peace in the clean room. On the screen, a couple of gauges suddenly shoot into the red.

Hendrik does not panic easily, but with a telephone that he cannot use and not a soul in sight on the deserted dike, his belief in a positive outcome is diminishing rapidly.

No matter how he turns his telephone and what buttons her presses, the only thing he gets on his phone is no service. Why did his car break down here and why now? In the distance, there is a growling sound of a howling storm. He looks around but there is nothing to see and there is nothing else to hear but the sound of the storm, which overrules any other sound. There it is again, that growling sound that is carried with the storm and it is coming from behind him. Hendrik tries to turn his body around as best he can with his legs stuck in the mud. Is that a light? It seems like something is coming through the grey darkness. Suddenly two lamps are shining on him and growlingly come closer in approach. A tractor stops about ten metres from him.

Somebody jumps off, starts walking towards Hendrik and shouts: What are you doing up there? Hendrik yells back: I am stuck in the mud. Can you pull me out? The man, wearing a cap and wooden shoes, grabs his arm and pulls. We do not need a
tractor for that, he says. Slowly the mud around Hendrik’s legs eases off and he pulls his legs out of the mud. His boots remain in the dike, stuck in the mud. Thank you, thank you very much, says Hendrik. Who are you?
I am Kees Praaij from the farm De Volharding [Perserverance]. Come with me, says the farmer as he walks back to his tractor. On the way back, the farmer asks: What were you doing on the dike in this weather?
I was on my way home and decided to drive past the dike to see how high the water level was in this storm. All of a sudden, my car just died on me. So, I started walking to find help.
Praaij nods. And then the dike got hold of you. They reach the farm about ten minutes later and the farmer says: Take off your socks and your trousers. I’ll give you my work trousers and my indoor clogs. The missus does not like mud.’

On the Dashboard, two indicators are red. The operators are well trained and they do not panic.

Spokesman Meyer walks over to the group, Karin following close behind. It seems like something is going on with the stability of the Spuidike, says Ton. One of the operators zooms in. On the big screen, which says Current Status of Dikes, two indicators along the dike are in the red. On the screen that states Evacuation routes a message has appeared: Prepare for Activating Evacuations App.
Karin asks Ton, the operator: What’s wrong?
Meyer answers her: It would be best if you left now, the operators are busy with this situation now and do not have time for questions.
The journalist looks the spokesman square in the eye. The chairman himself personally asked me to give an account of the complete storm period so, I will be staying right here. Meyer is taken aback and blinks: Well, if the chairman personally …… well,…yes, who am I to argue?

From the discussion between the operators, it turns out that apparently eleven sensors along the Spuidike are not operational. That dike is sensitive to liquefaction and preparations were started improving the embankments this quarter, says Ton. So how do you know that the Spuidike is actually giving problems? Karin asks.
Temporary sensors have been installed that measure the groundwater pressure at two locations along the inner toe of the dike. At the moment, the registered pressure is too high.
Meyer says: Do we have to scale up? Or do we first inform the Chairman of the situation? One of the operators says: A message has already been sent to the Chairman. He is on stand-by.
The team leader says: Good. We should actually have somebody on the dike who can give us the current status. Given the temporary sensors, I am unable to really assess the present situation properly from here and really know what is going on.

At the van Praaij farm, Hendrik Balk is warming his hands by holding a cup of coffee with both hands. There is something going on with that dike. The crest has become totally soft. I must call the water board to tell them what I saw there. But tell me, Praaij, why were you driving around on the dike? The farmer says: I could not sleep. The storm was keeping me awake. I was standing at the window and I saw a small light out there on the dike. Hendrik takes another sip of his coffee.
That must have been my Smartphone, I was waving it around, trying to pick up a signal.
Praaij asks: But aren’t they able to see the status of the dike at the water board?
Indeed, says Hendrik: They have large computer screens where they are able to see the status of all the dikes. But I would like to know whether they are able to pick up this problem with the dike.
How do they know what the status of the dike really is?, asks Praaij.
Hendrik says: There are sensors in the dikes and these sensors indicate what is going on inside the dike.
Farmer Praaij smiles: Electrical equipment is nice, but my sensors are between my ears.
Hendrik smiles: And thanks to those sensors of yours, I am sitting here, quite safe and warm.
Never go on a dike during a storm if you are by yourself.
Hendrik nods and thinks back to nineteen fifty-three, the journey with his father, on their way seeking shelter together. My phone has service again. I’m going to phone the water board.

In the clean room, not much has changed and the discussion still continues. There are no additional gauges that show red but the situation around the Spuidike seems to be critical. The hydraulic model is forecasting maximum water levels along the Spuidike within three hours.

A phone starts ringing on one of the desks. Meyer walks over and answers, then puts his hand over the receiver and says: It is the previous chairman of the water board.
The team leader takes the phone from him: Hallo Hendrik, where are you?
The clean room is filled with silence and now and again, Tom says something in response. When he puts the phone down, everybody is looking at him questioningly. He says: That was Hendrik Balk, the previous chairman of our water board. He got stuck on the soaked crest of the Spuidike between here and here, he says indicating the position on the large screen on the wall. That is exactly the stretch where the sensors have been removed.
Meyer sighs: What a terrible concurrence of circumstances. Normally, we would not have high water this early in winter.
Karin says: Coincidence or not, it is a good thing that someone was walking on the dike and reported this.
One of the operators calls out: The previous chairman has rescued us, kind of like a Hans Brinker.

The team leader says: Ok, that was enough chatting for now. Everyone at their stations, we are going to use the Evacuation App to warn the inhabitants of the North Polders.
Karin sits down at a table, opens her laptop and starts typing. The spokesman walks over to the team leader: Ton, will you send me the status reports every 15 minutes so I can update the Message Centre and put the latest status on social media. The team leader nods and clicks the button Activate Status Reports so that it is on.

Three days later, the first winter storm is being evaluated. Hendrik Balk tells the story of his adventure on Spuidike. The only useful thing my Smartphone had on that dike, was the screen light, he says. Without that bit of light in the dark, farmer
Praaij would never have found me. The team leader says: The fact that those sensors had been disengaged in that dike section was not such a smart thing to do. We should amend the procedure and add that in these kinds of circumstances, more temporary sensors are required in replacement. The team leader acknowledges that: Thank goodness we were well prepared for this situation. Last year, we experienced something similar in the regional training. That has proven to come in very handy indeed.

Karin is also present at the meeting and explains her report on the event. Did the activation of the Evacuation App go well?, she asks.

The team leader answers: About two hundred inhabitants were informed about the status in the first message. An hour later, we asked them to start preparing for evacuation. The wind speed subsequently decreased and after that the tide started going out. The two temporary sensor gauges were back in the green and we were able to send the End of threat message out.

How do you know that the inhabitants have read your messages? Karin asks.

The App is equipped with a ‘Message read’ announcement. We were able to tell that almost ninety three percent of the inhabitants had read our message. In the future, we would like to expand the App with a report back on whether the receiver was inside or outside the area under threat.

Hendrik Balk smiles: Exquisite, all those digital miracles, but nineteen fifty-three taught me that I should also listen to myself. Or, in the words of farmer Praaij, your own sensors are between your ears.
Consortium members
Deltares is an independent institute for applied research in the field of water, subsurface and infrastructure.

Throughout the world, we work on smart solutions, innovations and applications for people, environment and society.

Our main focus is on deltas, coastal regions and river basins. Managing these densely populated and vulnerable areas is complex, which is why we work closely with governments, businesses, other research institutes and universities at home and abroad.

Our motto is *Enabling Delta Life*. As an applied research institute, the success of Deltares can be measured in the extent to which our expert knowledge can be used in and for society. For Deltares the quality of our expertise and advice is foremost. Knowledge is our core business.

All contracts and projects, whether financed privately or from strategic research budgets, contribute to the consolidation of our knowledge base. Furthermore, we believe in openness and transparency, as is evident from the free availability of a selection of our software and models. Open source works, is our firm conviction.

Deltares employs over 800 people and is based in Delft and Utrecht.

TNO is an independent research organisation whose expertise and research make an important contribution to the competitiveness of companies and organisations, to the economy and to the quality of society as a whole.

TNO’s unique position is attributable to its versatility and capacity to integrate this knowledge. Innovation with purpose is what TNO stands for.

We develop knowledge not for its own sake but for practical application. To create new products that make life more pleasant and valuable, and help companies innovate. To find creative answers to the questions posed by society.

Research takes place in three expertise areas: Technical Sciences, Defence, Safety & Security and Behavioural & Societal Sciences.
HKV CONSULTANTS is an independent company that provides consultancy services and research in water and safety.

We build our services on a profound understanding of physics, mathematics and decision-making processes. Established in 1995, we have grown to a firm with 70 experts working from offices in The Netherlands, Germany and Indonesia.

HKV CONSULTANTS earned a leading reputation in consultancy and research in flood risk management by taking the initiative in the development and implementation of many innovating concepts that found their way into Dutch risk management practice. Such developments are supported by our own extensive R&D program, through collaboration with universities and research institutes and through continuous learning and research, from internal research funds, such as in New Orleans, after Katrina, and in France, after Xynthia.

Our scope of work covers most aspects of water and safety including:
- Safety, drought and flood risk analyses for regional and urban water systems;
- Disaster management and evacuation plans;
- Research of rivers and estuarine systems;
- High-water analyses for regional water systems;
- Flood forecasting, management and control.

HKV CONSULTANTS completes over 300 projects per year in these fields. Our ability to translate successful innovative solutions and concepts in different physical and institutional settings enables us to make important contributions to foreign governments in Europe, Asia and the Americas.

Fugro is a Dutch company listed at the Amsterdam stock exchange, end May 2011 with approximately 14,000 employees in over 60 countries.

Fugro’s mission is to be the world’s leading service provider for the collection and interpretation of data relating to the earth’s surface and sub-surface and for associated services and advice in support of infrastructure development on land, along the coast and on the seabed. Fugro’s activities are carried out across the world, onshore, offshore and from the air, and are primarily aimed at the oil and gas industry, construction industry, mining sector and governments. To be able to meet their needs in the best possible way, Fugro’s organisational structure is decentralised and client-oriented, delivering a wide range of services in a variety of operating environments and conditions. Fugro achieves this mission through customer focus, the provision of high-quality innovative services, professionally specialised employees, advanced unique technologies and systems, and a worldwide and regional presence. Participation in research programs such as Flood Control 2015 contributes to Fugro’s state-of-the-art dike integrity testing and monitoring capabilities.
ARCADIS is an international company providing consultancy, design, engineering and management services in the fields of infrastructure, water, environment and buildings.

We aim to enhance mobility, sustainability and quality of life by creating balance in the built and natural environment.

With 21,000 people worldwide and € 2.4 billion in revenues, the company has an extensive international network that is supported by strong local market positions. We rank among the top 10 management and engineering consultancies in the world. In Europe, Brazil and Chile we have a top five position. In the global environmental market, we are positioned in the top three.

For ARCADIS, ‘water’ means much more than water alone. We work on developing solutions that also benefit nature, the landscape, residential and commercial areas, the environment and the climate. Enabling people to live safely in the Dutch water delta by developing and maintaining a sustainable and flexible water system: that is the major challenge facing government and enterprise today. You can rely on ARCADIS as a professional and competent partner.

Stichting (Foundation) IJkdijk is the innovative dike-monitoring organisation for inspection and testing based on sensor systems.

This development programme results in nationally and internationally marketable dike monitoring systems (smart dikes). The smart application of the monitoring philosophy leads to significant cost savings and deferred investments for water management authorities in the Netherlands and abroad.

Stichting IJkdijk anticipates that all Dutch water management authorities will start making use of the smart dikes concept and will be monitoring their dikes with innovative systems in cases where it is worth doing so.

Between 2007 and 2010 Stichting IJkdijk conducted ground-breaking experiments in dike monitoring with the aid of sensor technology. The next stage of the IJkdijk development program began at the end of 2011.
Royal HaskoningDHV is one of Europe’s leading independent project management, engineering and consultancy service providers, ranking globally in the top 10 of independently owned, non-listed companies and top 40 overall.

With its headquarters in Amersfoort, The Netherlands, the company’s 8,000 staff provide services worldwide from more than 100 offices in over 35 countries. Royal HaskoningDHV has a turnover in excess of euro 700 million.

The company carries out some 30,000 projects every year in planning and transport, infrastructure, water, maritime, aviation, industry, energy, mining and buildings. In combination with its international office network, Royal HaskoningDHV delivers world-class solutions locally to clients around the globe, for the public and private sector.

Royal HaskoningDHV, with its proud heritage of bringing leading expertise and innovation to the market, is deeply committed to business integrity and sustainable development. As leader in sustainability and innovation, Royal HaskoningDHV provides the next exciting step in working towards enhancing society together.

IBM is a global technology and innovation company headquartered in Armonk, NY. It is the largest technology and consulting employer in the world, with approximately 427,000 employees serving clients in 170 countries.

IBM offers a wide range of technology and consulting services; a broad portfolio of middleware for collaboration, predictive analytics, software development and systems management; and the world’s most advanced servers and supercomputers. Utilizing its business consulting, technology and R&D expertise, IBM helps clients become “smarter” as the planet becomes more digitally interconnected. This includes working with organizations and governments to build systems that improve traffic congestion, managing water, and the health and safety of populations.

IBM invests more than $6 billion a year in R&D, just completing its 18th year of patent leadership. IBM Research has received recognition beyond any commercial technology research organization and is home to 5 Nobel Laureates, 9 US National Medals of Technology, 5 US National Medals of Science, 6 Turing Awards, and 10 Inductees in US Inventors Hall of Fame. The company was behind the inventions of the PC; SABRE travel reservation system; UPC codes, Watson, the Jeopardy!-playing computing system, and much more.
ITC – space for global development.

One of mankind’s greatest challenges is to achieve an appropriate balance between developing natural resources and maintaining an optimal natural environment. To meet this challenge, we need detailed and reliable geo-information and geo-information management tools.

At the Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente, knowledge of geo-information management is readily available and is continually being developed and extended. By means of postgraduate education, research and project services, we contribute to capacity building in developing countries and emerging economies. In doing so, considerable attention is paid to the development and application of geographical information systems (GIS) for solving problems. Such problems can range from determining the risks of landslides, mapping forest fires, planning urban infrastructure, and implementing land administration systems, to designing a good wildlife management system or detecting environmental pollution.

The key words characterising our activities are geo-information management, worldwide and innovative. We concentrate on earth observation, the generation of spatial information, and the development of data integration methods. Furthermore, we provide tools that can support the processes of planning and decision making for sustainable development and the alleviation of poverty in developing countries and emerging economies.
Executive board
Piet Dircke (Arcadis) (chairman)
Martin van der Meer (Fugro)
Toon Segeren (Deltares)
Kees Vermeer (HKV CONSULTANTS)

Program office
Leo Voogt (Deltares) (program director)
Erdal Colakoglu (Arcadis)
Jos Maccabiani (Deltares)
Ellen Tromp (Deltares)

Programming committee
Marcel Bastiaanssen (Arcadis)
Karel Heynert (Deltares)
Leo Zwang (Fugro)
Mirjam Walbeek (RoyalHaskoningDHV)
Astrid Janssen (HKV CONSULTANTS)
Roeland Nagel (IBM)
Nico Pals (Stichting IJkdijk)
Robert Hack (ITC|Twente University)
Kees van Dongen (TNO)

Feedback committee
Jan Geluk (Waterschap Hollandse Delta) (chairman)
Roeland Allewijn (Rijkswaterstaat)
Hoite Detmar (Rijkswaterstaat)
Rob Hagman (Rijkswaterstaat)
Evelien van der Kuil (Water board Groot Salland)
Robert Slomp (Rijkswaterstaat)
Gerard van Vliet (Rijkswaterstaat)
Ludolph Wentholt (STOWA)
Illustrations

Archive Flood Control 2015
23, 29, 37, 42, 43, 44-45, 50, 53, 54, 55, 56, 57, 61, 67, 69, 71, 72, 74, 75, 77, 79, 83, 89

Gisella Klein
19

Guus Schoonewille
92-93

https://beeldbank.rws.nl, Rijkswaterstaat, Ruimte voor de Rivier / Martin van Lokven
39

https://beeldbank.rws.nl, Rijkswaterstaat / Bart van Eyck
26, 49

Istockphoto
64, 69, 74

Shutterstock
4, 12, 31, 32, 34, 35, 36, 38, 62-63, 69, 70, 73, 84-85, 86, 99
Rufous / Shutterstock.com
21
mountainpix / Shutterstock.com
10-11

Studio Nuijten
9, 17, 22, 41, 50, 57, 61, 64, 81, 84-85, 90, 100, 105

Training facilities of the Dutch Water Management Centre, Christiaan de Bruijne
79

United States Army
94

Water board Brabantse Delta
15

Water board Groot Salland
24-25, 33, 46, 59, 84-85
Credits

Editorial staff
Kees Vermeer (HKV CONSULTANTS), Judith de Bruijne (Arcadis), Karel Heynert (Deltares) and Alet Nijhof (HKV CONSULTANTS)

Text editing
Eric Burgers | Tekst & Redactie, Delft

Design
Gerda Mulder bno, Arnhem

Illustrations and image improvement
Studio Nuijten, Kekerdom

Translation Dutch-English
Charlotte Friedman | Technical Translation & Training, Emmeloord

Printing
Drukkerij Feiko Stevens, Emmeloord

Edition
1.500 copies

ISBN
9789090272474

Publisher
© November 2012, Foundation Flood Control 2015
No part of this book may be reproduced or transmitted in any form or by any means without express written permission from the publisher.

This publication has been produced with the assistance of
Sharon Cundill, Kees van Dongen, Kees de Gooijer, Robert Hack, Marten Hillen, Astrid Janssen, Bas Kolen, Jamie Lescinski, Martin van der Meer, Nico Pals, Paul Termes, CorJan Vermeulen, Hanneke Vreugdenhil, Jurjen Wagemaker and Karolina Wojciechowska

For more information, please surf to www.floodcontrol2015.com or send an email to info@floodcontrol2015.com
Safety through informed action - that is Flood Control 2015. Since 2008, a consortium of Dutch companies and knowledge institutes, in conjunction with public bodies, have been committed in a collaborated effort to raise the information supply on all levels of water and crisis management to a higher plane. This is achieved through smart use of advanced technology and by focussing on the human dimension. No matter how accurate a water level forecast or a dike strength measurement, the decisions made in the face of an imminent flood need to be based on reliable information to prevent disasters and mitigate damages.

This book provides an overview of the results of five years of research, development and application at home and abroad: dashboards for flood risks, decreased uncertainty in computer model calculations, a Dike Strength Information System, new means of crisis communications, new (training) methodologies, an information lab for higher education, a Global Flood Observatory and more.

Flood Control 2015 provides water managers, crisis teams, emergency service providers and the population with usable, practical knowledge, tools and information.