Societal need for multifunctional flood defenses

Introduction

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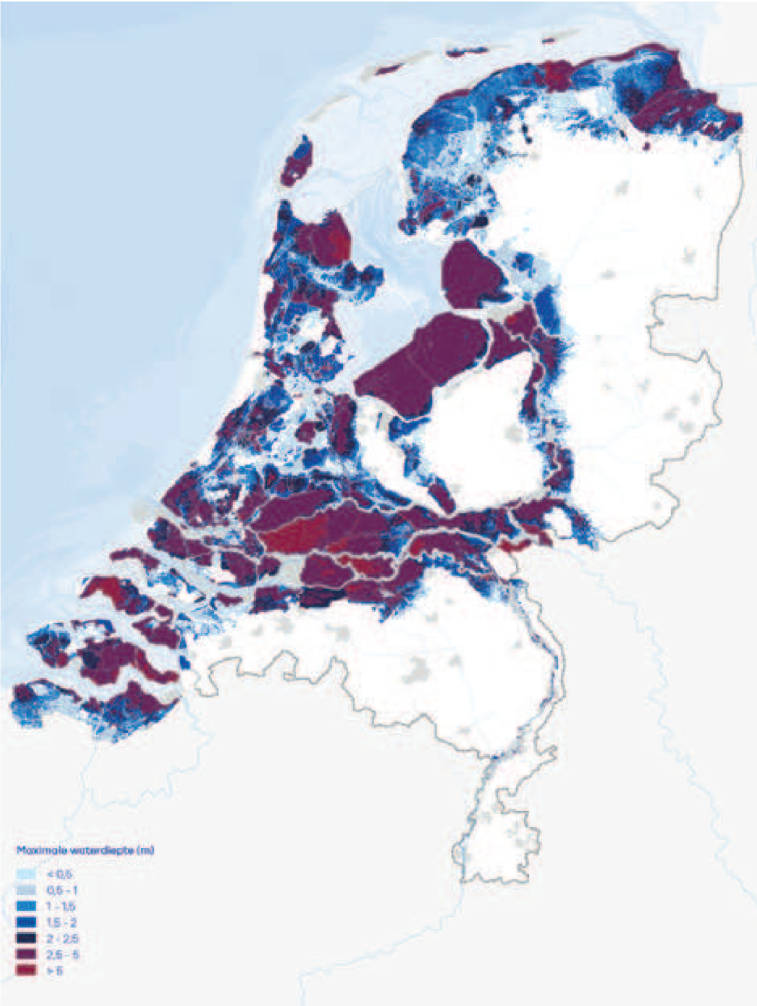


Figure 1.
Sixty percent of the Netherlands is liable to flooding from the sea, lakes and major rivers, to water depths exceeding five metres in some places.

Legend: Maximum water depth in meter. (Image courtesy: ENW, Fundamentals of Flood Protection, Utrecht, December 2016).

Matthijs Kok

SOCIETAL NEED FOR MULTIFUNCTIONAL FLOOD DEFENSES

INTRODUCTION

Prof.dr.ir. Matthijs Kok is Professor of Flood Risk at the Faculty of Civil Engineering and Geosciences at TU Delft; he was Program leader of the 'Integral and Sustainable Design of Multifunctional Flood Defenses' research program, funded by the Dutch Science and Technology Foundation STW. Presently, he is Program leader of the STW-Perspectief research program 'All RISK', which will study the implementation of new risk standards in the Dutch national flood protection program (2017-2022).

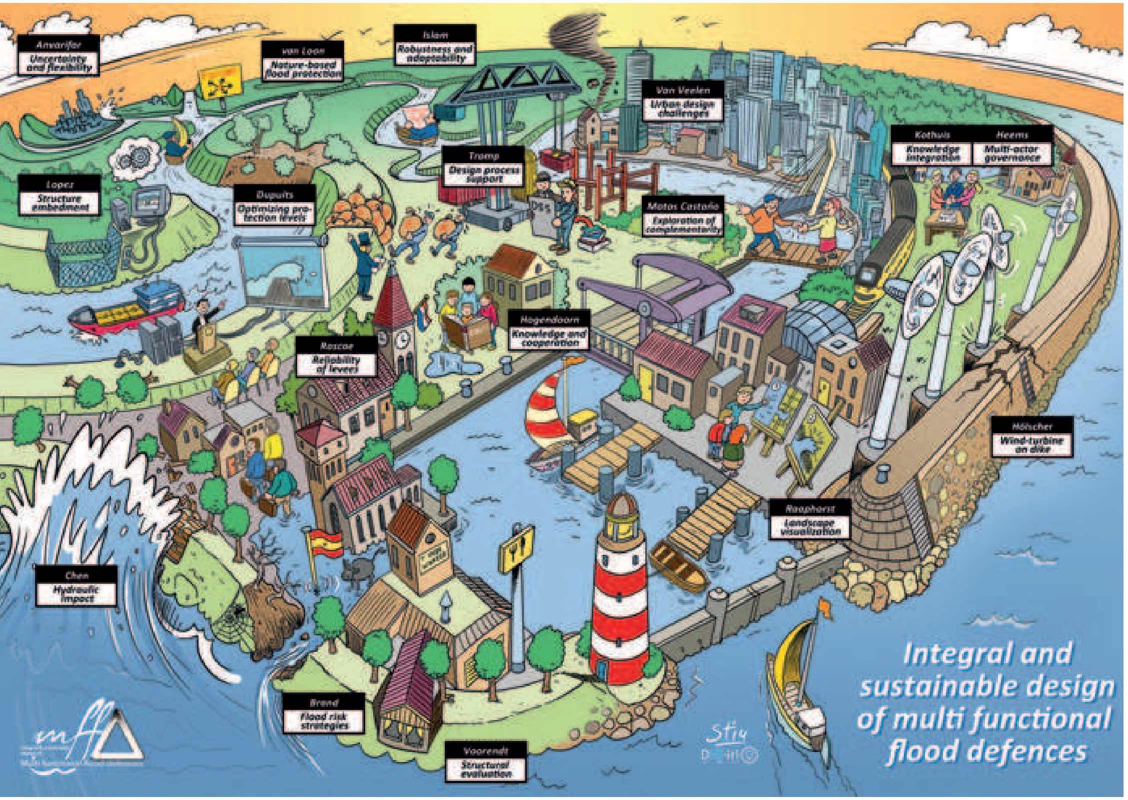
It is widely recognized that floods affect more people globally than any other type of natural hazard, causing some of the largest economic, social and humanitarian losses. Many measures are available to reduce flood risk, among them spatial planning tools, early warning systems and the construction of flood defenses. Since more and more people are expected to live in deltas in the near future, flood risks will substantially increase unless measures are taken. Flood defenses are one of the measures available in our toolkit to reduce the risk of flooding: structures intended to protect land from inundation. These can come in many types, ranging from soil structures, sheet piles to storm surge barriers. The Netherlands is a country that would not exist without flood defenses (for an overview of the protected area, see Figure 1). A common design parameter included in all these flood defenses is the failure probability of the structure, which depends on its strength and the hydraulic loads it faces. Unfortunately, the actual failure probability often differs from the design failure probability (often called the safety standard), for example due to deterioration of the structure or increasing water levels.

A multifunctional flood defense is a flood defense that also serves other purposes. This could include a variety of functions, for example pasture for grazing cattle or sheep, a walking path, a bicycle path or road on the top of the defense, a parking garage or tunnel inside the flood defense itself, pipelines near the toe or windmills on the top of the defense. Of course, multifunctional flood defenses are nothing new: they can be seen in every city with flood defenses, as well as in rural areas, where many flood defenses serve agricultural or transport functions.

On a worldwide scale, the importance of flood defenses in the toolkit to reduce the risk of flooding seems to be increasing. More attention needs to be paid to integrating these structures into the environment, and this explains why the research program 'Integral design of Multifunctional Flood Defenses' (MFFD) was started. The program aims to gain a deeper understanding of multifunctional flood defenses in order to provide a foundation for their design, assessment, and management. The ultimate goal is to substantially increase safety over current defense designs, so that the yearly failure probability might (for example) be less than 10^{-6}. Another advantage of a multifunctional flood defense is that it potentially broadens the financial basis of the project. For example, if a parking garage is combined with a flood defense, than the parking garage can help to finance the flood defense, and vice versa.

The functions of multifunctional defenses were investigated for both urban and rural areas, and on both regional and local scales. In built-up areas, these include infrastructure and development (or redevelopment) of real estate for housing, work and leisure; in rural areas, these include infrastructure, ecological values, and recreation (via landscape design). Research assessed the safety of multifunctional structures, but also the 'governance' of multifunctional flood defenses in the context of multiple users, varying administrative rules, and in some cases different legal frameworks. The flexibility and robustness of the defenses was investigated integrally, considering both economic and engineering perspectives. Case studies addressed the practical need for safe and multifunctional solutions, with the goal of facilitating the integration of disciplinary knowledge.

The research program had the following objectives:
- To gain insight into the behavior of the multifunctional flood defenses during extreme storms (e.g., extreme water levels and high waves);
- To develop and design new risk assessment methods for multifunctional flood defenses, in both urban areas (for example, constructions in or near the flood defense) and rural areas (for example, landscape design or ecological values);
- To develop new governance and asset-management principles for multifunctional flood defenses in both design and management phases;
- To integrate physical and safety knowledge into the assessment of failure probabilities of all types of flood defenses (including multifunctional ones), and optimize this knowledge economically;
- To include uncertainty (e.g., due to climate change or socio-economic developments) in the design of multifunctional flood defenses, and to develop new design principles incorporating flexibility and robustness.



The program faced a number of scientific challenges:

- Evaluating the reliability and risk of multifunctional flood defenses requires new methodologies, since the risk to a multifunctional defense is not simply the sum of the risk to the individual functions. Current approaches neglect extra functions when assessing future failure probability. For example, it is not known how a road on top of a dike influences failure mechanisms.
- The behavior of objects in soil bodies (e.g., concrete structures or pipes) is not completely understood. Modern numerical modeling tools need to be combined with experimental work (e.g., laboratory experiments to validate these models) in order to assess the structural behavior.
- Governance strategies, financial forecasting and real estate predictions need to be made under uncertain future conditions. The challenge of multifunctional flood defenses lies in the long term: flood defense managers tend to prefer mono-functional flood defenses because the reliability of multifunctional dikes has not been properly investigated, and because the time scale of the other functions can differ from the function of flood protection.
- Multifunctional flood defenses need to be integrated into urban and rural (riverine) landscapes. The flood defense is sometimes seen as an unwanted obstacle, and the challenge is to find ways to integrate protection into landscapes in an appealing manner.
- Multifunctional flood defenses need to be flexible and able to accommodate for large uncertainty in future conditions, such as changing hydrological conditions due to climate change or social and cultural factors caused by socioeconomic changes.

Case studies serve a key role in this program. The NWO domain Applied and Engineering Sciences (TTW: *Toegepaste en Technische Wetenschappen*; previously Technology Foundation STW) explicitly involves users of technology, in order to develop techniques that fit practical needs and contribute to societal demands. Applying case studies involving users has several advantages: new knowledge can immediately be tested, and users receive the knowledge in a very efficient way. The program includes two research tracks: disciplinary 'extension research themes', and 'multidisciplinary integration challenges' (see Figure 3). Extension research themes aim to extend disciplinary theories and to develop new theories and knowledge, while trans-disciplinary integration challenges (interdisciplinary research) extends knowledge to adjacent research fields.

The expertise of three universities, with seven different research groups within these universities, were combined in the MFFD program. The Delft University of Technology (TU Delft) was heavily involved, since flood defenses research in the Netherlands is concentrated there, in particular in the Faculty of Civil Engineering and Geosciences (CEG). The input of hydraulic engineering knowledge by this faculty is complemented by the wider urban design and governance perspectives of the TU Delft Faculties of Architecture and the Built Environment (A&BE) and of Technology, Policy and Management (TPM). The Environmental Sciences Group of Wageningen UR offers a combination of practical and scientific research in a multitude of disciplines related to the green world around us, and the sustainable use of our living environment: knowledge of water, nature, biodiversity, climate, landscape, forest, ecology, environment, soil, landscape and spatial planning, geo-information, remote sensing, flora and fauna, urban green, man and society. The research group at Twente University in the department of Water Engineering and Management is renowned for its research on the behavior and management of large-scale natural water systems. Combining this wide variety of complementary knowledge resulted in five years intense research and collaboration, which we have summarized in this publication for this STW program's 'end-users', all participants, and other interested parties.

Figure 2 (left page). Overview of all research topics and researchers in Multifunctional Flood Defenses program (cartoon by Stephan Timmers, TOTAL-SHOT in colaboration with all MFFD researchers).

Figure 3 (right). Structure and scientific approach of the research program featuring the importance of case studies as a base for knowledge development for integral design.