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THE DELTA PROGRAMME AND UPDATED FLOOD RISK MANAGEMENT POLICIES IN THE NETHERLANDS, PAP014368

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ABSTRACT: The Delta Programme develops strategies that are aimed at protecting the Netherlands against flooding, while anticipating climate change. The programme was launched in 2010 and it is aimed at avoiding a disastrous flood, rather than responding to it after the event. This requires a multi-governmental approach, strategies dealing with uncertainty and adequate institutional arrangements to guarantee future flood-proof implementation.

The Delta Programme will result in updated standards for flood protection, a policy framework regarding flood-proof urban (re)development and efforts to improve disaster management. The programme will include the necessary measures for the short term (maintenance and improvement of flood defences and an “aging infrastructure”), framing these measures into the long-term perspective of socio-economic developments and climate change. The multifunctional design of these measures has been stimulated, since this increases societal “added value” (regarding nature, recreation or urban development) and enhances their acceptance.

Within the Delta Programme one of the largest challenges is dealing with uncertainties about the future climate, population, economy and society. The Delta Programme tries to tackle uncertainty by an adaptive way of planning i.e. maximizing flexibility, keeping options open and avoiding “lock in”.

The Delta Commissioner directs this multi-governmental process of policy development and implementation, monitors progress, reports to Parliament every year in September and takes the necessary steps when problems arise. From 2020 onwards, a Delta Fund of about 1 billion euros per year will provide stability in financial resources, reducing dependency on economic developments and securing continuous political attention. The new Delta Act forms the legal basis for the implementation of the programme, the responsibilities of the Commissioner and the Delta Fund.

Key Words: flood risk management, climate change, the Netherlands

1. INTRODUCTION

The Netherlands is situated by the North Sea, in the delta of the rivers Rhine, Meuse, Scheldt and Ems. Living in this delta has large benefits. At the end of the river Rhine, the Rotterdam harbour is an important gateway to the north west Europe hinterland. In addition, the rivers Rhine and Meuse guarantee a stable fresh water supply, which is one of the prerequisites of a flourishing agricultural sector. In 2014 about 17 million inhabitants produce a GDP of about 600 billion euro’s, making the Netherlands the 18th economy worldwide (IMF, 2013).

But deltas are also hazardous environments. 60% of the Netherlands’ land surface of 34,000 km^2 is prone to floods from the North Sea, rivers or the lakes. To defend their land against flooding, the inhabitants, about 1000 years ago, started to cooperate in so-called water boards, democratic organisations only responsible for water management and flood protection. These organisations are funded by taxes paid by the inhabitants and land owners who benefit from this protection. In this way a long tradition developed to live with (and sometimes battle against) the floods, resulting in a comprehensive system of flood protection measures such as dikes, storm surge barriers, and strengthening of beaches. In the mid-nineties, after threatening river floods, this “toolbox” was extended to include “room for the river” measures, such as floodplain excavation, side channels, bypasses and backward dike realignments. These measures are necessary to handle increasing river discharges. The last major flood in the Netherlands occurred on 1 February 1953. Poorly maintained flood defences in the south western part of the coastal area could not withstand an extreme storm surge on the North Sea. A devastating flood covered 1700 km^2, 1853 people drowned and the damage was approximately EUR 0.7 billion (about 10% of the GDP at that time). To prevent such a disaster from happening again, the Dutch government launched a comprehensive programme to improve flood protection. This approach was aimed at reducing the length of the coastline by building dams and storm surge barriers. In addition, flood protection standards were established, based on a cost benefit analysis, expressed as exceedance frequency of the design flood level: 1/10,000 for the coastal area in the central part of the Netherlands, in which the capital Amsterdam, the government seat The Hague and the harbours of Rotterdam are situated. This is among the highest levels of protection worldwide.

In 1995 the Flood Protection Act (Water Act since 2009) provided a legal basis for these flood protection standards and also introduced a six-year assessment of the flood defences by the water boards. If this assessment reveals that these legal standards are not met, the water board has to take measures to improve its defences to comply with the standards. The results of the assessment and the related improvement plans are reported to Parliament.

Presently, flood protection is delivered by a system of 3700 km primary flood defences, (dikes, dunes, sea walls, dams and storm surge barriers) which prevent [] flooding from the North Sea and major rivers and lakes. In addition, a system of 14,000 km of secondary dikes prevents flooding due to the regional water systems. Expenditure for maintenance and improvement of the flood defences accounts for about EUR 940 million per year (OECD, 2014).

The main objective of the Dutch government is to maintain The Netherlands as a safe and attractive place to live for present and future generations. This requires dealing at least with a measurable rise in sea level of about 2 mm/y, and already existing saline seepage of brackish groundwater, salt intrusion in the estuaries and land subsidence (on average 1 mm/y, with a maximum of about 5 mm/y). Climate change and socio-economic developments might aggravate these water challenges, but are uncertain in rate and extent (Figure 1).

2. DELTA PROGRAMME

Against this background, and as a follow up to the so-called Delta Committee's advice (Delta Committee, 2008), in 2010 the Delta Programme was set up (see also www.deltacommissaris.nl, Van Alphen, 2013). The main objective of the Delta Programme is to create a safe and attractive Netherlands, now and in the future, by providing adequate flood risk management and fresh water supply. The Delta Programme is a national programme, in which national, regional and local authorities prepare key decisions, develop strategies and implement measures, in close cooperation with the public, stakeholders and knowledge institutions.

National and regional sub-programmes are directed by the Ministry of Infrastructure and Environment (I&E) or the Ministry of Economic Affairs (EA). Activities in a sub-programme are organized in project teams, in which national, regional and local authorities are represented. Every project team is supervised by a regional Administrative Steering Committee (ASC). The Delta Programme Commissioner, an independent high-level government official, supervises this process regarding progress, uniformity and consistency. Important, supra-regional decisions are discussed in the National Administrative Steering Committee, which is chaired by the Delta Programme Commissioner. He prepares an annual report to Parliament, which is presented to Parliament by the Minister of Infrastructure and Environment, who bears political responsibility for the Delta Programme. Stakeholders are involved in the process at project level, by representation in the National Administrative Steering Committee, and by contacts with Parliament.

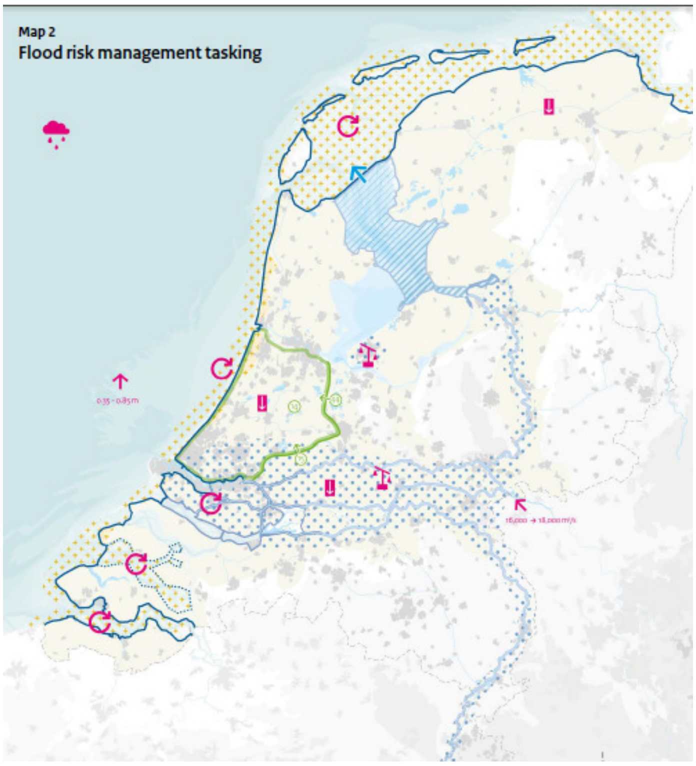

Figure 1: Flood risk management challenges in the Netherlands in the 21st century: sea level rise, sediment deficit in tidal areas (yellow dots, circular arrow), increase of extreme river discharge, subsidence (downward arrow) and growth of damage potential (blue dots) (Ministry of Infrastructure and the Environment, 2013).

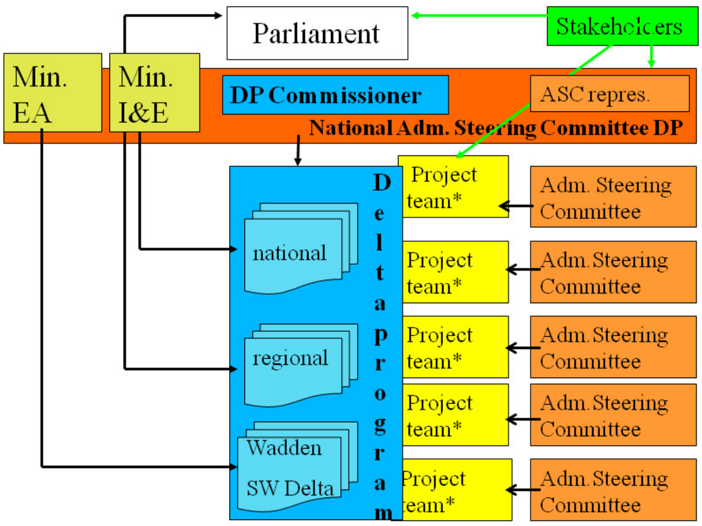

Figure 2: Multi-governance organizational structure of the Delta Programme:

The implementation of the measures proposed in the Delta Programme is essential for the future of the Netherlands. Since 2013, a **Delta Fund** of about EUR 1 billion per year will provide stability in financial resources, reducing dependency on economic developments and changing political priorities. Since January 2012 the **Delta Act** has formed the legal basis for the implementation of the programme, the Delta Commissioner and the Delta Fund.

In 2014, after 4 years of analyses and strategy development**, five key decisions** will be presented to Parliament:

- 3 national policy frameworks: on flood risk management; fresh water supply; water-proof and climate-proof reconstruction and new developments of the build environment.

- 2 overall strategies for areas where flood risk and fresh water supply interact: the transitional areas between the rivers and the North Sea: Lake IJssel and the Rhine-Meuse estuary. Measures in these 2 areas affect the surrounding regions or impose boundary conditions on upstream regions.

These key decisions form a framework for **regional strategies** regarding 6 specific hydraulic regions in the Netherlands: the Coastal Area, The Wadden Sea valuable tidal area and adjacent land, the southwestern estuaries, the Rotterdam-Dordrecht tidal rivers (see Kind et al, 2014), and the upper stretches of the river Meuse and Rhine-branches (within the Netherlands territory) (Schielen and v.d. Aarsen, 2014).

These key decisions and regional strategies have been developed with a long term perspective, i.e. a time horizon up to 2100. This long term perspective stimulates the combination of investment agendas of different policy fields or authorities. In addition, it helps to anticipate on climate change gradually by making future-proof decisions on nearby capital investments in infrastructure, flood defences and the built environment. On the other hand, this long term perspective introduces uncertainty about the future conditions for which these measures have to be designed.

To tackle this uncertainty, four so-called **Delta Scenarios** present the “corner flags of the playing field of plausible futures”. Each scenario describes a plausible future in which climate change (rapid or moderate) and socio-economic development (growth or decline) are combined (Figure 3). The climate change parameters are downscaled from the IPCC AR5 and elaborated for the Netherlands (KNMI, 2014). Socio-economic parameters describe the future size and spatial distribution of population and land use, and constitute basic data for flood risk potential and fresh water demand. The Delta Scenarios are used to determine the water related challenges in 2050 and 2100 and establish when present policies become insufficient. In addition, the scenarios act as an inspiration for strategy development, and present a framework for checking the performance of the strategies under different future conditions.

Like most deltas, the Dutch water system consists of an interconnected system of rivers, lakes, estuaries, coastal area, regional waters and ground water systems. Measures in one part of the Delta may impact other areas or water users. The **Delta Model** is a comprehensive set of 1D and 2D hydrological models that enables supra-regional analyses of water related issues, like prevention of extreme flood levels, salt intrusion or finding a regional balance between fresh water demand and supply (Slomp et al, 2014).

Strategies consist of an objective, set of measures and a timetable. Regarding this timetable, adaptation to climate change starts with future-proof close decisions regarding the development of infrastructure and urban areas, since these decisions involve large investments and will determine future land use (and water challenges) for many decades. With the end of technical lifetime of many post-war constructions approaching in the coming decades, reconstruction of aging infrastructure becomes an important driver for adaptation. The Delta Programme tries to frame these short term investment agendas within a future perspective, seeking an optimum between “too much too early” and “too little too late”. Adaptation paths identify where a change of strategy is still possible, and how to avoid “lock in”. (See Haasnoot, 2013)

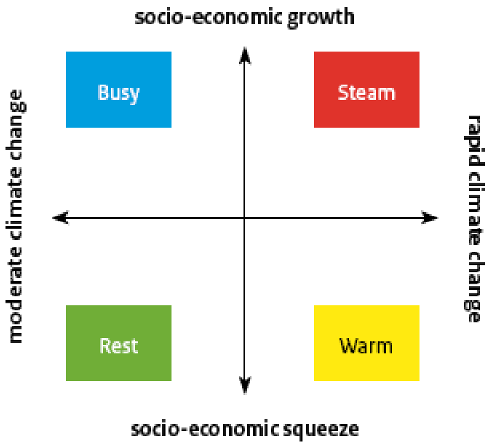

Figure 3: Four Delta scenarios, combining rapid or moderate climate change with socio-economic growth or decline, as plausible futures for adaptive strategies. Climate change is specified by sea level rise, precipitation, evaporation and extreme river discharge (according to IPCC 2014), socio-economic developments are characterized by population size, land use, risk potential, fresh water demand (from Slomp et al, 2014).

Measures in adaptive strategies should be flexible, i.e. easy to alter, speed up or slow down depending on measured climate change. Measures that are based on natural processes are more flexible than fixed or concrete structures. Examples of these so called "building with nature" measures include beach nourishments, create natural shallows, or vegetation in front of flood defences to reduce wave- and current-induced erosion (see Ecoshape, 2014).

Acceptance of these measures (and cost reduction) can be achieved by combining water related measures with other policy objectives, such as urban, recreational or nature development. This **multifunctional approach** results in more added value for society but requires the fine tuning of different investments agendas, trust in each other's commitment and new technical requirements regarding the design and maintenance of flood defences. Promising results have been achieved in flood protection works in combination with urban development (see Figure 4)

Figure 4a: Bypass Veur Lent (Nijmegen) accommodating 600 m^3/s during extreme flood conditions (centre), in combination with an urban development project "Waalsprong", consisting of 12,000 houses (right)

Figure 4b: Enforcement of the Katwijk coastal defence and dunes, in combination with the construction of an underground car park

3. THE NEW INTEGRATED FLOOD RISK MANAGEMENT APPROACH, THE BASIC CONCEPTS

Up till now, Dutch flood protection policy was based on a semi-quantitative risk approach. After the disastrous coastal flooding in 1953, flood defences were designed and maintained on an exceedance frequency of extreme flood levels. This frequency was obtained for Central Holland from a cost-benefit analysis on flood defence improvement investments vs. avoided damage and was translated to other regions. It was assumed that failure results from overtopping and that a flood covers the entire dike ring. Based on this approach a flood protection system of dikes, dams and dunes was realized up to a design frequency of 1/10,000 for the coastal area and 1/1250 for the rivers.

Despite this high level of protection, a small probability of flooding always remains, the so-called residual risk. Flooding in Central Europe in 2002 and in New Orleans in 2005 illustrated the large scale of damage and disruption of modern society when flooding does occur. The European Floods Directive (EU, 2007) prescribed all European countries to develop flood policies based on this risk-based approach. Also Dutch policy started to change to a real **risk-based approach**, explicitly including the consequences of flooding in policies and preparing measures to reduce these consequences by spatial planning, building codes and disaster management (Figure 5). Nevertheless, protection against flooding, by dikes, sea walls and storm surge barriers, is still the cornerstone of Dutch flood risk management, simply because the consequences of a flood are so great that a flood should be prevented from happening at any cost (Ministry of Transport, Public Works and Water Management, 2009).

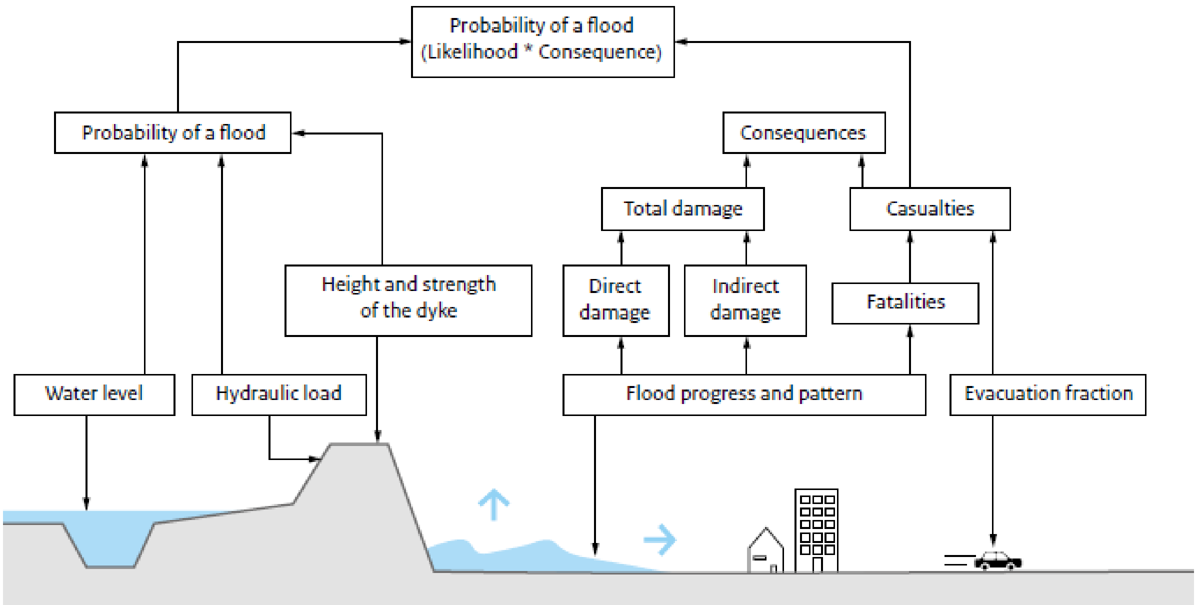

Figure 5: Elements of the Netherlands' integrated flood risk management approach: Risk as a result of flood probability (determined by hydraulic load and defence strength/height) and flood consequences (damage and casualties, determined by flood characteristics, buildings and evacuation success)

The new risk-based approach involves a fundamental change in the type and level of flood protection standards. New knowledge on failure mechanisms of flood defences, inundation patterns, damage and casualty functions and powerful computer simulations enabled analyses with detailed information on the probability and consequences of floods. It became clear that dike failures not only originate from overtopping (the basic assumption behind standards expressed as “exceedance frequency”), but may also be triggered by “piping”, a mechanism induced by the head between flood water outside the dike and the flood-free polder behind, that results in ground water (and finally sediment) transport under the dike that weakens its foundation. Flood simulations showed that floods from a breach do not always behave like a bath tub, but may leave some areas flood-free or affect adjacent dike rings (“cascade effect”).

Analyses on preventive evacuations showed that in central Holland there is not enough time to evacuate the millions of inhabitants before a threatening storm surge. In addition modern societies are vulnerable to disruption and do not accept fatalities due to floods.

As a result of these new knowledge and perceptions, new flood protection standards have been developed, that are expressed as **flood probability** (instead of the former exceedance) frequencies. These standards are derived for the year 2050, including climate change (sea level rise and increase in extreme river floods) and expected population and land use developments (Van der Most et al, 2014). So there are 35 years to go to implement measures to meet these new standards.

Another new element in this approach is that the level of protection (the new design probability) is based on the principle that every inhabitant should have a probability of drowning due to a flood (**Tolerable/ Local Individual Risk,** LIR) of no more than 10^{-5} per year. The probability of drowning is a result of dike failure probability, assumed evacuation rate (see below), flood pattern (progress and depth), and the fatality function of those who remain. When the latter three are known, the required level of flood protection (design probability of the flood defence) can be derived.

Even with this level of LIR-based protection, urbanized areas may experience large damage or disruption, due to the large number of inhabitants involved, and assets that are present. Therefore these areas receive a higher protection level. This increased protection level is based on a **cost-benefit analysis** on improvement costs vs avoided damage (see Kind, 2013) and an analysis into the effects of increased protection on the reduction of large numbers of fatalities (**Group Risk) (D**e Bruijn et al, 2014).

The figures resulting from these analyses were discussed with local authorities and experts. From these discussions it became clear that some alterations were necessary, due to e.g. important vital infrastructure (nuclear power plant, natural gas production and storage), the effect of secondary defences on the flood pattern, assumed evacuation rates (see below). The resulting level of protection varies between 1/100 – 1/100,000 (Figure 6). The extremely high level of protection (1/100,000) can be achieved by a breach-proof “delta dike”: a dike that is so high, wide or strong that it might be overtopped, without uncontrollable breaching.

The new protection standards are realized by **measures** that improve the flood defences, such as dikes, dunes, sea walls and storm surge barriers to withstand extreme flood conditions. These measures are combined with so-called “Room for the River” measures: floodplain and side channel excavations, backward dike realignment and flood retention that reduce extreme flood levels. The flood probability approach enables prioritizing these measures regarding their cost-effectiveness in risk reduction (see Kind et al, 2014).

It is estimated that the measures that are required to meet the new standards (including climate change and subsidence) may cost EUR 11-14.4 billion when executed as dike reinforcements. When combined with “Room for the River” measures the investment costs rise by about EUR 4 billion. However, these types of measures often create additional value, such as valuable habitats or recreational areas. The extra costs of these measures have to be met by the local or regional authorities who benefit. As a result of these protective measures it is estimated that the LIR improves significantly: compared with the present situation, areas where LIR is larger than 10^{-4} will disappear. In addition, the economic damage will be reduced by a factor of 20, whereas the probability of 1000 fatalities due to a flood will be reduced by a factor 45 (Ministry of Infrastructure and Environment, 2014) (see Fig. 7).

In time, the different types of measures can be phased: up till 2050 the effects of climate change are expected to be rather limited, along the main rivers elimination of “piping” is the most urgent challenge. Design and execution of the necessary measures can be performed in such a way that the result meets new standards as well. Then, from 2050 on, increasing extreme discharges can be tackled by a new generation of “Room for the River” measures. Spatial reservations (with permits for temporary land use) should be made to guarantee the implementation of future bypasses, dike realignments and flood storage areas.

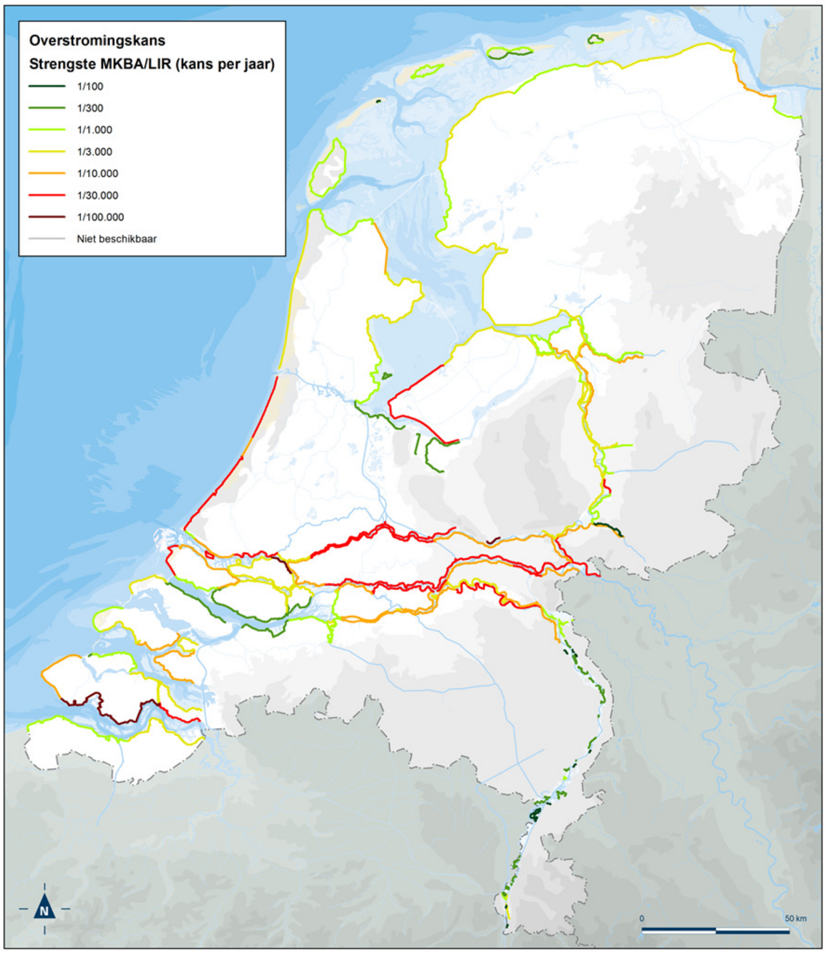

Figure 6: Proposed flood protection levels, expressed as flood probability per year for flood defence sections (Van der Most, et al 2014).

Despite this significant effort in (and result of) protective measures, there will always remain a small probability of flooding, e.g. during extreme situations that exceed the design conditions. Additional policies have been developed on flood-proof land use planning and disaster management, to reduce damage, disruption and fatalities under these conditions.

Land use planning is the responsibility of local and regional authorities. The national Ministry of Infrastructure and the Environment supports them with knowledge, instruments and policy frameworks. Within the Delta Programme national, regional and local authorities have agreed upon a comprehensive policy in order to stabilize (and if possible reduce) the risk potential of assets in flood-prone areas. It involves a stepwise approach for decision making on new developments: 1) assess flood risk 2) formulate a common vision and explore different flood- or water-proof options 3) implementation of agreed measures.

This approach receives a legal basis in the so-called "*watertoets*" (water assessment), in which the water authorities have a kind of "watchdog" responsibility. Special attention is paid to infrastructure and services that are of vital importance for society: power supply (electricity, gas), communications, drinking water, hospitals. Agreements have been signed between the main authorities and private companies, so that flood-proofing has been included in new investment plans from 2020 onwards, and that these vital infrastructure and services are flood-proof by 2050.

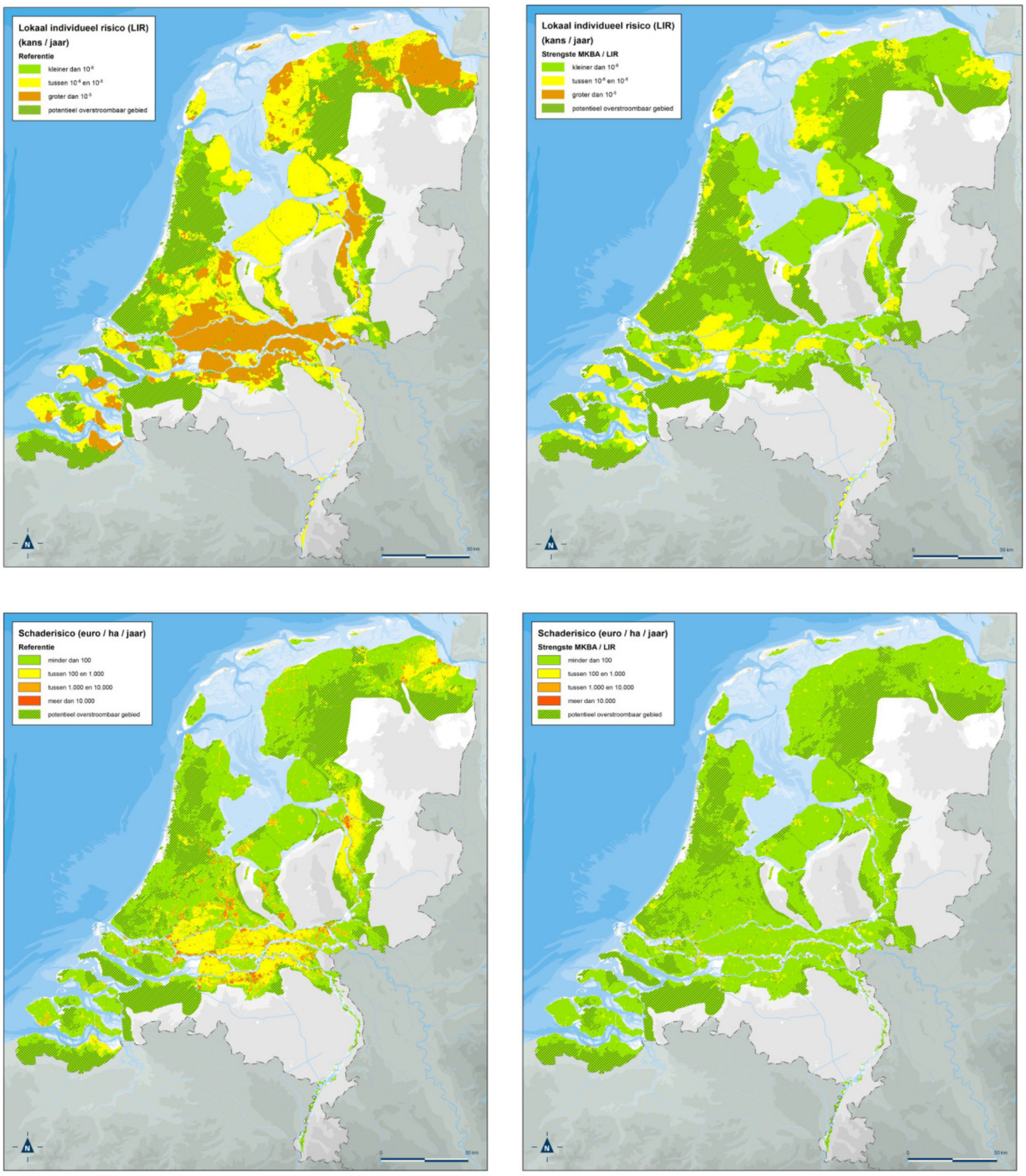

Figure 7: Flood risk reduction effects of the new flood protection standards: a/b regarding LIR, c/d regarding economic damage (EUR/ha/yr)

Adequate **disaster management** can reduce fatalities, especially by preventive evacuation of inhabitants before a flood occurs. This requires timely warnings, inhabitants knowing what to do/where to go, enough infrastructure and transportation capacity, adequate traffic management and overall command. Regional differences exist in warning time (1-2 days for a storm surge, up to 4 days for river floods), and population figures in relation to the infrastructure capacity. Taking these differences into account, regional expected evacuation rates were assumed, ranging from 15% (central Holland Coast) to 90% (small dike rings in the river Meuse valley). These figures were derived after consultation of the regional authorities who are responsible for disaster management. In addition, the Ministry of Security and Justice (responsible for disaster management policy and frameworks) will make safety region specific agreements to improve disaster management planning and response, especially on the supra-regional scale. Progress will be monitored, in parallel to the six-year evaluation of the flood defences.

In some locations dike improvement might be very costly or have large social impacts, e.g. when there is abundant cultural heritage along the dike. When land use measures and/or disaster management seem promising for reducing the damage or fatality potential, an inventory may be conducted to establish whether these alternative measures reduce the flood consequences to such a degree that dike improvement is no longer necessary. A cost effectiveness analysis can be performed with the Integrated flood risk management tool (see Kind et al, 2014) When this idea is proven, and the effectiveness of the alternative measures is guaranteed (e.g. by an administrative agreement), additional funding is available from the now smaller scoped dike improvement project. These kinds of "**smart combinations**" (integrated flood risk solutions) are investigated for e.g. the city of Dordrecht (Hoss, 2010)

4. CONCLUSIONS

Flood risk management of delta areas is a never ending effort. Large-scale capital investments require a long-term perspective, to make future-proof decisions, taking into account climate change and socio-economic developments. The development of adaptive strategies and the implementation of flexible measures should be guaranteed by adequate institutional arrangements in governance, leadership and finance. The Dutch Delta Programme combines this long term perspective and institutional arrangements. Within this programme, a new flood risk management approach will be implemented during the decades ahead. New flood risk management standards will be achieved by a combination of measures to improve the flood defences and to increase the river discharge capacity ("Room for the River"). In addition, the consequences of flooding will be reduced by improving disaster management, protection of vital services and stimulation of flood-proof urban developments. In this way, the Dutch government aims to maintain the Netherlands in this century as a safe and attractive place to live.

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