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Water Robust Building

A three step approach for the Netherlands linking planning, design, construction and exploitation

Reportnumber: KvR 016/2010

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Executive summary

In the future The Netherlands will continue to urbanise, resulting in a higher economic and societal value of the urban area. This will result in an increased vulnerability of the urban area to extreme weather conditions. Drought, heat and flooding can have a major impact on the economy, environment and public health.
Due to climate change, an increase in extreme weather conditions is to be expected. So, if climate change is ignored, The Netherlands can expect an increase in damage due to extreme weather conditions. To prevent damage, now and in the future, adaptation measures are to be taken. This requires changes in spatial planning, urban design, in construction and in maintenance practice.
The results of the definition study Water Robust Building offer a methodology and an extensive overview of measures to make the urban area water robust. The methodology aims to embed water robust building in the process of increasing urbanisation. Moreover, it offers all involved stakeholders, for example policy makers, urban developers and property owners, the opportunity to reduce risks. Water Robust Building also offers the possibility to introduce a response to climate change in sustainable spatial planning.
Water robust building is a methodology which is recognized in The Netherlands as an effective way to ensure our urban environment is able to cope with climate change.

Creating water robust urban environments in The Netherlands: a three step approach linking planning, design, construction and exploitation

Climate change will likely have major implications for the design of cities, buildings and for the residents. This paper details the work of a project in The Netherlands for developing an approach for water and climate robust building. The first objective of this project was to increase the awareness of climate change of stakeholders engaged in urban planning, design, building and maintenance and to increase their receptivity to respond.

Another objective was to promote water robust expansion and redevelopment of urban areas through integrated planning and action at local level to that end. A three step approach has been developed. The three steps are (1) a vulnerability analysis, (2) selection of a strategy to improve the protection level and (3) selection of an appropriate set of measures. The three-step approach deliberately gives much freedom to the parties involved in a specific urban area. As local conditions to a large extent determine what can be done, it is up to the stakeholders to select a vulnerability reduction strategy. This strategy helps us to make a selection of over 180 measures to make an area even more water robust. An appropriate set of measures provides a level of robustness that is acceptable for all stakeholders. Acceptable also means financially acceptable, both on the investment side and on the maintenance side.

Creating a water robust urban environment is not a single moment effort. Specific and continuous attention is required to involve all the people from different organizations, often including

the residents of an urban area. The threestep approach is to be applied three times during an urban development or rehabilitation project; (1) during the planning phase, (2) the development and design phase and (3) at the transfer to the operation and maintenance phase.

The final product and the results of this project are published in the book ‘Waterrobuust bouwen, de kracht van duurzaamheid in een kwetsbaar ontwerp’. This book is available in Dutch only.

The results of the project are summarized in English and shown in the following publication.

1. Introduction

The urban population is expected to double from 2 billion to 4 billion in the next 30 to 35 years (United Nations, 2004). For the first time in history, the proportion of people living in cities is equal to the rural population (UNFPA, 2007). The percentage of population living in cities is expected to increase further to 60% in 2030. More than 200,000 people move to cities every day (UNFPA, 2007). Urbanisation predominantly takes place in coastal and river plains, areas that are exposed to flooding risks. In 2003, 23% of the world population lived within 100 kilometres of the coast (Small and Nichols, 2003). In 2030, this percentage is expected to increase up to 50% (Adger et al., 2005).

This continuing urban expansion amplifies the influence of the city on the local climate. The well-known urban heat island (Oke, 1982) does not only cause a raise in local temperature, but also induces more drought stress, more severe rainstorms, it boosts cloud cover and reduces radiation (Salcedo Rahola et al., 2008). Pluvial flooding risk increases. Wind speed at ground level is reduced. Urban vegetation is often sensitive to drought stress, due to the limited capacity of most urban soils to retain water. And dry and dead vegetation has negative effects on urban wildlife. This drought sensitivity also brings another, often underestimated risk to the urban fringe. Forest fires destroyed numerous houses lushly located in semi forested areas at the cities boundaries (Burns et al., *in press*). Numerous examples reveal that these effects individually or acting together can disrupt critical urban functions and threaten our quality of life.
Climate change aggravates all these risks. In most parts of the world more extreme weather conditions are expected to occur

more frequently, thus increasing the risk for damage to residents, economy, ecology and cultural heritage (World Bank / ISDR, 2008; Colette, 2007). Climate change will in many cities result in more extreme flooding (Kron, 2005), more severe droughts and more frequent and more extreme heat – bringing extra water demand. And these natural hazards are expected to be more devastating than in former times, when societies developed slower and in a more robust way (Rosegrant et al., 2002). E.g. public health is threatened directly. The risk of flooding is often aggravated in urban areas in delta regions by sea level rise, by increased river discharges and by land subsidence. Land subsidence is stimulated by groundwater abstractions – abstractions to avoid adverse effects of droughts. Droughts can therefore seriously aggravate the land subsidence problem and, as a result, flooding risk. Infrastructure, public space and private gardens are sensitive to extreme weather damage. Drought can be as detrimental as flooding. That is why we have to investigate options to reduce the vulnerability of a city to the extreme effects of climate change. We have to increase the cities robustness – we prefer to use robustness as resilience implies a 100 % recovery to the status before the event, which is hardly ever desirable. The city and its inhabitants should be made capable to deal with an extreme weather shock in a better way.

In the past decade, much research has been conducted on flood resilient repair and on flood proofing existing and new individual properties such as residential buildings (Crichton, 2006; Garvin and, Kelly, 2007; Kelman, 2004, Bowker et al., 2007). However to date there is relatively few research devoted to the protection of the urban fabric, as a complex integrated urban system at neighborhood or at city level, against flooding, drought and heat.

This paper introduces an approach for water robust and heat robust building. The approach aims to reduce the public health risks, economic and ecological risks that are caused by ongoing urbanization and climate change. Water robust building is defined as “a way to plan, design, build and maintain our living and working environment to make it better capable to cope with the changing water stresses due to climate change and other factors”. Water stresses include flooding, drought and extreme water demand of cities due to heat stress (Van de Ven et al., 2008). Heat robust building is defined as “urban development in a way that the city is better capable to cope with extremely high temperatures, both outdoors and indoors, without boosting artificial, external energy- dependent climate conditioning systems. In the remainder of this article we will focus attention on how to make an urban area more water robust.

2. Review of available responses

A detailed literature review was carried out to identify response options to improve water robustness of single properties, streets and/or subdivisions. A wide range of possible measures - more than 180 in number - have been identified (Van de Ven et al., 2008). A brief selection of these measures is listed in Table 3. It is common to distinguish structural (hard) measures as interventions involving the physical construction of a system for urban water management from non-structural (soft) measures. Here the definition of non-structural measures has been adapted from the original Australian definition (Taylor and Wong, 2002): "Non-structural measures are responses to urban water problems that may not involve fixed or permanent facilities and their positive contribution to risk reduction is most likely through a process of influencing behaviour, usually through building capacity in all stakeholders through active learning and appropriate and effective engagement between stakeholders."

As numerous measures exist to strengthen the water robustness of an urban area, the real challenge is the selection of an appropriate set of measures. The measures should fit local conditions, expected future conditions and the demands of all stakeholders, including the residents, for greenfield developments, brownfield developments and retrofit. The question is which response is to be considered robust enough and who is going to pay for what? A strategy is required to structure the negotiation process that will lead to the selection and realization of an appropriate set of measures. Such a strategy has been developed in this project: A three step approach to water robust building.

3. *The problem of selecting*

Numerous structural and non-structural measures can be taken to strengthen the water robustness, at different spatial scales, ranging from single properties to the whole cities. And numerous parties are involved. Selection of an appropriate set of measures is evidently a multi-stakeholder problem, with sometimes even conflicting objectives of the various stakeholders. This makes water robust building a complex problem, and it is therefore necessary to consider methods capable of solving such problems (Geldof, 2002). According to governance theory, see Table 1, we have to deal with a semi-structured, political problem or even an unstructured wicked problem rather than with a structured or scientific problem. The way to find a solution is not so much a matter of optimization, in an attempt to find the “best” solution. It is more a negotiation problem for the stakeholders, attempting to find a solution acceptable to all parties. In this both the viewpoints of techniques and acceptable rest-risk, as well as from the viewpoint of costs (investments and maintenance) and benefits are relevant. Van Woerkum (2000, p.118) uses the term ‘integrative negotiations’ to describe the process to come to ‘negotiated knowledge’ and to a shared vision on a set of measures that is considered an appropriate response. And if there is also uncertainty on the means to be used, we have to deal with a collaborative design problem. Such a negotiation and design problem requires a process approach to achieve agreement on the set of response measures (De Bruijn, 2002)

Table1. Differences in stakeholders views on objectives and acquaintancy with the means lead to different types of problems and different ways to solutions (adapted from Tuden and Thomson, 1964; Van Slobbe, 2002; Christensen, 1985; Hoppe, 1989, and Geldof, 2002)

Means and available measures	Problems & Objectives: **Known and agreement about**	**Unknown and/or no agreement about**
known	Optimisation Programming ‘structured problem’	Negotiation Mediation ‘political problem’
not known	Innovation Experimenting, Testing ‘scientific problem’	Design Free research ‘unstructured or wicked problem’

Another reason to consider water robust building a negotiation and design problem is the fact that measures can be counterproductive. Improved drainage to avoid flooding could increase the risk of drought. Heat control requires water for evaporation, which could aggravate a problem of water shortage. Creating moulds to build houses on could increase land subsidence. Choices in counterproductive measures can only be made by negotiating pro’s and con’s of the whole set of measures with the stakeholders. To enable this negotiation and design process, (1) local knowledge about the physical circumstances, infrastructure and urban functions is to be available to all parties and, (2) a clear structure for the negotiations is to be available. To that end a three step approach was developed.

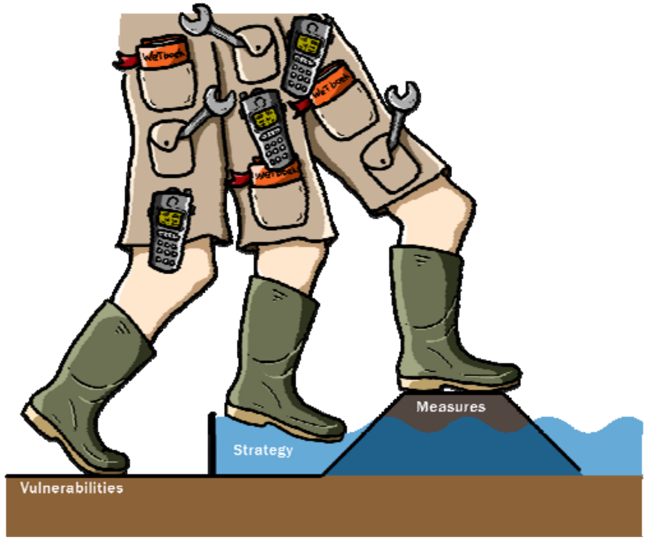

Figure 1: Three step approach

4. Three step approach

Three steps structure the negotiation and design process that stakeholders have to go through. With the three step approach the stakeholder are able to select an appropriate set of measures to make a specific urban area more water robust. These three steps are outlined in Figure 1.

- Step 1: Vulnerability analysis. A quantitative assessment of the effects and consequences of climate change and of ongoing urbanization on the local system. This local system is analysed with help of the Layers Approach.

- Step 2: Decide on a comprehensive strategy to deal with the adverse effects and consequences assessed in Step 1. This strategy is based on the theory of the Vulnerability Framework.
- Step 3: Selecting an appropriate set of measures from a catalogue of measures, using the results of Step 1 and Step 2. With help of the instruments and insights developed in Step 1 the effect of this set of measures can be assessed. And if the effect is considered insufficient a new set of measures is to be drafted.

Although it is technically possible to reiterate the three step approach a full reprise is not recommended because of the strategic choice made in Step 2. This choice is based on fundamental considerations and it is hard to renegotiate these. Most common will be a long and difficult dialogue in Step 3 on the appropriate set of measures and on the funding.

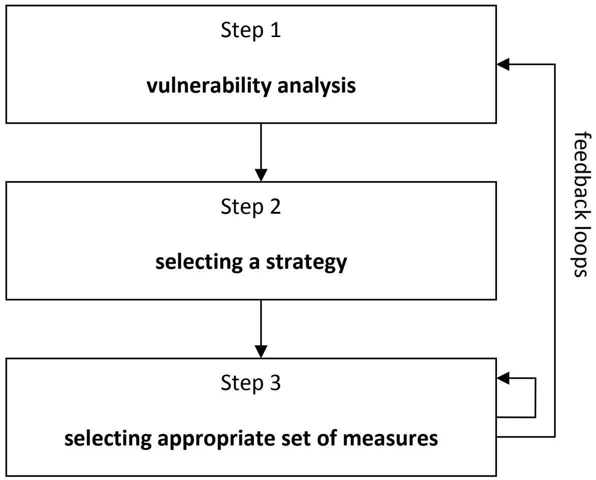

Figure 2: Schematic presentation of the Three Step approach. Each step is elaborated in more detail subsequently.

1. Vulnerability analysis

The objective of Step 1 is to gain detailed understanding of the effects and consequences of climate change and of the ongoing urbanization on the study area and it surroundings by applying a systems analysis to the urban system. The result is used to quantify the vulnerability of the study area.

For this systems analysis we make use of the Layers Approach. According to the Layers Approach the urban system is considered to be composed of three interactive layers: substratum, networks and occupation patterns. It assumes that the characteristics of the substratum impose physical conditions for infrastructure networks and that these infrastructure networks then condition the occupation patterns, including the locations for housing, business activities and related services. These more or less hierarchical relationships are supposed to produce clear physical boundary conditions. The Layers Approach was developed in The Netherlands in the 90's as a conditioning and stimulating framework for the spatial planning of urban and regional areas (Priemus, 2007).

Figure 3: Wilnis (source Deltares)

This Layers Approach is made instrumental to addressing the spatio-temporal effects of climate change and urbanization. The consequences of climate change and urbanization on the substratum, the networks and on the occupation layer are quantified with help of simulation models, using all available systems information on the three layers. To present the results of this analysis in a systematic way, a fourth, virtual layer is introduced, which is mapping the hazards of climate change in the study area. This layer includes in the risk of coastal, fluvial, pluvial, and groundwater flooding, land subsidence, drought sensitivity, saltwater intrusion and other water quality problems, and the risk of a (ground)water deficit.

These climate change effects on their turn can influence the occupation and the networks layers. They certainly have effect on the appropriate set of measures that is to be selected in Step 3. To some extent the results of the analysis even influence the land use choices determined in spatial planning (Hounjet, 2008), so that housing, industry and infrastructure are located on the geophysically best suited places.

2. Selecting a strategy to reduce vulnerability

The next step in the process is the determination of a strategy to select an appropriate set of measures to reduce vulnerability of the study area as assessed in Step1, given all the properties and the boundary conditions of the area. All this information was collected in Step 1, as part of the systems analysis. As the type and number of potential measures is very large, parties have to agree first on a *selection* strategy before they can successfully enter step 3. The strategy we propose is based on the concept of vulnerability.

Vulnerability is often defined as the sensitivity of a system to exposure to shocks, stresses and disturbances, or the degree to which a system is susceptible to adverse effects (White, 1974; IPCC, 2001; Turner et al., 2003; Leurs, 2005), or the degree to which a system or unit is likely to experience harm from perturbations or stress (Schiller et al. 2001). The concept of vulnerability is closely related to concepts such as robustness, resilience and climate adaptation. Based on a literature review De Graaf et al., (2007) defined a vulnerability framework as a combination of four capacities of a complex system to decrease vulnerability to hazards that threat the system, these are: threshold capacity, coping capacity, recovery capacity and adapting capacity. Table 2 illustrates the four capacities framework.

Table 2. Characteristics of the vulnerability framework (De Graaf et al., 2007)

	Type	Frequency of hazard	Time orientation	Responsibility
Threshold Capacity	Damage prevention	High	Past	Clear
Coping Capacity	Damage reduction	Medium	Instantaneous	Not clear
Recovery Capacity	Damage reaction	Medium	Instantaneous /Future	Not clear
Adaptive Capacity	Damage anticipation	Low	Future	Un defined

Threshold capacity

Threshold capacity is the ability of a society to build up a threshold against variation in order to prevent damage. In flood risk management, examples are building higher river dikes and increasing flow capacity to set a threshold against high river flow. The objective of building threshold capacity is prevention of damage. Past disaster experiences of society are the guiding principle to determine the height of the threshold. In The Netherlands, for ages dikes have been constructed that had the same height as the highest experienced flood.

Coping capacity

Coping capacity is the capacity of society to reduce damage in case of a disturbance that exceeds the damage threshold. Coping capacity is created by taking structural and non structural measures. Examples of non structural measures are effective emergency and evacuation plans, a communication plan to create risk awareness among residents, and a clear organizational structure for disaster management. Examples of structural coping capacity measures are wetproofing of buildings, the construction of emergency refuge areas and an elevated ground floor level of houses, well above the road level. The time orientation op coping capacity is instantaneous, because in case of emergencies only 'here and now' is important. Multiple stakeholders such as firefighters, water boards, municipalities, and other government agencies are involved.

Recovery capacity

Recovery capacity is the third component and refers to the capacity of a society to recover to the same or an equivalent state as before a disaster. It is the capacity of a flooded area to reconstruct buildings, infrastructure and dikes. Examples of structural measures are the availability of spare parts and machinery. Non structural measures include reconstruction plans and effective communication with residents. The objective of developing and increasing recovery capacity is to quickly and effectively respond after a disaster. The time horizon is instantaneous right after the disaster, but will change gradually towards a focus on the future.

Adaptive capacity

Adaptive capacity is the capacity of a region or of a community living in the study area to cope with, and adjust to uncertain future developments and catastrophic, not frequently occurring disturbances such as extreme floods. Therefore the time orientation lies in the future. Although a system may be functioning well at present, human and environmental

developments, both from inside or outside the considered system, can put a system under strain and threaten its future functioning. Examples are climate change, population growth, and urbanization. The objective of developing adaptive capacity is to anticipate on future developments and impacts. This can be done by constructing a flexible living and working environment, able to adapt the system in the future if required. The uncertainty on the long term climate conditions may be high. That is why we have to develop flexible solutions for long time horizons and why we have to make financial and spatial reservations to allow for adaptations.

Complex interactions between vulnerability components

It is a societal objective to become less vulnerable to all kinds of hazards, long term and short term. However, to decrease vulnerability – so to increase robustness - is a complex task. Vulnerability components are highly interconnected. Consequently, increasing one vulnerability component often decreases one or more of the other components, resulting in higher, rather than reduced vulnerability. Constructing flood control structures for example, leads to a decreased flood risk perception and increased urbanization and economic value. As a result, the overall flood vulnerability increases. Another problem is the lock in of technical, structural measures. Tendency is to install more and stronger facilities, rather than invest in non structural measures. In The Netherlands, a good example is the recently released report of the governmental advisory commission on flood protection and climate change in The Netherlands, the report of the Delta Commission. This reports states that threshold capacity should increase tenfold (Veerman et al. 2008). This will create a sense of absolute security in which it is unnecessary to develop coping, recovering and adaptation strategies. The recently re-introduced concept of 'unbreakable dikes' is a case in point (Vellinga, 2008). If we accept however, that absolute security is both theoretically unattainable and practically unaffordable, and that we are facing uncertainties with regard to urbanization, climate change and globalization, then developing comprehensive strategies that address all four components of the vulnerability framework is essential. Table 3 gives an example of specific measures for each vulnerability component.

Successfully coping with future change uncertainties is best accomplished by explicit acknowledgement and this can be achieved by embracing and implementing flexibility in this process (Ashley, 2008). In the future responses need to be able to accommodate changes in response to advancing knowledge (Ingham et al. 2006). This requirement is most appropriately addressed by using a portfolio of structural and non-structural responses rather than one-off infrastructural solutions.

Table 3. Overview of vulnerability decreasing options for flood control classified according to the four components of vulnerability

	Possible measures to reduce flood vulnerability of urban areas
Threshold capacity (damage prevention)	• Higher and stronger dikes • Increasing river capacity • Underground floodways • Increasing urban drainage capacity • Stormwater runoff reduction
Coping capacity (damage reduction)	• Emergency plans and timely flood warning • Improved communication of risks to inhabitants • Social capital (first aid capacity, neighbourhood networks) • Elevated major infrastructures • Flood proof infrastructure and buildings • Emergency refuge areas
Recovery capacity (damage reaction)	• Insurance • Disaster funds • Forming flood relief organisations • Social capital (first aid capacity, neighbourhood networks) • Availability of machinery • Availability of spare parts

Adaptive capacity (damage anticipation)	• Integrating flood management and spatial planning • Experimenting with other modes of urbanisation • Flexibility and reversibility of infrastructures

3. Selection of measures

The third step is to find agreement with all stakeholders on the set of measures that is to be applied in the study area. A portfolio of specific measures is to be selected (e.g. like the one in Table 3) that, taken together, fulfill the ambitions of the water robust urban development. This portfolio comprises first of all control measures for surface and ground water management, and accordingly adapting the urban water management. However strengthening water robustness also involves adapting the design, lay-out, use, and management of the urban environment, the buildings and the networks. It includes not just implementing structural measures, but also deals with non structural measures such as adaptations in policy, regulation, design and building procedures, management, organization, and financing.

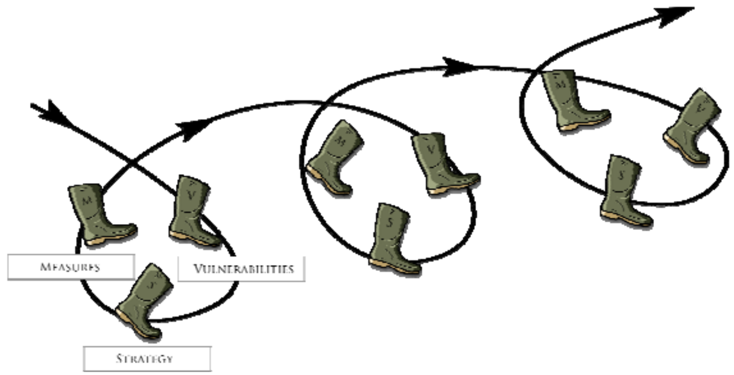

Figure 4: Three step approach during different phases of spatial planning

As explained above, this selection is part of a multi-stakeholder negotiation and design process. Evaluation criteria and values of each potential solution depend on the judgement of all participating stakeholders. And it is therefore virtually impossible to define a general decision supporting framework for this selection process (Kwadijk and Asselman, 2008). An evaluation framework is to be formulated for each specific study area.

Urban development process

The next question is when, how and by whom the three step approach is to be applied during the development process of an urban area or while redeveloping an existing urban area? In order to answer that question we first of all characterized the various steps in an urban development project. See the phases mentioned in Table 4. Urban redevelopment and retrofit projects show a similar buildup.

Table 4. Phases in the urban development process and the way water robust building could be dealt with in each of these phases. Only the first and second phase show significantly less degrees of freedom (Van de Ven et al., 2008)

		Phase	Actions for water robust building	Leading actors	Instruments, e.g.
1		**Spatial planning**	Vulnerability analysis using layer approach. Select outline for robustness strategy and optional set of measures.	Municipality, waterboard and province	Spatial masterplan, site selection, spatial plan, water assessment
2		**Location development**			
	a	*Land acquisition and initiative*	Embrace the idea of water robust development	Municipality, water board, project developers, housing corporation and industries/ companies	Declaration of intent

		Phase	Actions for water robust building	Leading actors	Instruments, e.g.
	b	*Fist sketches and designs; outlines of the plan*	Preliminary choices in water robust building and in ways to implement these measures	Municipality, water board, project developers, housing corporation and industries/ companies	Concurrent engineering; water assessment
3		Market feasibility study	-	Project developers and housing corporations	
4		**Design and building preparation**			
	a	*Plan develop ment 1.Contract negotiations 2. Formal commitment*	Choices on measures for water robust building	Municipality, water board, project developers, housing corporation and industries/ companies	Contracts, permits. Agreements balancing costs and benefits for all parties

		Phase	Actions for water robust building	Leading actors	Instruments, e.g.
5		**Building process**			
	a	*Engineering detailed design (program of demands, specs, etc.)*	Detailed technical design. Construction graphs and instructions	Municipality, water board, building companies.	Concurrent engineering

	b	*Building site preparation (BSP)*	Prepare construction of structural measures for water robust building	Municipalities and water boards; Building companies	Supervision Realization of BSP actvities
	c	*Constructing buildings and infrastructure*	Prepare construction of structural measures for water robust building	Municipalities and water boards; Building companies	Supervision Realization of BSP actvities
	d	*Procurement and delivery*		Municipality and water board	Procurement inspection
		Phase	**Actions for water robust building**	**Leading actors**	**Instru-ments, e.g.**
6		**Management, operation & maintenance; exploitation**			
	a	*Property-, asset- and portfolio management*	Management, operation and maintenance of the measures that were installed	Municipality and water board	Knowledge transfer from designer to operation & maintenance groups Management plans
	b	*Natural hazard preparedness and calamity relief organization*	Preparedness and operation rescue and safety organization	municipality	Risk communicati on training, operational calamity plans

Three periods during the whole process seem to be crucial to realizing a water robust urban environment. These are (1) the planning phase, (2) the development and design phase and (3) the moment of transfer to the operation & maintenance phase. All these phases end in formal documents: The planning phase in a land use management plan, the development and design phase in a development contract between municipality, project developers and constructors and the start of the operation and maintenance phase in a management plan. These are the documents to fix all agreements for a more water robust future.

Different people are involved in each of these three phases. That is why continuity in developing a water robust urban environment can only be provided by going through the same three step approach each time, to 're-invent' the decisions on water robust building taken in earlier steps. Only this way knowledge transfer is guaranteed to a new group of people that is involved in the next phase of development. The three step approach is therefore to be applied three times for each urban development.

Knowledge transfer is essential to the level of robustness that is achieved. Understanding the ideas behind the portfolio of the structural and non-structural measures is essential for being able to construct, operate and maintain a smoothly operating system of water robust measures. Having knowledge locked within an expert community is insufficient. The people that are actually installing and building the facilities have to understand what they are making and why that is important. If these people are unaware of the backgrounds and the way the system should function, significant mistakes will be made easily. The same holds for the knowledge level of maintenance staff.

Maintenance of public, structural facilities is relatively easy because authorities are used to make a maintenance and asset management planning. The maintenance of structures on private property and non-structural measures however require more continuous communication with the targeted residents. Only this way they will remain aware of the relevance and importance of hard or soft measures they have to maintain. They have to be convinced of the benefits of keeping these measures operational. And as this group of residents and the maintenance staff changes over time this communication and knowledge transfer is more or less a continuous effort. It should therefore be part of the maintenance plan of municipalities and water boards.

Conclusions

The ongoing urbanization, changing demands of society and climate change are major drivers for more climate resilient and water robust urban development and urban rehabilitation. Increased risks of flooding, droughts and extreme heat are to be expected. Moreover, extreme heat brings an increased water demand. This asks for a response. Numerous structural and non-structural measures can be taken to reduce this vulnerability. This can be done both in the public domain and on private properties and both at a scale of houses and buildings, at the scale of streets, subdivisions and the whole city. The interests of many parties are at stake. This makes climate and water robust building a complex problem, to be solved by collaborative design and negotiation.

A three step approach was formulated as a guiding model for the process. The three steps are (1) a vulnerability analysis, (2) selection of a strategy to strengthen robustness and (3) selection of an appropriate set of measures. This three step approach deliberately gives much freedom to the parties involved in a specific problem. As local conditions to a large extend determine the consequences of climate change in a specific study area, it is up to the stakeholders to select a vulnerability reductions strategy and an appropriate set of measures. This set should provide a level of robustness that is acceptable for all parties and that parties are willing to pay for, both for the investments and for the maintenance costs.

Creating a water robust urban environment is not a single moment effort. It requires specific and continuous attention of a large number of people from different groups, often including the residents of an urban area. The three step approach is to be applied three times during each urban development or rehabilitation project: during (1) the planning phase, (2) the development and design phase and (3) at the transfer to the operation and maintenance phase. This way all the people involved can be made aware of the backgrounds of the protection strategy and of the selection of measures. Different people are involved in each of these phases. Therefore continuity of the knowledge and understanding of the system and all its arrangements to provide protection against extreme rainfall, drought and extreme heat is essential. Results are anchored in formal plans and contracts, to guarantee continuity in implementation and maintenance.

The three step approach developed in this project was recently distributed in The Netherlands. It is now ready for testing in practice. Application over the next coming years will certainly lead to additions and changes, in interaction with the institutional context in which the approach is applied. An evaluation and update seems required in a couple of years.

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