MULTI-LEVEL SAFETY: WATER RESILIENT URBAN AND BUILDING DESIGN

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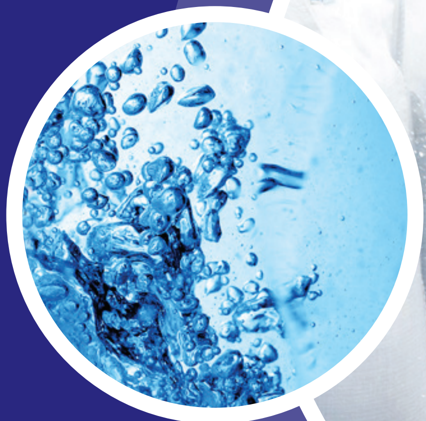

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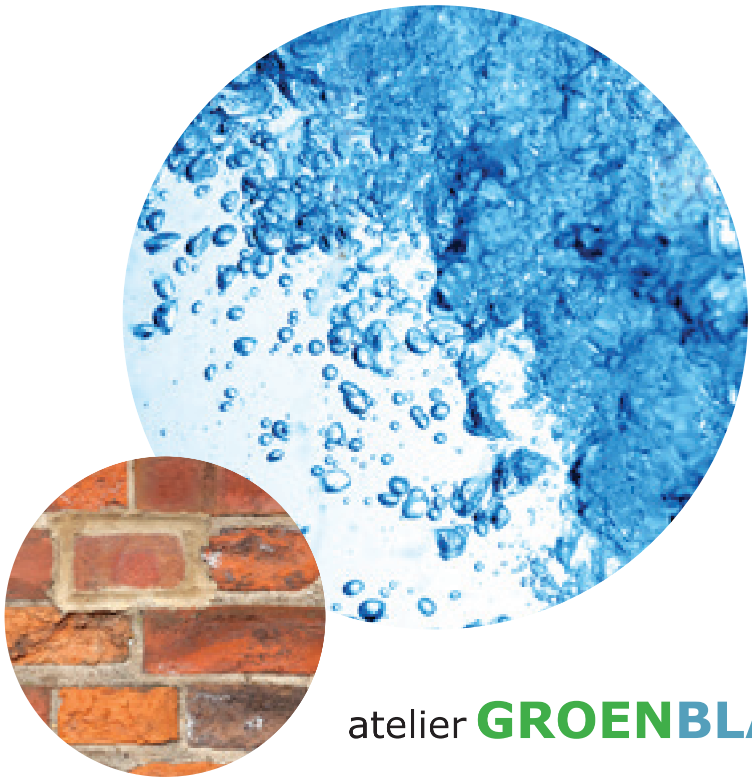

atelier GROENBLAUW

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FOREWORD

The changes in climate are causing greater weather extremes: higher sea- and riverwater levels, heavier precipitation, longer periods of drought and extreme heat, and more severe storms. More and more people live in cities and are experiencing there the effects of these weather extremes. This calls for the 'water-robust' and 'climate-proof' designing of our cities.

For centuries the Netherlands has devoted much attention to water safety. Significant investments are made in building and maintaining strong dikes in order to prevent flooding to the greatest extent possible. Sometimes the high economic costs or societal resistance makes investment in strong dikes alone unattractive. In such situations it is important to also investigate other possibilities of limiting the effects of a flood. Furthermore, it can be desirable to provide extra flood protection to vital and vulnerable functions such as energy infrastructures, hospitals and chemical plants by means of water-robust designs. We call all of this "Multi-leveled water safety": investing in a combination of preventive measures such as dike reinforcements and river widening (layer 1), investing in effect-limiting measures through spatial planning and water-robust construction (layer 2), or investing in disaster management and evacuation (layer 3).

The aim of this book is to provide inspiration for, and give form to, Multi-leveled water safety in cities. It sketches possibilities for a different kind of spatial design as well as the construction of buildings in a 'water-robust' manner. The examples provided in this book illustrate that sometimes even with small adjustments significant effects can be achieved.

Cities change, often slowly, sometimes quickly. We hope that this book will inspire water boards, municipalities, designers and project developers to contribute to creating water-robust cities, both now and in the future, so that our cities can remain safe and attractive places in which to live and work.

JOOST BUNTSMA,
Director, STOWA

DAVID VAN ZELM VAN ELDIK
Programme Director, Delta Programme New Construction and Restructuring

STOWA IN SHORT

STOWA (Foundation for Applied Water Research) is the knowledge centre of the regional water managers (mostly the Water Boards) in the Netherlands. Its mission is to develop, collect, distribute and implement applied knowledge, which the water managers need in order to adequately carry out the tasks that their work supports. This expertise can cover applied technical, scientific, administrative-legal or social science fields.

STOWA is a highly demand-driven operation. We carefully take stock of the knowledge requirements of the Water Boards and ensure that these are placed with the correct knowledge providers. The initiative for this mainly lies with the users of this knowledge, the water managers, but sometimes also with knowledge institutes and business and industry. This two-way flow of knowledge promotes modernisation and innovation.

Demand-driven operation also means that we are constantly looking for the 'knowledge requirements of tomorrow' – requirements that we dearly want to put on the agenda before they become an issue – in order to ensure that we are optimally prepared for the future.

We ease the burden of the water managers by assuming the tasks of placing the invitation to tender and supervising the joint knowledge projects. STOWA ensures that water managers remain linked to these projects and also retain 'ownership' of them. In this way, we make sure that the correct knowledge requirements are met. The projects are supervised by committees, which also comprise regional water managers. The broad research lines are spread out per field of practice and accounted for by special programme committees. The water managers also have representatives on these committees.

STOWA is not only a link between the users of knowledge and knowledge providers, but also between the regional water managers. The collaboration of the water managers within STOWA ensures they are jointly responsible for the programming, that they set the course, that several Water Boards are involved with one and the same project and that the results quickly benefit all Water Boards.

STOWA's fundamental principles are set out in our mission:

Defining the knowledge needs in the field of water management and developing, collecting, making available, sharing, strengthening and implementing the required knowledge or arranging for this together with regional water managers.

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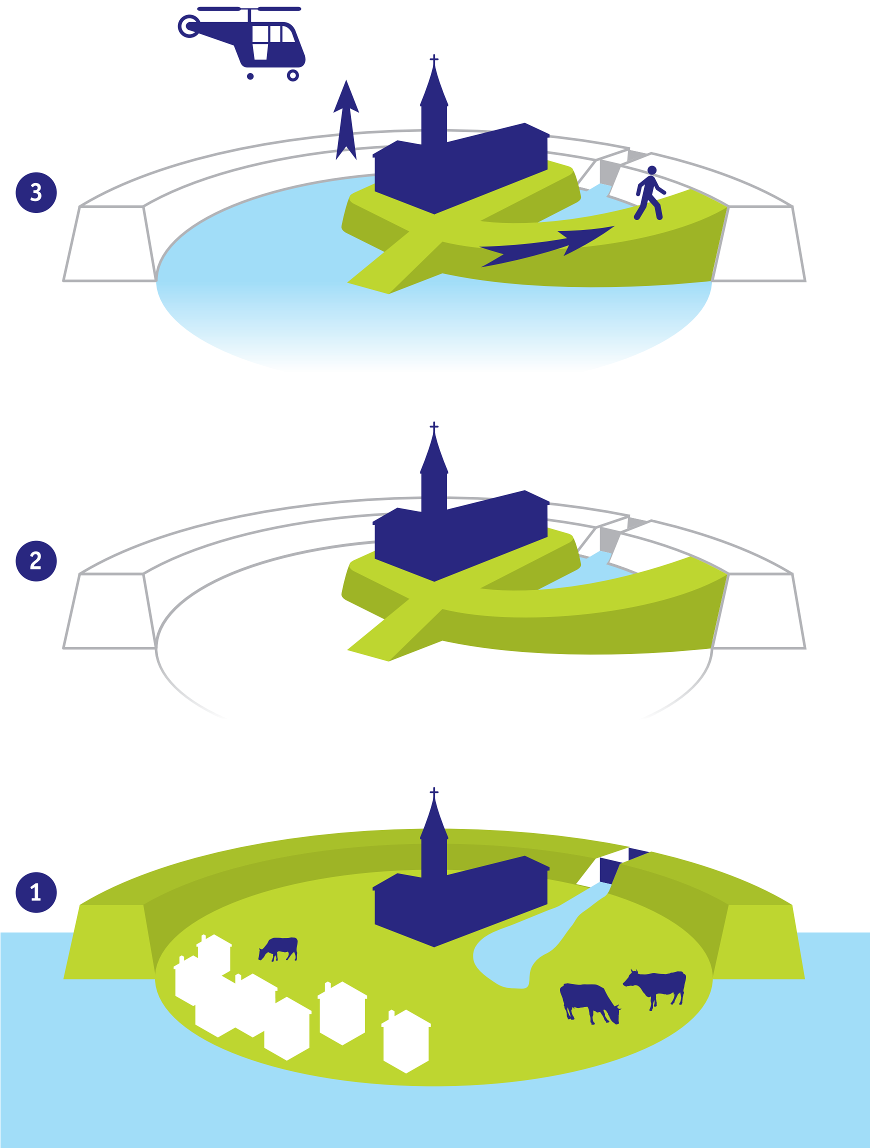

Multi-level safety: 1|Prevention, 2|Sustainable spatial planning and 3|Disaster management

INTRODUCTION

Global climate change is causing more extreme weather patterns, such as heavier precipitation within shorter time periods. Existing drainage systems cannot process these large amounts of water, making it imperative to design and implement more water-robust infrastructure for our cities.

Delta cities face the additional threat of extreme storms that come in off the sea. The Netherlands has traditionally devoted much attention to building dikes as primary flood protection. Yet successfully making cities climate-proof now requires additional attention to water-robust building in urban areas.

The world's largest cities, including those in the Netherlands, are located in delta areas. Internationally as well as nationally, both in research and in practice, better ways are being sought to be able to protect delta areas from the expected rise in sea level and extreme weather.

The Netherlands has traditionally protected itself from high water with dikes. Before the Middle Ages, when people started building dikes, it was common practice in low-lying areas to build on man-made mounds or on ground that was naturally higher than the surroundings. Yet when people began to intensively use and build on lowlands as well, the switch was made to use dikes as primary flood protection. Exceptions to this are the harbour areas found in many historic towns, which lie outside the dike walls and are raised in their entirety.

With regard to water safety along the coast and rivers, a fundamental differentiation must be made between high ground outside of dike-protected areas and low-lying areas enclosed by dikes. There is also a difference in nature between flooding in riparian zones, which is predictable and where measures such as evacuation can be taken in time, and flooding from the sea, which has less advance warning and where evacuation is therefore usually not possible.

Of course, the recent floods in Germany and other countries in Central Europe (June 2013) show that riparian floods are also not always predictable, due to the extremely large amount of rainfall and the exceptional pressure this places on the dikes. On the other hand, an earthen dike near Wilnis in the Netherlands collapsed in August 2003 because it became too light due to drought. The increasing extremes in weather also mean extreme loads for the levee system.

Multi-level safety approach in the Netherlands

In 2008 the principle of Multi-level security was launched in the Netherlands. Within this concept are three distinct layers:

1. Prevention. By this we mean the primary dike system. The safety level of this system is determined on the basis of a cost/benefit analysis and a victim analysis based on the chance of flooding.
2. Sustainable spatial planning. This refers to spatial partitioning, for example compartmentalisation by means of secondary dikes or other structures. Efforts are underway to find opportunities to use spatial measures to address multiple purposes, such as nature conservation, recreation and infrastructure. In this second level of water safety, zoning is based on flood risk. Second layer measures are already common in rural areas of the Netherlands, and these have recently been redeveloped for urban areas, such as in the concept of the "Self-reliant Island of Dordrecht".
3. Disaster management. This involves realising better co-ordination between the various emergency service providers, administrative decision-making, communication modes and evacuation plans. Water-robust construction and infrastructure, as well as the development of emergency refuges, are other measures that belong to this third layer.

Whereas in the past all attention was given to the first layer of prevention in the form of dikes, nowadays efforts are being made to also investigate the potentials of spacial planning and disaster management.

The introduction of the second and third layers means that current measures are now tailored to local areas in order to help minimise flood damage. In the Netherlands there are clear requirements for the dimensioning of the first layer, i.e., the dikes. Measures undertaken in layers two and three have no influence on the required degree of safety provided by layer one.

The introduction of the Multi-level security concept makes the task of water safety management more complex. While only RWS (Rijkswaterstaat, Directorate-General for Public Works and Watermanagement) and local water boards are responsible for the first layer of dike rings, responsibility for the second and third layers are shared among several parties, including provinces, municipalities and private parties. This requires a much higher level of co-ordination.

Naturally, realising increased safety levels and limiting the impact on local critical points is always desirable. The complexity of the MLS-concept additionally lies in the need to take into account future developments such as climate change, population growth and decline, economic developments, changes in spatial development and so on.

Within the MLS-concept, the costs of layers 2 and 3 fall to new parties, such as developers, local governments, businesses and citizens.

In the Netherlands, where the first level provides strong protection, leaving only a slight chance of flooding, it is usually not profitable to invest in the second layer within diked areas. This kind of investment often meets with resistance, particularly when the costs must be met by developers and other parties instead of by the water boards as is now the norm. For areas outside of diked areas, this is different. Here, due to frequent flooding, investment in layers 2 and 3 can indeed be rewarding, and the motivation for this investment is greater among the public and businesses.

Because in most cases land use is already established, it is not easy to find support for second-layer measures. Combining measures, such as a climate dike with homes, often meets with resistance because the responsibility and funding must then be shared by a number of investors and managers, both now and in the future.

In layer 3, better co-ordination and control of emergency services, good public information and the realisation over time of waterproof utilities will not only have a positive effect on the success of disaster management but will also make it easier to restore an area after a disaster.

For local problems, Multi-level safety measures are most efficient. Multi-level safety augments the possibilities for delta cities. Dordrecht has floodplains and low-lying areas which could be threatened in such a disaster as a combination of spring tide and high river water levels. Evacuation in these areas is only possible to a limited extent. Here, the safety of the population can be increased by combining measures in the first layer, such as primary defenses, with measures in the second and third layers, namely compartmentalisation dikes, more and better escape routes, shelters on higher ground and effective communication strategies.

Flood-proof construction is an option in flood-prone, though often geographically higher, urban areas outside the dikes. In recent years, various solutions for different field types and scales have been developed.

The "Island of Dordrecht" is protected by various measures. The port city of Hamburg has a second type of infrastructure against flooding. There the ground floors of the buildings are protected by flood defenses. Similar solutions are realised in the cities along the Rhine.

Possible solutions

The following solutions can protect buildings located in flood-prone areas and prepare people, buildings and installations for a possible flood:

The buildings can be designed in such a way that they can withstand a flood and be used again after a thorough cleaning. This requires waterproof construction and well-considered materials, equipment and infrastructure.

- The buildings can be sealed by means of bulkheads and hatches.
- The buildings can be built on raised ground.
- The buildings can be designed to float.
- Communication and information must be regulated. Buildings must also be evacuatable.
- The utilities within buildings can be designed in such a manner that they are able to withstand a flood.
- Making buildings self-reliant allows them to be independent of the network infrastructure.

Also at the district level there are options such as surface elevation, floating areas, buildings on stilts, temporary dams, autonomous or raised infrastructure, and emergency refuges.

CHAPTER 1 MEASURES AT THE BUILDING LEVEL

1.1 COMMUNICATION AND INFORMATION

A good communication strategy that prepares citizens for a disaster is highly important. This starts with providing information and making people aware of the possibility, probability and magnitude of flooding, combined with a good warning system. This is especially the case for areas with a real chance of flooding, such as floodplains and polders at critical places. Municipalities and water boards will then need to regularly provide information and distribute map materials with all relevant information. Information regarding emergency kits, evacuation routes and preventive measures in and around the home is also important.

Examples of critical points are polders that lie directly behind a dike where, when there is a breach, flooding is quick and deep, creating strong currents. Other examples are areas with functions such as gas winning, because their failure can lead to societal disruption.

*The Belgian government has published a manual for citizens in flood areas entitled "**Overstromingsveilig bouwen en wonen**" ("Flood-safe Building and Living"), which gives further practical measures for homeowners.*

www.integraalwaterbeleid.be

Coördinatiecommissie
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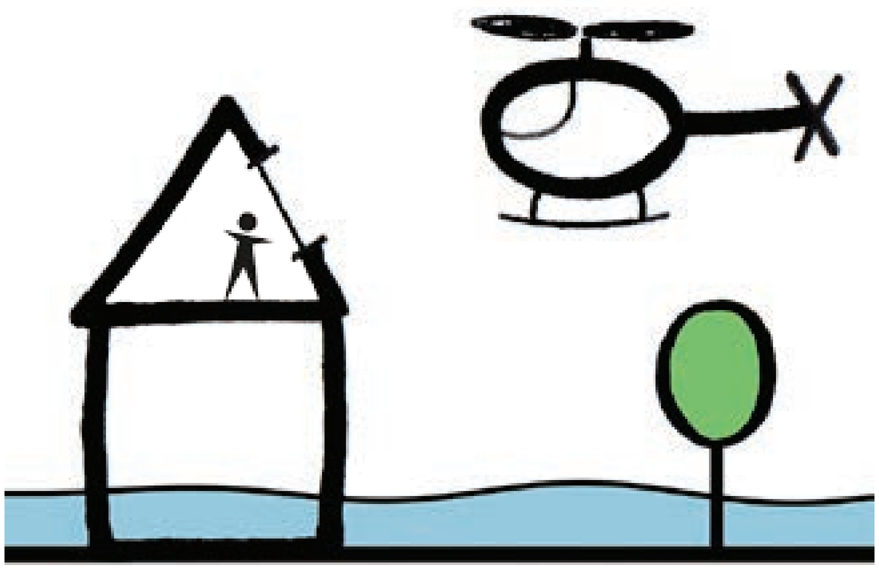
1.2 BUILDING WITH MULTIPLE STOREYS AND SKYLIGHTS (VERTICAL EVACUATION)

In polders where water can remain for a long time after a flood due to a break in the dike, making sure that buildings have multiple storeys and skylights is useful for purposes of vertical evacuation. Roads become impassable and dangerous, causing horizontal evacuation to be difficult.



Vertical evacuation by building with multiple storeys and skylights (image: atelier GROENBLAUW)

1.3 THRESHOLD OR RAISED FLOOR LEVEL

The reintroduction of a threshold or a slightly raised ground floor offers protection from mild flooding up to several centimetres.

1.4 SEALABLE BUILDINGS

Fitting buildings with means of sealing them, for example using bulkheads or shutters, makes it possible to keep the water outside the building. This applies not only to large openings, such as doors and windows, but also to the small openings such as perpends, ventilation grilles, conduits, letterboxes and the like. It is difficult to completely seal a building. Despite the measures and systems described here, water will almost certainly penetrate into the building, meaning that these measures will have to be combined with water-resistant materials.

In many situations, flood protection in a public area or outside the building will offer a stronger and more controllable measure. Mostly this will also be cheaper, since temporary flood protection around multiple buildings requires less effort than separate temporary protection for each individual building.

Buildings with functions that require few openings, such as underground parking garages, are easier to construct in such a way that they can be sealed off.

Speed bump as a measure to protect from mild floodings (photo: Floris Boogaard)

Sealable building (photo: WP WASTO flood protection system)

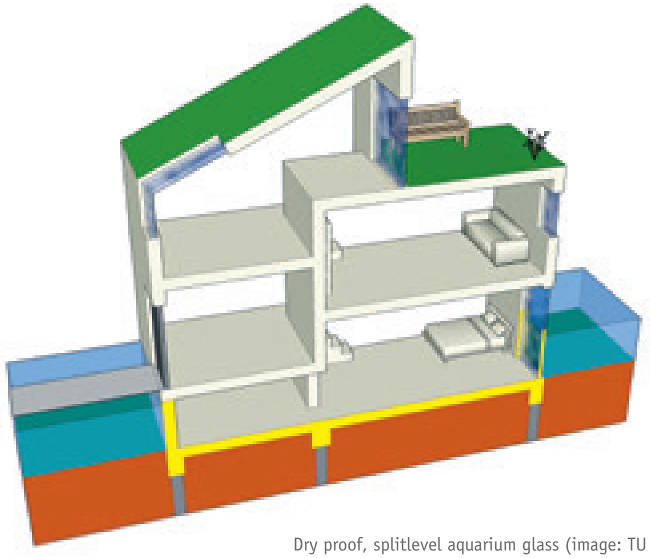
Resident Cees looks out the window from his house at the Korte Engelenburgerkade in the centre of Dordrecht to the high water (foto: Robin Utrecht)

1.5 WATERPROOF CONSTRUCTION METHOD AND MATERIALS (DRY PROOF)

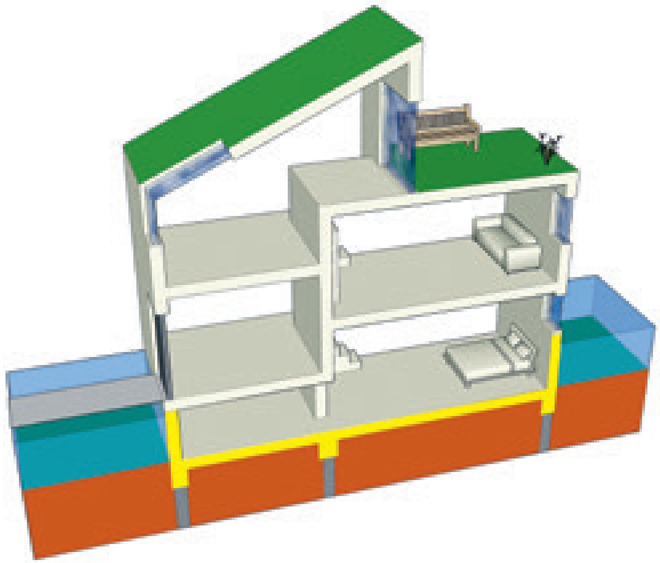
Buildings can be designed in such a way that floods do not cause structural damage. This involves such measures as using water-resistant construction and finishing materials like concrete, closed cell insulation, bricks, wall and floor tiles, aluminum and steel window- and doorframes, glass, etc.

Building structures without crawlspaces is a suitable construction method, since no water or pollutants will remain captured below the structure. Using these materials and construction methods makes it possible for buildings to become functional again relatively quickly after having been flooded; the only work that needs to be done after a flood is cleaning, painting and perhaps replacing damaged inventory. This solution is fairly common in many areas along large rivers.

Important factors to bear in mind are that the construction elements must be able to withstand water pressure or current and that the water must be able to run off or be pumped away easily.



Dry proof, splitlevel aquarium glass (image: TU Delft, Xplorelab)



Dry proof, splitlevel waterproof wall (image: TU Delft, Xplorelab)

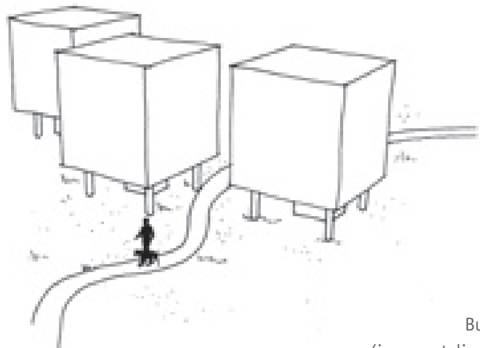
Apartments on stilts, Hoek van Holland by Herman de Kovel, DKV Architecten (photos: Bastiaan Ingen Housz)

1.6 RAISED CONSTRUCTION

Buildings can be realised at a raised level. They can be positioned on piles on raised ground, such as traditional dwelling mounds. Alternatively, the ground floor can be designed to fulfil a function such as storage space or garage, using the water-resistant construction methods described above. After a flood, and once it has been cleaned, the ground level is ready for use once more.

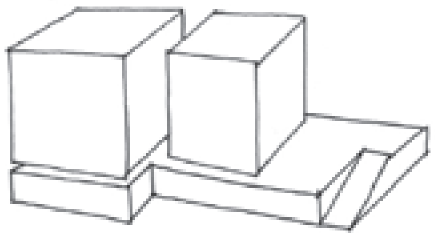
Using raised construction methods on piles, space becomes available at the ground level for other, less vulnerable or temporary functions, such as parking or storage. Where buildings are realised on a raised area (a dwelling mound or dike), the raised area might be part of the flood protection. In the Netherlands, it is currently not permitted to build on top of floodwalls. However, it is permitted to realise a raised area against a floodwall or dike.

People are very hesitant to build on dikes because in the past, when dike reinforcements have had to be made, this combination has often proven to be technically and financially unfavourable for all involved, including the residents.



Building on stilts
(image: atelier GROENBLAUW)

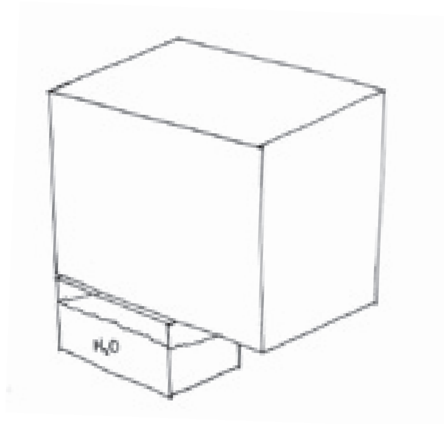
Flood Proof Hind House in Berkshire, United Kingdom, John Pardey Architects
(photos: www.jamesmorris.info)



Raised floor level relative to ground level
(image: atelier GROENBLAUW)

Drinking water reservoir included in the cellar of the treatment station Lekkerkerk (photo: Oasen)

Drinking water reservoir included in the cellar (image: atelier GROENBLAUW)



1.7 WATER-RESISTANT SYSTEMS

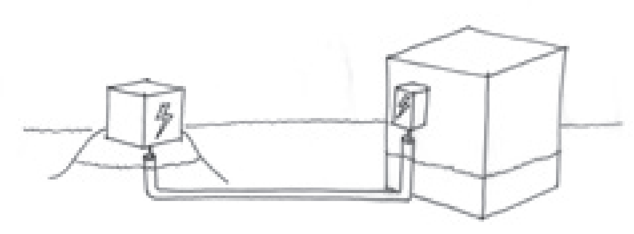
Connections to utilities (sewer, data, drinking water and energy/heat) need to remain functional during floods, or else alternatives must be provided. These connections should be designed in such a way that connection points, meter cabinets, etc. are not situated on the level that is exposed to the flood risk.

Closed drinking water or precipitation reservoirs can serve as temporary alternatives to the drinking water supply. Where water levels rise, sewers should be fitted with check valves to prevent buildings from being flooded with sewage. It is advisable not to locate vulnerable functions, such as computer rooms, on the ground level of the building.

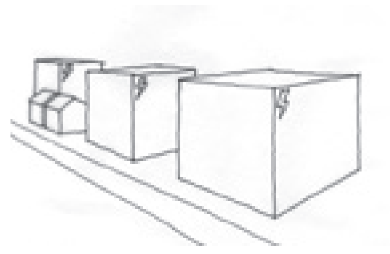
1.8 ENERGY-INDEPENDENT FACILITIES

An advantage of a decentralised energy supply is that it can continue to work independently of the network as long as it is robust against water.

Examples include solar panels, biomass, a CHP plant, wind power and a sealed drinking water tank.



Sketch decentralised energy supply
(image: atelier GROENBLAUW)



Sketch generators
(image: atelier GROENBLAUW)

1.8.1 Generators

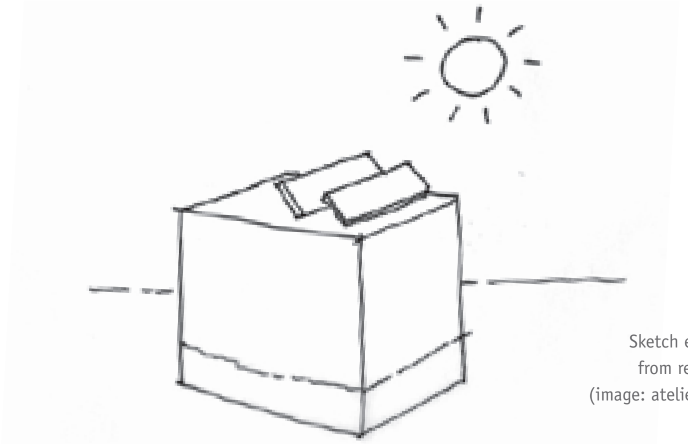
Generators make it possible for buildings to temporarily create their own energy supply. In combination with batteries, it is possible to ensure a continual supply, starting before the power outage.

In case of a regional or national energy supply failure, essential amenities remain functional, perhaps in combination with CHP and decentralised energy generation.

Commercial generator (photo: Dwight Burdette)

1.8.2 Energy from renewable sources

During a flood a building can generate the energy it requires, independently of the network. Energy is generated from renewable sources, such as solar cells.



Sketch energy generated from renewable sources (image: atelier GROENBLAUW)

Sideka Solartechnik Ibbenbüren (photo: Sideka Solartechnik)

Vertical-axis wind turbine Turby (photo: VanBuren)

Floating pavillion Rotterdam, The Netherlands (photo: R. de Wit, Deltasync)

1.9 FLOATING OR AMPHIBIOUS BUILDINGS

When buildings have a floating or amphibian construction, no water damage occurs when the water level in the vicinity rises. A point of attention in this type of construction is the connection to infrastructure and utilities: these must be flexible or self-sufficient.

Rising water levels means that the building – or rather, the foundation – floats. Conditions necessary for this type of construction are the presence of surface water and a lightweight building style, for example with a (wooden) skeleton construction method.

Floating or amphibian homes must be well anchored into position. This can be done in a number of ways. In Maasbommel, homes have been built to be able to move up and down along the mooring posts. In other situations homes can be fastened to the quay or anchored to the ground with steel cables.

Attention must be given to ensuring that no large objects can become lodged under the homes, causing them to tilt when water levels subside. Measures must also be taken against ice build-up.

Although the homes themselves vary in vertical position, they must nonetheless be connected to the utility infrastructures, which are fixed. The connections must therefore be flexible (and insulated).

Amphibious homes Maasbommel (photo: Dura Vermeer)

CHAPTER 2 MEASURES AT THE DISTRICT LEVEL

Image: Flooding at Paulus-Akkermanwei (photo: Weblog Staphorst)

2.1 REINTRODUCING PAVEMENTS (SIDEWALKS)

In times of flooding from a heavy rainstorm, pavements can keep the water in the streets. The pavement then remains passable and the homes and buildings stay dry.

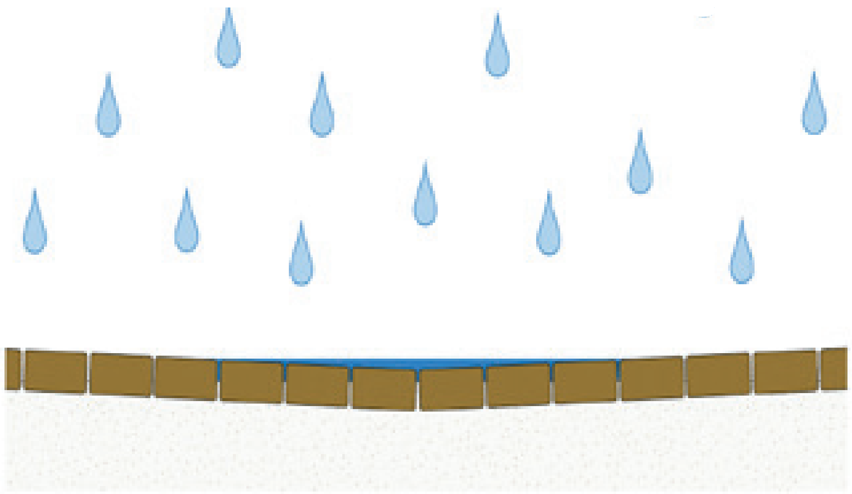
2.2 SUNKEN ROADS

Making a road lower than its surroundings increases its water capture and drainage capacity. Combined with a pavement (sidewalk) and a slightly raised floor level in the homes built alongside it, this can prevent flooding in the homes.

2.3 CHANNELING RAINWATER ON THE ROAD

Through restructuring or in new construction, roads can be graded so that rainwater is directed to areas where it can be safely captured or where the damage will be limited.

On the other hand, streets can also be designed in such a way that they buffer vulnerable low-lying areas.



Section scheme (image: atelier GROENBLAUW, Marlies van der Linden)

Surface rainwater runoff (photo: Atelier Dreiseitl)

Tanner Springs Park, Portland, US (photo: atelier GROENBLAUW, Madeleine d'Ersu)

2.4 ADDITIONAL WATER STORAGE

Extra water storage can be achieved in parks, on sports fields or empty lots.

Solar City, Linz (photo: Atelier Dreiseitl)

Potzdamer Platz (photo: Atelier Dreiseitl)

Dalmannkai (photo: LBE&FLUT, HafenCity Hamburg GmbH)

2.5 RAISING THE GROUND LEVEL

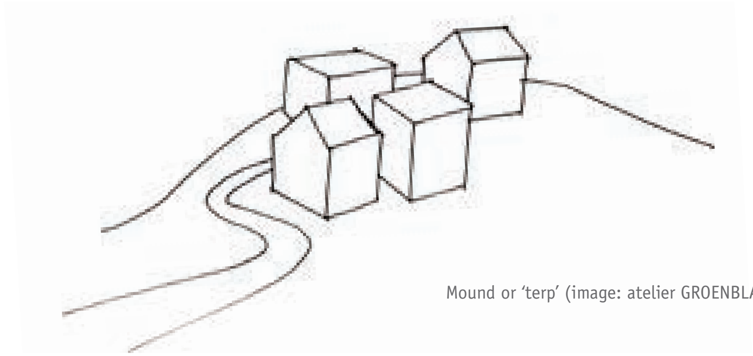
Areas outside dikes can be raised in their entirety. The drawback is the amount of soil needed. Examples of this method in practice can be seen in the harbours of Rotterdam, IJburg in Amsterdam, and Stadswerven in Dordrecht. In Amsterdam's IJburg district, the aesthetic appeal of the water was one of the main reasons for raising the ground level as opposed to the more common practice of building in a deep polder.

IJburg Amsterdam (photo: dRO Amsterdam)

2.6 MOUNDS AND ARTIFICIAL HILLS

Man-made hills that rise above the highest flood level can serve as a residence or as a refuge during a flood.

These raised areas are also suitable for protecting vulnerable functions such as utilities, emergency services and hospitals.



Mound or 'terp' (image: atelier GROENBLAUW)

The highest mound (or 'terp') of the Netherlands: Hegebeintum, 8,8 meter above Normalnull (photo: Erica Schaafsma / Kerimafotografie)

Compartmentalisation by a building and valves (photo: Hiltrud Pötz)

Western Harbour riverbank, Malmö (photo: Madeleine d'Ersu)

2.7 COMPARTMENTALISATION ON AN URBAN SCALE

Dividing a large dike ring into a number of smaller compartments, even within urban areas, can limit the consequences of flooding to a smaller area.

2.8 HEIGHT DIFFERENTIATION

To bridge the gap between the water level and the raised landscape of residential and business functions, a stepwise transition can be implemented. For example, by the use of a stepped construction additional height can be created. This can contribute positively to the urban space.

Magdeburger Hafen (photo: HafenCity Hamburg GmbH)

Raised road HafenCity Hamburg (photo: Mathieu Schouten)

2.9 RAISED EVACUATION ROUTES AND PATHS

Raised roads ensure not only reliable evacuation routes but also that an area remains accessible during a flood.

2.10 FLOATING AREA

Like floating homes, districts can also be constructed on floating platforms. Not just buildings, but other urban functions as well, such as public spaces and facilities can be designed to float. Here, too, the anchoring and infrastructure connections are important factors to consider.

As a rule, these are relatively expensive solutions compared with standard land-based solutions. Compared with draining or raising land, it can be a viable alternative. For temporary functions, a floating and movable design can be an interesting solution.

Floating areas are not always viable solutions, due to the relatively high construction costs. Scaffolding must be erected, and special facilities are needed for the infrastructure. For example, the drinking water pipes in IJburg in Amsterdam must be chilled in the summer and heated in winter to prevent legionella or freezing, respectively.

Waterbuurt West, IJburg Amsterdam (photos: ABC Arkenbouw)

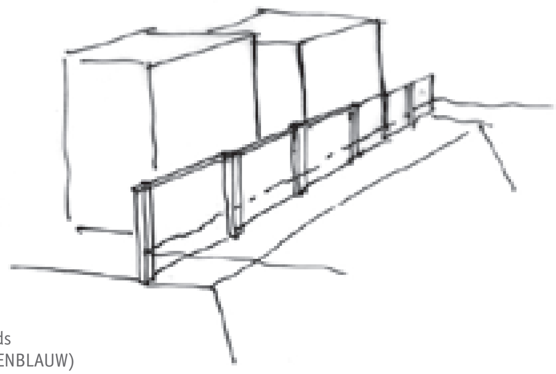
2.11 TEMPORARY DAMS

Various methods and systems exist for realising temporary flood protection. Besides movable panels and bulkheads, inflatable tubes can also be used. The benefit of these facilities is that they can help control and protect an entire area at once. Since their management, maintenance and repairs and operation are in public hands and do not depend on the views and cooperation of private individuals, they are more reliable. However, the costs are relatively high, and they add nothing to the town or city's aesthetic appeal. These systems are suitable for protecting existing areas and can be realised around existing constructions.

2.11.1 Waterproof bulkheads

The system consists of vertical H-sections which are attached to the foundation.

Hollow aluminium beams are attached between the sections.

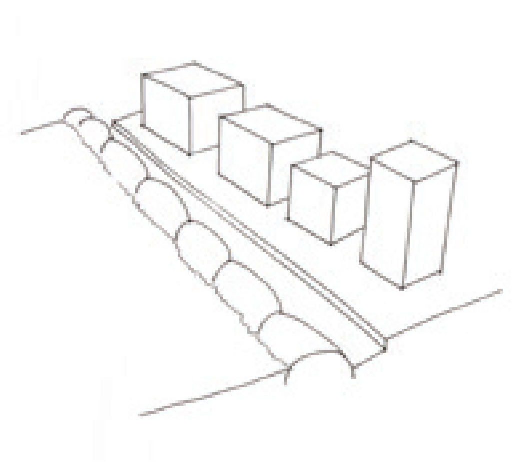


Waterproof bulkheads
(image: atelier GROENBLAUW)

Temporary embankment in the centre of Kampen (The Netherlands) during the high water in January 2012 (photos: Cor van 't Hof)

2.11.2 Moveable dams, filled with water or sand

These can be applied flexibly in emergency situations.



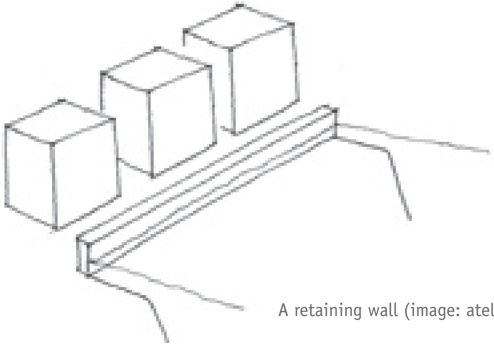
Moveable dams, filled with water or sand (image: atelier GROENBLAUW)

Huge sandbags have to protect the houses in Zwijndrecht from the high water (photo: Robin Utrecht)

Water-filled dam (photos: Hochwasserschutz Agentur)

2.12 RETAINING WALL

A retaining wall that holds back high water helps to keep the residential area behind it dry for a longer period.



A retaining wall (image: atelier GROENBLAUW)

Elisabethkai flood protection (photo: Stadtgemeinde Salzburg, J. Killer)

2.13 ALLOWING FOR THE NATURAL FLOW OF FLOODWATER

In areas prone to flooding, buildings can best be positioned so that they interfere as little as possible with the flow of water and runoff. This reduces the risk of buildings collapsing under water pressure or being washed away in currents.

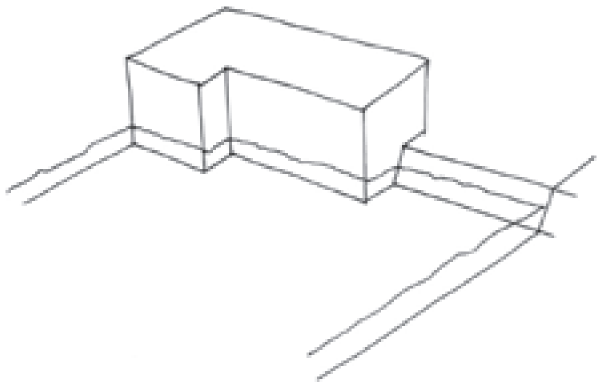
A layout that doesn't disrupt the flow of water, Tierpark Dählhölzli Bern (photo: Tierpark Dählhölzli)

By means of water-resistant doors and shutters, the building can function as a water barrier (photo: Salino01)

2.14 BUILDINGS AS FLOOD PROTECTION

Buildings are multifunctional and can act as barriers to excess water during floods.

Possible applications are mainly to be found in the borders between diked and undiked areas.



Buildings as flood protection (image: atelier GROENBLAUW)

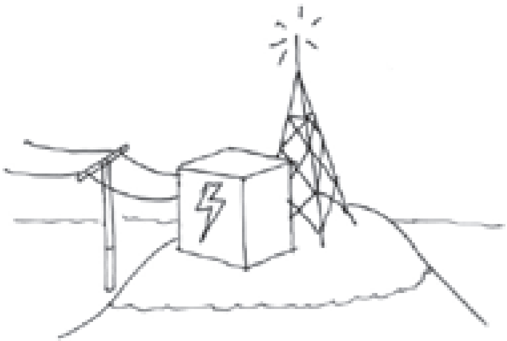
2.15 WATERPROOF UTILITIES

To allow neighbourhoods to continue to function during a flood and to ensure their speedy recovery afterwards, it is essential that vital infrastructure be water-robust. For example, a working power supply is important for pumping to continue. Energy and drinking water is essential if people are to stay in or to return to a flooded area.

Making infrastructure water-robust also ensures that it does not sustain excessive damage. For example, laying sewers deep enough ensures that they will not float. Drinking water pipes which are deep enough also are damaged less easily. Residential power lines and local transformers can best be located on high ground.

Raising at least the district's transformers and the power lines to the houses also ensures that communication networks continue to function properly, as this is obviously necessary as well.

(source: Eelko Wester, column telefoonverslaving)

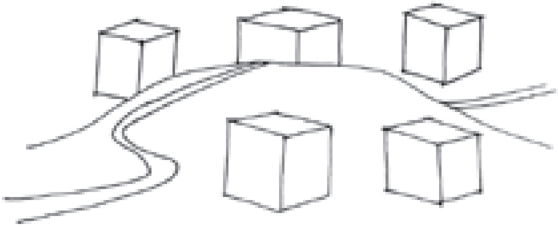

Waterproof utilities (image: atelier GROENBLAUW)

2.16 ELEVATED EMERGENCY REFUGES

In deep polders that cannot be quickly evacuated, raised evacuation areas provide a refuge. These buildings must be equipped with facilities to generate decentralised energy, while also providing drinking water and a food supply.

In an area such as the Eems Delta in the north of Groningen, the ancient mounds with their churches can serve this function.

There have been considerations to realise shelters on the higher ground outside of the dike protection areas near Dordrecht for the benefit of the residents of low-lying polders.



Elevated emergency refuges (image: atelier GROENBLAUW)

Of the many raised evacuation areas built in the 11th and 12th centuries on Walcheren and Zuid-Beveland, there are thirty-seven remaining, including this artificial hill at Koudekerke (1981) (photo: Bert van As, Rijksdienst voor het Cultureel Erfgoed)

Hallig Hooge, Germany (photo: Sandra Buhmann)

CHAPTER 3 EXAMPLES

Floating greenhouse Naaldwijk (photos: Dura Vermeer)

FLOATING GREENHOUSE | NAALDWIJK | THE NETHERLANDS

The floating greenhouse was developed for use in areas allocated for water retention, hereby giving these areas a multifunctional use. More areas will need to be set aside for water retention in the Netherlands in the future. The increasing pressure on the available space makes it necessary to use this space in a multifunctional way. Floating greenhouses can also limit the loss of land value when assigning additional locations for water retention. The use of floating greenhouses can limit loss and damage from flooding.

A point of attention when using floating greenhouses is that they need to be located in areas with permanent water, and that flexible connections for power, etc. are necessary to be able to adapt to fluctuating water levels. In existing water-rich areas greenhouses are not welcome, as these areas are generally already intended for housing, recreation or nature conservation.

The first floating greenhouse was built in 2005 and can be visited in the Flora Holland Business Park in Naaldwijk.

Engineering

The greenhouse's floating foundation consists of a combination of EPS (Expanded Polystyrene) and steel fiber reinforced concrete. The greenhouse's foundation is built directly on the water.

The greenhouse's wastewater is treated in an individual wastewater treatment system. The greenhouse is designed as a presentation and exhibition space covering some 600 m^2. The floating foundation has a dimension of 900 m^2. [Pötz *et al.*, 2009]

PROJECT DATA:

Address:	Middel Broekweg 29 | Naaldwijk | The Netherlands
Contact:	Flora Holland Naaldwijk
Design/Advisors:	Dura Vermeer
Scale:	900 m^2
Realisation:	2005

Urban plan Bellamyplein (images: dS+V Rotterdam)

GREEN WATER SQUARE | BELLAMYPLEIN ROTTERDAM | THE NETHERLANDS

Rotterdam's Spangen district has almost no open water at all, and a relatively high proportion of paved surfaces. A tiered approach has been chosen for making the district better capable of handling the heavier rainfall foreseen for the future: buffering in surface water, the realisation of a water square and wherever possible unhardening unnecessarily non-porous surfaces.

Bellamypark is one of the lower parts of the district, which is evident from flooding and mud on the present square during heavy rainfall. In the new Bellamypark, a water square will be realised in which the water mission is incorporated into the design in a natural-seeming manner.

The mostly green square has a lowered and paved central area that has been designed as a buffer for rainwater. The paved surfaces surrounding this central area are connected to it. This combination of vegetation and water storage is a comprehensive solution that also helps to reduce heat stress, enhance biodiversity and naturally improve the aesthetic value.

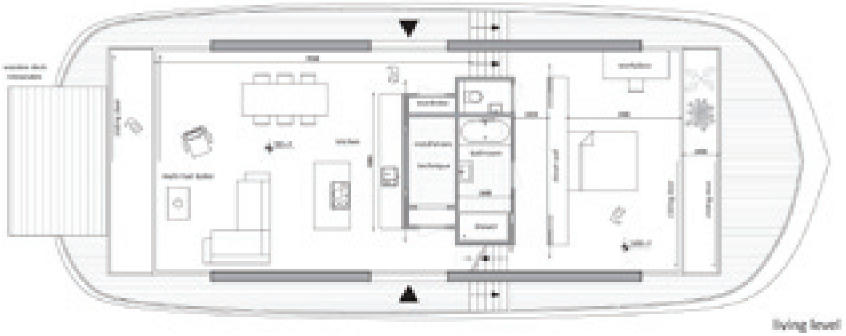
The approach chosen for Bellamypark involved an interesting and realistic look at the possibilities for dealing with the water mission in a subtle yet effective way.

As much of the quantified water mission of 5300 m^3 as possible - 1500 m^3 - will be realised using the existing surface water. Another large part of the mission has been executed using water squares with a capacity of 750 m^3 each. The remaining storage capacity requirement has been compensated by unhardening parts of the district, affording the capacity to process 1550 m^3 of water.

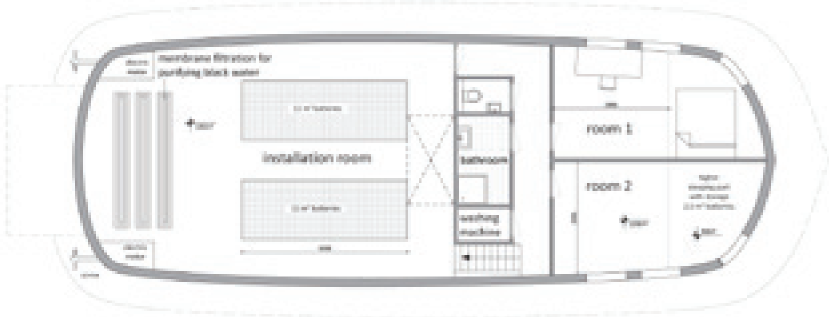
This subtle approach can be adapted to virtually any urban situation. The outcome is a greener and more appealing district with more water storage. [Nooijer, 2011]

PROJECT DATA:

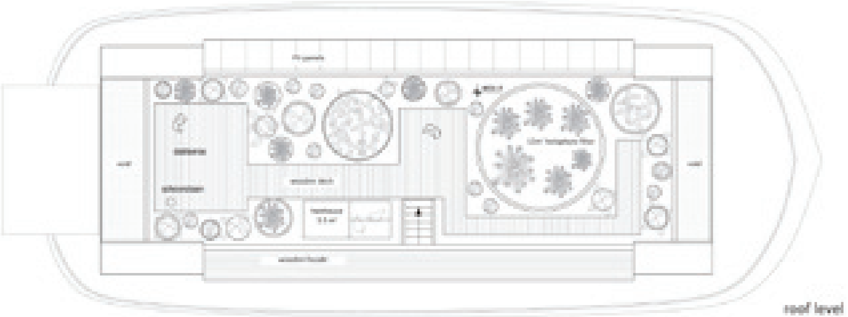
Design:	Rik de Nooijer, dS+V Rotterdam
Scale:	0,55 ha
Retention:	750 m^3
Max. buffer height:	120 cm
Realisation:	2012



living level



sleeping level



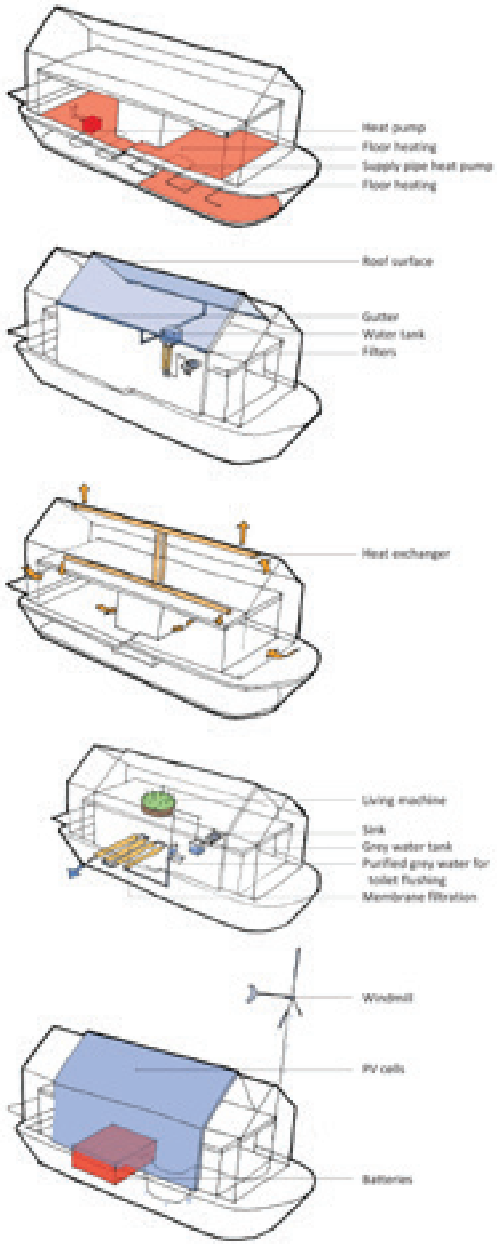
roof level

(all images: atelier GROENBLAUW/LA)

AUTARKIC HOUSEBOAT

In this study for a houseboat the theme of autarky is broadly worked out. This home is autarkic not only with regard to energy but also in terms of waste and food.

The energy concept is based on generating energy using photo-voltaic panels and a small wind turbine. The energy is stored in conventional batteries and air batteries. The stored power is enough for the boat to be able to function for a week on its own power, i.e., without solar and wind power. Such a concept is technically possible. The criterion of being able to function for one week without wind and solar energy makes the concept costly. The cost of the installation of this completely autarkic ship for four people amounts to around 200,000 euros, 100,000 of which is for the energy storage.


Heat pump
Floor heating
Supply pipe heat pump
Floor heating
Roof surface
Gutter
Water tank
Filters
Heat exchanger
Living machine
Sink
Grey water tank
Purified grey water for toilet flushing
Membrane filtration
Windmill
PV cells
Batteries

Energy

The energy that the ark uses is generated by the solar panels and the wind turbine. The energy is stored in batteries placed at the heart of the ark.

To reduce the amount of energy used and create a healthy living environment, a deliberate choice was made not to add a heat recovery system. The design incorporates the same principle in a natural fashion: the separate spaces act as compartments offering different classes of comfort. Ventilation air and cold air from outside are channelled alongside each other. Ventilating the ark through the sun rooms helps reduce the amount of heat lost as a result of ventilation.

Water

Precipitation falling on the roof of the ark is captured and used for the washing machine and shower. Wastewater is treated in the helophyte filter in the sun room located on the roof and is used in the low-flush toilet and for watering the plants used for food production.

Food

Under the folding roof (100 m^2), sufficient space is available for a 12 m^2 helophyte filter and a terrace and for growing vegetables, such as tomatoes, courgettes, peppers and lettuce, as well as figs, strawberries and grapes. There is even room to keep a few chickens for fresh eggs. Permaculture shows that, if used cleverly, a few square metres are enough for growing a significant proportion of the food that a household needs. [opMAAT]

PROJECT DATA:

Architect:	opMAAT/atelier GROENBLAUW and Lüchinger Architects
Design:	2009
Building physics:	Cauberg Huygen

(All images: atelier GROENBLAUW/LA)

Meander Medical Centre (photo: Dirk Verwoerd)

MEANDER MEDICAL CENTRE | AMERSFOORT | THE NETHERLANDS

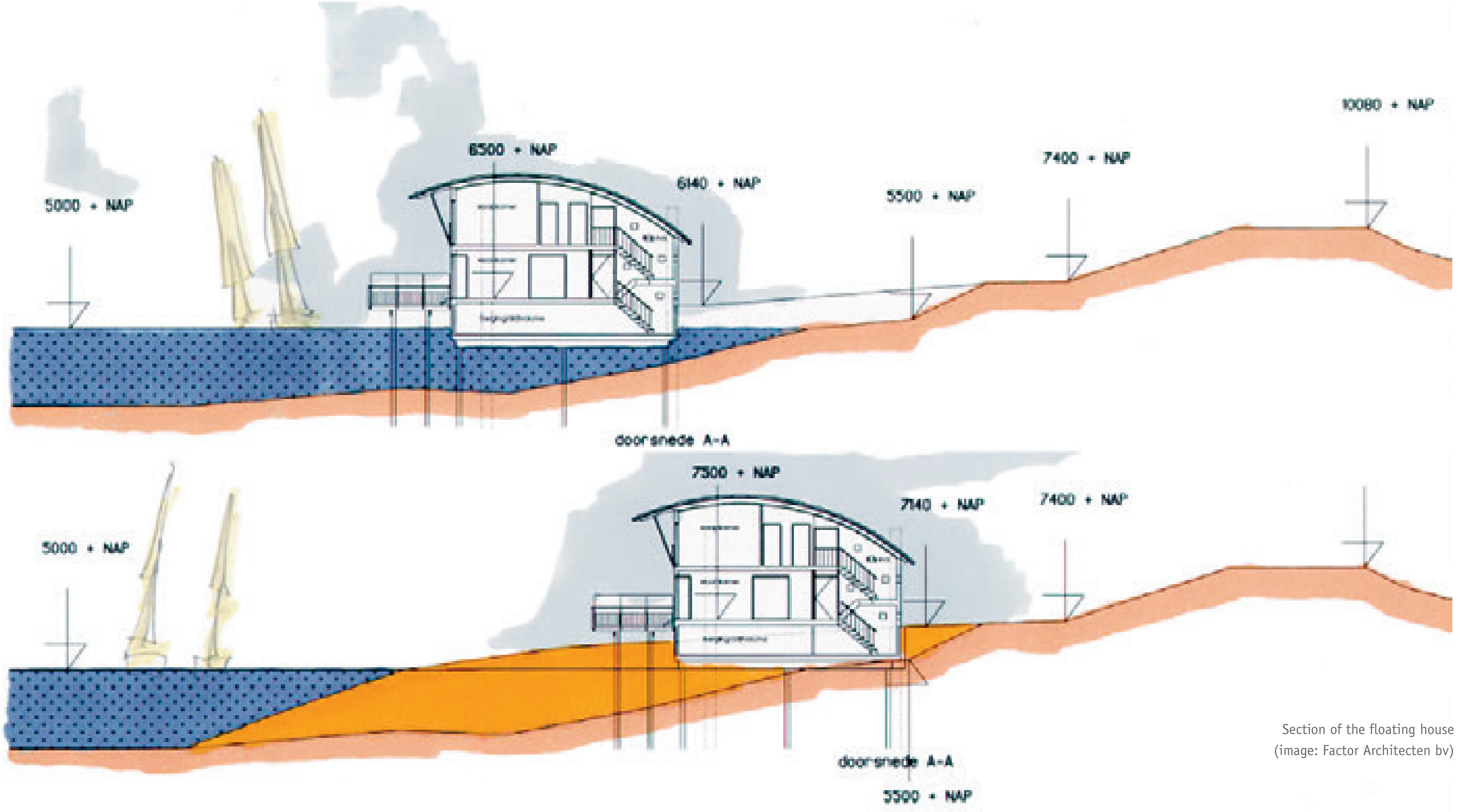
The design of this hospital takes into account the possibility of the River Eem flooding: all vital functions are situated at 2.6 metres above ground level. If the hospital floods, it can be evacuated safely. The lower spaces were designed with the flood risk in mind, and after a flood they are ready for use after cleaning. Construction began in 2010, and the hospital will become operational in 2013. [Meander Medisch Centrum, 2011]

Aerial view (photo: Staalverleggend.nl)

Interior (photo: Dirk Verwoerd)

PROJECT DATA:

Address:	Maatweg, Amersfoort | The Netherlands
Client:	Meander Medical Centre
Design:	Atelier PRO
Scale:	96,000 m²
Realisation:	2013



Section of the floating house
(image: Factor Architecten bv)

AMPHIBIOUS HOMES | MAASBOMMEL | THE NETHERLANDS

In a recreation area located outside the dikes near Maasbommel in Gelderland Province, 32 amphibious and 14 floating homes have been realised. The amphibious homes are fastened to flexible mooring posts and rest on concrete foundations. If the river level rises, they can move upwards and float. The fastenings to the mooring posts limit the motion caused by the water. The floating homes are lowered when the water level drops and come to rest on concrete foundations.

PROJECT DATA:

Address:	Bovendijk | Maasbommel | The Netherlands
Client:	De Gouden kust bv: Dura Vermeer Infrastructuur in cooperation with Watersportcentrum Maasbommel
Design/advisors:	Factor Architecten bv / Dura Vermeer
Scale:	14 floating and 32 semi-floating homes
Realisation:	2006

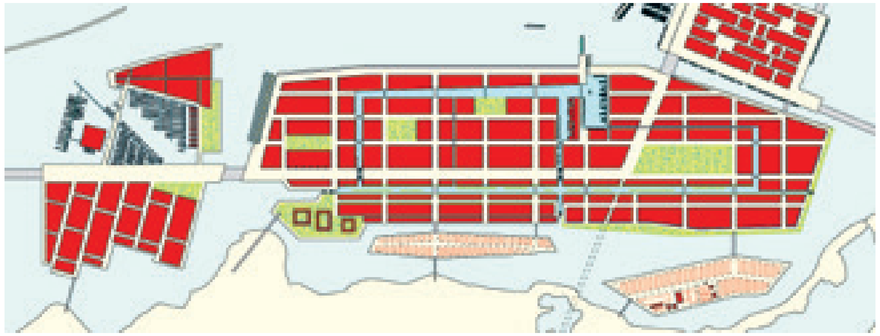
Amphibious homes Maasbommel (photo: Dura Vermeer)

The mooring posts in which the houses can move up and down according to the water level (photo: Dura Vermeer)

The floating and semi-floating homes are similar in construction: a concrete barge with a relatively light timber-frame construction on top. The concrete barges weigh 72 tonnes each, while the timber-frame constructions weigh around 22 tonnes. The low centre of gravity gives added stability. The concrete barges are made from ordinary concrete with an aggregate to render them waterproof. The joints are reinforced with an additional water-resistant sealing strip. The barges are approximately 2 metres high, and as such can only be used as basements or, if part of the home is designed with a split level, as bedrooms.

Projections indicate that the water level will rise by more than 70 cm once every five years, causing the homes to rise accordingly. The homes can handle fluctuations of up to 5.5 metres. [Pötz *et al.*, 2009]

IJburg Amsterdam (photo: dRO Amsterdam)



IJburg urban plan (image: dRO Amsterdam)

PROJECT DATA:

Address:	IJburg, Amsterdam | The Netherlands
Contact:	Project bureau IJburg
Client:	City of Amsterdam
Design/water concept:	dRO in cooperation with Waternet
Scale:	540 ha
Realisation:	since 1997

IJburg, Amsterdam (photo: atelier GROENBLAUW, Madeleine d'Ersu)

IJBURG | AMSTERDAM | THE NETHERLANDS

IJburg is an urban development district in the eastern part of Amsterdam. Once the project is complete, it will comprise around 18,000 homes. IJburg is located and is being built in the IJsselmeer. This means that the existing natural functions and requirements of the water system needed to be taken into consideration in the realisation of the district. Both the first phase of IJburg and the second phase, in enhanced form, seek to realise natural values, an extraordinarily high density of 71 homes per hectare on average (in the second phase this number rises to 90 homes per hectare), preservation of the quality of the water in the IJsselmeer, as well high aesthetic appeal.

Water can be experienced almost everywhere on the islands: along the edges of the islands of course, but also near almost every single home at the middle of the islands, because of the waterways. One of the islands, Haveneiland, has a more stony and urban character and the largest proportion of multi-level construction. On Steigereiland the focus is on living on and around the water: experiments with architecture and private projects are also permitted. The reed islands hold primarily ground-level homes.

Pursuant to the introduction of stricter national and European laws, improvement of the natural values in the immediate vicinity of the new islands will require attention in the second phase.

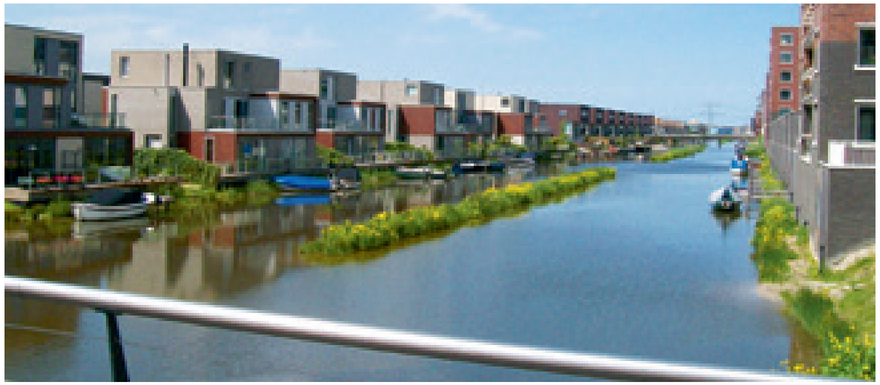
The IJsselmeer is a Natura 2000 area. Its shallow, sheltered, nutrient-rich character and the abundance of crustaceans and water plants make the area attractive for waterfowl. Around 100 species of birds are found in the IJsselmeer, a number of which are protected. Although IJburg itself is situated just outside the protected zone, the construction of the new islands must be conducted in such a manner that they do not have any significant impact on the protected area. Moreover, IJburg is situated in the main ecological structure between the Vecht River region and Waterland areas. Creating islands proved to be a better solution than draining land, both for environmental reasons and in terms of the quality of life. The plans devote a great deal of attention to natural shores and proper water flow. The realisation of IJburg does not necessarily mean that the natural values will be diminished: the new district will offer more shores and shelter, and the water will become clearer because the sludge will settle. However, the construction of the new islands will cover mussel beds, and so the source of food for many types of waterfowl; this will be compensated by creating new mussel beds.

To compensate the construction of IJburg, Amsterdam is working together with a large number of other parties to create three new nature areas: Hoekelingsdam, Diemer Vijfhoek and Zuidelijke IJmeerkust.

Water system

The water system for the first phase of IJburg is unlike the water systems in other land reclamation projects in the IJsselmeer: it was decided that IJburg would be raised rather than drained. This extraordinary approach to land reclamation was chosen because of, among other reasons, the standstill principle, which states that the creation of new land areas may not impact the quality of the surrounding water. As such, precipitation on the IJburg islands is retained for as long as possible and treated. Most of the impervious surfaces are not connected to surface water. The runoff is allowed to infiltrate into the ground via special drains. Once it has infiltrated, the water passes through reed banks that further purify the water and into the island's surface water. The clean water can then be discharged into the surface water of the IJsselmeer.

Traditional polders require continual close monitoring of the pumping of water from the drained area. The quality of the water that is discharged cannot be controlled, or only to a limited extent, particularly during peak drainage periods. Conversely, the system used for IJburg offers the possibility of treating the water before it is discharged. [Projectbureau IJburg, 2007] [Lang, 2009]



IJburg Amsterdam (photos: dRO Amsterdam)

IJburg Amsterdam (photos: dRO Amsterdam)

Steigereiland IJburg Amsterdam (photo: atelier GROENBLAUW, Madeleine d'Ersu)

STEIGEREILAND IN IJBURG | AMSTERDAM

On one of the IJburg islands, Steigereiland, all utilities (gas, electricity, drinking water, sewers, telephone, cable) are supplied on the central platform designed specially for that purpose.

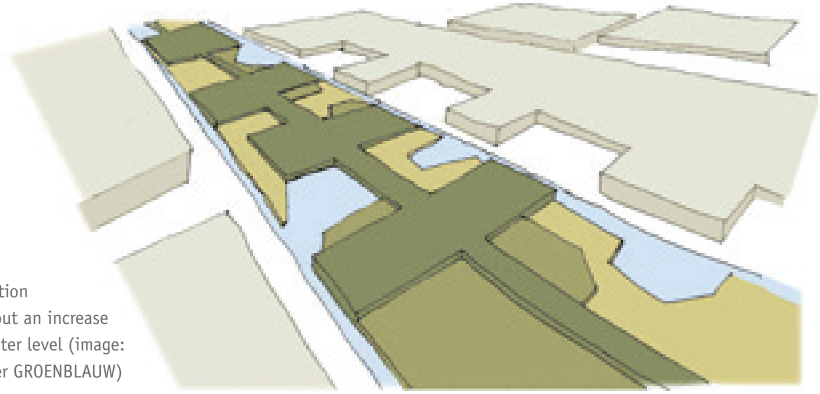
To ensure that the utility connections also function without difficulty in winter, pipelines heat the zone in winter to prevent the drinking water pipes from freezing. In the summer, they are cooled to prevent Legionnaires' disease in the drinking water. Although a lock prevents the water from entering the IJsselmeer, the water level fluctuates by up to 60 cm. The platform has piles as its foundation, giving it a fixed level. The floating homes move up and down according to the level of the water; the connections between the platform and the homes are flexible. Meter cupboards are situated on the platform rather than in the homes. The homeowners are responsible for the flexible connections between their meter cupboards and their homes; the responsibility of the utility companies ends at the meter cupboard.

Since planning utility connections for floating or amphibious homes requires additional consultation and coordination with the various utility companies, more time will be needed in the planning phase of such projects. [Projectbureau IJburg, 2003] [Pötz *et al.*, 2009]

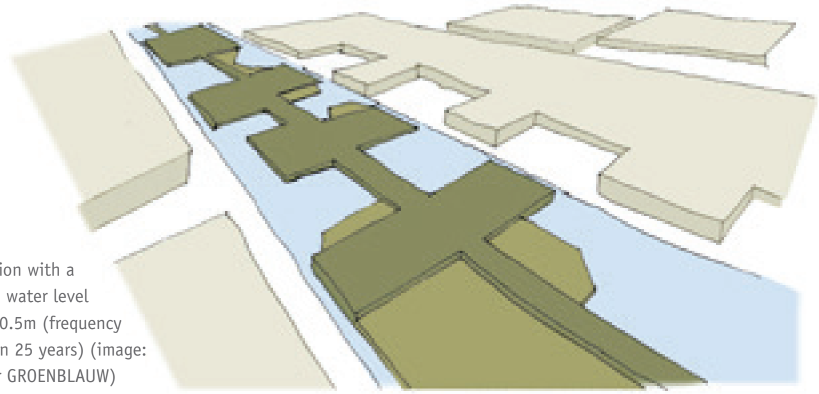
The floating houses are ankered with poles and the public facilities are transported underneath the landing stage (photo: Ilse de Jong, dRO Amsterdam)

(Image: atelier GROENBLAUW)

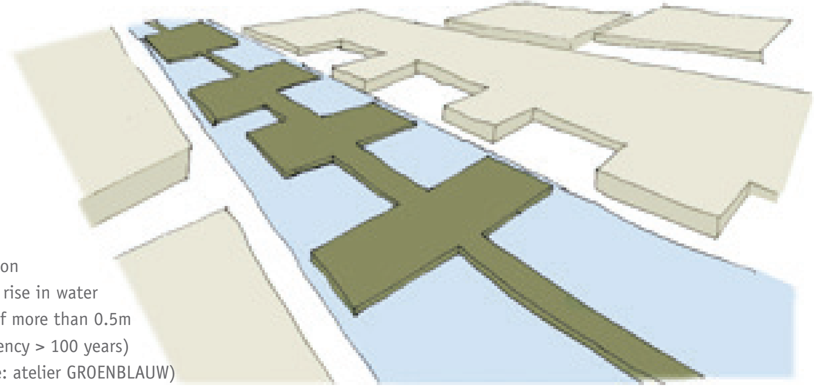
(Image: Willem van de Hoed)



Situation
without an increase
in water level (image:
atelier GROENBLAUW)



Situation with a
rise in water level
up to 0.5m (frequency
once in 25 years) (image:
atelier GROENBLAUW)



Situation
with a rise in water
level of more than 0.5m
(frequency > 100 years)
(image: atelier GROENBLAUW)

(Image: Willem van de Hoed)

(image: Willem van de Hoed)

ZUIDPLASPOLDER

A combination of greenhouses, homes, water storage and ecology. The houses are clustered on higher ground and are connected by raised infrastructure. The areas in between can be used as additional space for water storage. During so-called 'Westlandbuien' (storms in the Westland region), these areas can flood without their functioning, safety and liveability being adversely affected. In emergencies, the lower areas in the residential strips can also temporarily buffer part of the emergency discharge from the greenhouse areas.

PROJECTGEGEVENS:

Architect:	opMAAT/atelier GROENBLAUW
Design:	Pierre Bleuzé, Hiltrud Pötz
Design:	2009
With the cooperation of:	Janneke ten Kate, Afer Pastor
Drawings:	Willem van de Hoed

Aerial view (image: Stijlgroep)

PROJECT DATA:

Address:	Dordrecht	Area:	11 ha
Landscape architect:	Stijlgroep	Programme:	96 homes
Architect:	Klunder Architecten	Design:	2001-2004
Client:	VolkerWessels	Realisation:	2007-2010

PLAN TIDE, DORDRECHT | THE NETHERLANDS

At the border between the Biesbosch nature reserve and the city of Dordrecht is a residential project that lies outside of the dike-protected area. Here the tidal currents are allowed to come up close to the houses.

The ‘unpoldering’ of the existing polder and its return to a tidal landscape has created the conditions necessary for the formation of new natural areas. A closed soil balance was applied, and the homes are built on pilings. The area is designed in such a way as to provide water catchment despite the ebb and flow of the tides. Plan Tide, the transition area between Wantij (Neap Tide) Park and the adjacent residential neighbourhoods, has brought the area once again under the direct influence of the tides; the polder has been ‘given back to nature’. Ebb and flow again have free reign and in large part determine the residential experience. It is this constant tidal movement that gives this area its character. Reedlands, withy woodlands, thickets and marshy forests are interspersed with large surfaces of open water and dominate the landscape. The free-standing location of the dikes emphasises the contrast between the openness of the city and the dense plant growth on the side of the tidal shores. By means of a system of channels and creeks, the newly constructed water is carried to the wall of green at the edge of Wantij Park. The context of this landscape is continued by large ecological elements such as natural shores, islands and soft- and hardwood zones.

At the border between urban and natural landscapes, where land and water meet, a unique residential environment has developed – unique not only for Dordrecht but for the wide surroundings. It is a characteristic residential environment in which nature, housing and recreation coalesce. The gradients and transitions made with the help of water, soil and geographic relief ensure a diversity of ‘landscapes’. The approach of having the natural landscape be the central determinant of plans for the area has proven successful in creating an optimal integration between housing and nature, along with an attractive and sustainable living environment. Residents feel as if they are on holiday every day in their own community, and over time nature has made a home for itself as well. The newest residents of the Plan Tide are a beaver family who have lately settled here from the Biesbosch.

(photos: Klunder Architecten)

(photos: Stijlgroep)


(photo: Stijlgroep)

The area island of Dordrecht (image: Concept Gebiedsrapportage Eiland van Dordrecht)

ISLAND OF DORDRECHT | THE NETHERLANDS

In times of sea-borne storms, Dordrecht is threatened by high riverwater levels. Because it lies on an island, the possibility of evacuating the city in the case of a breach in the dike is extremely limited. Dordrecht is therefore working on optimising its Multi-leveled water safety strategy, in the form of the Self-Sufficient Island of Dordrecht. In addition to measures in layer 1 of the strategy, this particular geographic situation clearly requires measures from layers 2 and 3; these therefore also receive much attention. Dordrecht is a forerunner in this.

Area description

The Island of Dordrecht, with an area of approximately 9,000 hectares, lies in a transition region between sea and river. There is one dike-protected area on the island; it encompasses approximately 7,000 hectares and is managed by the district water board Hollandse Delta. The municipality of Dordrecht covers the entire Island of Dordrecht. The island is encircled by the waters of the Lower Merwede (Beneden Merwede) and the Old Muse (Oude Maas) to the north, the New Merwede (Nieuwe Merwede) to the south and the Dordtsche Kil to the west. The island is divided in two by the Wantij, which runs between the Lower Merwede/Old Muse and the New Merwede. Dordrecht lies in the northwestern part of the island. The southern region is part of the fresh water tidal area the Biesbosch. The daily tidal variation in water level is circa 80 cm in the historic inner city, which lies outside of the dike-protected area, and circa 30 cm in the Biesbosch. The island is connected to the surrounding areas by only a few bridges, tunnels and waterways. Dordrecht has approximately 119,000 residents, and the econmic value of the buildings in the area is approximately 15 billion euros (DPRD, 2012).

PROJECT DATA:

Address:	Dordrecht
Client:	Municipality of Dordrecht in cooperation with DPNH (Delta Programme New Construction and Restructuring)
Implementation:	de Urbanisten
Year:	2013

The part of Dordrecht within the dike-protected area lies at an average height of 0 metres Amsterdam Ordnance Datum (NAP). The areas outside the dike varies from approximately +1.7 m to +2.5 m NAP in the hisotric harbour area, to approximately +3 m to +4 m NAP in the dike's external flank areas, and from approximately 0 m tot +2 m NAP in the Biesbosch. The centre of Dordrecht is of great cultural and touristic value, which adds an extra dimension to the challenge. Local water safety solutions must be found that have as little as possible negative effect on the appearance of this historic area.

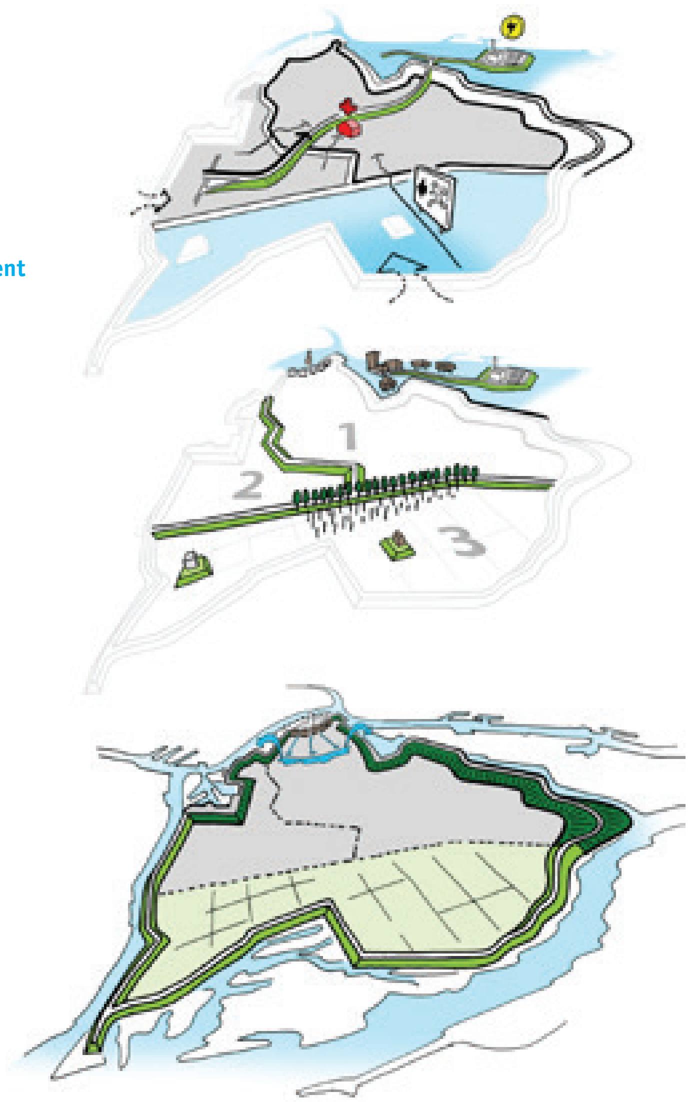
Hallmarks of water safety

Dordrecht has opted to aim for being a “Self-Sufficient Island” by the year 2035, because the possibilities for physical evacuation from the island are so limited (only 3 bridges) and because the surrounding dike-protected areas would likely also be threatened in times when a preventive evacuation would be necessary. If a breach in the dike were to occur, the majority of Dordrecht would be severely flooded. The potential scenario of extremely high water, with a sea-borne storm and high riverwater levels, inspired a pilot study which used a test plot of land to explore the possibilities of a self-sufficient island. In this study, “self-sufficiency” means that the residents have a concrete action plan to be able to survive for a certain amount of time (about a month) on the island in the case of a flood.

Multi-leveled water safety strategy

In the pilot study, attention was given to the three layers of the Multi-leveled water safety strategy. Layer 1 is the prevention of floods; layer 2 is sustainable spatial planning; and layer 3 is disaster control.

In the illustration (1), the Multi-leveled water safety strategy is depicted in terms of an area-specific risk approach for the Island of Dordrecht. Layer 1 shows a differentiated primary defense system, with the construction of a delta dike and a custom-made solution for the Voorstraat. Layer 2 shows the use of available compartimentalisation dikes, adaptive construction outside compartment 1 and the protection of vital infrastructure. Layer 3 shows possible evacuation routes, a life-line, shelters and how to guarantee the continued functioning of vital infrastructure.



Multi-leveled water safety strategy depicted in terms of an area-specific risk approach for the Island of Dordrecht (image: de Urbanisten)

Results of the pilot study

In de pilot study, Multi-leveled water safety proved to be an instrument for reducing the risks to water safety and making them more manageable in a situation such as that of the Island of Dordrecht. The limited evacuation possibilities and the unique location – threatened by both sea and river – make a Multi-leveled water safety strategy not only imperative but also attainable and, due to the positive feedback loops, possible. But even in this exceptional situation, second- and third-layer measures do not replace the need for first-layer safety measures.

Layer 1 (prevention) ensures the safety of the compartment 1 (in the figure “A different way of dealing with water” / “Anders omgaan met water”), in which 75% of all residents of the municipality of Dordrecht live. For this to happen, the northern part of the ring dike that protects the area must be raised to the level of a delta dike. This would reduce the chance of a breach to 1:100,000, meaning that this compartment could always serve as a safe haven on the island.

Realising Dordrecht’s delta dike can initially be limited to a local reinforcement of the dike segments Wantij and Kop van ’t Land (see figure), because these have the largest specific effect on water safety. In the long term (after 2030/2040) it will be necessary to rebuild or replace the Voorstraat, which serves as a water defense facility in the city centre.

Subsequently, in layer 2 (spatial planning and design), the preservation and standardisation of exisiting compartmentalisation defense works is necessary, so that they can function as water retention elements in the event of a breach in a primary water defense structure. This involves the utilisation of the existing ‘North/South and Dordrecht compartmentalisation’. Together with the primary defense works, these guarantee the availability of a sufficient number of safe/dry spaces in case of a flood and ensure that compartment 1 can function as a safe haven. Outside of this compartment, adaptive construction is encouraged (primarily outside of the dike-protected area), and in compartment 3 new construction is not stimulated. The protection of the vital infrastructure hubs in the northeastern areas outside the dikes deserves extra attention.

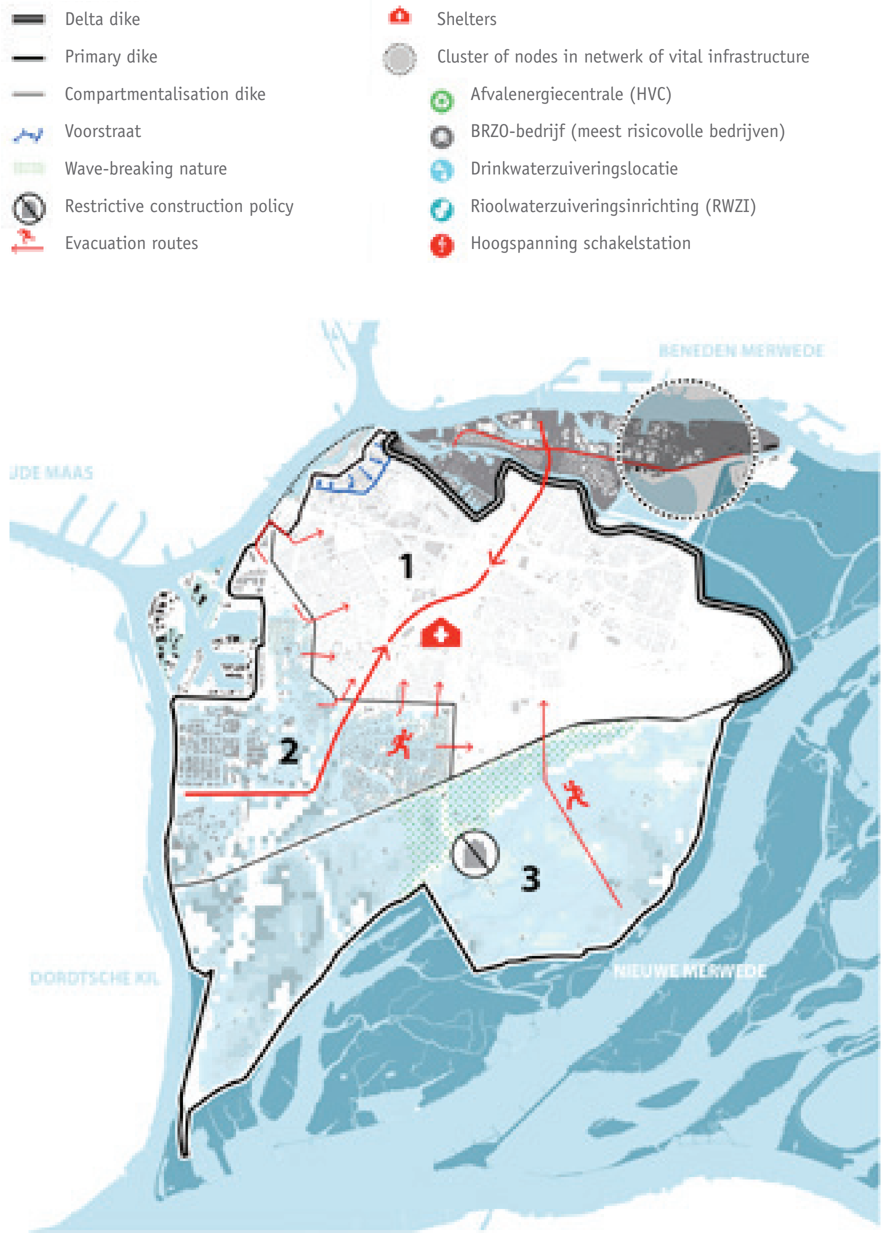
If these preconditions are met, the preventive evacuation of compartment 2 can be improved by measures in layer 3 (disaster management), such that the percentage of a successful local evacuation would increase from 15% to 80% (with 15% leaving the island and the remaining 65% evacuating to compartment 1). It is important that in addition to this, "smart shelters" are provided for those who are unable to leave, for example through the use of existing buildings or the new construction of schools and hotels, and that the cluster of vital infrastructure continues to function in order to keep supplying safe compartment 1. This includes primary functions that are necessary for the continued functioning of the island.

With this package of measures, the long-term problems and risks are limited as much as possible and the effects of a potential flood made manageable, through limiting exposure by means of a delta dike and by having water-robust planning and design. In all layers of the water safety strategy there is emphasis on finding "smart co-operation" between public and private investments so that the necessary preconditions for self-sufficiency can be created at limited extra investment cost.

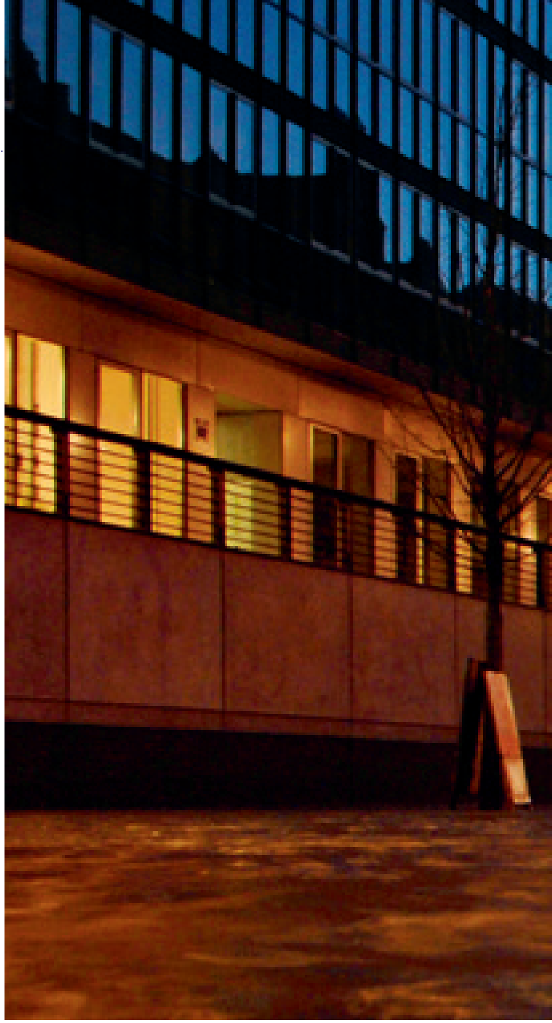
Source:

Boer, F., Peijpe, D. van, Marin, E., Wissing, A. en Matysiak, M. (2013) *Proeftuin Zelfredzaam Eiland van Dordrecht* - Deltaprogramma Nieuwbouw & Herstructurering, 13 juni 2013

Kelder, E., Gersonius, B. & Hulsebosch, M., (2012) *Concept Gebiedsrapportage Eiland van Dordrecht*, versie 2.0



Measures in the strategy 'A different way of dealing with water'/'Anders omgaan met water' (image: de Urbanisten)



Hamburg Hafencity luchtfoto (foto: Fotofrizz, HafenCity Hamburg GmbH)

PROJECT DATA:

Client:	HafenCity Hamburg GmbH
	www.hafencity.com
Scale:	126 ha
Realisation:	partly realized and still partially in development

On the left side of this photo the new buildings with the plinth that can be flooded and on the rightside the old warehouses of the harbour area © ELBE&FLUT, HafenCity Hamburg GmbH

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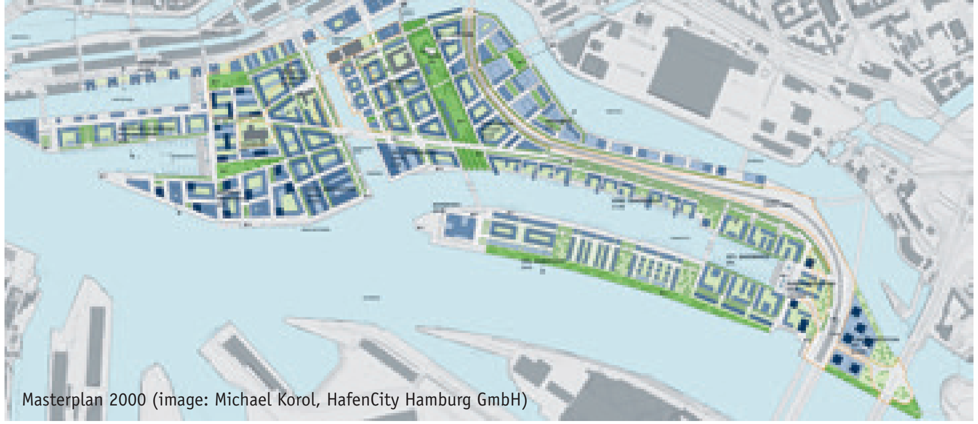
For this area of 126 hectares, situated outside the dikes and representing a realistic flood risk, the decision was made to realise a secondary partial infrastructure for pedestrians, at a height of 7.5 metres above NN (Normalnull, the German term for the Amsterdam Ordnance Datum). That higher level can also be used for emergency services in the case of high water. The existing ground level in HafenCity is 3.5-5.5 metres above NN, which is not high enough. The level of 7.5 metres is higher than the highest flood level on record. The ground floors of all buildings are also sealed up to that level, with the exception of entrances and similar openings. All openings (doors, windows, etcetera) can be closed in accordance with special guidelines.

The owners/developers are responsible for the costs associated with raising the



Masterplan 2000 (image: Michael Korol, HafenCity Hamburg GmbH)

Dalmannkai (photo: LBE&FLUT, Hafencity Hamburg GmbH)

(photo: atelier GROENBLAUW, Madeleine d'Ersu)

Magdeburger Hafen (photo: HafenCity Hamburg GmbH)

West part of the harbour (photo: Fotofrizz, HafenCity Hamburg GmbH)

buildings. The bases of most buildings are used as parking garages. The advantage is that this renders ground-level parking unnecessary and that a relatively large proportion of the land can be issued. The raised infrastructure, over which the district can be evacuated safely and quickly even in the case of high water, was funded by the Hamburg municipal authorities. [HafenCity Hamburg, 2011]

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