Rotterdam

Climate Change Adaptation Strategy

ROTTERDAM.**CLIMATE**.INITIATIVE
Climate Proof

Foreword

Rotterdam is a thriving world port city. Our city has a long tradition of continually adapting to new circumstances and anticipating and benefitting from economic and social change. The climate too is changing and will most certainly have an impact on the delta city of Rotterdam. Climate change adaptation is essential if Rotterdam is to be able to cope with these effects. Taking this into account now will provide a whole range of opportunities for our city.

Many businesses in the region are active in the hydraulic engineering sector, with Rotterdam accounting for 17% of the total Netherlands' production. Climate change adaptation provides unique opportunities for growth. Developing smart solutions for the city will not only make the city climate proof but will also make it a more attractive place in which to live and work. Rotterdam is already seen as an international role model by many other cities around the world.

The growth of Rotterdam has always been driven by visionary foresight - from the Oude Haven and the Nieuwe Waterweg to the Tweede Maasvlakte, from the dam in the Rotte to the delta metropolis of the Netherlands. Continuing in this tradition, the Rotterdam Climate Change Adaptation Strategy has been developed with the aim of making Rotterdam climate proof by 2025. By climate proof we mean:

- by 2025 measures will have already been taken to ensure that every specific region is minimally disrupted by, and maximally benefits from, climate change both then and throughout the following decades
- structurally taking into account the long-term foreseeable climate change in all spatial development of Rotterdam, while allowing for any associated uncertainties

We will only be able to achieve this through the cooperation and commitment of all parties working in and for the city. The City of Rotterdam, inhabitants, businesses, property owners and other government institutions must all contribute according to their own responsibilities, aims and ideas. The Rotterdam Climate Change Adaptation Strategy sets a course that will lead to a climate-proof city and provides insight into the opportunities that climate change presents.

Doing nothing is not an option. The proper functioning of the city is much too important to be left to chance. Rotterdam is and will remain a safe, attractive, lively and economically strong city. We are convinced that over the coming decades, by following in the footsteps of our ancestors, we will be able to achieve these aims.

Ahmed Aboutaleb
Mayor

Alexandra van Huffelen
City Councillor for sustainability, inner city and public space

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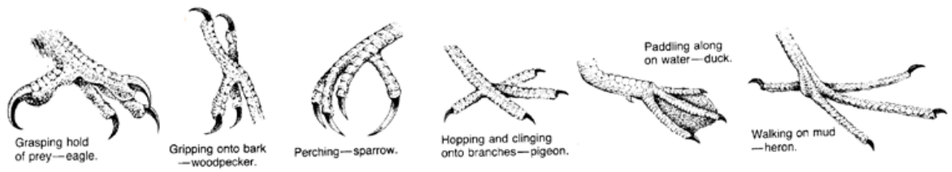
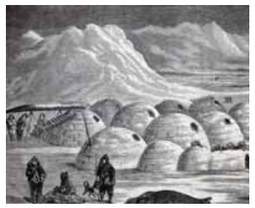
Biological adaptation



In the field of biology, adaptations are those changes to the structure or behaviour of an organism that improve its chances of survival or of successfully raising offspring.

Climate change adaptation



Adaptation to climate change is the process whereby society reduces its vulnerability to climate change or whereby it profits from the opportunities provided by a changing climate.

Summary

The Rotterdam Climate Change Adaptation Strategy sets the course that will enable the city to adapt to the changing climate. The goal is to create a climate-proof city for all the people of Rotterdam, both now and for future generations - a city that is both attractive and economically prosperous.

Rotterdam and the changing climate

What will be the consequences of global climate change for Rotterdam? What must we do to ensure that our city remains climate proof both now and in the future? With which parties must we cooperate, how can the people of Rotterdam play their part and how are we going to tackle the situation? Can climate change adaptation strengthen Rotterdam's social and economic aims and contribute to creating an attractive environment? The Rotterdam Climate Change Adaptation Strategy provides answers to these questions.

Our climate is changing. Predictions indicate that we will experience more extreme weather conditions, such as heavier rainstorms, longer periods of drought and more heat waves, as well as higher water levels in the river Meuse. Since Rotterdam is a delta city, it is especially vulnerable to these consequences of climate change.

Fortunately, throughout recent centuries, Rotterdam has already taken many measures. An ingenious and robust system currently keeps the city and its port safe and dry, making Rotterdam one of the safest delta cities in the world. In spite of this, the city is already being disrupted and damaged by, for example, extreme rainfall. In the face of these uncertain consequences of a changing climate, it is essential that Rotterdam continues to adapt. Doing nothing is not an option.

While the delta has brought Rotterdam its fair share of problems, it has also brought much more in the way of benefits. Thanks to the foresight of the people of Rotterdam such as Rose and Caland, the city has been able to evolve into an attractive and dynamic international port. With our economy continuing to thrive and our population continuing to grow it is essential that we make our city climate proof and carry on with the tradition of smart solutions, technical innovation and urban development, both now and in the future.

In line with this tradition we have developed the Rotterdam Climate Change Adaptation Strategy. This strategy provides guidelines for creating a climate proof city, what we intend to do and how the city can maximally benefit from climate change adaptation. This is the first time that the city has been viewed from the perspective of climate change. The consequences for the functioning of the city have been thoroughly researched and suitable measures proposed. Furthermore, this strategy intrinsically links climate change adaptation to the goals of creating a more attractive city and boosting the economy.

The basis of the adaptation strategy

Maintaining and strengthening the basics

In order to make our city climate proof we need to be able to continue to rely on our system of storm surge barriers and dikes, canals and lakes, outlets, sewers and pumping stations. In the future we must maintain and improve this system, which forms the robust basis of a climate proof Rotterdam.

Adaptation: making use of the entire urban environment

While being essential, the above basis alone is not enough. Adaptation involves solutions being found in all aspects of the urban environment that make it possible to alleviate the system and make it more resilient. In addition to the current system, small-scale measures will be taken in the 'arteries of the city', in public and private property. Green roofs and water squares are good examples of such small-scale solutions. We will become more in tune with the dynamics of the water and will focus more on nature when adapting Rotterdam to the changing climate.

Working together and linking in with other projects in the city

Maintaining the current robust system is and will remain the duty and responsibility of the government and local authorities. In addition to the City of Rotterdam, the water boards and national government also play a prominent role in projects such as, for example, the national Delta Programme. Furthermore, climate change adaptation requires cooperation with other parties. Adaptation concerns the urban environment, therefore inhabitants, businesses, universities and colleges and interest groups can all participate and actively contribute to making Rotterdam climate proof. The role of the City of Rotterdam is to provide a framework and to facilitate and stimulate. A good example is the 'Green Team' initiative 'Paving out, Plants in' in which the people of Rotterdam are encouraged to make their gardens greener.

We still have enough time to adjust to the changing climate. This means that it is possible to link the adaptive measures to other spatial development projects in the city and to intelligently combine them with existing management and maintenance programmes. This is known as 'moving to the rhythm of the city'. Linking in with other projects requires intensive cooperation with other partners who are active in the city. The City of Rotterdam will actively discuss climate proof approaches with the initiators of all new and existing projects. The emphasis is on joint responsibilities and shared aims for climate-proof urban development.

Added value for the environment, society, economy and ecology

Climate change adaptation provides a multitude of opportunities to strengthen the economy of the city and the port, to improve the living environment of neighbourhoods and districts, to increase biodiversity in the city and to encourage the people of Rotterdam to become involved and actively participate in society. Incorporating more green into the city will make the city less vulnerable to extreme rainfall, drought and heat stress. This 'green adaptation' will simultaneously make our surroundings more attractive, become the motor for green growth and will inspire the people of Rotterdam to actively participate. Businesses will benefit from the increasing interest in climate change adaptation, which at present accounts for 3,600 jobs in the region. In the Rotterdam region the many businesses in the maritime, hydraulic engineering and delta technology sectors all have excellent growth prospects. Climate change adaptation contributes to the city's goals in physical, economic and social terms and the Rotterdam Climate Change Adaptation Strategy is in line with the targets expressed in the Rotterdam implementation strategy ('Uitvoeringsstrategie Rotterdam').

Climate *adaptive* measures in the city

Research carried out in the context of the climate change adaptation programme Rotterdam Climate Proof (RCP), the national research programme Knowledge for Climate and the national Delta Programme has provided insight into the vulnerability of the city, the threats to the city's functioning and the specific work that must be carried out to create a climate proof Rotterdam. Climate adaptive measures in the city contribute to creating an attractive, lively and healthy city. This requires precise, area-specific spatial design and multi-functional usage.

The principal priority in outer-dike Rotterdam is multi-layered flood protection based on adaptive construction and design. Examples include 'flood-proof' buildings, construction of flood-proof public areas, floating communities and 'building with nature'. Special attention is paid to the port and essential infrastructure, which are well protected from flooding. The protection of inner-dike Rotterdam, however, focuses on prevention. In cooperation with the various parties, the storm surge barriers will be optimised and where necessary the dikes reinforced to create multi-functional dikes that are seamlessly incorporated into the city, for example as recreational routes, natural embankments or combined with area development.

Within the dikes, the 'sponge function' of the city will be restored by implementing measures to capture and store rainwater where it falls and to delay drainage. These measures include green roofs and façades, less paving and more flora in the public streets and neighbourhoods, water squares and infiltration zones as part of the infrastructure. These measures will be especially effective in highly populated, built-up areas with little open space. In those parts of the city where there is more space, robust measures such as increasing the water storage capacity of canals and lakes and constructing green-blue corridors will significantly contribute to making the city climate proof. This green-blue adaptation of the city is a 'no regret' measure that will not only play a part in making the city climate-proof but will also make the city a more attractive and pleasant place in which to live.

Getting started

This strategy outlines the course to be taken. The Rotterdam implementation approach, which has yet to be drawn up, indicates what the priorities are, which links will be made with the plans and projects in the city and the timeframe within which actions will be carried out. Core aspects of 'how' the implementation will be carried out include joining in with existing planned projects, linking in with specific area development, creating added value and working together. All parties working in and for this city will be involved in drawing up this implementation approach, which will be based on clear agreements and shared ambitions. By setting up pilots and example projects Rotterdam will continue to lead the way as an innovative and climate proof delta city.

1

Introduction

In 2008, the City Council of Rotterdam ratified the Rotterdam Climate Proof programme. This part of the Rotterdam Climate Initiative consists of three main activities: development of knowledge, implementation of climate change adaptation measures and presenting Rotterdam internationally as an innovative delta city. Devising an adaptation strategy is a vital step in the process of creating a climate proof Rotterdam.

Mitigation and adaptation

In the context of the sustainable development of Rotterdam, the City of Rotterdam is working together with its partners to implement mitigating measures to reduce CO2-emissions. However, these efforts will not prevent the consequences of a changing climate from becoming apparent throughout the world and in Rotterdam in particular. We therefore need to gain an insight into what effects climate change will have on the city and what we can do about it. Which strategic decisions must be taken to ensure that Rotterdam becomes climate proof?

The Rotterdam Climate Change Adaptation Strategy outlines the course for a climate proof city so that by 2025 Rotterdam will be well-prepared for the consequences of climate change, while at the same time reaping maximum benefits. If the situation is tackled effectively, adapting the city to climate change will also make it more attractive and economically and socially stronger.

A solid foundation

The Rotterdam Climate Change Adaptation Strategy is based on research that has been carried out within the Knowledge for Climate and the national Delta Programmes. Both programmes will be completed in 2015 but the development of knowledge concerning climate change will of course continue unabated. One thing is certain: climate change is a slow process and its consequences will only gradually become apparent. Adapting the city to this change will take time, which is why outlining the course for a climate proof Rotterdam in 2025 is a priority issue today.

Research and innovative projects will continue to be necessary. However, the focus will shift to embedding climate change adaptation into existing work, development and planning processes being carried out by the City of Rotterdam and the partners working in the city. For this reason the topic of climate change adaptation will remain on the agenda for discussions with our partners and we will continue to make concrete agreements about working together towards a climate proof Rotterdam.

The Rotterdam Climate Change Adaptation Strategy describes and depicts the main features of the strategy for a climate proof Rotterdam. Separate reports covering themes such as flood protection, urban water system, urban climate and accessibility & infrastructure, provide an in-depth basis and justification for this strategy as well as describing relevant scientific and technical research.

A unique approach

The Rotterdam Climate Change Adaptation Strategy is unique. There are four reasons for this. Firstly, it is the first time that Rotterdam has ever been viewed from the perspective of climate change and that the consequences for all the important aspects of the functioning of the city have been detailed. This has led to the creation of a more complete and cohesive picture of the task ahead and of the types of measures required in the different parts of the city.

The second reason is that the measures in the Rotterdam Climate Change Adaptation Strategy are the result of specific research carried out by external parties, by the Delta Programme and by the national research programme Knowledge for Climate. Thirdly, right from the start, the RCP-programme (Rotterdam Climate Proof) focussed on gaining knowledge and implementing climate change adaptation measures that would result in ‘spin-offs’ for Rotterdam. The aim is to contribute to creating a lively and attractive city with a strong economy and an involved society. Finally, in an international context, the Rotterdam approach to climate change adaptation is regarded as exceptional and has greatly improved the image of Rotterdam as an ambitious delta city.

Guidelines

The people of Rotterdam have been adapting their city to the ever-changing delta for centuries. If the city is to be made climate proof, we will once again have to roll up our sleeves and set to work. Rotterdam has already made a start, with adaptive measures such as the construction of green roofs and water squares now under way. However, that is not enough. This Rotterdam Climate Change Adaptation Strategy provides a framework for all parties working in and for the city that will lead to a climate-proof Rotterdam. Agreements with initiators regarding projects and activities will focus on climate proof urban development. This is one of the priorities of the City of Rotterdam.

2

Rotterdam and the climate

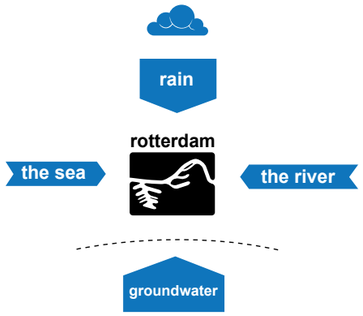
There is no denying it: the climate is changing. Although climate change is not a recent phenomenon, global warming will cause the rate of change to accelerate.

We cannot predict the exact speed and extent of the changes. The effects and consequences of climate change on urban development are similarly uncertain. However, we simply cannot wait until we are 100% certain.

The potential consequences could be catastrophic, especially in delta cities. Furthermore opportunities are there for the taking: to improve the attractiveness of our environment, to work together and to strengthen the economy.

2.1
The climate is changing

Global warming is changing our climate. What consequences will this change have for the Netherlands and for Rotterdam in particular? It is predicted that the Netherlands will be subject to increasingly milder winters and hotter summers. On average our winters will become wetter and the rainfall increasingly extreme. During summers in particular, the frequency and severity of the rainfall will increase, although the total number of rainy summer days will decrease. Meteorologists predict that extreme weather conditions will become ever more likely, for example in the form of heat waves. Moreover (and this is especially significant to Rotterdam) sea levels will continue to rise, at least for the time being.



The consequences of climate change that will affect Rotterdam:


Rise in sea levels


More intensive rainfall


Lower river discharges


Higher river discharges

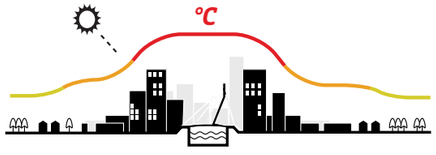

Longer hot periods


Longer dry periods

The water in Rotterdam comes from four sides:

- from the sea
- from the river
- from above (precipitation)
- from below (groundwater)

For this reason Rotterdam, like many other delta cities, is vulnerable to the consequences of climate change. The rise in sea levels and increase in water levels directly influence the city's flood risks. During periods of extreme rainfall, it is very difficult for the water to drain away. Drought manifests itself for example by low water tables and low river levels. Furthermore, the negative effects of a heat wave are more apparent in a highly populated, compact city such as Rotterdam than in the surrounding countryside.



2.2
Rotterdam is vulnerable to climate change

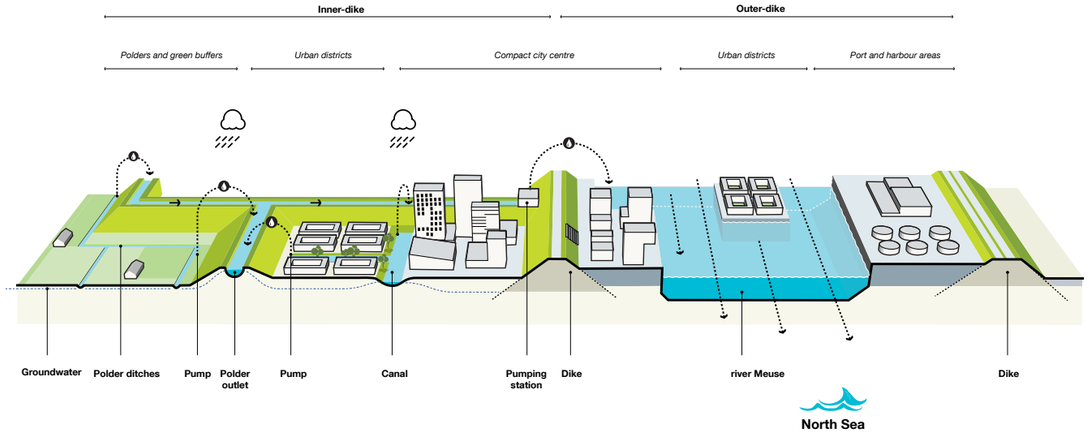
Rotterdam is a delta city

Climate change is taking place in a changing world. The global population has grown exponentially over recent centuries. More than half of all people now live in towns and cities, most of which, due to their population density and economic value, are vulnerable to climate change. In particular, the densely populated and economically prosperous cities in the large river deltas that open out into the sea will be directly affected by the consequences of climate change.

Rotterdam is one such vulnerable delta city. Rotterdam is located in the delta of the rivers Rhine and Meuse. Via the Nieuwe Waterweg (New Waterway), the city has open links to the sea and is influenced by the tide. Much of Rotterdam, including the main port, lies in outer-dike areas. Within the dikes, the inner-dike city of Rotterdam is mostly well below sea level, with the lowest point being as much as 6.67 metres below NAP in the Alexanderpolder district (NAP the National Amsterdam Level, is an agreed ordnance measurement that is almost equal to mean sea level). If the region were to flood, the consequences would be disastrous. Pumping stations run by the water boards regulate the water levels and keep the polder dry.

An ingenious but vulnerable system

An ingenious system keeps our city safe and dry (and sometimes wet). The lower-lying polders are well-protected from high water levels in the river Meuse by robust dikes and barriers such as the Maeslant storm surge barrier. The city keeps the water levels in the polders stable by means of a system of canals and lakes, outlets and waterways, sewers and pumping stations. The outer-dike city districts and harbours are generally constructed on higher ground and are therefore inherently safer. The system is truly a masterpiece of Dutch technical engineering. However, it is also a complex, inflexible system. If anything should go wrong, the damage to people and property in the lower-lying and densely populated city would be catastrophic.



Rotterdam has its affairs in order

Rotterdam's tradition of adapting to the natural circumstances in the delta dates way back to the very origins of the city. Living with the threat of water is in our genes. While Rotterdam's position at the river estuary has presented many problems over the years, it has also brought far more in the way of prosperity to the city.

Rotterdam has been protecting itself from the threat of the water from the rivers and especially from the sea for centuries. The dams, dikes and land reclamation have brought the dangers and risk of flooding under control and the wetlands of the inner-dike city have been drained. This has made Rotterdam – although still vulnerable – one of the safest delta cities in the world. Rotterdam has its affairs in order.

1270
Dam in the Rotte

The dam separated fresh water from salt water, provided protection and gave the city its name. Rotterdam's growth as both a commercial city and a port stemmed from this dam, which still forms the heart of the city today.

1854
Canal plan

Rose's canal plan for water management in the polder city improved the water quality and the water level management, and at the same time made the city more attractive. Rose introduced water as an urban quality in Rotterdam. To this day the canals are attractive assets to the city.

1953-2010
Delta works

Following the disastrous floods of 1953, the Delta works were constructed to permanently protect our country from the threat of water, so that we would never again have to suffer such a catastrophe. The Delta works epitomise Holland's decisiveness and ingenuity in its fight against the adverse effects of water. The culmination of the Delta works, the Maeslant storm surge barrier, protects Rotterdam and keeps the connection between the port and the sea open.

Flooding in Noordereiland

Water quality

Excess stormwater on the streets

Dike subsidence

Inundated cellars

Heat and bridges

The situation now

Although the system that is keeping Rotterdam safe and dry is robust and well-maintained, in extreme situations the city is already noticing the consequences of very high water levels, heavy downpours and long periods of drought or high temperatures. Whereas in the past these weather conditions occurred infrequently, over recent decades they have become more common. Such events show how vulnerable the city is to the changing climate.

In the city itself, the problems manifest themselves for example in the form of flooding along the quays in the older outer-dike parts of the city, flooding in the streets and inundated cellars during periods of extreme rainfall. When temperatures are very hot some bridges do not close properly and the water quality in the canals and lakes deteriorates. Fortunately the consequences so far have not been too severe. They have merely been inconvenient and caused minor damage and mild disruption to the city.

However, faced with the uncertain consequences of the changing climate, it is essential that Rotterdam makes itself less vulnerable. Rotterdam must continue adapting to changes in the delta.

Doing nothing is not an option!

2.3
Rotterdam is changing

A long tradition of urban development in the delta

It is not only the climate that is changing. The city of Rotterdam itself is also continually changing and evolving, as you would expect of a delta port. Throughout recent centuries, Rotterdam's tradition of 'protecting itself against and living with water' has shaped the development of the city. The strategic location of Rotterdam in the Dutch Delta has brought prosperity and growth.

The city developed around the dam in the river Rotte, along and behind the high sea dikes and around the historic outer-dike harbours. In the 19th century, constructions such as Rose's canals formed the context for urban development. The port developed rapidly, partially due to the construction of the Nieuwe Waterweg (New Waterway), and the city grew along with it. In the 20th century, as the port slowly moved further out towards the sea, the abandoned old harbours such as Kop van Zuid became part of the city. In this way Rotterdam has evolved into a modern and dynamic international port.

The Willemskade with a view of the Erasmus Bridge and the Wilhelmina Pier

Rotterdam is continuing to change

Rotterdam is forever in motion. The city is continually adapting to its changing population and social-economic circumstances. Rotterdam is a densely populated city and is still growing. For the foreseeable future, it is expected that the number of inhabitants in the city will increase. The good news is that the people of Rotterdam are becoming more and more satisfied with life in their city and the economy is continuing to grow. With its port and industrial complex Rotterdam is internationally oriented and the city is home to a number of strong, promising economic clusters such as maritime-professional services and delta technology.

Binnenrotte

Nesselande

Maasvlakte 2

Boompjes

RDM campus

In a physical sense Rotterdam will continue to change. The emphasis over the coming period will mainly be on compacting and gradually transforming the existing city rather than on growth outwards, as was the case in the 20th century. In particular, the inner city, Stadshavens and South Rotterdam are priorities for urban development. As residential and recreational amenities on the waterfront are highly desirable, the prospects for waterfront development in Rotterdam are extremely promising. The port is also continuing to develop and modernise. New areas such as the Tweede Maasvlakte are being constructed and the focus is shifting to sustainable and efficient process chains.

Over recent decades the population of Rotterdam and the economy of the city, in both inner- and outer-dike regions, have grown considerably. As a result, there is a far greater likelihood of casualties, damage and economic losses if, for example, flooding were to occur. Adequate long-lasting protection from the consequences of climate change is therefore essential to the city of Rotterdam and its inhabitants.

3

The Rotterdam Climate Change Adaptation Strategy

"Rotterdam is the city of the future. A city for everyone. The city continually provides new opportunities for the many people of Rotterdam, some of whom are new to the city while others have been associated with it for generations. Together, we look to the future and seize opportunities with both hands. We in Rotterdam are proud of our city and its port, active and involved as we are in our neighbourhoods and districts."
(from the City Council Agreement 2010-2014)

Trial closure of the Maeslant storm surge barrier (such as shown here in 2010) attracts many spectators.

3.1
Rotterdam's ambitions

The Rotterdam Climate Change Adaptation Strategy outlines the course that will enable Rotterdam to adapt to climate change and discusses the consequences for the city. The primary goal is to create a climate proof city for the people of Rotterdam now and for future generations. However, Rotterdam also hopes to take advantage of the opportunities presented by climate change adaptation to strengthen its economy, to improve the environment, to enhance the natural resources and to increase the involvement of the inhabitants of Rotterdam with their city. As such, the Rotterdam Climate Change Adaptation Strategy is in line with the city's aims as presented in the 'Stadsvisie Rotterdam' (Rotterdam urban vision, spatial development strategy) and with the implementation as set out in the Rotterdam implementation strategy.

The world is changing and Rotterdam needs to change with it. The Rotterdam implementation strategy discusses the four themes on which the city intends to focus: the development of talent, the strength of a caring society, an attractive (inner) city and a strong economy.

The strategy requires us all to work together. By doing so we can broaden our scope and set ourselves more ambitious targets. With these joint efforts we are working towards the future and ensuring that Rotterdam remains an attractive, healthy, lively and economically strong city.

Making Rotterdam climate proof by 2025

Rotterdam aims to be 100% climate proof by 2025. This is the goal expressed in the city's climate change adaptation programme. This means that by 2025 measures will already have been taken in Rotterdam to ensure that each specific area is minimally disrupted by and maximally benefits from climate change both then and throughout the following decades. Furthermore, all spatial development in Rotterdam will structurally take into account the long-term foreseeable climate change while allowing for uncertain eventualities. This goal of a climate proof Rotterdam is in line with the Rotterdam implementation strategy and is also a prerequisite for achieving the city's more wide-reaching aims.

Rotterdam Municipal Executive Committee

3.2
The primary objectives for climate change adaptation

The city and its inhabitants are protected from the rivers and the sea

It is vital that Rotterdam and its inhabitants remain protected from flooding and that investors retain their confidence in the city and region.

The city and its inhabitants experience minimal disruption from too much or too little rainfall

Rotterdam needs to be able to cope with extreme weather situations such as prolonged downpours, heat waves and periods of drought. To this end, we are already working together with the partners of the Rotterdam water plan and will continue to do so.

The Port of Rotterdam remains safe and accessible

Rotterdam needs to remain accessible to people, goods and services. It is crucial that the essential urban (public utilities) networks are robust and that weather conditions, no matter how extreme, do not lead to uncontrollable situations.

The inhabitants of Rotterdam are aware of the effects of climate change and know what they themselves can do

Inhabitants and businesses in Rotterdam need to be aware of the consequences of climate change, to become conscious of their own responsibilities and to know what action they themselves can take. The City of Rotterdam provides the framework within which they can assume their own responsibilities.

Climate change adaptation contributes to a comfortable, pleasant and attractive city in which to live and work

Rotterdam must continue to be a city in which it is pleasant to live and work and where climate change does not adversely affect the health and welfare of its inhabitants. The measures used to guarantee this will directly contribute to making the city more attractive and to improving the environment.

Climate change adaptation strengthens the economy of Rotterdam and its image

Making the city climate proof will benefit the economy of Rotterdam. Climate change adaptation will create new, economic impulses in the city and strengthen the international image of Rotterdam as an ambitious and progressive delta city. In this way Rotterdam will confirm its ability to take charge of a situation and promote itself as a role model for other cities.

3.3
The Rotterdam Climate Change Adaptation Strategy

Rotterdam's location in the delta, dominated as it is by the great rivers and the sea in particular, makes the city vulnerable to the effects of climate change. Furthermore, the region is densely populated and has considerable economic value. When these aspects are combined, it becomes clear that a strategy to make Rotterdam less vulnerable to the effects of climate change is essential.

As has already been mentioned, Rotterdam has the situation under control. We can rely on a robust system for the supply of urban water and for flood protection - a system that is both durable and resilient. However, we cannot afford to rest on our laurels. Inaction will eventually lead to greater risks and an increase in (repairable) damage and expensive adaptations.

The good news is that the climate-related tasks facing the city are not acutely critical. In other words Rotterdam has enough time to adjust to and to evolve with the 'delta dynamics'. We will be able to adapt to the unpredictable effects of a changing climate in a changing city.

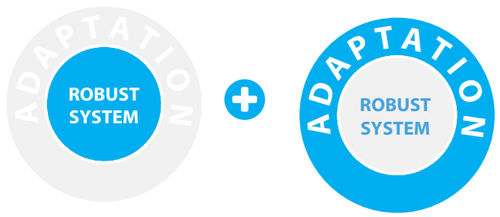
In the 20th century the emphasis was on combating the threat posed by water. In order to make the country, and Rotterdam in particular, safe and dry, the emphasis was on protection, and above all on prevention. The Delta works epitomise such an approach.

In Rotterdam, society can still rely on this protection today. However, patterns are changing. Climate change and social and economic growth mean that the emphasis is shifting towards an adaptive approach. Rather than just fighting against it, one way of coping is to be prepared to live with the effects of climate change.

The basis of the strategy

Robust system

When it comes to adapting the city to cope with the effects of climate change, Rotterdam can continue to rely on the current robust system, which consists of storm surge barriers and dikes, of canals and lakes, outlets, sewers and pumping stations. We will continue to keep this system in good shape, to maintain it and to improve it where necessary. This system forms the basis for a climate proof Rotterdam.

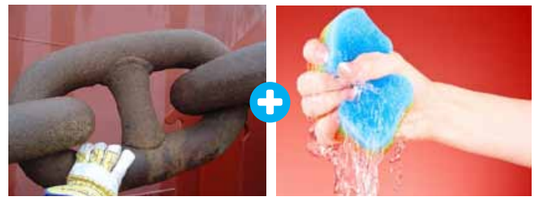


Adaptation

However, this basic robust system alone is not enough. Adaptation means that we must also focus on adapting the city to make it less vulnerable and more resilient. Throughout all aspects of the urban environment, solutions must be found to alleviate the system and make it more flexible. Adaptation also involves focusing on adapting the city to move in tune with the dynamics of the delta and its rising and falling water levels. In addition to the immense technical construction works and barriers, we need to devise small-scale solutions - the large-scale application of small-scale measures in the heart of the city. We are gradually taking small 'no-regret' steps. We do not intend to rely solely on technical systems, but will also make use of nature's own potential to adapt Rotterdam to the changing climate. There is plenty of time, so we can create opportunities for experimentation and innovation. Successful developments will be directly implemented in Rotterdam.

Guiding principles

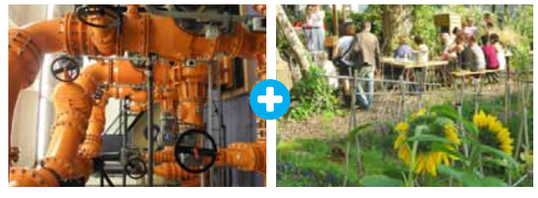
This adaptive approach is based on the following guiding principles:



Robust and resilient

Protection and moving in tune

Delta works and small-scale projects



Technology and nature

Working together and linking in with other projects

Working together

Adapting to climate change is not a task for the City of Rotterdam alone. Maintaining the technical system of storm surge barriers, robust dikes, sewers and pumping stations is of course the responsibility of national government, the water boards and the City of Rotterdam, and will remain so. The people of Rotterdam will continue to be able to rely on this.

However, climate change adaptation involves much more. To become resilient and flexible, extra space must be created for adaptive measures in both public and private areas of the city. This means that climate change adaptation has become the responsibility of many other parties, and not just the local authorities. The authorities must work together with new partners and stakeholders.

In the past, traditional joint ventures have included the water boards, the province and national government working together in the fields of flood protection, urban water supply and urban development. For climate change adaptation in the city, the inhabitants and businesses, corporations and network providers, educational establishments and societal organisations (NGO) will all have to become involved, each in their own way.

Providing Information

Few of the inhabitants of Rotterdam are currently sufficiently aware of the risks of living in the low-lying polders or of the protection that the dikes provide. It is essential that the regional authorities educate the citizens and businesses and provide information about the risks of climate change. The digital environment has an ever-increasing range of communication tools, for example the apps for smart phones and interactive communication via social media. A good example of such a tool is the 'Climate Game' that was developed within the framework of the Rotterdam Climate Change Adaptation Strategy. In an active and accessible digital environment the effects of climate change can be brought to life and it is possible to play an active role in the adaptation of Rotterdam and to learn more about the various interests involved.

Taking action

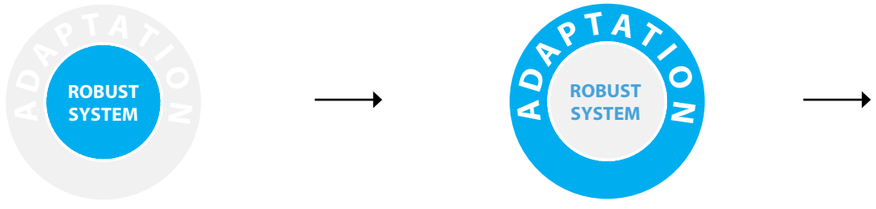
Thanks to good, targeted information, citizens and businesses are becoming more aware of the effects of climate change. This improved awareness has resulted in measures being actively supported and in particular in positive individual actions being taken. Small-scale adaptive measures throughout the 'veins' of the city provide opportunities for active participation and lead to broader cooperation between the regional authorities and other parties. In this way inhabitants, collectives and corporations, organisations and businesses can all contribute to a climate proof city. Green roofs are a good example of this. Climate change adaptation is both top-down and bottom-up.

Linking in with other activities

The challenge is to link climate change adaptation measures to other urban programmes and projects such as regular management and maintenance of the roads and public areas. Not only to large-scale urban area development plans, but also, and above all, to current projects taking place in the city. Only then can the city become climate-proof through and through. In these unstable economic times, less money than ever before is available for implementing ambitious plans. By working together with other parties that are investing in Rotterdam, it is possible to link in with area development, network maintenance or the transformation of real estate. The small-scale initiatives carried out by citizens and businesses also provide opportunities for linking in.

Setting up frameworks, facilitating and initiating

In the process of working together towards a climate-proof Rotterdam, the regional authorities have a new role to play. In addition to their customary role as 'guardians of public affairs' they need to become active facilitators and initiators, as well as supporters and driving forces behind initiatives in the Rotterdam community. This will create conditions whereby inhabitants and businesses can independently contribute to the city's climate proof future. Citizens and businesses alike will play an active and positive role as 'producers'. People of Rotterdam have already accepted the challenge, as can be seen by the many entries to the 'city initiatives' programme. The City of Rotterdam will discuss climate proof approaches with initiators of all development projects and activities. The emphasis is on joint responsibilities and shared aims for climate proof urban development.



The city benefits from climate change adaptation

Rotterdam aims to profit from climate change adaptation and to create added value

Working together towards a climate proof Rotterdam is not enough. The city is aiming to capitalize on the opportunities provided by climate change adaptation. Rotterdam's ultimate objective is to adapt to climate change while at the same time creating added value for the city.

Climate change adaptation provides a multitude of opportunities for boosting the economy of the city and port, for improving the environment in neighbourhoods and districts, for increasing the biodiversity in the city and 'last but not least' for encouraging the inhabitants of Rotterdam to actively participate in the community. In this way climate change adaptation will contribute to achieving the aims that the city has in physical, economic and social terms and the Rotterdam Climate Change Adaptation Strategy is in line with the targets expressed in the Rotterdam implementation strategy.

An attractive city

Added value for the environment

Climate change adaptation provides opportunities for reinforcing Rotterdam's image as an attractive city and for improving the environment. Making the city climate proof can easily be combined with making it even more attractive. We can link in with the characteristics of the delta, the river and the harbours, the quays and the parks along the Meuse, and we can also combine it with the attractions of the dikes, canals, parks and lakes in the city itself.

Climate change adaptation is based on integrating and improving the whole urban environment. Dikes are well integrated in the city and are multi-functional. Making space for water storage in the city can create new and attractive public areas, for example water squares. Waterproof designs may include extending the green-blue network while simultaneously densifying the city. On a smaller scale, homes and gardens can be used to create added value for the environment for example via the many initiatives for removing paving stones and replacing them with plants.

The benefits to Rotterdam can already be seen in many parts of the city. A good example is the Eendragtspolder district, where extra water storage has been intelligently combined with a rowing course and other sport facilities. In Nesselande, the surface of the Zevenhuizerplas Lake has been doubled and it now forms the centrepiece of an attractive area in which to live and spend leisure time. In the Rijnhaven the floating pavilion marks the start of the development of 'floating communities', while at the Bellamyplein water square, the water storage has been used to create an attractive public area in the heart of the neighbourhood. Following on from the ideals expressed in Rotterdam by the 19th century urban architect W.N. Rose: a climate proof city is a beautiful and attractive (water) city.

The people of Rotterdam benefit from adaptation

Added value for the community

Anticipating the effects of climate change provides a multitude of opportunities to strengthen and inspire the community of Rotterdam. Increasing the amount of natural vegetation and flora right in the heart of the city, for example, enables the people of Rotterdam to play a direct and active role and to work together. Climate change adaptation presents opportunities for individuals to implement their own initiatives, frequently in their own street or neighbourhood. This active participation not only improves relationships between people but also encourages mutual involvement with the environment.

There are already many green urban initiatives in progress, each in their own way encouraging people to play an active part in making the city more attractive and to improve the environment. Examples include urban farms on (temporarily) unused plots in the city, collective gardens and the construction of wilderness playgrounds and child-friendly districts.

The indirect benefits for society include the creation of new jobs for the people of Rotterdam in the 'green-blue' economy and delta technology sectors. These sectors are increasingly becoming the driving force behind economic growth and provide job opportunities for both the highly educated and the unskilled alike.

Finally, specific emphasis on delta technology and adaptation in schools and other educational programmes provide ideal opportunities for the young people of Rotterdam. Opportunities arise at all levels from practical training to higher technical education, for example on the RDM campus. Climate change adaptation is the development of talent and knowledge.

Climate change adaptation pays off

Added value for the economy

Its economically favourable location in the delta has enabled Rotterdam to evolve into a modern and bustling international port. Investor confidence is essential to the main port of Rotterdam. In order to stay ahead of the international competition it is vital that the business district and the essential infrastructure are protected from flooding and other negative climate change effects. The safety and security of the region and port must be guaranteed, both now and in the future.

The Rijnmond-Drechtsteden region, and Rotterdam in particular, are home to many businesses that operate internationally in the maritime service, hydraulic engineering and delta technology sectors. It is estimated that 3600 jobs in the construction industry, in consultancy offices and in ICT are currently directly related to climate change adaptation. Rotterdam can work to further improve this favourable situation. The city is focusing on 'green growth' as a promising and sustainable development strategy for the economy. Climate change adaptation presents ample economic perspectives. Investing in climate adaption now will pay off in the long-term: a wide-ranging European study has indicated that the cost of implementing adaptation measures is on average only about seven per cent of the cost of repairing the flood damage that may otherwise occur. This is a clear case of prevention being better than cure.

Rotterdam is a showcase and testing ground for innovative adaptive measures and hopes to remain so in the future. In line with the city's motto 'Actions, not words', the first results are already noticeable in the city and are helping to enhance Rotterdam's image. This will encourage more new businesses to invest in the Rotterdam region and to relocate here.

Added value also includes exporting the 'knowhow' that has been amassed in Rotterdam by businesses, universities and colleges and the regional authorities. Rotterdam hopes to share this climate change adaptation knowledge with other delta cities via networks such as C40 and Connecting Delta Cities. Rotterdam is demonstrating its leadership skills by devising, for example, an adaptation strategy for Ho Chi Minh City in Vietnam. Already, dozens of international delegations visit Rotterdam each year to learn about the city's approach to climate change.

There is another important reason that proves that climate change adaptation does in fact pay off. Step-by-step investment in making the city, buildings and public areas climate proof is frequently cost effective in the long-term and is therefore advisable. At times when the economy is struggling, the rate of adaptation can be tempered. Combining climate change adaptation with other investments in the city and linking in with other projects is also profitable. In this case you really do get more for your money.

Green-blue adaptation

Added value for the ecology

Climate change adaptation can easily be combined with improving the ecological quality of Rotterdam. More water and flora (making the city greener) will make the city more resilient during periods of extreme rainfall or drought. In outer-dike areas, 'building with nature' can become an alternative for solid constructions to prevent flooding during high water levels. Green banks improve the quality of the water and make it easier to enjoy it.

Adaptation can lead to increased biodiversity in Rotterdam and can stimulate ecological added value for the city. This can be seen throughout the city, from green roofs and wilderness school playgrounds to natural riverbanks and pleasant green surrounding countryside. At the same time the city is becoming a more attractive place to live.

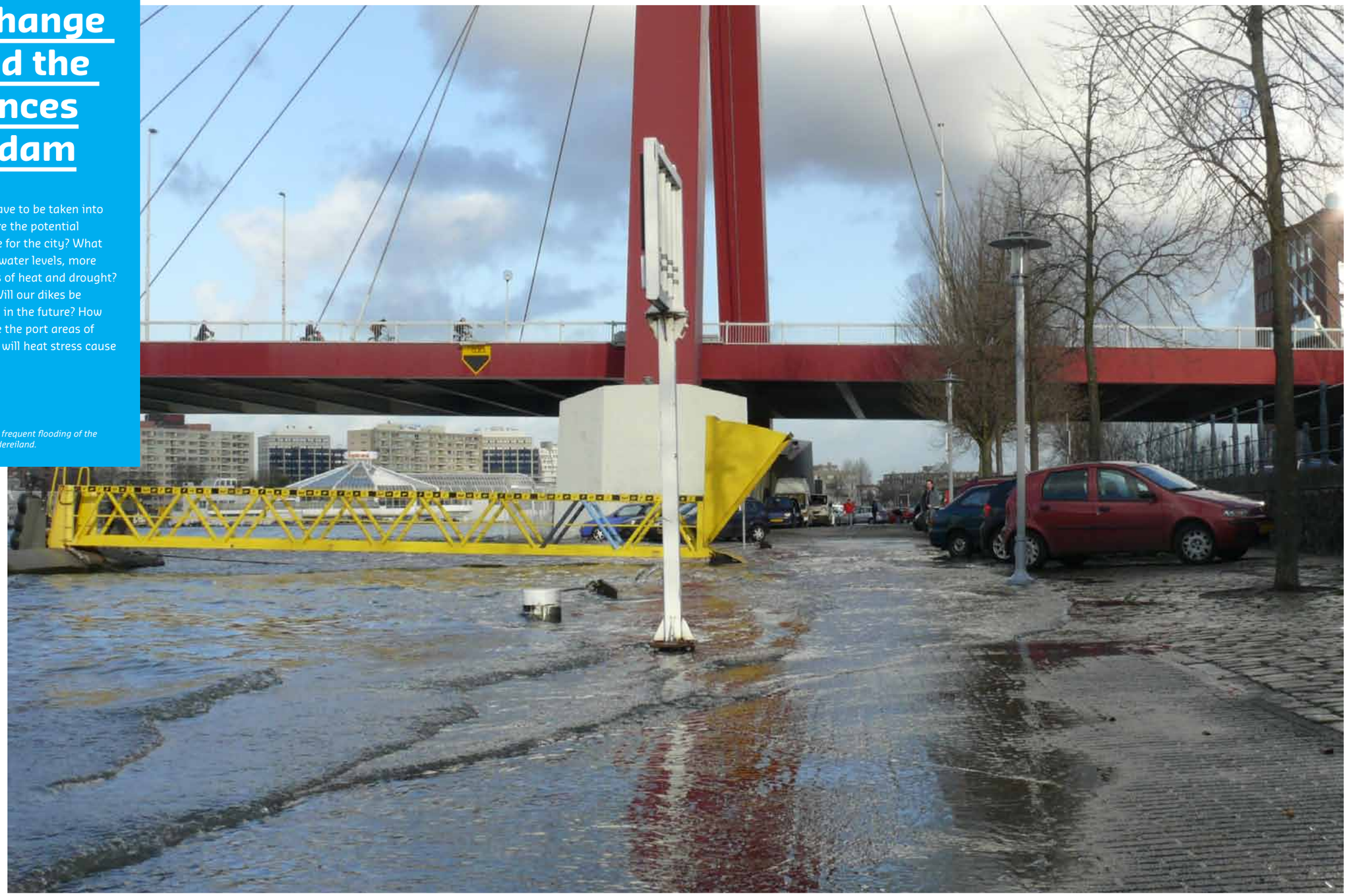
Finally, climate change adaptation presents a range of opportunities for strengthening the area-specific eco-system of the delta. The estuary ecology with its gradual transition from fresh water to salt water and from wetlands to dry land can be reincorporated in the city in the form of tidal parks and tidal nature. A good example is the Green Port by the peninsula in Rozenburg. There is also great potential for creating ecological added value in Stadshavens.

Making better use of ecological solutions and eco-system services is a win-win situation. The city becomes greener and at the same time more climate proof.

4

Climate change effects and the consequences for Rotterdam

Which climate change effects have to be taken into account by Rotterdam? What are the potential consequences of climate change for the city? What are the consequences of higher water levels, more intensive rainfall, longer periods of heat and drought? How vulnerable is Rotterdam? Will our dikes be high enough and strong enough in the future? How well-protected from flooding are the port areas of Rotterdam? And what problems will heat stress cause in the city?



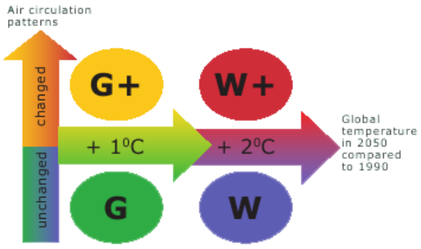
Higher sea and river levels will cause more frequent flooding of the lower-lying outer-dike areas such as Noordereiland.

4.1
Climate and delta scenarios

Climate scenarios

In the Netherlands, climate change is mainly dictated by global warming and the changing air circulation patterns in Western Europe. Based on these climatological variables, in 2006 the KNMI (Royal Meteorological Institute of the Netherlands) drew up four potential climate scenarios. These scenarios are consistent and plausible visions of the possible future climate in the Netherlands. They show how the temperature, rainfall and wind may change depending on the particular global climate change.

The four KNMI scenarios are: Moderate (G), Moderate with changing air circulation currents (G+), Warm (W) and Warm with changing air circulation currents (W+).



G	Moderate*	1°C temperature rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europe
G+	Moderate +	1°C temperature rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds
W	Warm	2°C temperature rise on earth in 2050 compared to 1990 no change in air circulation patterns in Western Europe
W+	Warm +	2°C temperature rise on earth in 2050 compared to 1990 + milder and wetter winters due to more westerly winds + warmer and drier summers due to more easterly winds

The four climate scenarios are an important aid when it comes to calculating and hypothesising on the effects of climate change. They are used for all climate research and policy-making in the Netherlands, for example in urban climate change adaptation plans and in the national Delta Programme.

The Delta Programme uses the two extreme KNMI climate scenarios (G and W+) to determine the upper and lower limits for the rise in sea level and the normative river flow at Lobith. Based on the W+ scenario, the sea level will have risen by between 35 cm and 85 cm in 2100. In this scenario the normative river flow will be 18,000 m3/s in 2100, an increase of 2,000 m3/s compared to the current situation. Based on the G scenario, in 2100 the sea level will have risen by 15 cm to 35 cm and the normative river flow will be 17,000 m3/s.

The G and W+ scenarios are frequently used when analysing flood protection measures in this country. Through complex programmes and models, the various normative high water levels can be used to identify potential dike height deficiencies and calculate the probability of flooding of the inner-dike polders and outer-dike areas.

Delta scenarios

In addition to the direct consequences of climate change, the risks to society are also affected by the social and economic changes in the Netherlands. For example an increase in the economic value of an area brings with it a greater risk of damage if flooding does occur, even if the actual likelihood of the flooding itself does not increase. An increase in the population means that there is a greater risk of people getting hurt. This can be expressed by: risk = probability x consequences

In the Delta Programme the two KNMI scenarios (G and W+) are linked to two socio-economic scenarios; one in which the population and the economy continue to grow in the very long-term and a second scenario in which the population shrinks and the economy barely grows at all. This combination has led to four delta scenarios looking ahead to 2050 and 2100. The Rotterdam Climate Change Adaptation Strategy is based on these delta scenarios.

4.2
Climate change effects

Research into climate change in Rotterdam

Within the framework of the Rotterdam Climate Proof climate change adaptation programme, the Knowledge for Climate programme has carried out extensive research into how climate change will affect Rotterdam and what the consequences will be. Within the Delta Programme considerable knowledge has also been developed concerning the Rijnmond-Drechtsteden region. In the Rotterdam Climate Change Adaptation Strategy, this knowledge is applied to describe the climate change effects, the consequences affecting Rotterdam and the risks that the city must take into account. Much of this information has been included in the newly developed Rotterdam interactive climate atlas.

Differences between the inner-dike and outer-dike areas of Rotterdam

When describing the consequences of higher sea and river levels in terms of flood risks and water safety, there is a clear distinction between the outer-dike areas and the inner-dike areas of Rotterdam. The outer-dike regions are directly exposed to the river and the sea and there are no protective dikes. This means that the outer-dike areas are much more likely to flood than the inner-dike areas. However, as the outer-dike areas are generally on much higher ground, the floods are short-lived and the flood (inundation) depth is relatively low. The responsibility for the outer-dike region primarily lies with the municipality, the inhabitants and specific parties making use of the area.

In inner-dike Rotterdam the consequences of higher sea and river levels are of a different nature. An excellent system of primary flood barriers effectively protects the lower-lying polders from flooding. It is extremely unlikely that conditions will exceed the safety standards for the dikes. For example, the probability of the dikes on the north banks collapsing is 1 in 10,000 years. However, there is always a risk of flooding. The consequences of a potential inner-dike flood would be disastrous both in terms of the number of casualties and the amount of damage caused. The national government and the water boards are primarily responsible for inner-dike flood protection.

In summary, the direct consequences for the delta city Rotterdam could include:

higher sea and river levels
- increased risk of outer-dike flooding
- more frequent closure of the Maeslant storm surge barrier
- increased risk of inner-dike flooding

more intensive rainfall
- water is less able to drain away
- increased risk of disruption and water damage

longer periods of drought
- lower water tables
- decrease in the water quality
- increased likelihood of damage to built-up areas, flora and fauna
- low river levels obstruct shipping

longer hotter periods (heat waves)
- decrease in the thermal comfort in the city
- negative effects on health and well-being
- increased likelihood of damage to flora and fauna

4.3
The consequences of higher water levels for outer-dike areas

The outer-dike areas of Rotterdam are not protected by dikes and are directly affected by the water levels of the river and by the tide. This means that they are vulnerable to the effects of high water levels caused by storm tides at sea and high river discharge.

Most of the outer-dike areas are on higher ground than the inner-dike city. During development of the city and port, the outer dike areas have always been raised in order to reduce the risk of flooding. In all new developments in outer-dike Rotterdam the risk of flooding will continue to be taken into account when determining the construction elevation. The elevation of the quaysides varies from a little less than 3 metres above NAP (+/- sea level) in the city to 5.5 metres above NAP in the Tweede Maasvlakte. The outer-dike areas rise high above the polders, which can be as low-lying as 6 metres below NAP.

The likelihood of floods in the outer-dike areas of Rotterdam is much greater than in the inner-dike areas. The outer-dike areas are protected by the Maeslant storm surge barrier. This barrier closes when water levels reach 3 metres above NAP, thereby greatly reducing the likelihood of flooding. Due to the higher elevations and the effects of the tide, floods in the outer-dike areas are usually short-lived and the flood inundation depths are limited. The risk of fatalities or large-scale social disruption is very low. However, material damage in these urbanised areas, including the largest port and industrial cluster in Europe, could be considerable. Unlike the city's inner-dike areas, the primary responsibility in outer-dike Rotterdam lies with the municipality, the inhabitants and specific parties using the area.

Increased risk of flooding

With high sea and river levels, the risk and frequency of flooding in the outer-dike areas of Rotterdam will increase, as will the flood inundation depth.

The maps on page 37 illustrate the predicted flooding of outer-dike Rotterdam in 2015 and 2100 (W+) with a probability of 1 x 1,000 years. In other words, the maps depict the flooding due to water levels that will on average occur once in every thousand years. In the scenario based on a rapid climate change (W+), with extreme rises in sea level of 85 cm, by 2100, in addition to the already vulnerable outer-dike areas in the heart of the city, such as Noordereiland, Stadshavens and some post-war harbour areas will also be more susceptible to flooding.

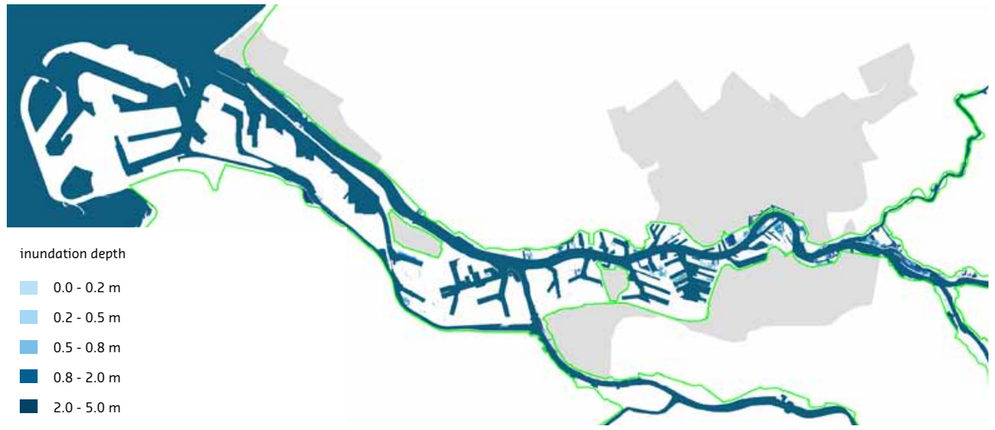
The relatively low-lying historic outer-dike areas such as the Noordereiland, the Scheepvaartkwartier, the Kop van Feijenoord and Heijplaat are the most vulnerable to the effects of high water levels. If sea levels rise by 60 cm, the frequency of flooding of these areas will increase from once every 50 years to an average of once every year. Moreover, much larger areas will be affected.

Recently developed areas such as Katendrecht, the Wilhelmina Pier, the Lloyd Pier and the Muller Pier will also suffer the consequences of higher water levels. A rise in sea level of 60 cm will increase the risk of water damage from 1 x 10,000 to 1 x 1,000. This is the probability of the areas flooding in any particular year and can be seen as a frequency. The risk of floods affecting Stadshavens (Merwe-Vierhavens), which are in the process of transformation, will also increase.

The new port areas including the Botlek, Europoort and the Maasvlakte have been constructed at such high elevations that for many years to come, far into the 21st century, the risk of flooding will remain extremely low. The main port of Rotterdam is, and will remain, one of the safest ports in the world as far as flood protection is concerned.

Map 1: Outer-dike flooding in Rotterdam in 2015 *(source: Deltares)*

with a frequency of 1 x 1,000 years



Map 2: Outer-dike flooding in Rotterdam in 2100 *(source: Deltares)*

W+ climate scenario with a frequency of 1 x 1,000 years

Consequences of flooding

An increased probability of flooding of the outer-dike areas will lead to an increasing likelihood of economic losses and social disruption. It is very unlikely that casualties will occur as a direct result of flooding of outer-dike Rotterdam. The region has a relatively high elevation and the flood water flow rates and flood depths will be limited.

However, flooding of the outer-dike areas in Rotterdam can lead to considerable damage in the affected areas. In addition to general disruption, the main effects will be damage by flood to private property as well as damage to the public areas of the city. The disruption to business activities or the temporary inaccessibility of the area will cause economic losses. Furthermore in addition to this damage, flooding can directly cause other environmental damage such as pollution resulting from the discharge of hazardous substances.

Essential infrastructure in the outer-dike areas is potentionally vulnerable. This includes power stations, electricity supply, water purification plants, motorways, major roads, railways, the gas distribution network, sewers and ICT. Transformer stations and electricity substations in the historic outer-dike region of Rotterdam in particular are also at risk. Many of these facilities and networks were properly constructed at the time, for example on higher ground. However the higher water levels and their mutual dependence on various networks will make them more vulnerable. This is especially true for the port and industrial clusters.
Power cuts or other disruptions to services can paralyse businesses and cause serious problems in inhabited areas. The utility networks in the outer-dike areas serve the inner-dike areas of the city, so failures there can lead to large-scale disruption of social life in the city.

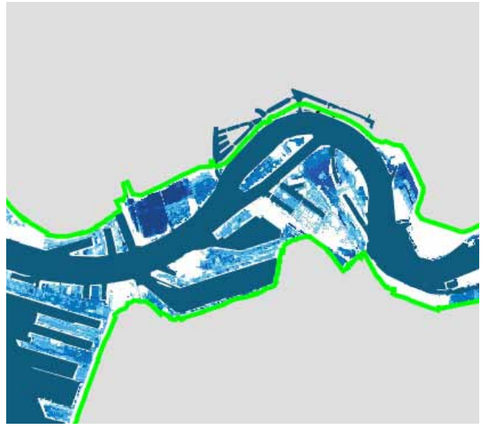
If floods do occur, the resulting damage may lead to a long recovery period in which essential functions (for example waste water purification) do not work properly for weeks or even months. This can have serious consequences in many parts of the city. This essential infrastructure is generally well-protected from floods by its safe elevation or by other protective measures.

As the likelihood of disruption and damage increases, in the long-term the region will become a less attractive place in which to live and work. The historic harbours will be one of the first areas affected. If the Noordereiland experiences disruption and damage due to flooding more frequently than once a year then the social acceptance of this flooding will decrease and, for example, those based in the region may seek to move to another, less flood prone, region.

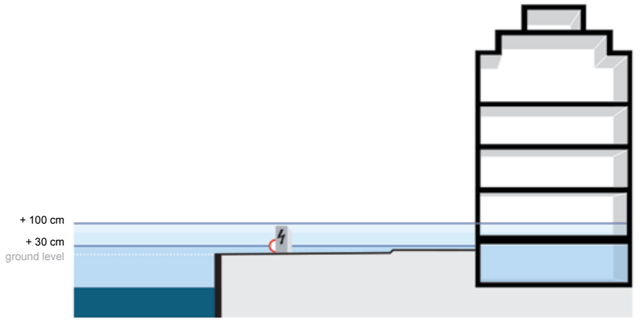
Increase in the consequences due to the development of the outer-dike area

It is predicted that the economic value of outer-dike Rotterdam will increase over time. This means that, if no climate adaptive measures are taken, the risks of economic losses will also increase. This is especially true for the outer-dike urban development areas such as Stadshavens, but also applies to the further redevelopment of the port areas such as the Waalhaven.

Zoom: Rotterdam centre, flooding in 2015

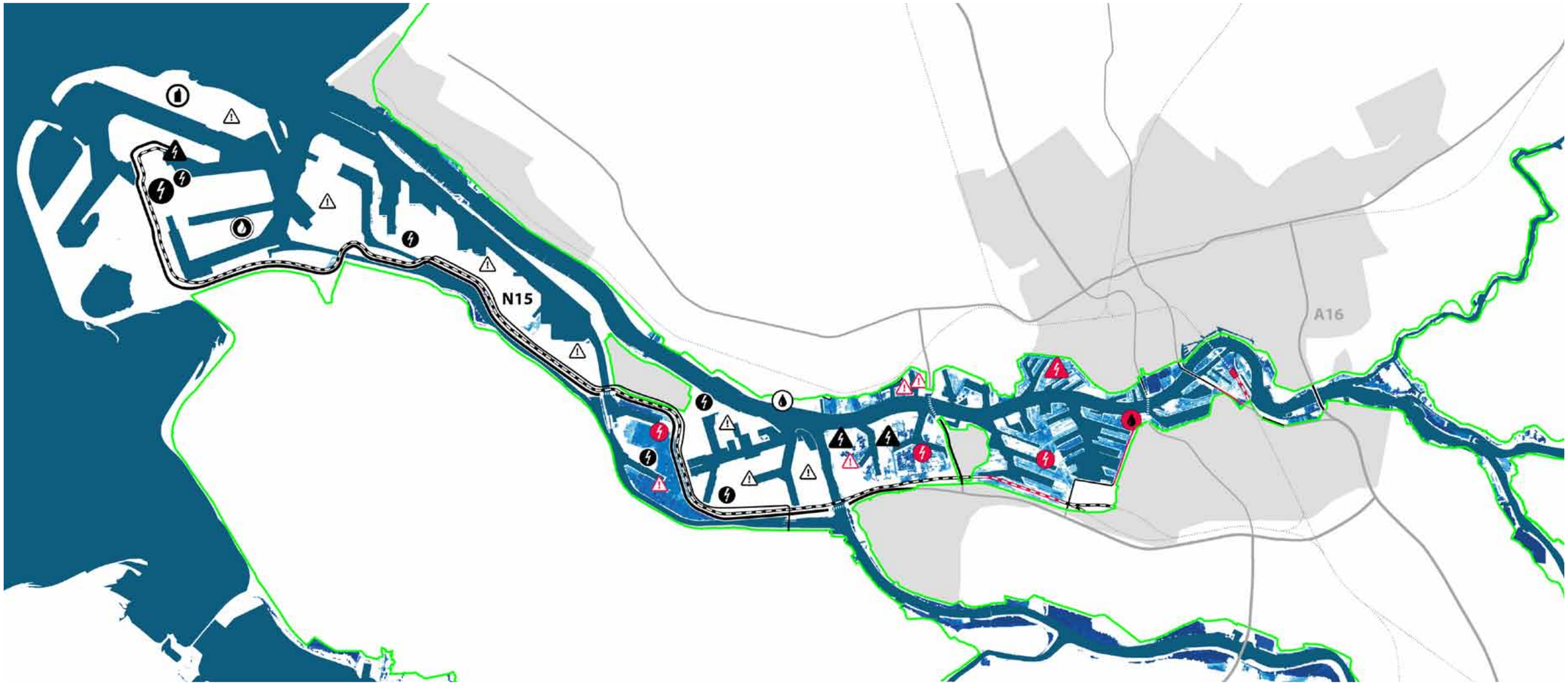


Zoom: Rotterdam centre, flooding in 2100
(W+ climate scenario with a frequency of 1 x 1,000 years)



The historic outer-dike areas are the most vulnerable to damage by flooding

Transformer stations are vulnerable to inundation depths greater than 30 cm



Inundation depth

Current system, no measures implemented

source: Deltares

2100 t = 1000 inundation depth

- 0.0m - 0.2m
- 0.2m - 0.5m
- 0.5m - 0.8m
- 0.8m - 2.0m
- 2.0m - 5.0m
- > 5m

- municipal area Rotterdam
- primary dike

Risk map essential infrastructure

- potentially floodable / vulnerable
- may not become flooded / vulnerable

Infrastructure

- motorway
- main access route
- tunnel
- railway
- railway tunnel
- station

Businesses at risk

- BRZO-cluster [3]

Essential infrastructure junctions

- 380kV switching and transformer substations [1]
- 150 kV switching and transformer substations [1]
- power generating station more than 250Mwe [1]
- gas compressor station [2]
- oil terminal [2]
- water purification installation

bronnen
1 www.TenneT.org
2 Structure Vision Pipelines 2012-2035
3 www.risicokaart.nl

Outer-dike water safety risk map - 2100

The risk map illustrates the essential infrastructure in 2100 that may potentially become flooded (W+ climate scenario), based on the current system, assuming that no other climate adaptive measures are taken, and with a frequency of 1 x 1,000 years (such water levels are expected to occur on average once every thousand years). The BRZO clusters (businesses with large quantities of hazardous substances), a number of essential power and transformer stations and some roads and railways are especially vulnerable.

4.4
The consequences of higher water levels for dikes and inner-dike areas

Rotterdam is structurally protected by a primary flood defense system consisting of dunes along the coast and dikes along the rivers. In addition there are flexible barriers that can be closed when storm tides are expected; the Maeslant-, Hartel- and Hollandsche IJssel storm surge barriers.

Within the dikes, there are many polders and outlet systems that drain water to and from the polders. These waterways are flanked by regional secondary dikes to prevent flooding of the inner-dike areas.

Each ring of primary dikes protecting inner-dike Rotterdam has its own agreed level of protection and safety standards. The standards refer to the so-called 'frequency of exceedance'. This is the probability of water levels occurring that are higher than the normative high water levels (MHW) for which the dike was constructed. In a delta city such as Rotterdam, this normative high water level (MHW) is mainly dominated by the sea (storm tides); high river flows play much less of a role.

In Rotterdam, the level of protection varies from 1:4,000 years in IJsselmonde (dike ring 17) to 1:10,000 years for the north bank of the river Meuse (dike ring 14). Given its location (mainly below sea level) and the potential catastrophic consequences of a flood, Rotterdam has set itself one of the highest safety standards in the world.

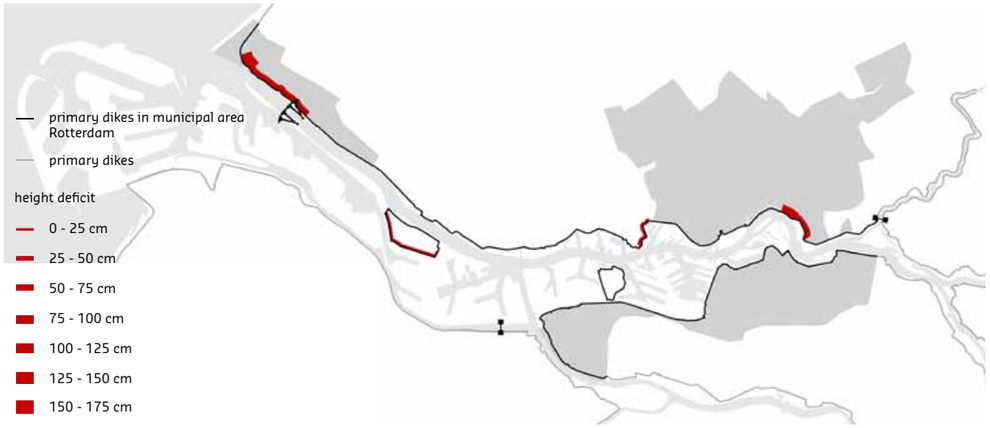
The dikes in Rotterdam serve more than just to protect the city against the water; they also are part of the spatial structure of the city and are frequently interwoven into the urban fabric. In some places the dikes are green and recreational, but elsewhere, such as the Boompjes, they are an integral part of the urban infrastructure. In addition to their protective function, the dikes have other functions such as major access roads or recreational cycle routes.

3D model representing the height of land in Rotterdam. The inner-dike area is lower than the river. (source: I. Bobbink, TU Delft)

Map 1: Current levels of protection

Map 2: Dike height deficit in 2100 *(source: Deltares)*

W+ climate scenario



Higher water levels

Rising sea levels and changing river flows will lead to an increase in water levels. In the W+ climate scenario, the normative high water levels (MHW) expected at the end of the century will on average be one metre higher. This effect in the Rotterdam region is mainly due to rises of sea level. In the W+ scenario, by 2100 the sea level is expected to have risen by between 35 cm and 85 cm.

The increasing normative high water levels (MHW) mean that it is likely that the frequency of exceedance of dike design levels will increase. The dikes will then no longer meet the required statutory standards. If no measures are taken, the risk of inner-dike Rotterdam flooding will increase.

Consequences for the Maeslant storm surge barrier

Rising water levels mean that the Maeslant storm surge barrier will have to close more frequently. As things currently stand, it is expected that by 2080 (W+) the barrier will have to close once a year on average, rather than the current average of once every twelve years. It is of course possible to alter the criteria that determine when the Maeslant storm surge barrier closes. It currently closes when the water level reaches 3 metres above NAP. A good balance must be found between 'protection' and 'accessibility'. If the decision is made to only close the Maeslant storm surge barrier when water levels are much higher, there will be a greater risk of the lower lying outer-dike areas flooding. However, closing the storm surge barrier sooner, at lower water levels, will cause more frequent obstruction to shipping.

The Maeslant storm surge barrier is designed to cope with rises in sea level of up to 50 cm. In the rapid climate change scenario (W+) the barrier will be able to fulfil its function until about 2070, after which it will need to be replaced. In the milder climate change scenarios, the barrier will be able to remain in operation longer.

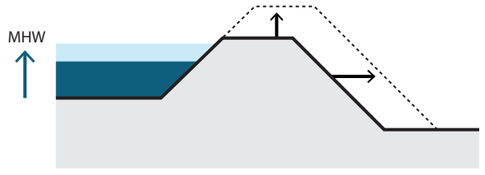
Consequences for the dikes

Currently nearly all the primary dikes in Rotterdam meet the agreed standards and provide the desired level of protection. However, an increase in normative high water levels resulting from climate change will mean that at some locations this will no longer be the case. If no measures are taken, in both scenarios (G and W+), sections of the dike will not be high enough.

By 2100 (W+) this will have become a problem for the Merwe-Vierhavens, the Maasboulevard and the Hook of Holland. The situation along the Rozenburg south dike ring requires further study. The height deficit varies from about 20 cm in the Merwe-Vierhavens to about 40 to 60 cm along the Maasboulevard. If no measures are taken, the risk of these dikes flooding will increase.

Moreover, a number of the more easterly regions such as the Krimpenerwaard and the Alblasserwaard are facing a much tougher flood protection challenge. The flood protection along the Hollandsche IJssel in particular must be substantially improved, and this directly impacts the safety of the Alexanderpolder district of Rotterdam.

Maeslant storm surge barrier in the Nieuwe Waterweg (New Waterway)



An increase in MHW (normative high water level) leads to dike height deficits

The dikes in the Merwe-Vierhavens and the Maasboulevard are multi-functional and tightly woven into the surrounding urban infrastructure. There is limited scope for dike reinforcement. Reinforcing these areas is a challenge, providing opportunities for linking it in with the urban spatial area development.

Consequences for the regional dikes

The water levels in the polder outlets will continue to be maintained using a system of pumps and pumping stations. The risks of flooding will therefore not increase. Regional dikes in the western part of the Netherlands are frequently constructed of or on peat. Such peat dikes are vulnerable to long periods of drought as they dry out and compact, which may cause them to subside. However, the volume of water involved in such a dike breach is considerably less than it would be in the event of a breach in the primary dike ring. It is unlikely that there will be many casualties. However, a breach could cause wide-scale disruption and considerable damage, for example due to the failure of utilities or flooding of the national roads and railways.

Vulnerabilities and risks

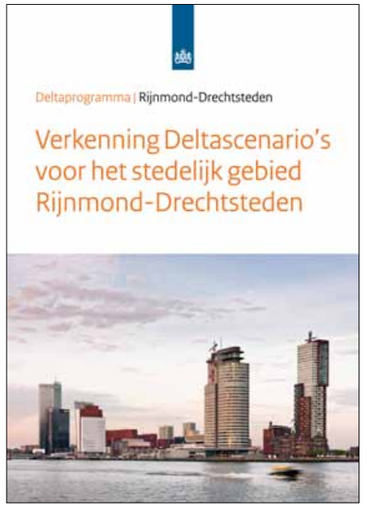
Inner-dike Rotterdam is extremely well-protected from flooding. Other than in the outer-dike region, the rising sea and water levels will initially only indirectly affect the inner-dike areas. After all, the primary dikes provide a high level of protection from flooding. Nevertheless, there is always a chance, however small, that the dikes will be breached or collapse.

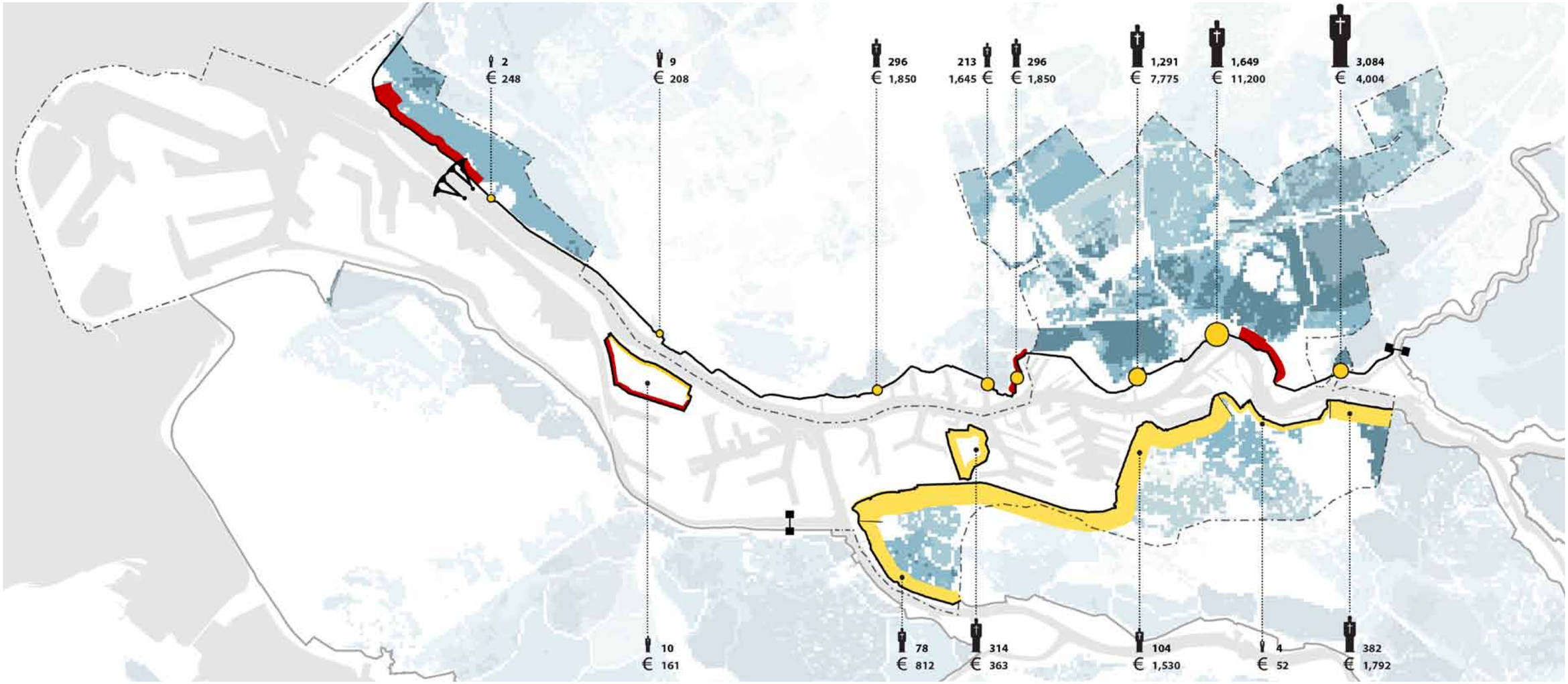
The consequences of flooding are shown in the risk map. If flooding were to occur, the impact on the city and region would be considerable, both in terms of the number of casualties and in terms of damage to the economy. If a dike is breached, the water will surge deep into the city and will not be able to drain away. Furthermore, over recent decades, after the current safety standards were drawn up in 1960, the number of inhabitants and the economic value of the inner-dike city have both grown considerably. This has significantly added to the risks.

Delta Programme

The national Delta Programme is currently reassessing the flood protection measures on a national level and working on an approach to guarantee protection from floods for both present and future generations. The focus is shifting from 'prevention' to 'risk management'. This means that in addition to the likelihood of a specific water level occurring, the consequences for the areas within the dike will also be taken in to account. After all, the risk is the product of the probability and the consequences. It is not yet clear what impacts this risk management approach will have on the level of protection and on future dike reinforcement operations.

More knowledge about dikes has become available. Nowadays, account is taken not only of the height of the dike, but also of its stability and other failure mechanisms. In addition to prevention (dike reinforcement), damage restriction is also being considered in terms of local protective measures (spatial design) and evacuation plans. This is known the Multi-layer safety and security strategy.





Dike height deficit

Based on the current approach and current standards in 2100, W+ climate scenario

source: Deltares

- primary dikes in municipal area Rotterdam
- primary dike
- dikes that need to be reinforced based on the 2nd and 3rd safety assessments

height deficit

- 0 - 25 cm
- 25 - 50 cm
- 50 - 75 cm
- 75 - 100 cm
- 100 - 125 cm
- 125 - 150 cm
- 150 - 175 cm

Areas at risk during floods

Maximum inundation depth and minimum flood warning time

source: Delta Program 2013 Problem analysis

	< 6 hour	6-24 hour	> 24 hour
> 2 m			
0.5 - 2 m			
< 0.5 m			

Damage and casualties

source: WV21-Gevolgenspoor

- € Damage following dike breach (in millions)
- Damage following technical failure of a flood barrier
- Casualties

Inner-dike water safety risk map - 2100

The risk map shows the areas that are at risk of flooding together with the potential economic damage and the number of casualties resulting from a dike breach (south side) or the failure of a technical engineering works (north side). In many places, such a situation would result in water rapidly surging deep into the city.

4.5
The consequences of extreme rainfall

The urban water system keeps the polders of Rotterdam stable and dry. It is a robust system that consists of surface water (canals, lakes and waterways), outlets to drain the water in and out and a sewer system whereby rain and wastewater are discharged into the Meuse after first being treated in the sewer treatment plants. It is an ingenious, but rather inflexible, system.

During extreme rainfall, the vulnerability of the system becomes apparent. Peak downpours are already causing disruption and damage as water floods the streets, cellars become inundated and sewer overflow discharges directly into the canals and waterways. Over recent years the city has made extra room for water, both in the water system (for example, the underground water storage under the Museum Park and additional surface water in the Zuiderpark) as well as in individual projects deep into the veins of the city such as the Bellamyplein water square and green roofs.

More intensive rainfall

We are already experiencing heavy downpours during the summer months. Climate change is expected to lead to these downpours not only becoming more frequent but also more intensive. The KNMI has calculated that for each degree rise in temperature, the intensity of the rainfall will increase by 14%. By the middle of this century, the type of shower that currently occurs once every five years will on average occur once a year.

Consequences of more intensive rainfall

More intensive rainfall as a result of climate change will increase the pressure on the system and therefore increase the likelihood of flooding, resulting in damage to public areas and buildings as well as mild disruption, for example by the inundation of tunnels.

The likelihood of flooding is increased by the fact that the low-lying peat on which many areas of Rotterdam are built is still settling and compacting. The long periods of drought as a result of climate change will compound this problem as the rate of compacting increases (see also section 4.6, The consequences of drought).

Heavy rainfall causes more frequent flooding of the streets

Map 1: Current locations with insufficient water storage capacity according to NBW – National Water Agreement *(source: Interactive Climate Atlas)*

Map 2: Future locations with insufficient water storage capacity *(source: Interactive Climate Atlas)*

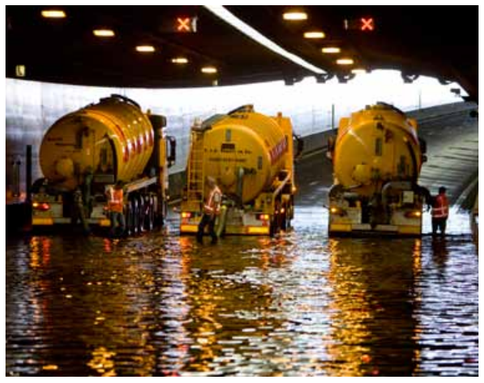
Vulnerability and risks

Exactly how and where the negative consequences of more intensive rainfall will manifest themselves depends not only on the functioning of the water system itself but also on the physical characteristics and the design of the area. Outer-dike Rotterdam is the least vulnerable area. Ground levels are relatively high and future rainfall can usually be easily drained directly to the river. The post-war outskirts (garden cities) usually have sufficient space for extra water and green. In these districts there are sufficient opportunities for surface water storage or groundwater storage.

The 19th century urban districts are the most vulnerable areas. These are densely built-up, generally paved over, have relatively little open water and green. The inner-city centre of Rotterdam is especially vulnerable to extreme rainfall because it is densely built-up, the public areas are used intensively and there is very little vegetation. Furthermore, areas with unequal subsidence are vulnerable to the effects of more intensive rainfall. This specifically applies to areas of the city that are built on peat.

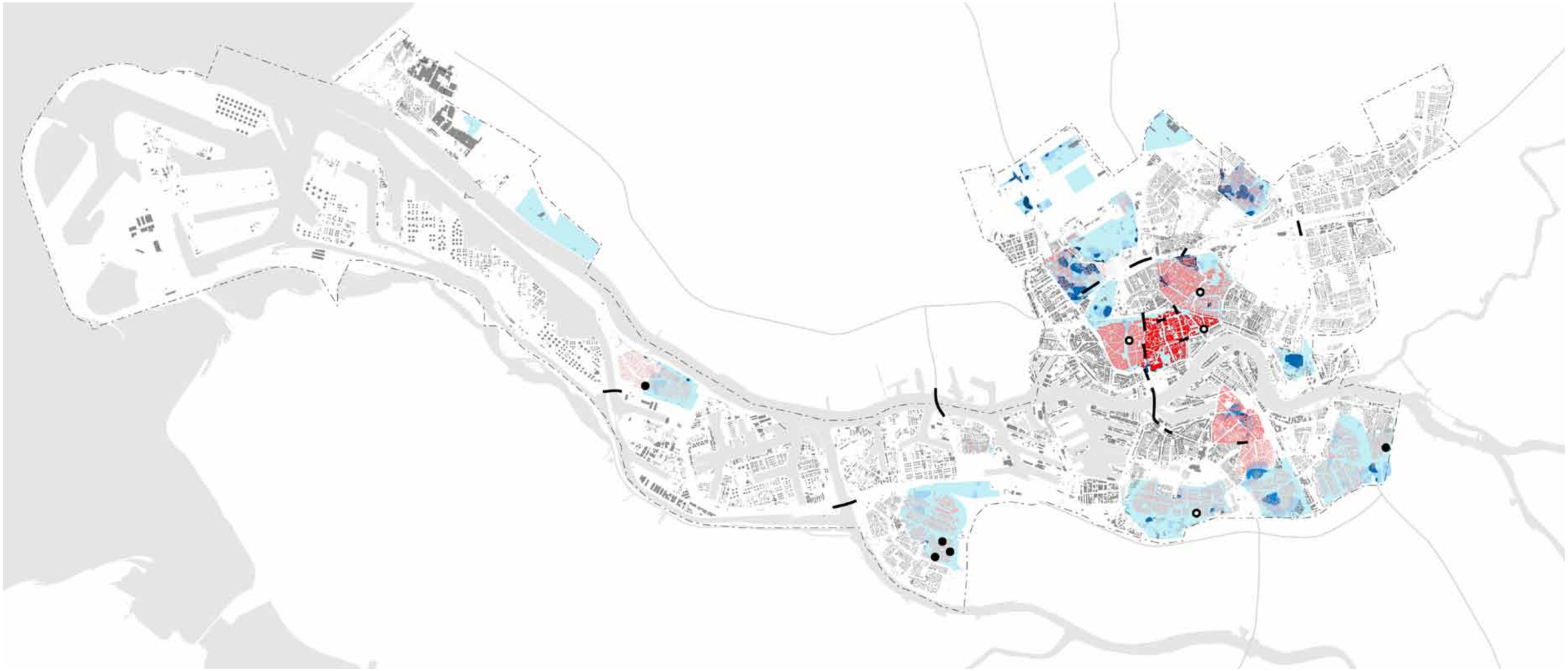
Finally, the inundation of tunnels and flooding of the streets can result in parts of the city become poorly accessible. If this happens on one of the main access roads or motorway, this could cause significant indirect damage to, for example, shops and other businesses (provisioning). Furthermore, other important functions in the city can temporarily be disturbed.

The reassessment carried out in the context of Rotterdam water plan 2, identified districts where the physical characteristics of the urban water system (sewerage and surface water) do not currently meet the agreed standards. It is not possible to accurately predict the exact consequences of the anticipated increased rainfall resulting from climate change. The urban areas are too diverse and the computation models are (as yet) inadequate. It is expected that more intensive rainfall will lead to an increase in flood-related problems in the more vulnerable areas in particular, and that the extent of these vulnerable areas will increase. This hypothesis is shown in the map illustrating the future water management issues.



Flooding in the Botlek Tunnel in 2008 caused long traffic jams

Flooding of the city streets after a downpour is becoming more frequent and causes more damage



Water issues

source: Interactive Climate Atlas

current water storage deficit areas (NBW)

subsidence (cm/year)

- -0.1 - 0.5
- 0.5 - 0.1
- >1

Bottlenecks and vulnerable areas

- bottleneck sewers
- bottleneck flooding due to groundwater
- city centre with considerable consumer pressure on the open spaces
- urban area with little open space
- urban area with much open space
- low-lying infrastructure

Flood risk map - 2100

The risk map depicts the areas where it is expected that water storage deficits will occur in the future, and where unequal subsidence makes the area more vulnerable to the effects of intensive rainfall. These are mainly areas that are built on peat. Furthermore, the map shows the bottlenecks: the sewer system, groundwater and low-lying infrastructure such as tunnels.

4.6
The consequences of drought

As a result of climate change, long periods of drought and a shortage of rainfall will occur more frequently, especially in the W+ scenario. The probability of a dry summer will also increase. Extreme dry summers such as in 2003 currently occur on average once every ten years. In the W+ scenario, the frequency will increase to once every two years.

Rainfall deficit and drying out

An initial direct effect is that drought will lead to a groundwater deficit and lower water tables. A second consequence is that longer dry periods in the river catchment areas will lead to lower river levels.

Long periods of drought are the principle reason for groundwater deficit. Summer rainfall is mainly concentrated in short periods, with few light summer showers. These summer peak downpours contribute to the groundwater deficit, as the excess rainwater drains away through the sewers and surface water and has insufficient time to infiltrate the sub-soil. It is expected that infiltration volumes will decrease, leading to lower water tables.

The drying up of the sub-soil in certain areas will lead to further compacting and subsidence. Peat areas in particular are susceptible to drying out, oxidising and settling. This process is irreversible. The long periods of drought as a result of climate change will probably influence and accelerate this subsidence process.

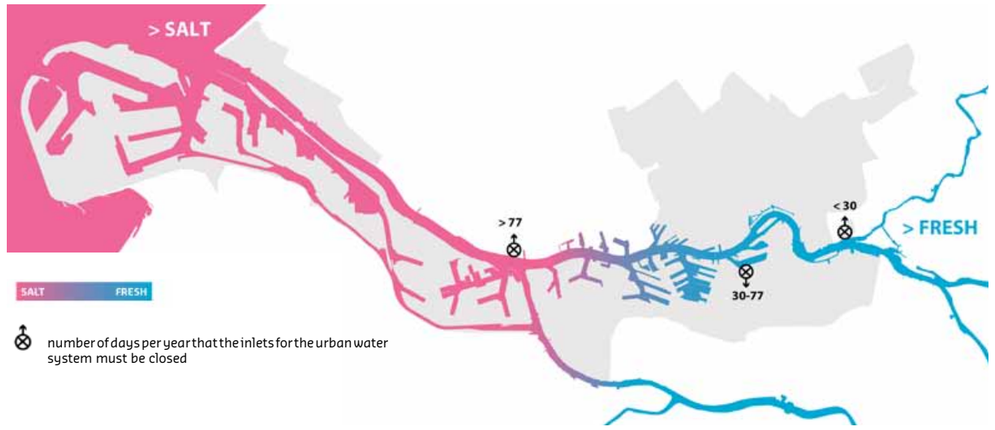
Subsidence and lower groundwater levels in turn pose a threat to buildings on wooden pile foundations. If the wooden piles dry out they may collapse, causing serious damage to the buildings. Furthermore, subsidence is also a problem for roads and pipeline infrastructure, which may have to be replaced sooner. During very wet periods, subsidence can lead to more flooding as the ground level sinks down to the water table. Housing that has not been built on pile foundations can become flooded as it subsides too.

The peat dikes have already been mentioned. These dikes, that frequently form part of the regional defence line, are vulnerable to drying out. They can become unstable and subside, leading to flooding of inner-dike areas.

Finally, long periods of drought are detrimental to the ecological quality of the surface water. Higher concentrations of nutrients lead to increased algal growth. Sewerage overflow resulting from extreme downpours will exacerbate this problem.

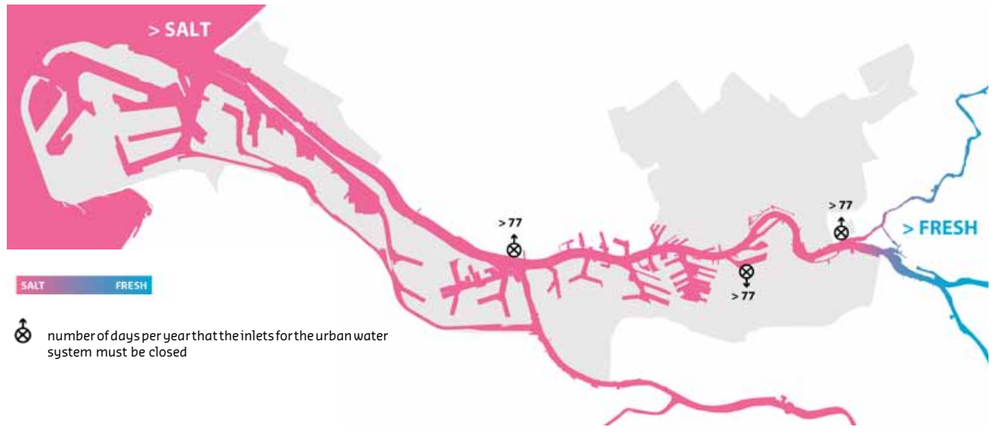
Extreme low river levels in Rotterdam 2100++ (enhanced image)

Map 1: Current saltwater intrusion *(source: Interactive Climate Atlas)*



Map 2: Saltwater intrusion in 2050 *(bron: Interactieve klimaatatlas)*

W+ climate scenario



Saltwater intrusion

Every day the tide brings water with high concentrations of salt in and out of the delta. The water is becoming more saline as far inland as the Hollandsche IJssel. Low river levels, combined with high sea levels, mean that this saltier water is intruding ever further inland. River water is currently let into the Rotterdam urban water system at three different points. The direct result of this advancing salt intrusion is that the quality of the water being added to the urban water system is declining. In order to maintain the levels of the canals, water must be let in, even if the salt concentration of this water is high. If no water were let in, the canal levels would become too low, leading to the risk of subsidence, lower water tables and greater concentrations of hazardous substances in the water. The reduction in the water quality directly impacts the flora and fauna depending on it.

Research in the Delta Programme indicates that by around 2050 (W+) the freshwater supply for the south-western part of the Randstad will be at risk. The inlet at Gouda will need to be closed too frequently. The saltwater intrusion will not however threaten the supply of drinking water in Rotterdam because the inlets lie further upriver, and in addition the storage buffers are more than adequate.

Obstruction to shipping

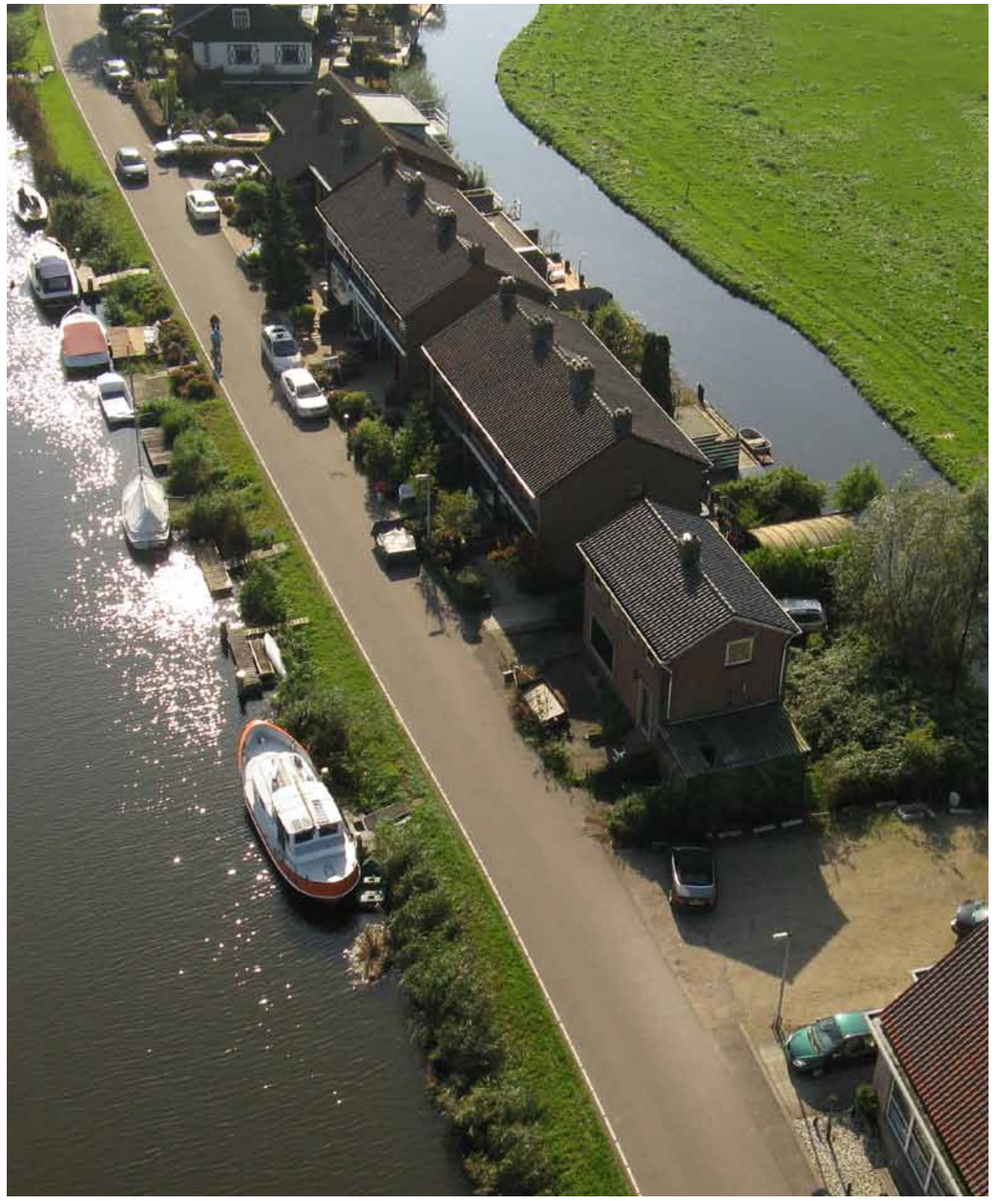
Finally, the lower river levels will obstruct shipping as the navigable depths decrease. This will hamper and maybe even temporarily block upriver economic traffic. Important inland connections will be affected by the longer droughts caused by the changing climate.

Vulnerabilities and risks

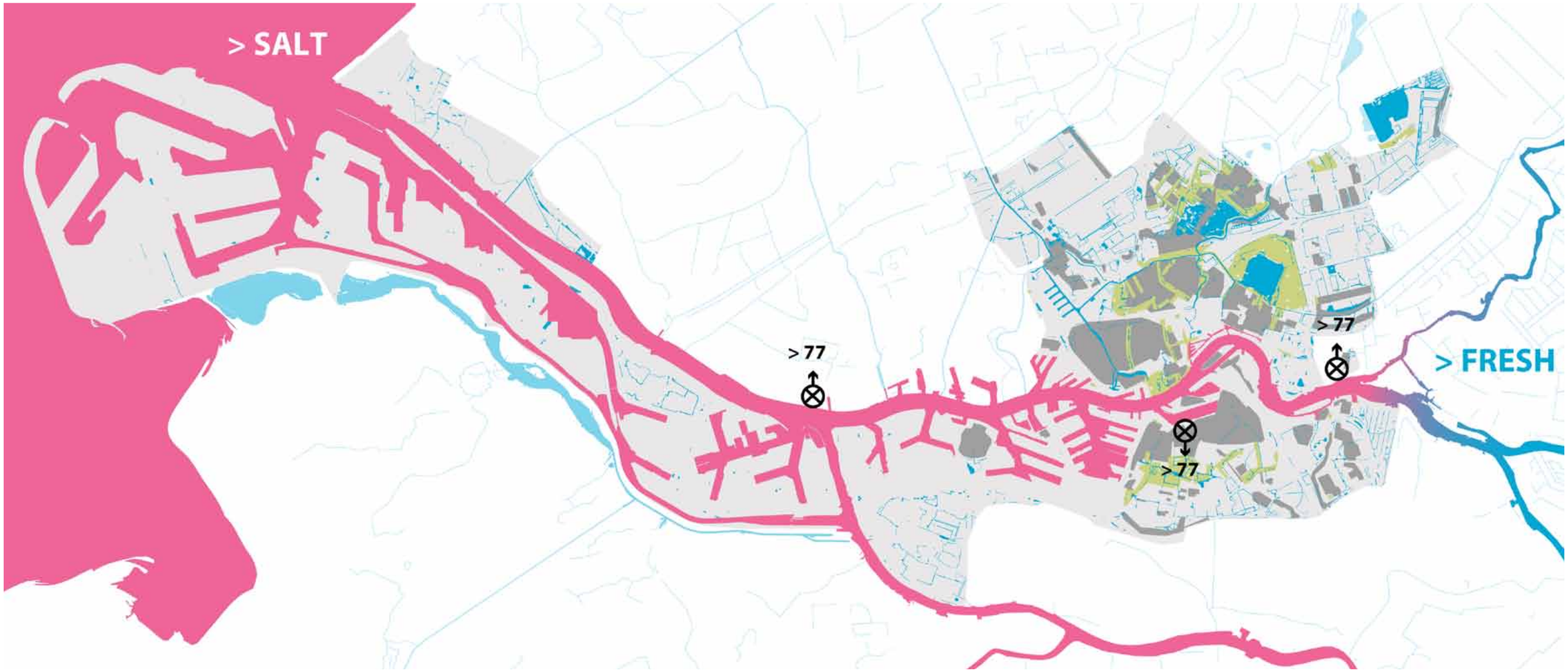
Firstly, the north-east areas of the city, such as Kralingen and Schiebroek, are built on peat ground and are therefore vulnerable to long periods of drought. The city centre and the surrounding densely built-up 19th century city districts are also relatively vulnerable. The main problems of drying out are caused by the lower water table due to the lack of rainwater infiltration and limited drainage to open water. Furthermore, some of the parts of the city on higher ground and areas with a lot of vegetation but little surface water are also at risk. The drying out will, in turn, threaten the quality of the urban flora.

Subsidence as a result of drought

Low water levels combined with lack of sluicing is detrimental to the water quality



Peat dikes along the river Rotte are especially vulnerable to drying out



Areas at risk and threats to inlets

source: Interactive Climate Atlas

SALT — FRESH

number of days per year that the inlets for the urban water system must be closed

areas with wooden pile foundations at risk

vulnerable urban flora

Drought risk map - 2050

The risk map depicts the saltwater intrusion in 2050 (W+ climate scenario). During long periods of drought, when river levels are low, the salt water will intrude further and further into the delta. This can cause problems for freshwater inlets, wooden pile foundations, water quality and urban flora.

4.7
The consequences of higher temperatures

Longer warmer periods

Global warming will affect the Netherlands. The KNMI scenarios assume a climate change in our country in which periods of higher temperatures are more frequent and longer. The number of summer days (warmer than 20 °C) and tropical days (hotter than 30 °C) will increase, as will the likelihood of a heat wave.

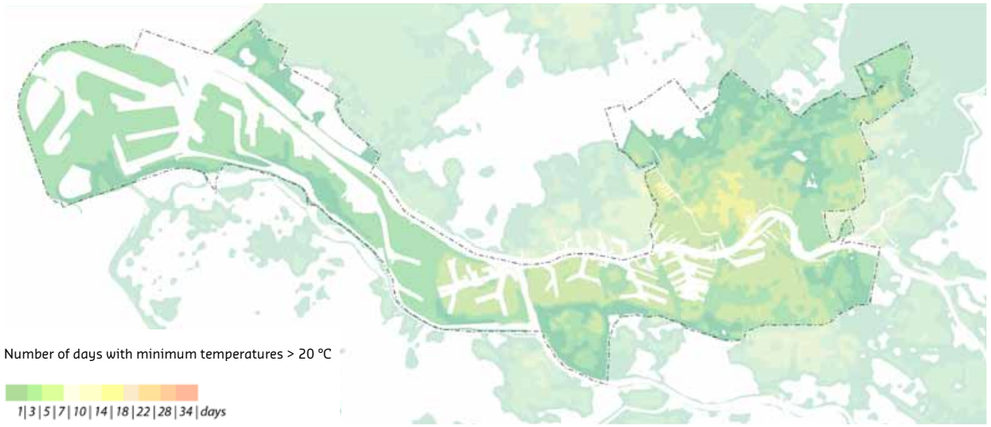
The Urban Heat Island Effect

In addition to the effects of a warmer climate there is a second issue that affects the heat in the city: the Urban Heat Island (UHI) effect. The UHI effect is the phenomenon whereby the average temperature of an urban area is higher than that of the surrounding open countryside. During the daytime, the city absorbs and retains much heat while at night this heat dissipates more slowly. The resulting differences in temperature between the city and surrounding rural areas are greater at night. The main causes of the UHI effect are the high levels of paving and the density of urban areas combined with the lack of flora and stretches of open water, which have a cooling effect.

The UHI effect is also apparent in Rotterdam. Research carried out within the framework of the Knowledge for Climate programme has shown that on warm, clear days the temperature differences in Rotterdam can be significant. The difference in temperature between the city and surrounding countryside can be as high as 8 °C. Measurements have shown that the coolest areas of Rotterdam are those districts with low buildings and plenty of vegetation. The warmest areas are the city centre and neighbouring urban districts. The UHI effect also occurs in the mostly paved-over industrial areas and harbours.

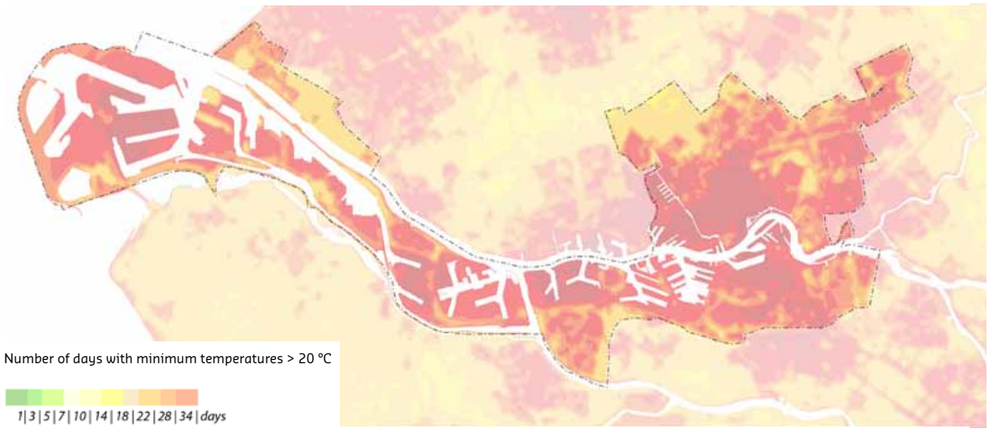
Blue algae flourishes in warmer surface water

Map 1: Urban Heat Island Effect, current situation *(source: Interactive Climate Atlas)*



Map 2: Urban Heat Island Effect in 2050 *(source: Interactive Climate Atlas)*

W+ climate scenario



Consequences of longer warm periods / heat stress

Higher temperatures affect public health and well-being, flora and fauna and the functioning of the city as a whole. It is the combination of the UHI effect together with a warmer climate that will have an impact on the city and its inhabitants. During heat waves, the UHI effect exacerbates the discomfort.

More frequent and longer periods of higher temperatures may lead to an increase in health problems. The elderly and people suffering from respiratory diseases are particularly vulnerable. Significantly more people die during heat waves. The air quality in the city declines rapidly, leading to additional health problems.

Higher temperatures affect the 'thermal comfort' in the city. Life inside the city's buildings, as well as outdoors, becomes significantly less pleasant during prolonged periods of high temperatures. This can lead to lower productivity in offices and factories, for example. During longer hot periods, energy consumption will increase due to extra cooling (air conditioning) and watering.

Flora and fauna will also be affected by higher temperatures. For example an increase in pests such as mosquitoes and ticks is to be expected. Furthermore global warming affects the water quality. Warmer surface water will enable blue algae and botulism to flourish, which in turn will result in increased fish mortality and render the water unsafe for swimming.

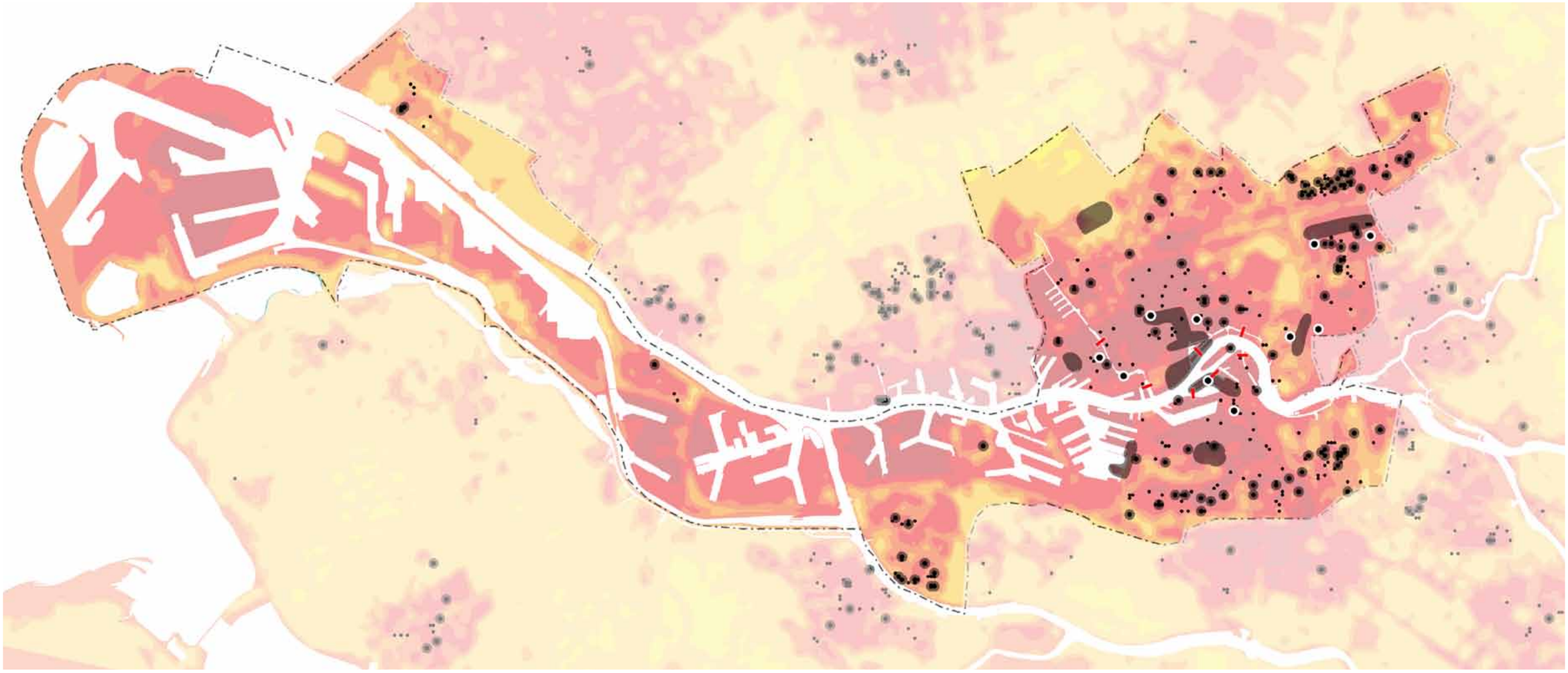
The elderly are especially vulnerable to the effects of heat

Malfunctioning of essential structures in the road network, such as bridges not opening or closing properly due to heat or melting asphalt on major roads, can disrupt the traffic in the city and affect the local economy. Further research by the urban stakeholders involved needs to be carried out into the vulnerability of the utilities, ICT networks and data centres.

Vulnerable areas and risks

Intensively used, paved-over areas with little shade or greenery are the most susceptible to heat stress. The compact urban business areas such as the inner-city and areas with concentrations of vulnerable groups of people such as nursing homes and homes for the elderly are also expected to suffer from higher temperatures. Furthermore, flora and in particular city parks with (swimming) pools and lakes are vulnerable to heat. Finally bridges, major roads and railways are vulnerable to extreme temperatures, thereby putting the accessibility of the city at risk.

Spraying a bridge with water to prevent malfunctioning due to heat expansion



Urban Heat Island effect

number of days with minimum temperatures > 20 °C

source: Interactive Climate Atlas

1 | 3 | 5 | 7 | 10 | 14 | 18 | 22 | 28 | 34 | days

Groups and areas at risk

source: Interactive Climate Atlas

concentration 65+ / the elderly

- > 50 / ha
- >100 / ha
- nursing home
- ares with a high concentration of offices
- bottleneck moveable bridges

Heat risk map - 2050

The risk map shows the Urban Heat Island effect for 2050. This effect exacerbates the discomfort during heat waves and affects the quality of life in the city. The elderly are particularly vulnerable. However, the UHI effect does not only have an adverse impact on people. Infrastructure, such as bridges, is also vulnerable.

5

Setting the course for a climate proof Rotterdam

Although vulnerable, Rotterdam is one of the safest delta cities in the world. A long tradition of combining urban development with measures to protect us from floods has brought us this far, and we intend to continue in the same way. The tasks facing us are not urgent but do need to be taken into account now. The city is continually developing. This provides the opportunity to evolve and to adapt to the uncertain changes in climate. We need to make explicit choices and set ourselves a clear course.

This is the core of the Rotterdam Climate Change Adaptation Strategy:

- We maintain and optimise the existing robust system.
- We improve its resilience by taking adaptive measures throughout the whole urban environment.
- We do this together with other parties and in combination (linking in) with other changes in the city.
- We take advantage of the opportunities that climate change adaptation provides.

Adapting to climate change goes hand in hand with strengthening the economy of the city and improving the environment. Climate change adaptation also provides opportunities to contribute to creating an involved and caring society and to improve the ecological value of the city.

The Bellamyplein during the opening celebrations in 2012. This water square enables rainwater in the city to be seen and experienced.

5.1
Outer-dike flood protection

Summary of the task ahead

Climate change will lead to higher sea and river levels, which will increase the likelihood of flooding. The higher elevation of the outer-dike areas limits the extent and depth of the flooding there. It is unlikely that there will be many casualties; the consequences of flooding will mainly be limited to an increased risk of economic losses and environmental damage. Failure of essential functions could cause large-scale disruption of the city. The Maeslant and Hartel storm surge barriers will have to close more often. In addition, the density of the city and the expansion of the port in the outer-dike region are further increasing the consequences of flooding.

Core of the strategy

In the outer-dike areas the strategy focuses on a combination of prevention and adaptation. The robust system of protection, consisting of raising the elevation and closing the storm surge barriers during storm tides, will continue to form the basis of outer-dike flood protection.

This strategy of 'protection' will be augmented with adaptive measures aimed at increasing resilience and evolving with climate change. This will include measures such as adaptive building and the redevelopment of outer-dike properties, construction of floating buildings and the adaptive design of outdoor areas including roadways, utility infrastructure, wilderness areas and parks.

Inhabitants and businesses have an important role to play in the outer-dike areas and their flood protection in particular. The active provision of information about risks and specific measures that individuals themselves can take will better prepare the inhabitants and businesses for future floods. Integral policies for the risks of outer-dike flooding are being devised.

Adaptive measures in the outer-dike areas will play a part in making the city and harbour more attractive and in strengthening the economy. The key concern is to integrate measures with urban spatial development.

Outer-dike residential areas in Rotterdam, such as the St. Jobshaven, are attractive, desirable and distinctive places to live

Measures

Optimising the protection provided by the storm surge barriers

The Maeslant storm surge barrier protects outer-dike Rotterdam. Operations can be optimised to reduce the likelihood of the barrier failing to close when required. This is being investigated as part of the Delta Programme. In the long-term – not until at least the second half of this century – replacing the Maeslant storm surge barrier or the construction of a second barrier could structurally improve the outer-dike flood protection.

Adaptive building and design

An important measure is adaptive building and the adaptive design of outer-dike Rotterdam. An alternative to the integral raising of whole areas is to locally raise property and quays. Beneficial measures include making buildings flood-proof and the flood-proof design of public areas such as incorporating local flood walls. Adaptive building can also take place on the water itself. Rotterdam has already gained experience in the construction of floating communities. With flood-proof and floating buildings, the outer-dike areas can become more in tune with the water and at the same time the city can experience and live with the dynamics of the delta, without compromising on flood protection. Nature also provides a wide range of opportunities for the adaptive design of outer-dike areas, for example tidal forests and green banks. Key infrastructure such as hospitals, utilities and chemical companies will be maximally protected from floods. It is possible and desirable to differentiate between the levels of protection and the construction methods for each amenity.

Robust essential infrastructure

Essential infrastructure in outer-dike Rotterdam is and will remain water robust. After all, main ports cannot function properly without essential infrastructure such as power stations and transformer stations. The outer-dike areas need to continue functioning even during a flood. Evacuation routes must remain open. Measures could include placing essential infrastructure on higher ground or providing them with local protection.

Making inhabitants and businesses aware of the risks

Inhabitants and businesses will be made aware of the risks of living in outer-dike areas. Brochures and the Internet (Water Counter) structurally provide information, including specific details of safety measures that can be taken by individuals themselves. During periods of high water levels, areas will be cordoned off, cars towed away and sand bags made available. Social media and communication via smart phones will become vital tools for inhabitants and non-locals such as tourists and employees working in the area.

An area-specific approach

The flood protection strategy focuses on a combination of a robust system together with adaptive measures and targets the whole outer-dike region. This requires area-specific approaches: the right approach at the right place at the right time! A topical issue is the development of an adaptation trajectory for the Kop van Feijenoord and combining it with the area development taking place there and on the Noordereiland. In order to be able to design and build robust waterproof constructions, new building regulations are being developed. Over the coming years, city harbours will provide a location for floating communities, with the first project starting in the Rijnhaven. A multi-level safety and security pilot project is being implemented at the Heijplaat and experiments in climate proof construction are being carried out in the Concept House Village at the RDM campus. The Merwe-Vierhavens provides an ideal opportunity to combine flood protection with urban transformation.

Adaptation over time

We are already putting this strategy for outer-dike Rotterdam into practice. Adaptive building can already be incorporated in redevelopment and new construction projects, the functioning of the Maeslant storm surge barrier is being optimised and the essential infrastructure improved. Inhabitants and businesses are already being informed about the risks of flooding, their own responsibilities and potential adaptive measures. Policy-making, licensing and authorisation procedures include an assessment of the flood risks posed to public amenities. An integral policy is being developed for protecting the outer-dike areas from flooding.

In the mid- to long-term, decisions will be made about whether or not to actively protect existing areas with barriers or dikes. The construction of a new storm surge barrier or replacement of the old Maeslant storm surge barrier will not take place until at least the second half of this century.

Linking in with other projects

The Rotterdam Climate Change Adaptation Strategy is based on linking the development of the outer-dike areas with the urban dynamics. Linking in with other projects in this way leads to reduced costs both in the short- and long-term. Measures will be implemented as soon as an opportunity arises: during area development or new construction and by replacement or regular maintenance of outdoor areas (roads, cables and pipelines). The Feijenoord pilot project has shown how effective this approach can be.

The redevelopment of Stadshavens will incorporate adaptive construction and design. Many of the adaptive measures such as flood-proof construction and the development of floating communities will be effective here and can readily be integrated into the spatial structure. In existing outer-dike urban districts, adaptive measures can be integrated into the maintenance programmes and new project development, for example the local raising and waterproof design of the historic harbour areas such as the Kop van Feijenoord.

Working together

Maintaining the Maeslant storm surge barrier and making the essential infrastructure waterproof is the responsibility of Rijkswaterstaat and the utility network operators. The province is responsible for the urban and rural planning and in this role provides the integral policy framework for the outer-dike areas. However, in order to carry out the adaptation strategy, the province needs the cooperation of other government departments, private parties and the inhabitants of outer-dike Rotterdam. For the port areas, the details of the outer-dike policies will be developed in consultation with the Port of Rotterdam.

Developers, housing corporations and the City of Rotterdam have important roles to play in ensuring the practical implementation of the policies involving the construction of safe, secure, waterproof buildings and outdoor areas. We hope to work together with inhabitants and businesses to determine their own roles, such as implementing the necessary damage-limitation measures for their own private property.

Added value

The most important result of this strategy is the creation of a safe living and working environment for 'water-conscious' inhabitants and businesses. Rotterdam is one of the safest delta cities in the world and intends to remain so. This provides opportunities for the economy of the port and instils confidence in its investors. Closing the storm surge barriers, even if in the future this happens slightly more often, is not seen as a threat but rather as an important competitive advantage over other ports that are less well-protected. By focusing on adaptive construction and linking in with urban spatial developments, costs will be reduced.

Flood-proof and floating buildings, together with attractive water-based public areas, add new water-related urban environments to the city and not only strengthen the city's relationship with the water but also enhance Rotterdam's identity as a delta city. 'Building with nature' provides opportunities for increasing tidal nature in the city and improving the quality of the environment.

Floating buildings can withstand rising water levels

Concept House Village Heijplaat, flood-proof construction

Port City Rotterdam, wet-proof construction

'Building with nature' combines attractive flora with improved flood protection

Example

Adaptive development strategies for outer-dike Rotterdam

The aim of the project is the development of adaptation strategies and associated measures for existing and still-to-be-developed residential areas in outer-dike Rotterdam.

What is special about the project?

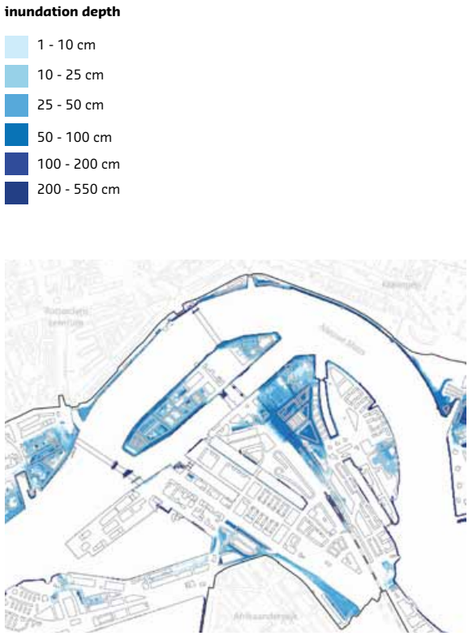
Using tipping point analysis, this project assessed which spatial adaptive measures would reduce the vulnerability of the region to high water levels. This method is used to systematically research when and at what water level adaptive measures need to be implemented. Depending on the rate at which the sea level rises, measures will need to be taken sooner or later. This generates opportunities to link investments in climate change adaptation with area development.

Who

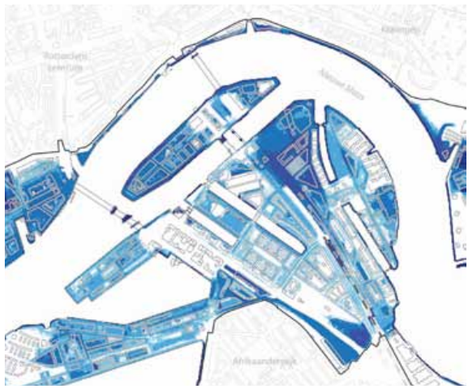
City of Rotterdam / RCP (P. van Veelen)
Doepel Strijkers Architects
Deltares
Unesco-IHE
University of Utrecht
VU University of Amsterdam
Arcadis

Commissioned by

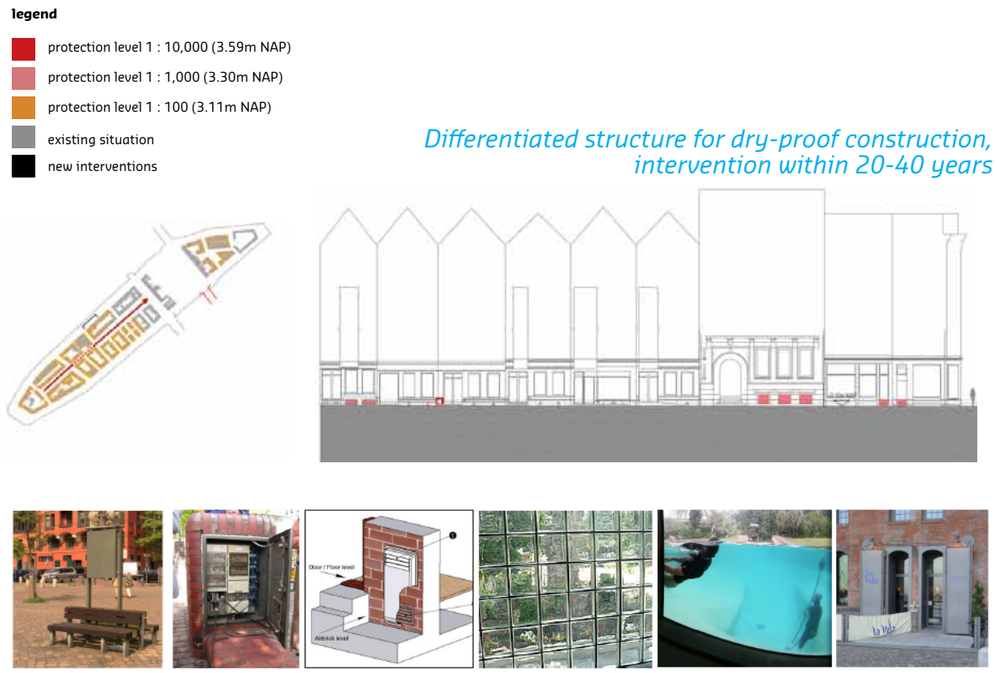
City of Rotterdam and Knowledge for Climate



Flooding in 2015 with an expected frequency of 1:1,000 (source: Deltares)



Flooding in 2100 based on the W+ scenario and with an expected frequency of 1:1,000 (source: Deltares)



5.2
Inner-dike flood protection

Summary of the task ahead

Climate change will lead to higher sea and river levels. This will place more pressure on the dikes and the agreed safety standards at a number of places in Rotterdam will be exceeded. At some locations the primary dikes will need to be reinforced. Another consequence of the high water levels is that if the closure regime remains unchanged, the Maeslant storm surge barrier will need to close more frequently. Drought and extreme rainfall will lead to an increase in the risk of flooding of the regional secondary dikes.

Even without climate change, the increasing number of inhabitants and growing economic value of the inner-dike areas increases the risks of flooding because there may potentially be many casualties and much more damage. It may be necessary to tighten the safety standards. Local measures will then become necessary.

Core of the strategy

The strategy is aimed at preventing flooding using a system of strong dikes and storm surge barriers, with a focus on prevention. For this reason the current robust flood protection system is well-maintained.

If the agreed standards are exceeded, then the first course is to reinforce the dikes. For the regional dikes, there is also a system of outlets that can be closed in the event of any disaster.

In Rotterdam there is always a chance, however small, that the inner-dike area will be flooded. In such a situation contingency management will be called upon. The emergency response organisation must be better prepared.

The primary dikes form an attractive green landscape with elevated cycle path along the Westzeedijk

Measures

Optimising the storm surge barriers

The Maeslant and Hollandsche IJssel storm surge barriers are the key structures protecting Rotterdam against storm tides. The likelihood of the surge barriers failing when needed is very small, but cannot be ruled out. Research into reducing the likelihood of failure is included in the Delta Programme. Partial closure is one such potential measure. In the long-term, in the second half of this century at the absolute earliest, it may be possible to structurally improve the protection by replacing the Maeslant storm barrier or adding a second barrier.

Primary dikes

The primary dikes form the basis of the flood protection system. The dikes are a robust method of optimally protecting the land behind them. At those places where there are currently problems or where problems are expected in the future, for example as a result of a height deficit, the primary dikes will be reinforced. Measures in the spatial design of the city (second layer), unlike in the outer-dike areas, are limited by the deep, low-lying location of the inner-dike areas.

Reinforcing the dikes is also part of the city's spatial design task. Within the densely built-up parts of Rotterdam the dikes are multi-functional, integrated, attractive structures. The recognisability of the dikes in the city plays a part in making the inhabitants more aware of the risks of flooding. The multi-functional use of the dikes must not be allowed to jeopardise good management and maintenance or limit potential long-term reinforcement.

Regional dikes

The addition of stretches of open water, green roofs, water squares and water storage will limit the flow of water to the outlets and will therefore increase the resilience of the water system. These measures will ensure that the flood risk of the system of outlets, such as the rivers Schie and Rotte, does not increase. If a dike is breached, then the consequences of the flooding can be limited by locally closing the outlets, for example by using compartment dikes.

During long periods of drought, the regional dikes, and the peat dikes in particular, will be monitored by dike surveillance. Cracks and other problems will thereby be discovered at an early stage. Keeping the peat dikes wet is an effective preventive measure.

Improving the crisis management

The transition to a flood risk approach with multi-level safety and security as suggested in the Delta Programme means that it is necessary to reassess the current evacuation plans. Crisis management is an explicit part of the agreed safety levels. In this context, specific attention must be paid to evacuation routes, and for example the use of Rotterdam-The Hague Airport as an 'emergency airport'.

An area-specific approach

In order to continue meeting the current dike safety standards, adjustments to the camp sheeting of the dike at the Merwe-Vierhavens are already necessary. Assessments are still being carried out in Rozenburg and in some parts of IJsselmonde. In the long-term, the higher normative high water levels will mean that the dikes in the Hoek of Holland and along the Maasboulevard will need to be reinforced. Tightening the protection standards within the framework of the Delta Programme, otherwise known as the 'new standards', may lead to additional dikes in Rotterdam requiring attention. The exact locations, the precise measures and the associated timeframe are not yet known.

At various locations in the city, measures are being taken to reduce the risk of outlets flooding. These measures are always linked to specific local area development.

Adaptation over time

The rate of climate change determines when particular measures must be taken. With rapid climate change (W+), between now and 2050, the dikes at the Hook of Holland, along the Maasboulevard and in the Merwe-Vierhavens will need to be reinforced. In the subsequent period up to 2100, the required dike reinforcements at the same locations will become necessary over longer dike trajectories. Furthermore, reinforcement will also be necessary at other locations, such as the Merwe-Vierhavens in Schiedam and Rozenburg. Tightening the safety standards could require the extra dike reinforcements to be implemented before 2050.

The Maeslant storm surge barrier can cope with a rise in sea level of up to 50 cm. In the rapid climate scenario (W+), the Maeslant barrier will remain effective until 2070-2080. After this, modifications or the construction of a new barrier will become necessary.

Measures are already being introduced in the urban water system, and these directly contribute to reducing the risk of the outlets flooding. Agreements concerning improving crisis management will be made within the context of the Delta Programme.

The primary dikes along the recently renovated Boompjes form an attractive recreational landscape by the river Meuse

Linking in with other projects

It is important to link the planning of the safety measures to the spatial development plans or regular management and maintenance. This can mean that the timing of the implementation of the plans needs to be changed. The priorities for the transformation of the Merwe-Vierhaven area will depend on the future dike reinforcement requirements. For example, this may mean that the dikes are reinforced earlier than strictly necessary. The regular maintenance of the dikes can also be linked in with other projects, such as the construction of infrastructure (cycle paths) and plans for the incorporation of extra flora.

The current instruments, for example financing arrangements and assessment tools, will where possible be used to encourage the combination of spatial development with dike reinforcements, even if the dikes have not officially failed an inspection.

Working together

The reinforcement of dikes and dunes and adjustments to the storm surge barriers are tasks for those bodies responsible for water control, namely the Ministry of Waterways and Public Works and the water boards. However, integration and multi-functional spatial use requires cooperation with the province, housing corporations, developers and property owners, and potentially also with the Port of Rotterdam and NGOs.

The Regional Security Department has the lead when it comes to improving contingency management, but the involvement of all government departments (City of Rotterdam, province, water boards, emergency services, armed forces) is essential.

Added value

Just as in the outer-dike areas, the most important result is the creation of a safe working and living environment for 'water-conscious' inhabitants and businesses. The dikes of Rotterdam form an integral part of the city. The tasks of maintaining and where necessary reinforcing the dikes provides opportunities for improving the spatial quality, for example through the construction of extra parks and gardens or by encouraging multi-functional use such as recreational routes. Combining area development with the construction of robust (climate) dikes can also be profitable.

It is important to link the planning of dike reinforcement with other spatial plans. Linking in with other plans improves the total integration, reduces costs and stimulates innovation. Knowledge concerning flood protection and adaptive delta management can be exported to other deltas. Rotterdam intends to play a leading role in this regard, supported by internationally oriented businesses, universities and colleges.

The roof top park Vierhavenstrip is a public outdoor area in a unique, multi-functional dike setting

Example

Rotterdam dike reinforcement. A lasting river dike

The Rotterdam river dikes do not require urgent attention, but in the long-term they will have to be reinforced to cope with the rising sea level. Analysis of the extent and locations of the tasks ahead, and how they can be combined with area development plans and existing characteristics, can reveal potentially beneficial opportunities for linking projects. This is for example the case in the Merwe-Vierhavens, which as part of Stadshavens is one of the main transformation assignments in Rotterdam over the coming decades. Development of this area is expected to span more than forty years. The dikes in the Merwe-Vierhavens will, at some point, need to be reinforced and this can be taken into account when setting priorities for the transition. Three different possible future scenarios have been outlined, each corresponding with different growth expectations and available financing.

What is special about the project?

It has been proposed that dike reinforcements should be carried out sooner than strictly necessary. The regular maintenance of the dikes can also be linked in with other projects, for example with the construction of infrastructure (cycle paths) and plans for the incorporation of additional flora.

Who

DE URBANISTEN

Commissioned by

The Ministry for Infrastructure and the Environment, Delta Programmes: Rijnmond-Drechtsteden, Rivers and South West Delta

Within the framework of

IABR 2012 (International Architecture Biennial Rotterdam)

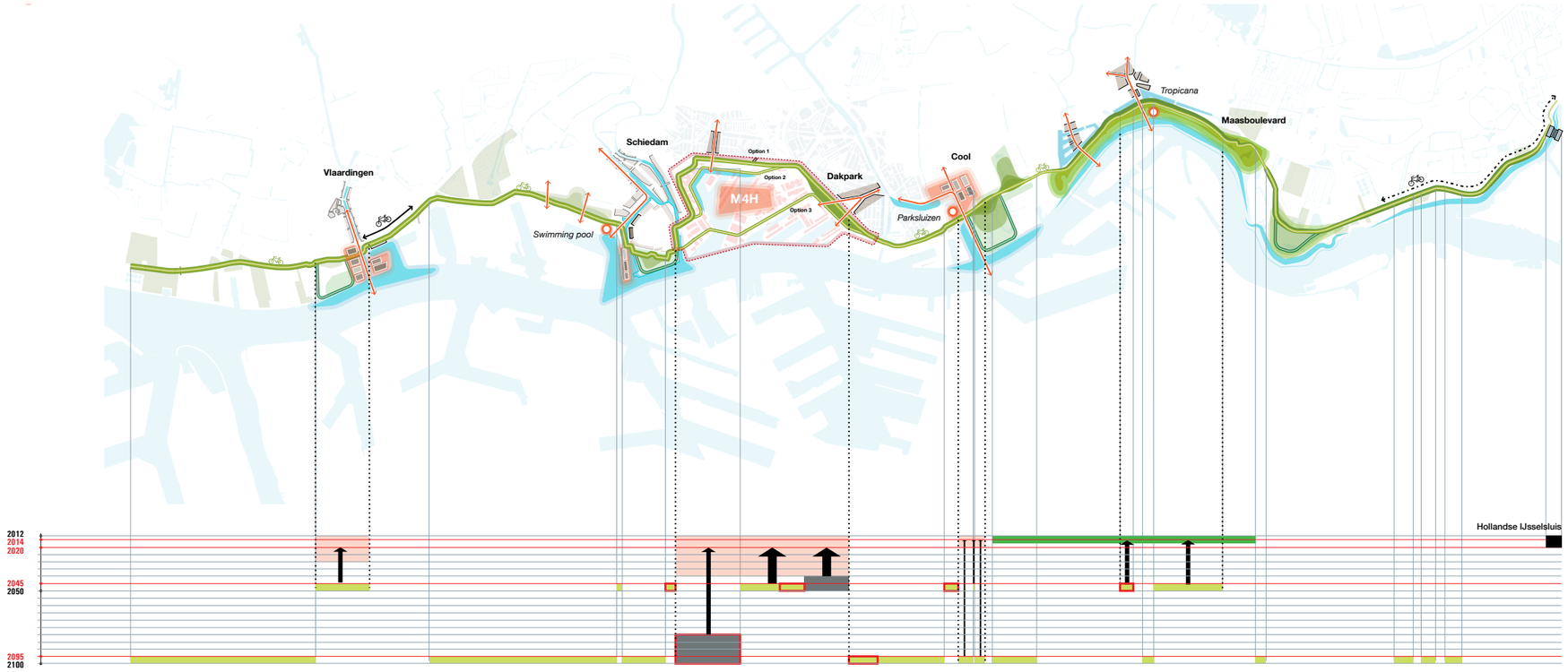
Illustration of three different ways in which dike reinforcement and area development can be combined in the Merwe-Vierhaven area depending on three types of economic conditions

A. STAGNATION

B. GRADUAL GROWTH

C. GROWTH SPURT

Strategic interventions in the highly urbanised Dike ring 14 south in which dike reinforcement and area development will be combined at favourable locations



5.3
Extreme rainfall

Summary of the task ahead

The changing climate will lead to more frequent extreme rainfall and heavier downpours. This will increase the risk of disruption and damage caused by flooding, particularly in areas that already have a water storage capacity deficit and densely built-up, paved urban areas.

The drainage and storage capacity of the urban water system is being adapted to deal with extreme rainfall. However, in spite of this, it is becoming increasingly likely that downpours exceeding the amount that the system can cope with will occur. This problem will affect not only public areas but also private property.

Core of the strategy

The initial priority is in accordance with the Rotterdam water plan 2: 'working with water to create an attractive, economically strong and climate proof city', or, to put it another way, a flood-proof city. To achieve this, the basics of the system must be in good working order. We will continue to maintain and where necessary improve the urban water system so that in the future the city will become less vulnerable to flooding, for example by increasing the storage and drainage capacity.

At the same time, we must take some of the pressure off the water system. Where possible, in all parts of the city, rainwater must be captured and retained where it falls and drainage delayed. Where necessary, rainwater should be used to augment the groundwater and to irrigate the flora of the city.

However, that in itself will not be enough. The increase in short, sharp downpours means that the urban water system has to become more resilient. The water storage capacity of public areas needs to be increased. Such waterproof public areas are capable of temporarily storing water on the streets without causing any damage.

If other parties, and the inhabitants of Rotterdam in particular, are informed and encouraged to become involved, they will become more conscious of their own responsibilities and more aware of the measures that they themselves can take.

Measures

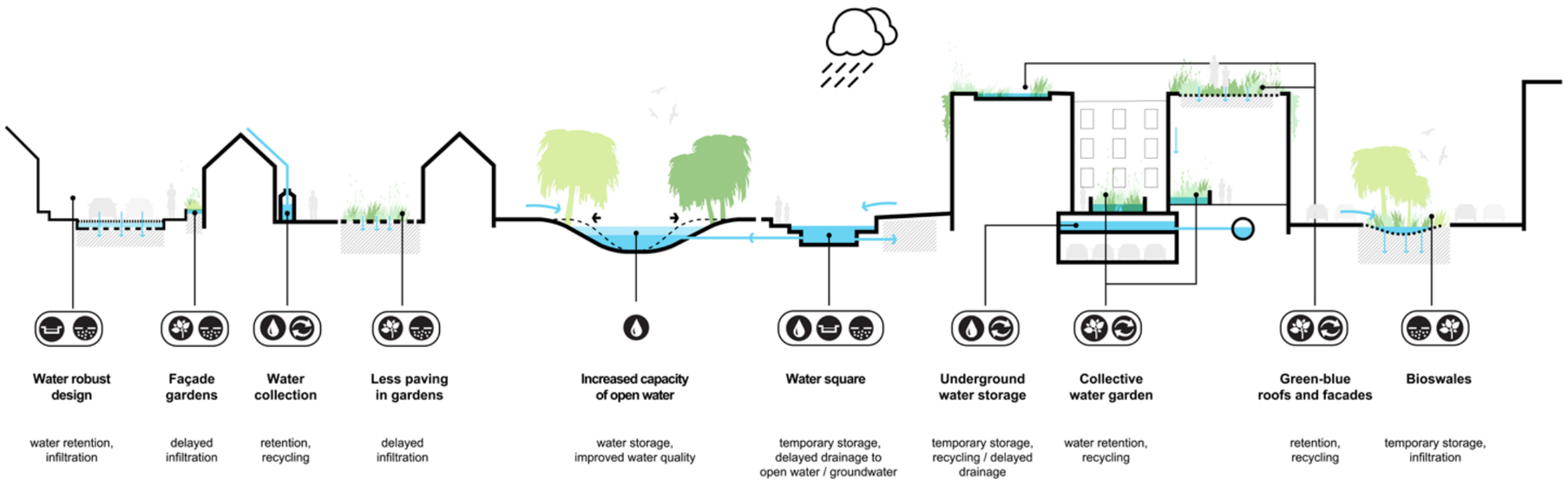
The 'waterproof city' is robust and resilient (grey and green-blue) with a mix of paving and vegetation. The focus is on adaptive measures whereby the rainwater is captured and drainage is delayed.

Effective measures in public areas include removing paving and planting trees and bushes along the streets and in open areas. Water squares can be an attractive solution for heavily used areas with little available space. In the linear arena of streets and roads, infiltrating vegetation (bioswales) or porous paving stones may provide fitting solutions.

Adaptive measures may also be taken on private property. Experience has already been gained with green roofs in the city. 'Blue roofs' that can be combined with the re-use of rainwater within the building are another possibility. Replacing paving in gardens with green, under the motto 'Paving out, Plants in!' and constructing façade gardens (Green Team) will both be actively encouraged.

Vulnerable areas must incorporate a water robust design in the buildings and public areas. The public areas will be adapted so that they can store the rainwater, for example by using intelligent street profiles. If there is a lasting risk of damage then the owners of the building will be informed and action taken, such as raising doorsteps or providing sandbags or partitions.

The basis of the system will be maintained so that it is robust and in good working order. Initially this will involve the provision of extra surface water where that is necessary and possible. The construction of underground water storage in combination with other techniques is useful in places with limited space, such as underneath the Kruisplein. Finally, the drainage capacity of the system can be increased through the above-ground drainage of rainwater, for example.



The Westersingel can store extra water on the lower-lying sculpture terrace

An area-specific approach

The measures required vary depending on the area and the specific characteristics, such as the relationship between paving, water and vegetation, the type of ground, the water table, the type of sewerage system and of course the functioning of the water system.

In densely built-up urban areas there is a lot of pressure on the public areas and on the land itself and very little space is available. Here, the focus is placed on the possibility of combinations such as underground water storage (Museum Park and Kruisplein) and water squares. Green and blue roofs, removing paving and planting trees and bushes in the streets and open areas and waterproof design all contribute to increased resilience. The post-war urban districts are more suited to the creation of additional stretches of open water, such as canals and lakes. There may even be room for solutions such as wadis in these districts.

Major roads, tunnels and stations, hospitals and healthcare institutions, regional shopping centres and businesses parks will in the future be especially well-protected from flooding caused by extreme rainfall. This higher level of protection is designed to guarantee accessibility and prevent damage.

Adaptation over time

The adaption strategy for extreme rainfall and the associated measures are laid down in the Rotterdam water plan and the urban sewerage plan. Rotterdam has already started implementing 'no regret' measures, such as the construction of water squares, green roofs, underground water storage, infiltration facilities (Johan Idaplein and Centraal Station) and the 'Blue Corridor'. With its 'Paving out, Plants in' campaign, the City of Rotterdam hopes to involve the inhabitants in climate change adaptation and encourage them to replace paving in their own gardens with plants and vegetation.

Linking in with other projects

Where possible, the creation of extra water storage is combined with area development projects. Furthermore, we are focusing more and more on linking in with existing programmes for the maintenance of roads, parks and the sewerage system. Other programmes such as 'child-friendly districts' and 'wilderness school playgrounds' also provide opportunities. As time goes by, all parts of the city will gradually become greener and more climate proof.

Visual model instruments (3Di) can be used to gain a better insight into the vulnerability of the public areas and to develop and implement appropriate measures. These instruments can also be used to determine priorities in the timing.

Temporary water storage under the Kleinpolderplein motorway interchange

Water storage combined with the construction of the Willem Alexander rowing course

Working together

Creating a waterproof city requires individual approaches and intensive cooperation between the water boards, urban developers, the City of Rotterdam and spatial administrators. Other parties such as housing corporations, project developers and the inhabitants in particular all need to play their part. Public awareness and involvement will be stimulated by means of active and targeted communication. Everyone can contribute to making the city waterproof. Campaigns such as the Green Roof Information Days, the 'Green Team' and the campaign 'Paving out, Plants in' are concrete examples, more of which will follow in the future.

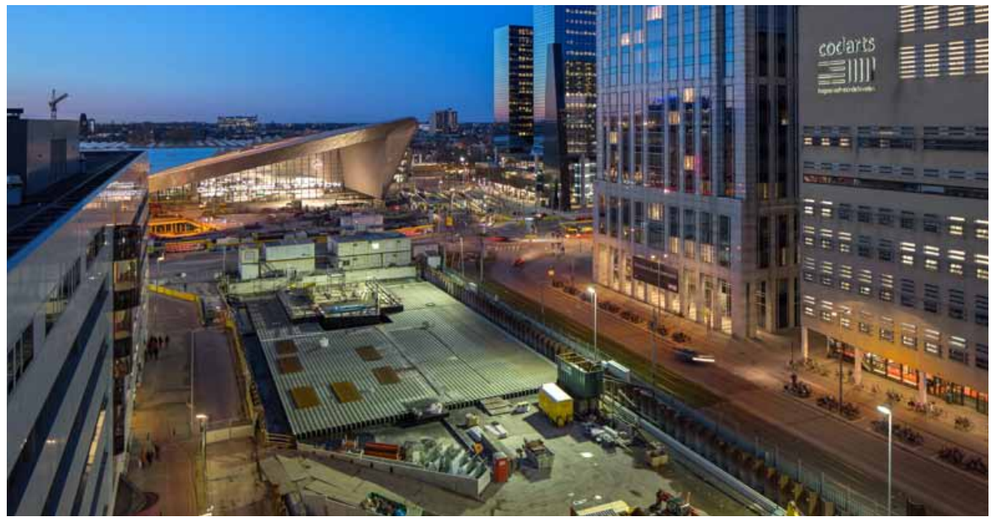
Added value for the city

The main added value for the city is the creation of an attractive and green-blue environment with sustainable solutions for coping with rainwater. The large-scale implementation of small-scale measures into the veins of the city is linked to the maintenance and replacement programmes thereby limiting and spreading the required extra investments. In this way, the city will gradually become greener and more resilient.

Rotterdam is a city in which innovative solutions for rainwater in urban areas are already being implemented. This makes Rotterdam the perfect breeding ground for the development and export of knowledge. Experiments with 'water in the city' reinforce the Rotterdam's international image as a progressive, ambitious delta city. Rotterdam's water squares are exemplary.

Blue-green adaptation will lead to an increase in the biodiversity of the city. This applies to all projects from the large-scale Blue Corridor and wilderness playgrounds to the small-scale 'rain gardens', façade gardens and green roofs.

Possible measures such as greening the streets and open areas, water squares and the removal of paving around houses provide a wide range of opportunities for getting the people of Rotterdam more involved with their city and with their own direct living environment in particular. The inhabitants can play an active role, which in turn improves social cohesion.



Construction of the water storage under the Kruisplein

Example

Water square, Benthemplein

The Benthemplein is being developed into the perfect example of a large, multi-functional water square, which combines the collection of rainwater with a special, public outdoor area. A considerable number of stakeholders from the Benthemplein worked closely together to produce the final design, including the Zadkine and Graphic College, a church community, a youth theatre, a sports school and local residents.

What is special about the project?

During the course of three workshops, such topics as potential usage, desired characteristics and the influence of rainwater on the area were discussed. The participants' enthusiasm led to a design in which water storage provides opportunities for sport and leisure. The water square is an innovative solution for preventing flooding, relieving the sewers and improving both the water quality and the living environment in the city.

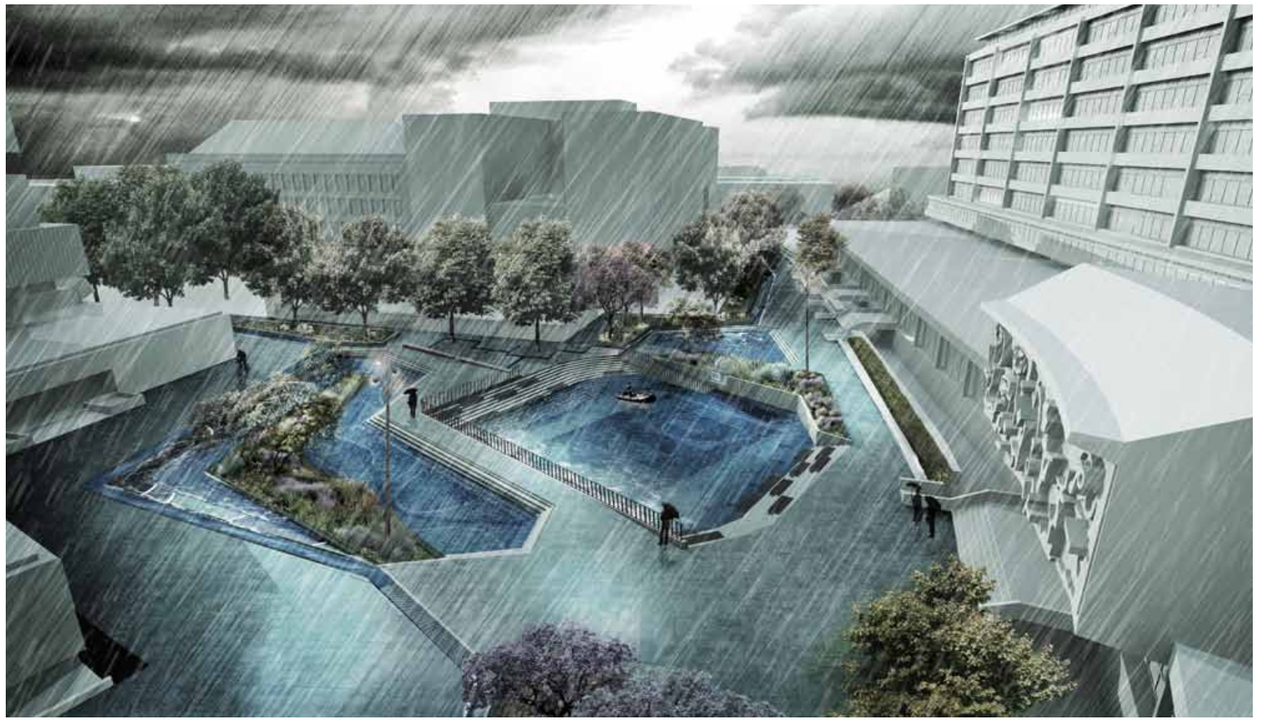
Who

DE URBANISTEN
City of Rotterdam

Commissioned by

City of Rotterdam and the Schieland and Krimpenerwaard Water Board

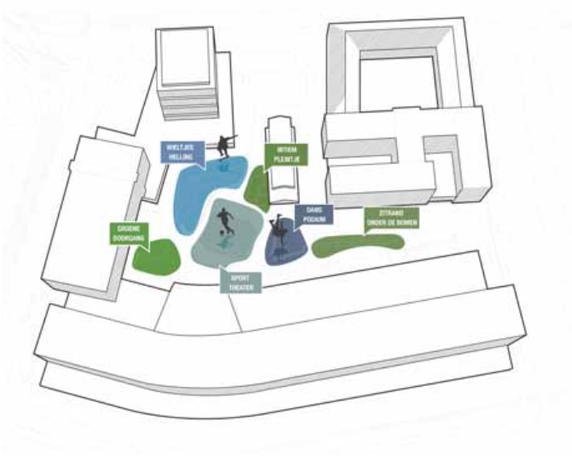
With financial support from: Ministry for the Infrastructure and Environment, Mooi Nederland (subsidy scheme for Beautiful Netherlands), European Union, Interreg IV



The Benthemplein water square as temporary water storage facility, artist's impression of the scene during a downpour

The Benthemplein after a shower

The Benthemplein on a sunny day



A multi-functional square with a variety of characteristics

The design was the result of an intensive participation process involving all stakeholders

5.4
Drought

The task summarised

Longer periods of drought and groundwater deficits affect the water table and can also lead to lower river levels. Lower groundwater levels in turn affects the peat ground drying out and sinking. This poses a risk to wooden pile foundations. Drying out can also cause peat dikes to subside and threatens the urban flora. Climate change will only increase these risks.

Lower river levels cause the salt water to intrude further inland. A direct consequence of this is that either poor-quality water will be let into the Rotterdam water system or river water will not be let into Rotterdam at all. Both these situations will lead to a reduction in the water quality in the city and be detrimental to its flora and fauna. Lower river levels will mean shallower navigation depths, which will obstruct shipping.

Core of the strategy

A robust and resilient water system

In order to make the city less vulnerable to the effects of drought and rainfall shortage, Rotterdam is focusing on retaining rainwater and replenishing the (ground)water where possible. The current robust water system is being maintained and strengthened by, for example, making more room for water in ditches, canals, waterways and lakes, controlling water levels and sluicing with relatively high-quality water. This will make the system robust so that it remains in balance even during longer periods of drought.

The implementation of adaptive measures to combat drying out will improve the resilience of the water system. We are making use of the ‘space in the city’, for example by increasing the infiltration capacity and capturing rainwater where it falls, deep in the heart of the city, thereby reducing the likelihood of sub-strata, plants and foundations drying out.

Furthermore, the above strategy ensures that the urban water system and the flora and fauna that depend on it are less vulnerable to the consequence of increased salinization of the river water and the lower quantities of fresh water that are let in during long periods of drought and low river levels.

Finally, it is important to identify and monitor the areas that are most at risk, for example the peat dikes and those areas where drying out could cause considerable damage, in order to be able to take adequate measures at the right time. Specific long-term research into the urban districts will continue to be necessary.

Measures

Many of the measures that effectively combat low groundwater levels and drying up are part of the standard measures for creating a ‘climate proof’ city; maintaining the basics – keeping the current water system in order – combined with adaptive measures to locally capture and delay the drainage of rainwater.

An effective robust measure is to create extra surface water in the city where necessary and possible. Examples here include the expansion of existing or the creation of new lakes, canals, waterways and ditches. On a city-wide scale, this can be achieved by extending existing green-blue networks and constructing new ones, such as in the south of Rotterdam. These networks are also known as ‘climate buffers’ and can be linked to the regional water network. Increasing the potential for sluicing is another robust measure.

Adaptive measures make the system more resilient and less vulnerable to periods of drought. Measures here include incorporating more flora and less paving in the city through small-scale projects on buildings, gardens or streets. Such projects directly contribute to increasing the infiltration capacity of the ground and making the city act as a sponge.

Examples include the construction of private ‘rain gardens’ and ‘façade gardens’. Linear, infiltrating vegetation such as ‘pavement planters’ and ‘bioswales’ are effective measures in public areas. Water squares can also be combined with infiltration measures. Porous paving is a good solution for the streets. Irrigating and spraying plants and bushes during periods of drought is not sustainable, but may occasionally be a necessary emergency measure. In the long-term, the use of less sensitive flora in the city should be considered.

An important advantage of nearly all the above measures is the combined contribution to reducing the city’s vulnerability to all aspects of climate change (rainfall, drought, heat).

Measures to combat the effects of the obstruction to shipping caused by lower river levels include the temporary use of other forms of transport and the carrying of lighter cargos.

Extra surface water along the Tjaklaan

More surface water in the Zuiderpark

Extra surface water in the form of a new canal

Community gardens create extra infiltration potential in the city

An area-specific approach

The vulnerability and the risks of drying out vary. The risks are greater in densely built-up urban areas with a lot of paving, little open water and few plants and trees, for example the city centre and the 19th century urban districts. The above-mentioned measures will be effective in such areas. These measures will also be effective in those areas where the ground is sensitive to drought (compacting and subsidence) and areas in which wooden pile foundations are used. The most appropriate measures for peat dikes are water level management and dike monitoring.

Adaptation over time

It is difficult to isolate the effects of climate change from the other causes of low groundwater levels in the city. The effects of the urban layout and the physical condition of the sub-strata on the soil hydrology depend on the specific local situation. Long-term, specific research would be required to determine the precise effects caused by climate change. However, many of the adaptive measures in the (public) areas of the city are 'no-regret' measures that are already being taken.

Linking in with other projects

When maintaining and improving the current water system and implementing adaptive measures to increase the capacity in the heart of the city, it is important to move with the 'rhythm of the city' and to link in with other programmes and initiatives. Examples of this include 'more flora in school playgrounds', urban agriculture initiatives and local residents replacing paving stones with greenery. The maintenance and management cycle for roads and parks also provide opportunities for linking in.

Working together

Rotterdam and the water boards are primarily responsible for the water system. Creating a waterproof city requires individual solutions and intensive cooperation between these organisations. Adaptive measures enable citizens, businesses and other organisations to actively participate, for example by incorporating more green in the immediate vicinity or by constructing water squares. The development of a green-blue network and climate buffers is already going ahead with the help of, amongst others, nature organisations such as WWF (World Wildlife Fund) and ARK.

'Paving out, plants in'

Added value

Inhabitants, businesses and visitors can all benefit from reinforcing the green-blue network in Rotterdam, both in the immediate vicinity of their homes and neighbourhoods (green roofs and façades) and in the city itself (water squares and lakes, green-blue network). Furthermore, the measures provide an attractive context for the transformation of the existing city.

There are also economic benefits. Firstly, there is the prevention of damage to private buildings and to the flora and fauna in the city. Secondly, there are potential reductions in maintenance costs and the costs of raising public areas. Thirdly, property values may increase as the quality of the parks, gardens and water in the city improves.

Small-scale measures in particular, such as green adaptation in the neighbourhoods, will increase the involvement of the people of Rotterdam with their own living environment and improve relationships between them. The main ecological added value is maintaining, and where possible improving, the ecological qualities of the city and creating a richer biodiversity. The Blue Corridor is a good example of this.

... an action reappearing in a variety of guises throughout the city

Paving out, plants in

Example

Blue Corridor

In 2012 work began on the construction of the Blue Corridor, a green-blue link between the Zuiderpark in Rotterdam, the future landscape park Buijtenland in Rhoon and the Zuidpolder in Barendrecht. This is a recreational, navigable route that provides clean water to the area, acts as a water storage facility and forms an ecological link between the various nature areas. The route will significantly improve many aspects of the local environment. The project will take 10 years to complete and is divided into six sub-projects.

What is special about the project?

Eight government organisations have committed themselves to the plan, ensuring a wide support base for the Blue Corridor. The scale of the project means that it can be especially effective in making the water system resilient to long periods of drought.

Who

Charlois District Council, City of Rotterdam
District Albrandswaard
District Barendrecht
Province of Zuid-Holland
IJsselmonde Recreational Community
Urban District Rotterdam
Hollandse Delta Water Board in cooperation with
Ministry of Waterways and Public Works
The World Wildlife Fund
ANWB
Canoe Association of the Netherlands

Commissioned by

City of Rotterdam

Artist's impression of the course of the Blue Corridor (source: brochure Fresh Water Buffer IJsselmonde, June 2012)

The Blue Corridor creates an attractive environment for living and spending leisure time

5.5
High temperatures

Summary of the task ahead

Climate change will lead to longer, more frequent periods of high temperatures. The Urban Heat Island (UHI) effect will compound the effects of heat in the city. In the summer, the most important consequences of this warming will be health problems and increased levels of mortality, a reduction in the thermal comfort both indoors and outdoors, higher energy consumption, lower productivity, reduction in air quality, reduction in water quality and biodiversity and malfunctioning infrastructure. The task is to reduce the vulnerability of the city and its inhabitants to heat stress.

Core of the strategy

Even with the changing climate, the urban climate in Rotterdam will remain pleasant and healthy, both indoors and outdoors. By a pleasant urban climate, we mean that in the outdoor urban areas there are enough cool places such as shady parks or water features.

The core of the strategy is to incorporate more flora in the city, especially in its paved, densely built-up areas. This is being done at all levels in the city, from pavements to city parks. In those places where it is not possible to incorporate greenery, other adaptation measures will be included in the design and maintenance plans. At the same time, use is being made of the opportunities provided by a warmer city. More parks and gardens create a more attractive environment, a richer urban biodiversity and extra activities in the field of recreation and tourism. All this is good for the urban economy.

Living and working in buildings that remain cool, even during a heat wave, is important for health and well-being. Owners are being advised and encouraged to invest in making existing buildings more heat-resistant. For maintenance investments, energy-saving choices are being made that will ensure that the indoor environment remains pleasant despite periods of extreme high temperatures. For all new construction, heatproof measures are being incorporated from the very start of the design phase.

The effects of hot periods on the urban climate and the consequences for people, plants and animals will continue to be monitored. As a result of these measurements and research into the effects of higher temperatures on the health of the people of Rotterdam, additional actions may be required.

Cooling off in the cultural grounds in the Museumpark

Relaxing in the shade of the trees in the Zuiderpark

Cooling off in the river Meuse

Measures

The approach focuses on two elements. The first element includes the adaptive measures that will be implemented to adapt the physical design of the city to better cope with heat (stress). A good example is incorporating more green in the city. The second element involves making citizens, businesses and in particular specific target groups such as the elderly more aware of the risks of extreme heat. They will also be informed about how they themselves can contribute to a healthy and pleasant working and living environment during hot periods.

Greenery in the city reduces urban heat levels, for example by providing shade and by evaporation. Incorporating more green and removing paving from the city is one adaptive measure that effectively combats multiple negative effects of climate change and at the same time contributes to making the city more attractive. Private initiatives include measures such as green roofs and façades and green inner courtyards and gardens. In public areas there are a wide range of potential measures, from incorporating more green in the streets and along the infrastructure (boulevards, quays, cycle and walking routes) to good management and extension of parks and greenbelts, such as the Blue Corridor, and from the construction of school nature playgrounds and wilderness playgrounds to 'building with nature' in outer-dike Rotterdam. Another adaptive measure is the use of highly reflective materials in public areas. Finally, incorporating water features (fountains) provides cooling and is both refreshing and attractive.

Measures to make buildings more heatproof include white and green roofs, easy-to-open windows, sun blinds, insect screens and ensuring that bedrooms are situated on the lower floors and on the north sides of buildings.

Finally, we intend to keep the people of Rotterdam well-informed about heat stress and the consequences for their well-being and health. This will enable them to implement their own measures and, during a heat wave, to modify their own behaviour so that they are minimally affected by the heat.

More flora around the Binnenwegplein

Green facades at Sint Jacobsplaats

An area-specific approach

The focus is on implementing measures in those districts, neighbourhoods, streets and buildings that are most vulnerable to heat. This concerns paved-over districts, such as the inner city, that are densely built-up and where there is little green. Vulnerable buildings and the presence of large groups of vulnerable, less well-off people require particular attention. During the redevelopment of property, the main focus is on improving poorly insulated buildings.

Adaptation over time

Information is already being provided at times when long periods of high temperatures are expected, and where possible tangible measures are being implemented in the urban areas. All opportunities for linking in with existing government or private initiatives for incorporating more plants in the city are being utilised. It is also possible to link in with the cycles for the management and maintenance of public areas (utilities and infrastructure). Finally, measures are being linked in with private redevelopment and building renovation plans, construction plans and area development. Needless to say, existing flora, parks and gardens remain cherished assets.

Working together

To reduce the vulnerability of the city and its inhabitants to the effects of heat, Rotterdam is working together with its citizens, employers, universities and colleges, housing corporations and other building and property owners as well as with stakeholders in the health care service to create a heatproof city.

Added value for the city

Adapting to cope with heat in the city will increase the health, welfare and personal well-being of the people of Rotterdam. The thermal comfort in the home, at work and in public areas will improve. Furthermore, many of the measures will also contribute to making the city more attractive, greener and cooler and creating a more comfortable environment in which to live and work. There are economic opportunities for entrepreneurs in the field of tourism and recreation, and higher productivity rates and lower energy costs will provide indirect profit. Rotterdam will also benefit from the development of knowledge regarding the changing urban climate and the most effective measures.

Green roofs provide cool relief in the densely built-up city

Example

The people of Rotterdam make the city

The study 'The people of Rotterdam make the city' researches sustainable densification of the Rotterdam inner-city area. Rotterdam would like to attract more people to live in and visit the centre. To do this the social climate in the city needs to improve. Research indicates that the presence of attractive public areas, of which greenery is an essential aspect, is an important prerequisite for urban life in terms of both the daily living and working environment and leisure time. The study comprises seven strategies to combat the Urban Heat Island (UHI) effect by incorporating more urban flora.

What is special about the project?

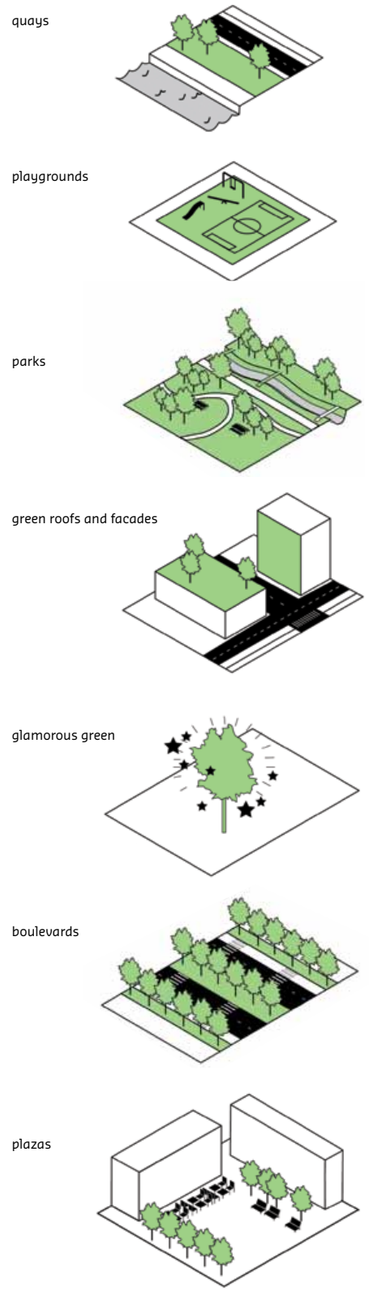
Various meetings were held to identify those concerned residents and businesses of Rotterdam who are prepared to look after the inner-city. At these meetings the creation of an attractive inner-city (by compaction and incorporation of more green) and other such topics were discussed, but the main issue was the realisation that everyone can make their own contribution. The study attempts to link in with existing projects in the city.

Who

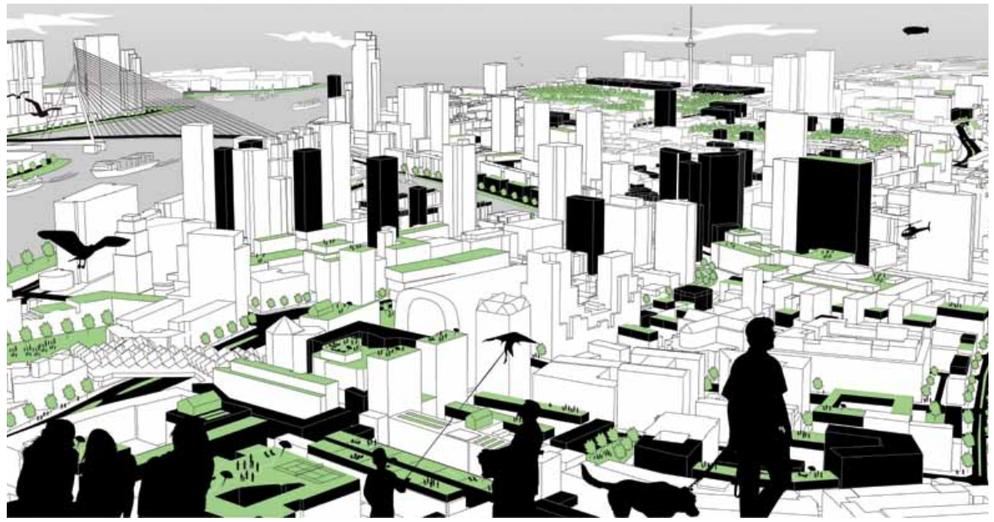
City of Rotterdam
Interreg IVB project MUSIC
TNO
Doepel Strijkers Architects
Sander Lap landscape & urban design
Drift, Erasmus University Rotterdam

Commissioned by

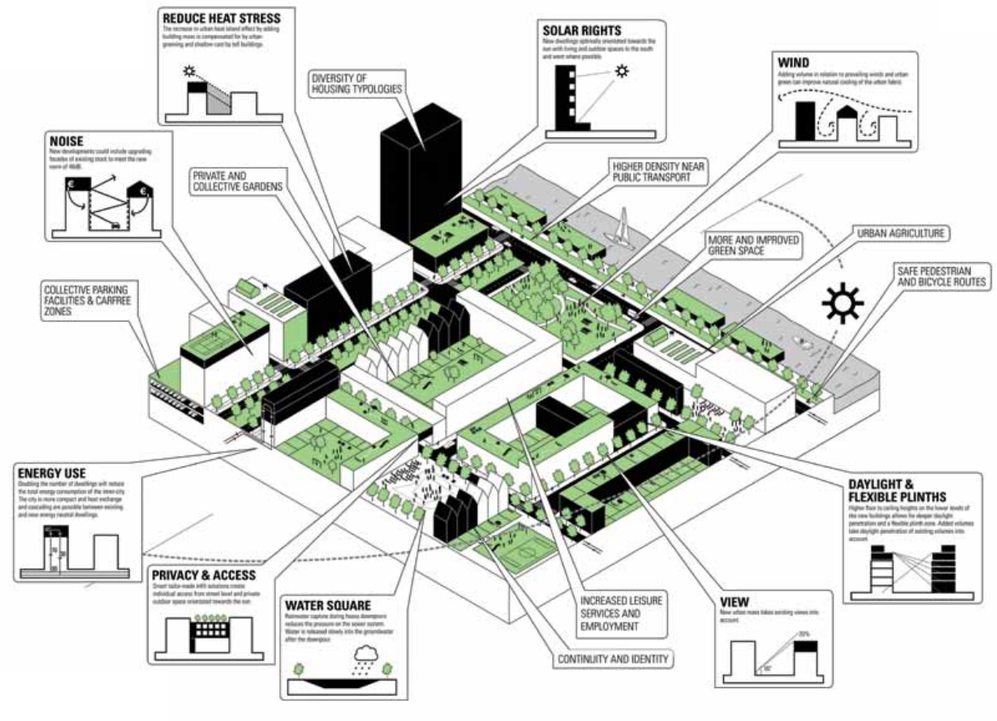
City of Rotterdam



Seven strategies for incorporating more green in inner-city Rotterdam



Overview of the potential for new residential areas and extra urban green in the inner-city, 2040



Overview of the potential for compacting inner-city Rotterdam

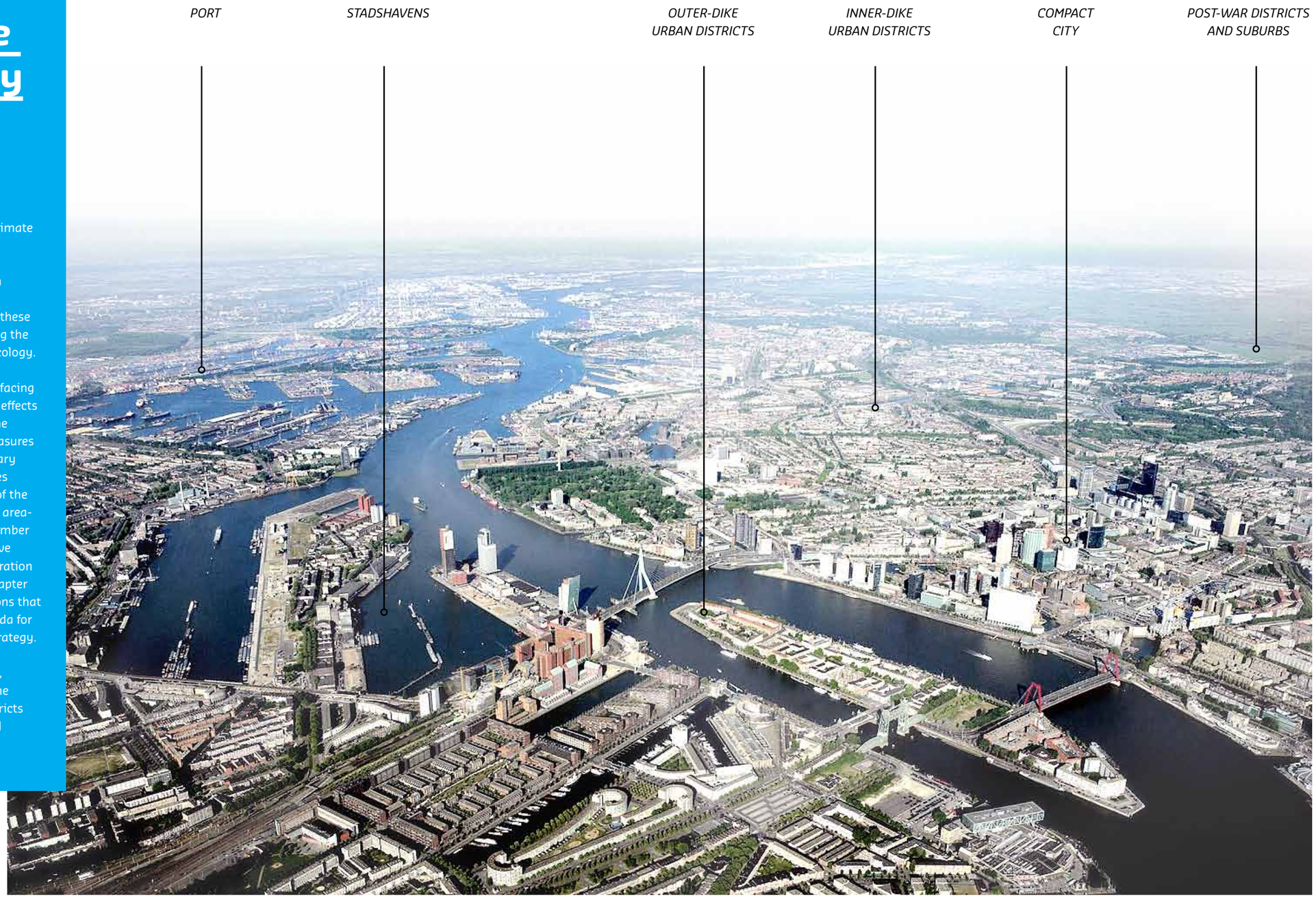
6

Perspectives for the climate proof delta city

This chapter sketches an integral vision of a climate proof Rotterdam in which adaptive measures combating various climate change effects can be combined. Descriptions from six Rotterdam perspectives illustrate which measures will be effective in different parts of the city and how these adaptive measures will contribute to improving the environment, society, the economy and the ecology.

Chapter 4 discusses the climate-related tasks facing Rotterdam and describes when and where the effects of climate change will become noticeable in the city. Chapter 5 describes the strategy and measures required for each of the climate tasks. Exemplary studies and projects illustrate the opportunities available while simultaneously solving some of the problems. The perspectives in this chapter are area-specific and for each 'type of urban area', a number of suitable combinations of robust and adaptive measures are proposed together with an illustration of the spatial characteristics involved. This chapter combines chapters 4 and 5 in six integral visions that act as guidelines for the implementation agenda for the Rotterdam Climate Change Adaptation Strategy.

Six types of urban area are identified: the port, Stadshavens, the outer-dike urban districts, the compact city centre, the inner-dike urban districts and the post-war suburbs with their parks and gardens.



6.1
Combined perspectives

The most important difference between the six urban types is their position in inner-dike or outer-dike Rotterdam. In addition, we distinguish between urban areas with little available space for adaptive measures and areas in which there is plenty of available space. This can involve physical space in the city, but also includes the potential for transformation such as in city harbours. Finally consumer pressure on the available space will also determine which adaptive measures are appropriate for a given area. Consumer pressure is intense in the compact city centre and in the neighbouring densely populated urban districts. The different areas are shown in colour on the map of Rotterdam. The darkly coloured parts of the map indicate where climate change adaptation is necessary and where it may be possible to combine measures.

In outer-dike Rotterdam the key principle is multi-level flood protection based on adaptive construction and design, including flood-proof construction and design, floating communities and 'building with nature'. The port and essential infrastructure are well-protected from flooding. City harbours provide opportunities for combining area development with adaptive measures.

Prevention is the key factor in the flood protection of inner-dike Rotterdam. Actions here include optimisation of the storm surge barriers and where necessary reinforcement of the dikes. Dike reinforcement is well-integrated in the city, with multi-functional, natural embankments, such as recreational routes, being combined with area development.

Within the dikes, the 'sponge function' of the city will be restored through a series of measures designed to collect the rainwater where it falls, store it and to facilitate delayed drainage. Examples here include green roofs and façades, replacing paving stones with plants in streets and neighbourhoods, constructing water squares and establishing infiltration zones within existing infrastructure. These measures are particularly effective in areas with high consumer pressure and little available space, such as the compact city centre and the neighbouring urban districts.

In areas of the city where there is more space, robust measures such as increasing the water storage function of canals and lakes and the construction of green-blue networks can contribute to creating a climate proof city. This green-blue adaptation of the city is a 'no regret' measure that will not only contribute to making Rotterdam climate proof but will also make the city a more attractive and pleasant place in which to live.

For each of the different types of area, two perspectives are compared. The first concerns climate change adaptation and working together, while the second illustrates the added value and benefits. Answers are given to the following questions:

- Which climate adaptive measures are appropriate for which parts of the city, and who will take the first steps?
- What added value do the combined measures generate for the environment, for society, for the economy and for the ecology and who will benefit?

6.2
Perspective for the port

The port area stretches out over forty kilometres and encompasses one third of the total land area in Rotterdam. The Port of Rotterdam has considerable economic value and directly provides many jobs for the people in the Rotterdam region. Many containers, hazardous substances and other goods are temporarily stored in the port. There is also a range of utilities that are essential for the proper functioning of the region, such as power stations and water treatment plants.

The port is situated in the outer-dike area and is directly linked to the river and the sea. This makes it vulnerable to high river levels and especially to storm surges. The older harbour areas are particularly vulnerable. In the new harbour areas such as the Maasvlakte, the higher water levels have already been taken into account and the main access roads are built at the same elevation as the dikes. This means that they will continue to function even during extreme conditions. For the older harbour areas, it is important that during extreme conditions the valuable and hazardous goods do not spill into the river.

Over the coming decades, measures, such as the construction of terps, compartment dikes and waterproof walls, can be implemented to relieve the most vulnerable locations. Major access roads are at safe elevations and must remain that way. Essential junctions require extra attention and need to be protected locally to ensure that even in an emergency the city can continue to function properly. Electricity in particular is of vital importance. By taking all these factors into consideration, we will ensure that the port continues to be seen as having good and secure investment potential, and also remains a source of economic prosperity for the city.

Warming up is also apparent in the port harbours. These areas are generally paved over and therefore retain much heat. Major access roads and pipelines can be further developed as ecological structures. This will reduce heat retention and at the same time create attractive recreational routes through the fascinating port landscape.

Perspective for the port

Which climate adaptive measures are appropriate for the port and who will take the first steps?

What added value is generated by the combined measures for the environment, for society, for the economy and for the ecology and who will benefit?

Strategies

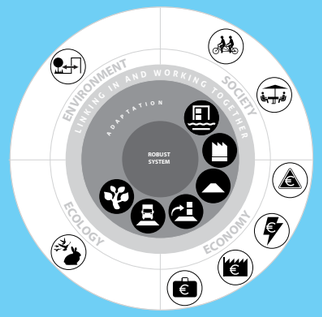
differentiated flood-proof outer-dike design

local reductions of heat stress

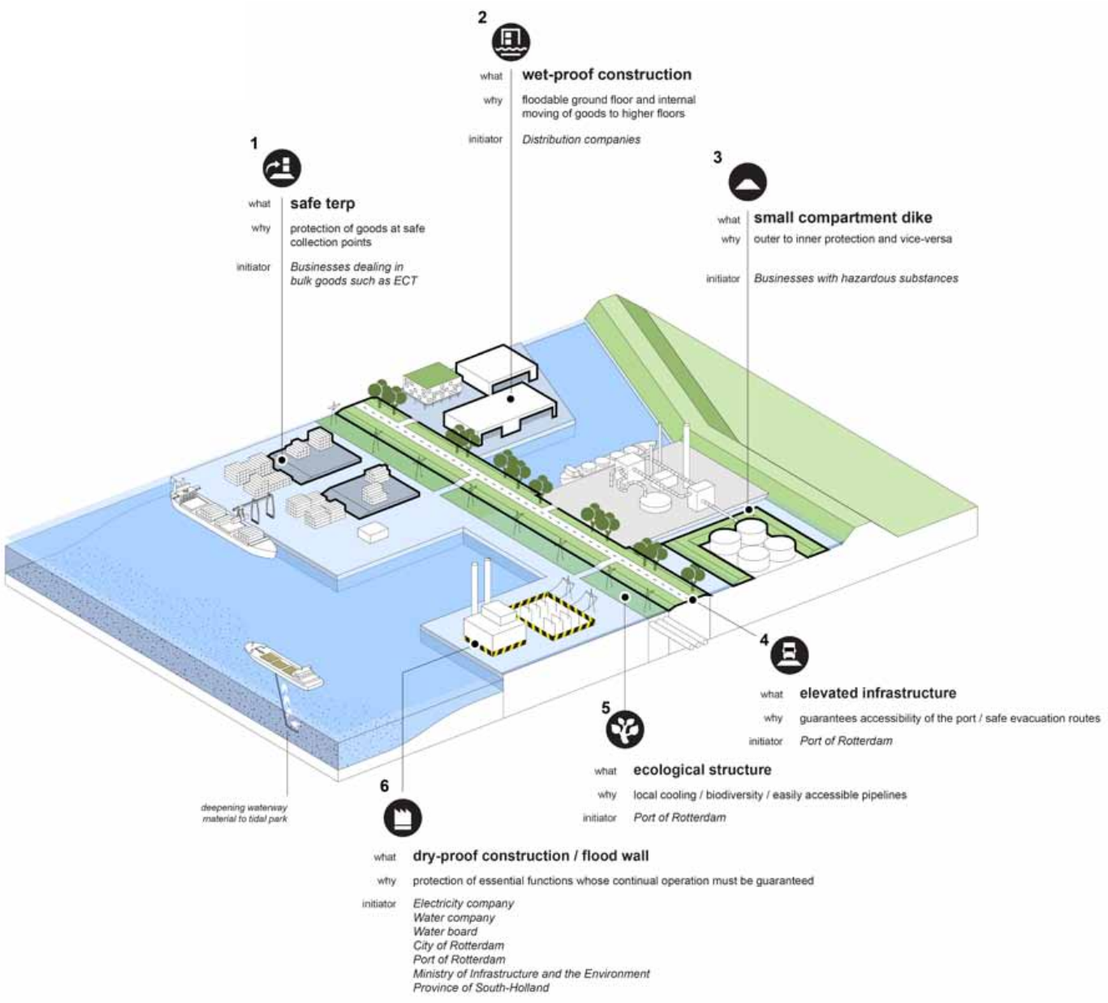
Measures

1 2 3 4 6

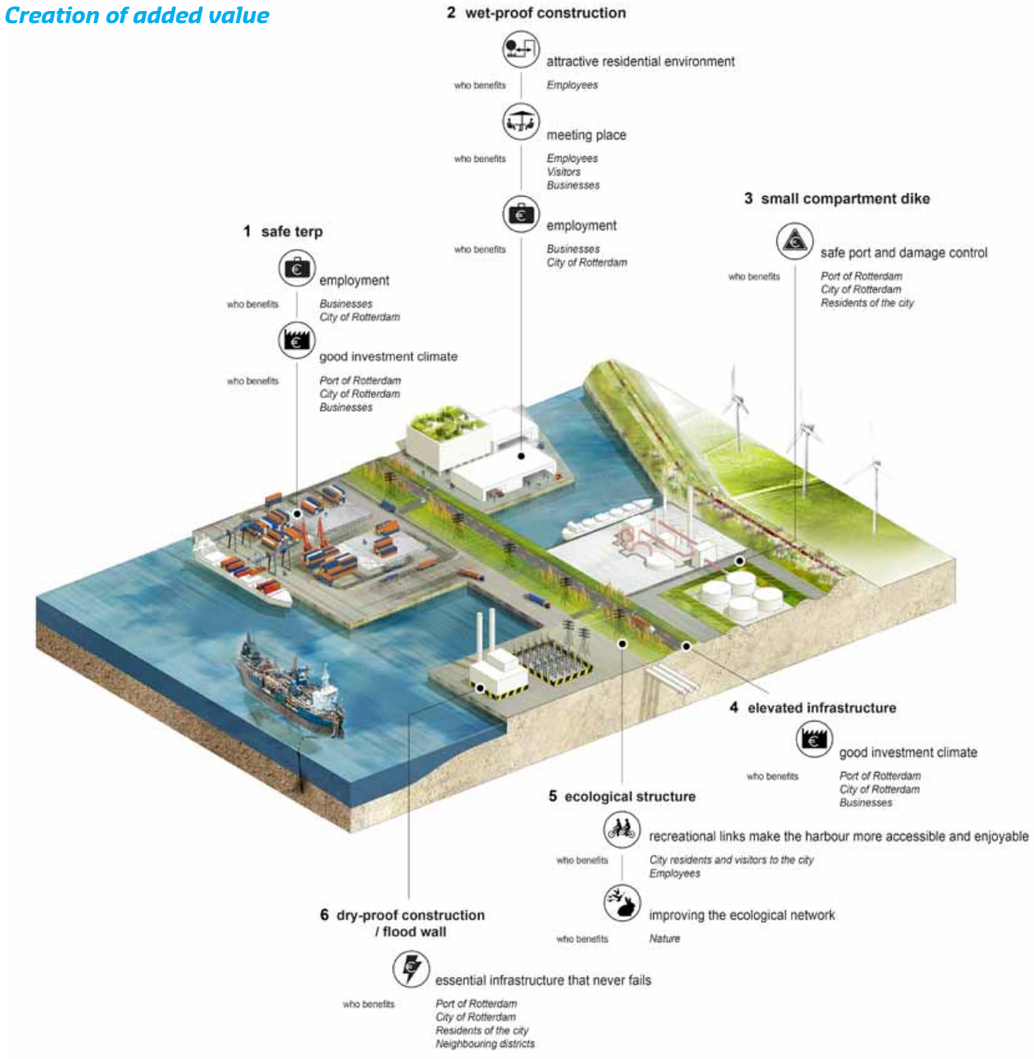
5



Climate adaptive measures



Creation of added value



6.3
Perspective for Stadshavens

Stadshavens is an area in transition. Over the coming decades, new links between the city and the port will be constructed in Stadshavens in order to strengthen the economy and to create an attractive city. The area will become home to a new generation of port and transport companies, innovative enterprises and knowledge institutes as well as special residential environments and cultural facilities. Stadshavens is the on-site experimental field for the delta technological development of the port and the city. The area of Stadshavens lies partially in the outer-dike region that is directly linked to the sea and the river, and partially on the boundary of inner- and outer-dike Rotterdam. Since it is part of the old harbour complex, it is vulnerable to high water levels. The considerable amount of paving means that it retains a lot of heat.

The transformation of Stadshavens provides an opportunity to convert weaknesses into strengths. The area is located on the water, is subject to tidal dynamics and forms the transition between the river Meuse and the inner-dike city districts. The need to reinforce the dike provides an ideal opportunity to kill two birds with one stone. When making the outer-dike area more robust, the dike can also be reinforced. Making the inner-dike area more robust could involve the construction of climate dikes on which it will be possible to build. Removing paving and introducing more plants and trees to the former harbour areas will provide opportunities for creating a greener city with better cooling potential. In inner-dike areas this will also contribute to increasing infiltration while reducing the effects of excess heat.

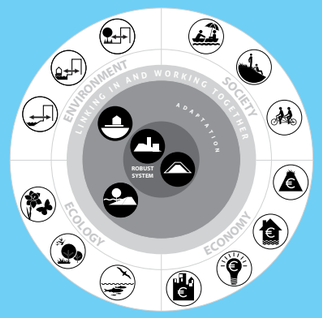
Stadshavens in transition provide an ideal opportunity to significantly improve the environmental quality of the city and the water. The harbour basins provide space for floating communities, more vegetation at the water's edge, diverse contact with the water and opportunities to experience tidal dynamics. This will contribute to creating a more attractive business climate and increase property values. Most importantly, it provides the potential for social interaction between the people of Rotterdam in the most beautiful outdoor region of the city: the river Meuse.

Perspective for Stadshavens

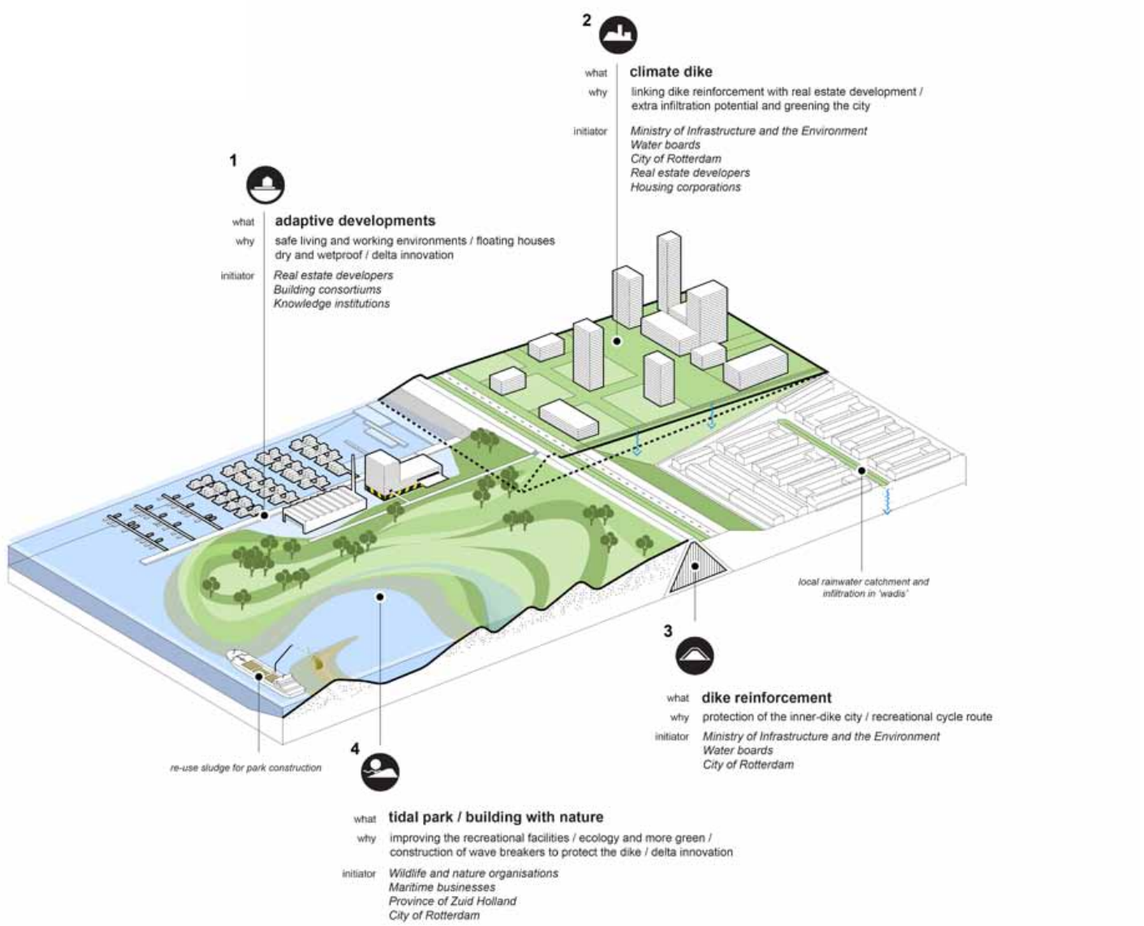
Which climate adaptive measures are appropriate for the port and who will take the first steps?

What added value is generated by the combined measures for the environment, for society, for the economy and for the ecology and who will benefit?

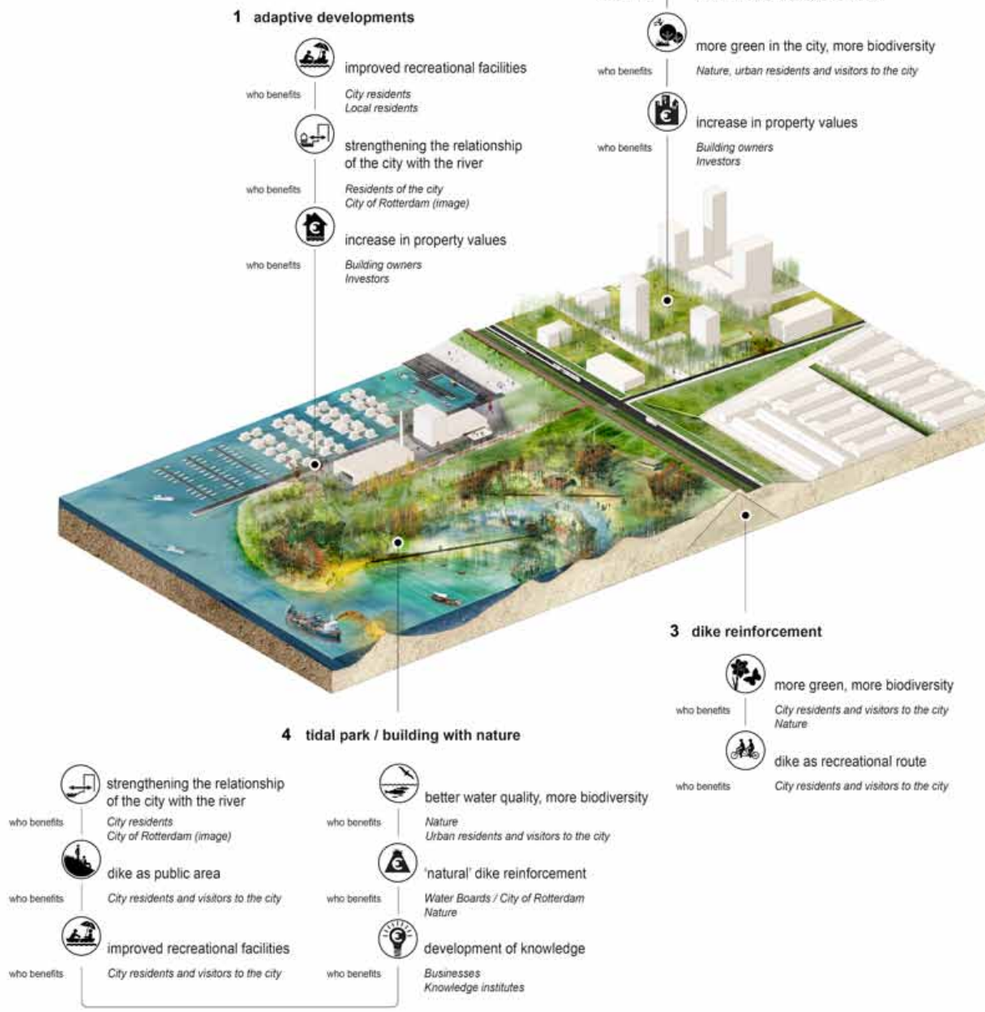
Strategies	Measures
differentiated flood-proof inner-dike design	1 4
dike reinforcement measures	2 3 4
reducing heat stress	2 4
reducing the effects of periods of drought	2



Climate adaptive measures



Creation of added value



6.4
Perspective for the outer-dike urban districts

The outer-dike urban districts are located in the most attractive parts of the city. They are central, lie directly on the river Meuse and are in contact with the water. Since these outer-dike areas are relatively low-lying, they are vulnerable to high water levels. Restructuring and design is difficult due to the characteristic old buildings and the limited space available. Furthermore, there is a lot of paving so much heat is retained.

In these areas, there are two distinct types of flood protection tactics: keeping the water back or facilitating controlled flooding. In the different outer-dike districts in Rotterdam, various solutions are possible and applicable. In some places, local flood walls are a sensible solution if they are combined with extra plants and trees and the construction of valuable parks along the Meuse. This will lead to the possibility of local water collection, infiltration and heat reduction and will furthermore encourage social gatherings and increase biodiversity and property values.

In other places, the contact with the water is more important and the functionality of a low quay is the main priority. In these situations, it may be sensible to choose a multi-stage flood model whereby the quay is flooded in controlled steps (as currently happens on the Noordereiland). This means that, in the worst-case scenario, measures need to be taken for individual properties, such as local waterproof thresholds at the entrances to houses and car parks. Terraces and plateaus could potentially become beneficial elements in the spatial design.

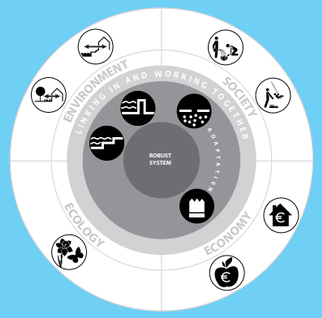
Incorporating more flora and removing paving from the streets and inner yards will enhance local water collection, heat reduction and social binding and will further increase the attractiveness of the immediate vicinity.

Perspective for the outer-dike urban districts

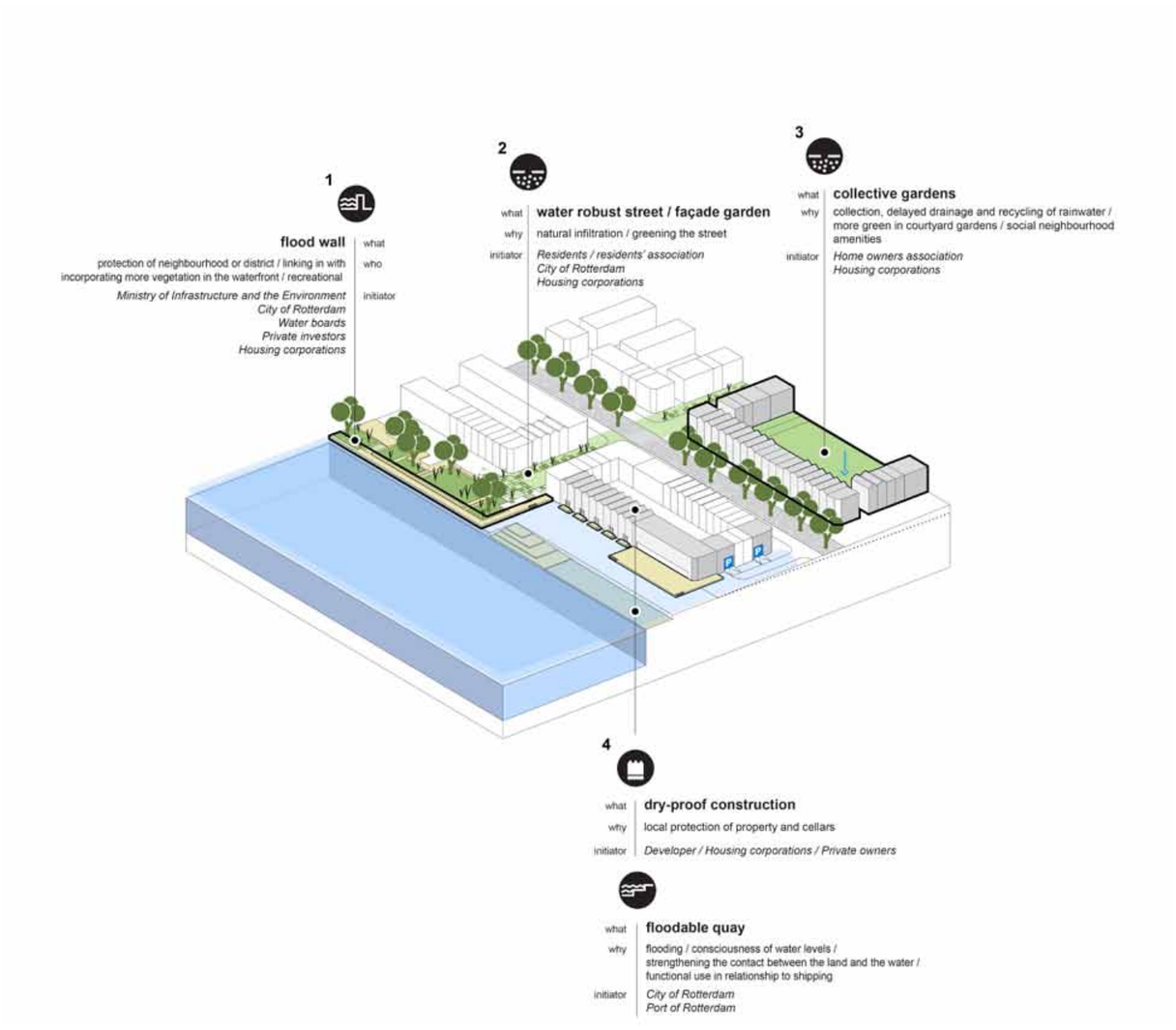
Which climate adaptive measures are appropriate for the port and who will take the first steps?

What added value is generated by the combined measures for the environment, for society, for the economy and for the ecology and who will benefit?

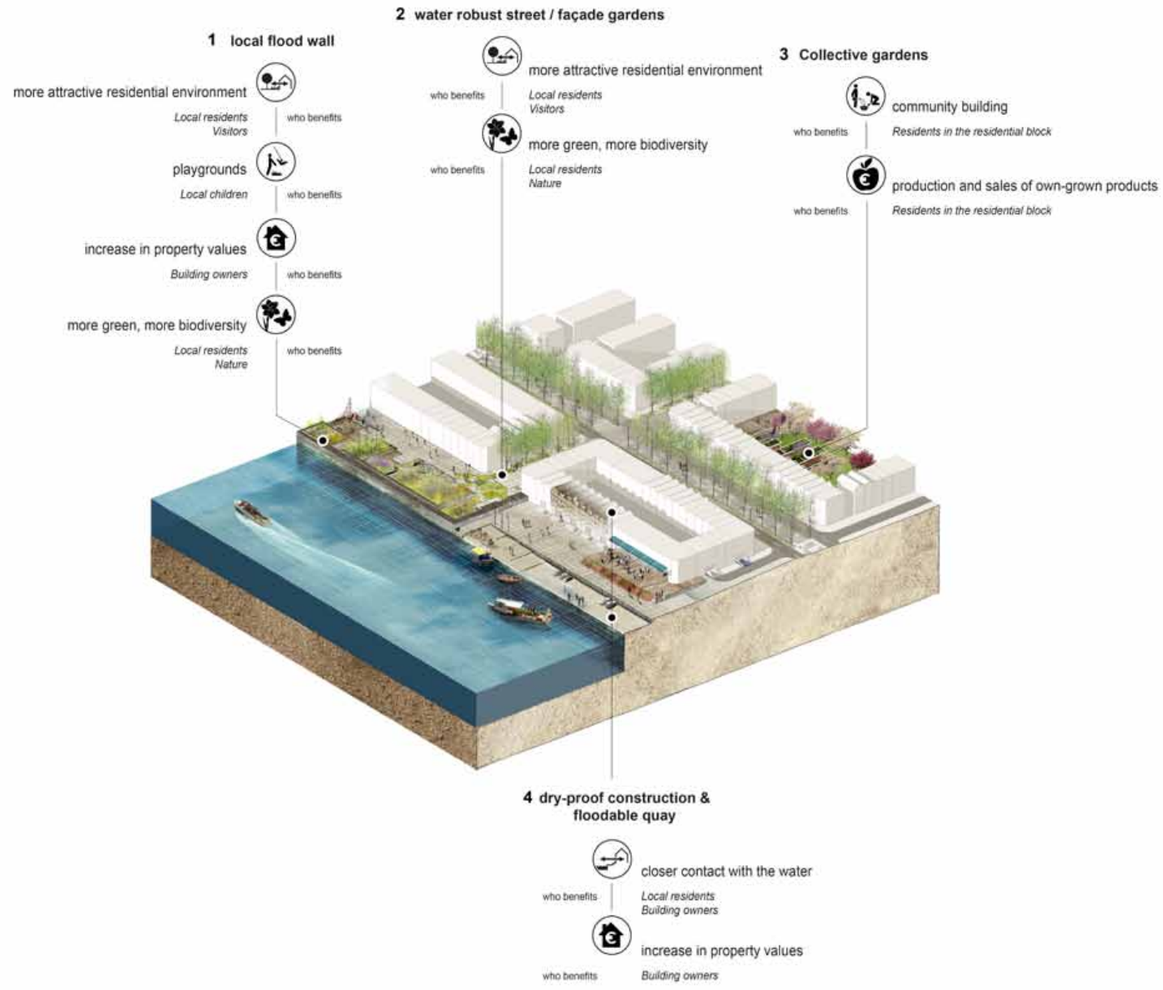
Strategies	Measures
differentiated flood-proof outer-dike design	1 4
reducing heat stress	1 2 3
local collection of rainwater	1 2 3



Climate adaptive measures



Creation of added value



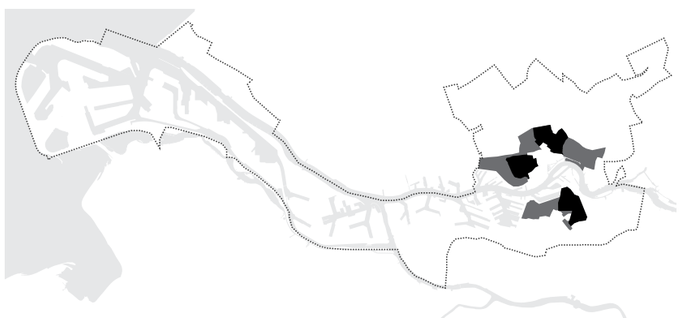
6.5
Perspective for the inner-dike urban districts

The inner-dike city districts of Rotterdam are located around the city centre and are all densely built-up. Restructuring in all these districts can only take place through small-scale interventions that maintain the character of the district. Problems of flooding and heat stress occur in nearly all the pre-war districts. The wooden pile foundations commonly found here are vulnerable to droughts.

Reducing the fluctuations in groundwater levels can be achieved by facilitating infiltration and incorporating more plants, trees and stretches of open water. However, there is often not enough space for this. The temporary storage of rainwater and delayed infiltration or surface drainage to open water are interesting possibilities because they also create locations for leisure activities and social gatherings, for example the innovative water squares. Where possible, options for reducing the amount of paving will be considered: façade gardens will be created in the streets, paving in collective and private gardens will be replaced by plants and more trees and plants will be incorporated in the public outdoor areas.

Measures are taken at all levels, from the small-scale re-introduction of water butts to the large-scale improvements to the water system, such as increasing the area of surface water. Efforts will be made to widen the canals using natural banks, which will increase the storage capacity while simultaneously improving the quality of the water. The focus is on incorporating many more trees and plants into the city districts so that they become more resilient, the quality of life improves and property values increase.

The various measures provide opportunities for stimulating social interaction, as has been shown by the various urban farming initiatives. Increased biodiversity and the innovative climate solutions can play a crucial part in creating a healthy educational and playing environment for the younger generation.

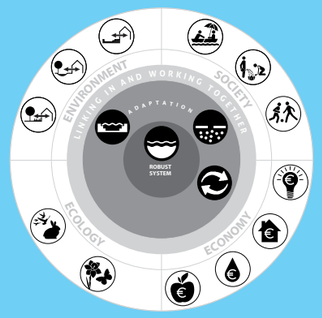


Perspective for the inner-dike urban districts

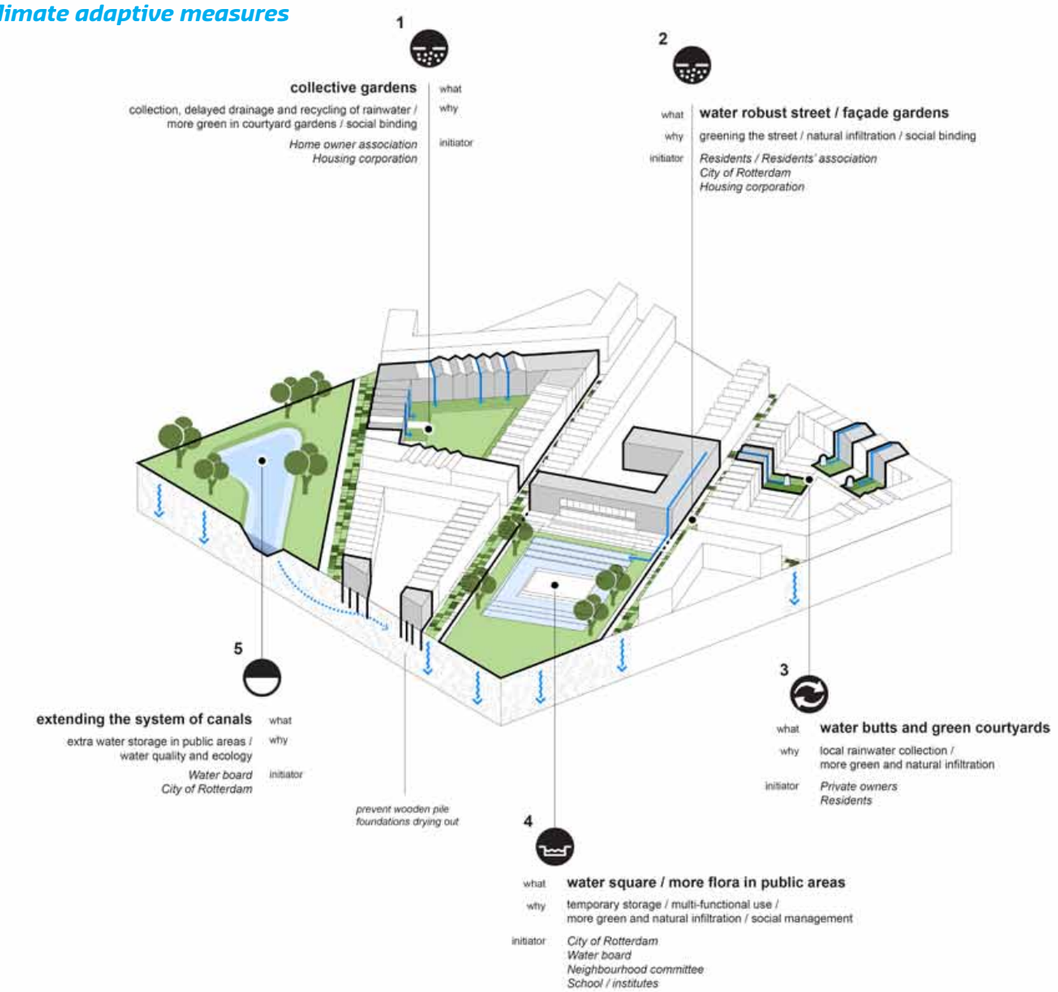
Which climate adaptive measures are appropriate for the port and who will take the first steps?

What added value is generated by the combined measures for the environment, for society, for the economy and for the ecology and who will benefit?

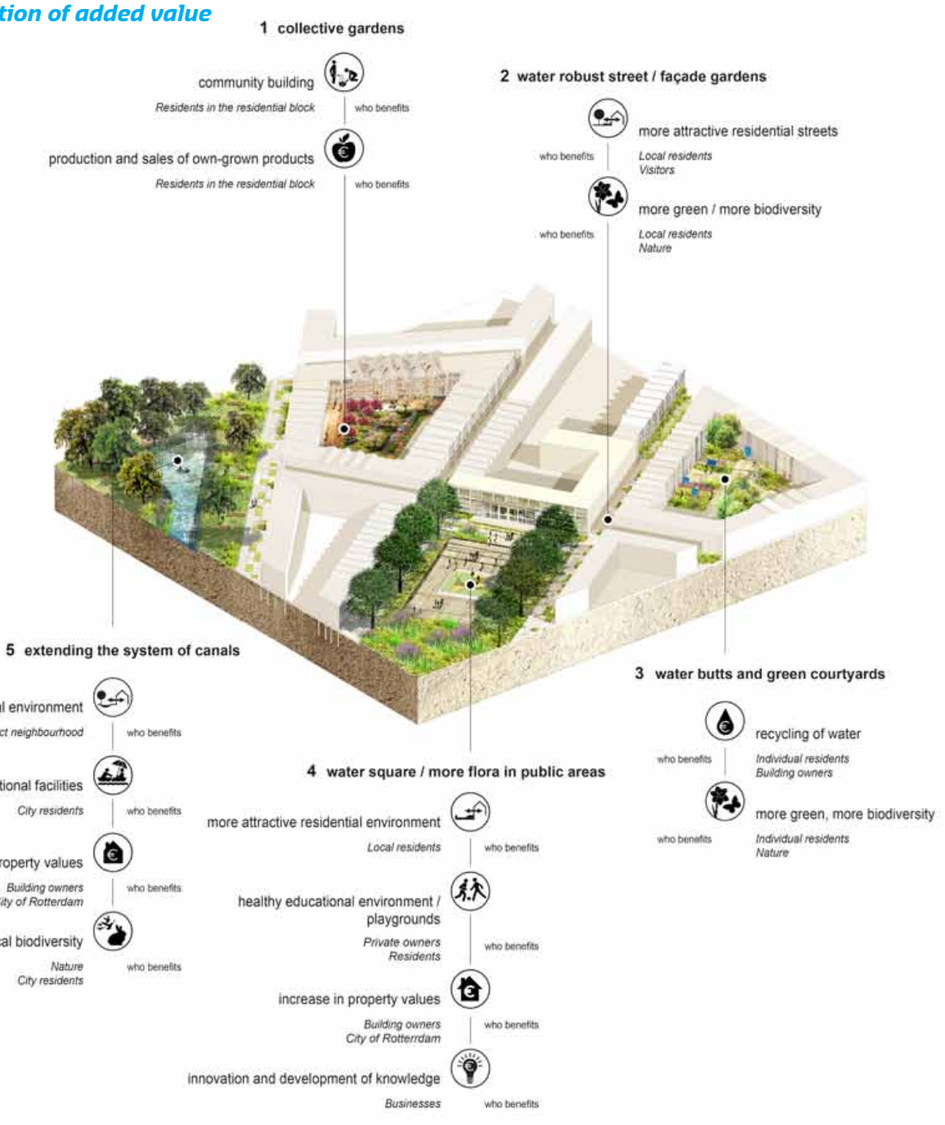
Strategies	Measures
water collection deep in the heart of the city / rainwater cascade	1 2 3 4 5
reducing heat stress	1 2 3 4
reducing the effects of periods of drought	1 2 3 4 5



Climate adaptive measures



Creation of added value



6.6
Perspective for the compact city centre

The city centre is compact. Unlike most other cities in the Netherlands, Rotterdam has a consolidated centre rather than a historic one. The post-war reconstruction of the inner-city has been completed and now further consolidation is taking place with the emphasis on additional residential accommodation in the centre. The compact city centre of Rotterdam is characterised by modern high-rise buildings. An interesting point is that it does not lie entirely within the dikes, with some areas being located on the other side or on the dikes themselves. The compact city centre has more space than most Dutch cities, but there is considerable consumer pressure. There is a lot of paving and considerable road traffic, which means that flooding and heat stress are already causing significant problems.

Since Rotterdam centre lies both directly within and outside the dikes, the flood protection measures implemented will directly affect the city. Dike reinforcement will have a major impact on the immediate environment, and requires creative solutions such as multi-functional dikes and intelligently combining the functions of the dike and the city. The focus will also be on replacing paving with plants. The entire major infrastructure in the city will become greener, friendlier and more suited to recreational activities, and will also facilitate water infiltration and heat reduction. The considerable consumer pressure in and around the high-rise buildings means that it is more difficult to incorporate green deep in the heart of the city.

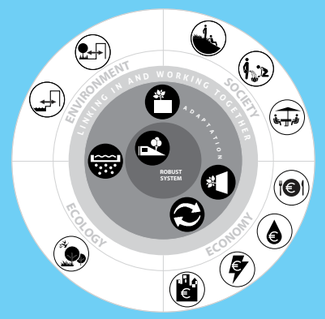
For this reason, the private owners of, for example, individual buildings will need to play their part. Green roofs are the symbol of the multi-facetted strategy of water storage, extra vegetation, heat reduction, improving the living environment and creating places for social gatherings. An interesting aspect is that for larger buildings (complexes), these measures have direct, positive results in the form of reduced energy bills, increased potential for the re-use of water and the creation of places for commercial recreation and gatherings.

Perspective for the compact city

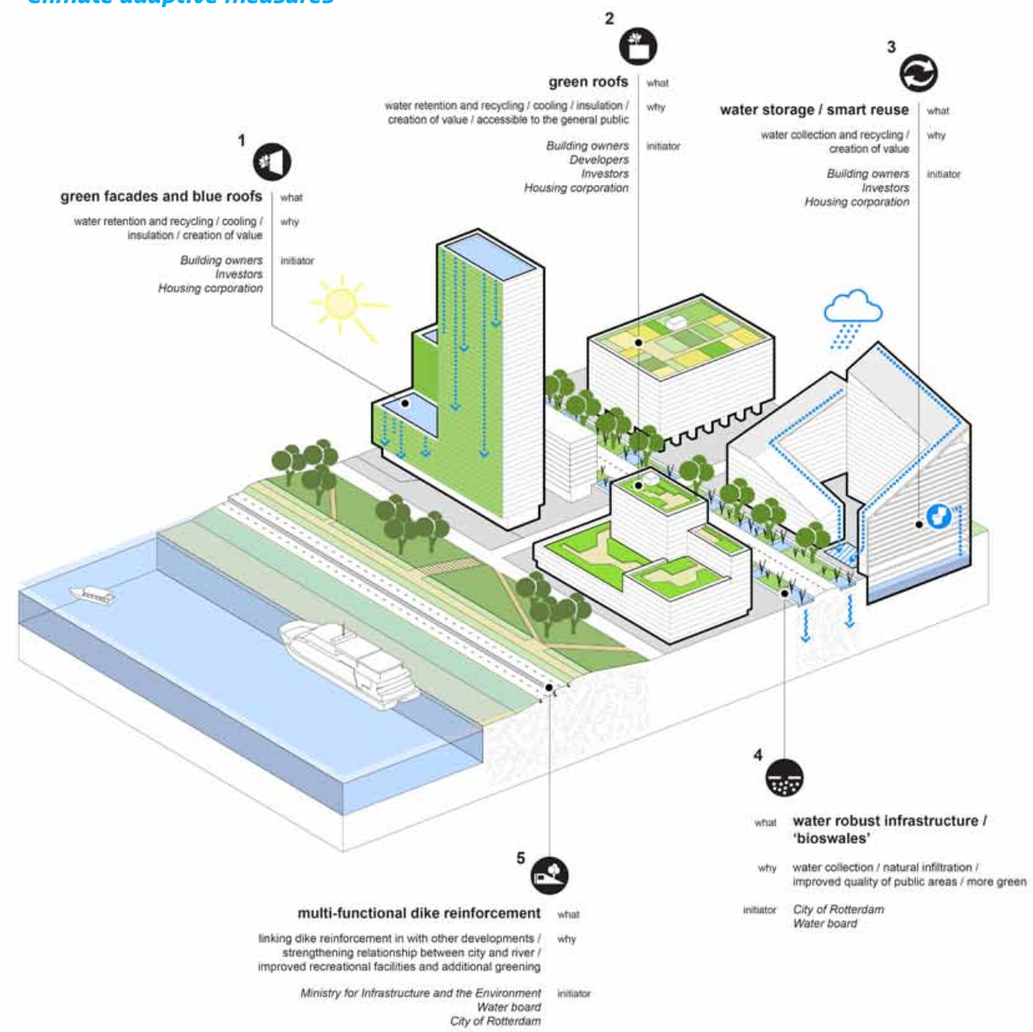
Which climate adaptive measures are appropriate for the port and who will take the first steps?

What added value is generated by the combined measures for the environment, for society, for the economy and for the ecology and who will benefit?

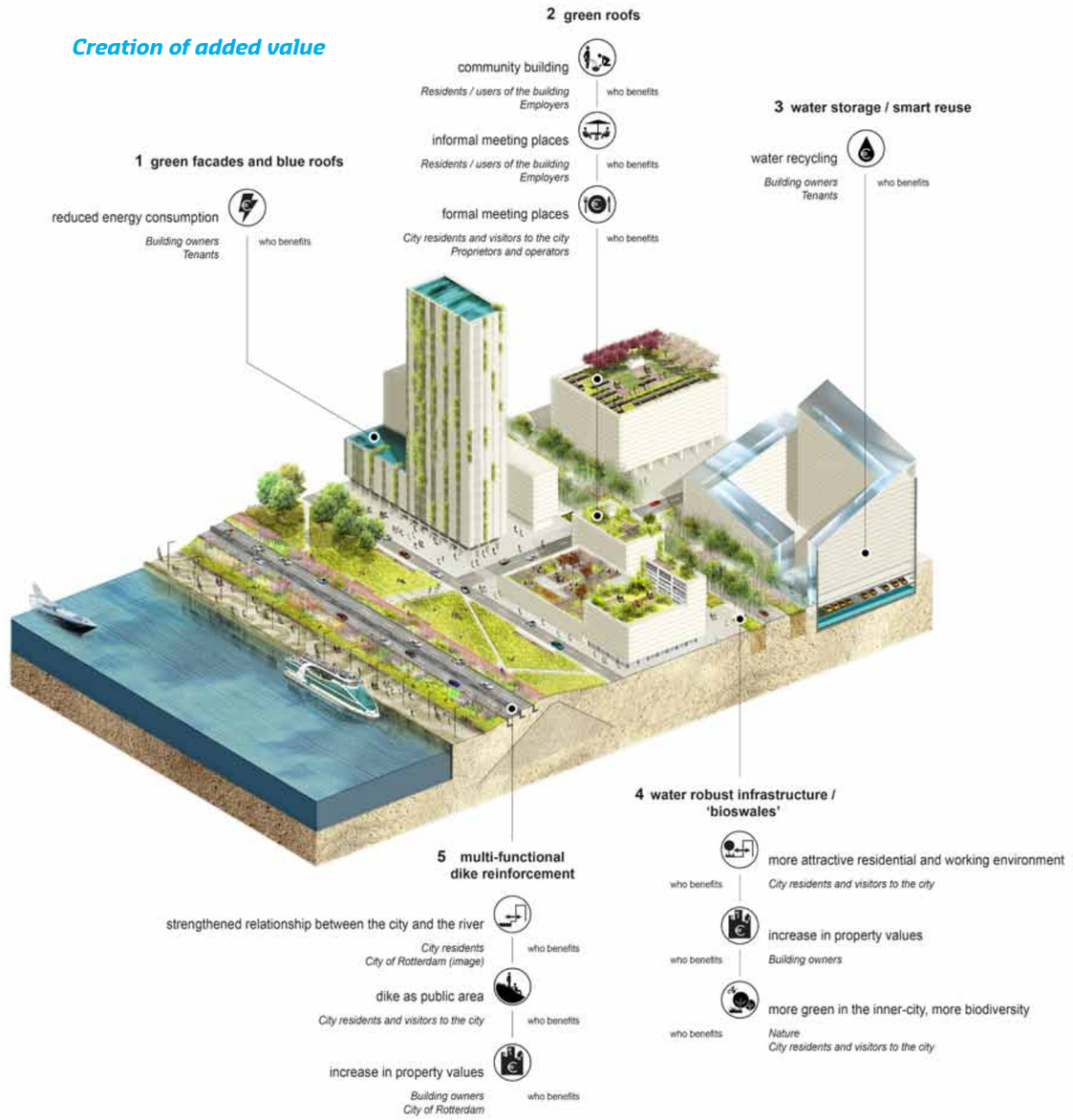
Strategies	Measures
dike reinforcement	5
reducing heat stress	1 2 3
reducing the effects of periods of drought	4
rainwater collection	1 2 3



Climate adaptive measures



Creation of added value

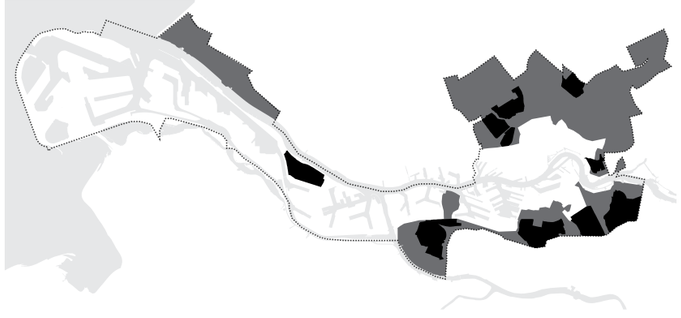


6.7
Perspective for the post-war districts and surrounding areas

The post-war districts are the large areas located on the outskirts of Rotterdam. In some of these areas, heavy rainfall already causes flooding. Drought is also a problem in most of these areas, especially because the green surrounding areas and the polders around the city are dependent on a sufficient flow of fresh water.

Many of the post-war districts are in the process of being restructured and improved. This provides opportunities for putting the open space that is generally available here to effective climate adaptive use. More stretches of open water can be created and linked to the surrounding outer areas in which the water table needs to be raised. These areas are generally rich in plants and vegetation, and raising the water table and linking them to each other will make them less vulnerable to both drought and flooding. At the same time, this will reinforce the characteristics of the delta city and provide more opportunities for the development of nature and for recreational use.

Raising the water table and creating a network of waterways will lead to a green-blue framework around the urban areas, which will be beneficial to property values. Within the spacious post-war building complexes, collective use of the excess space is a good alternative to public management. This will encourage social binding and stimulate contact with urban nature. In the outskirts, smaller-scale farms will be developed, making it possible for the inhabitants of the city to experience life in the country, and with the added benefit that the produce can then be used in the city's restaurants.



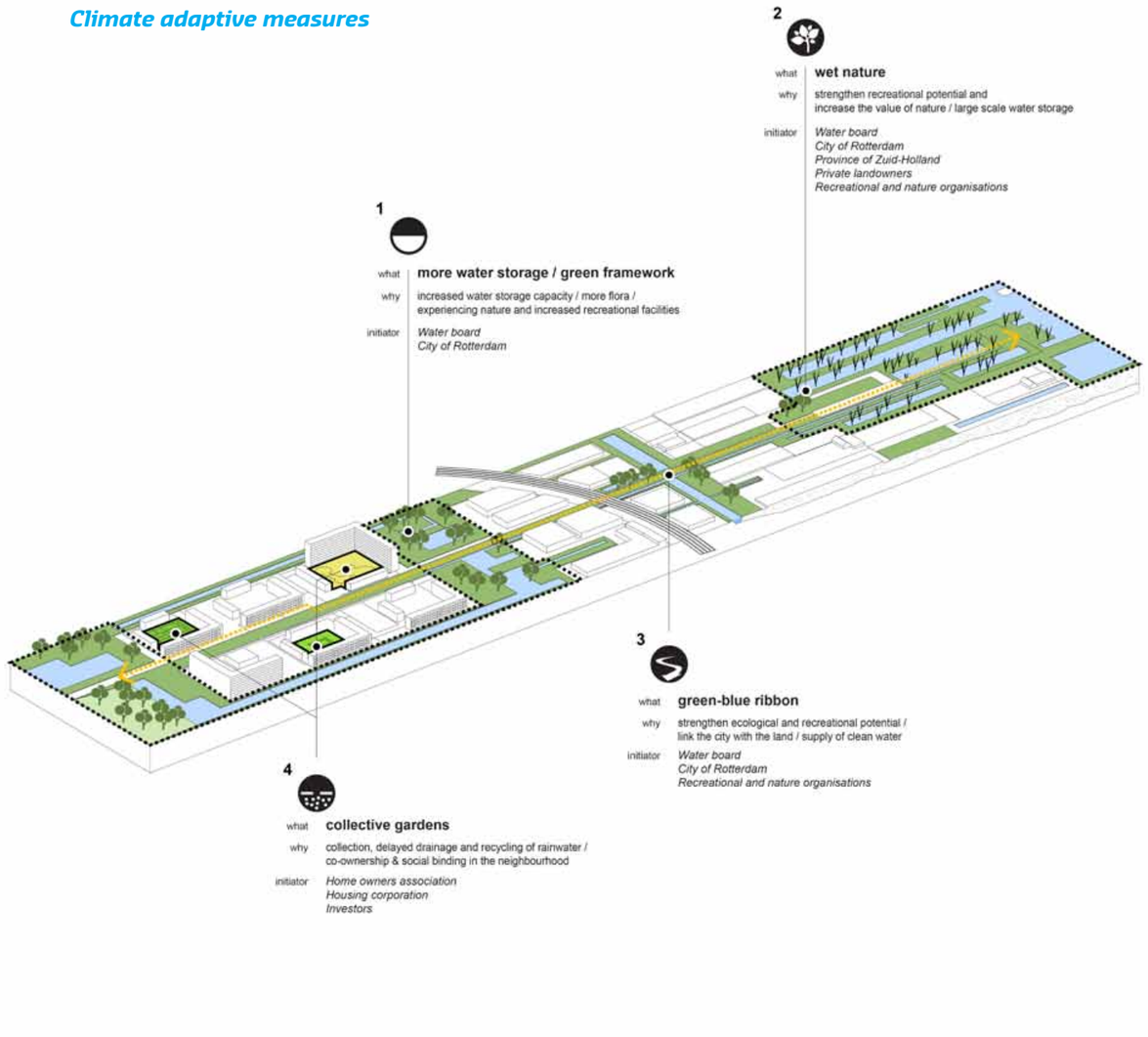
Perspective for the post-war districts and surrounding areas

Which climate adaptive measures are appropriate for the port and who will take the first steps?

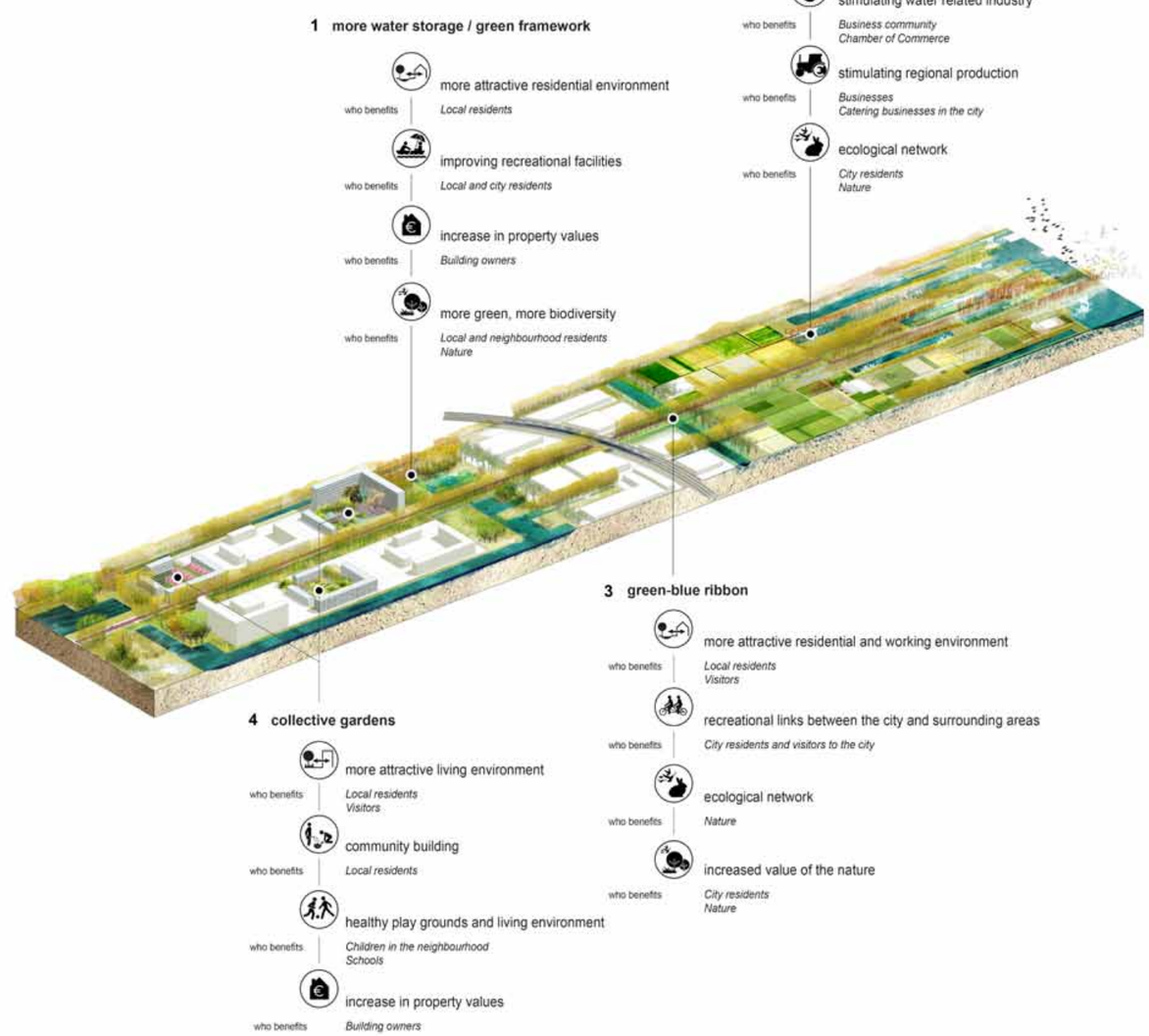
What added value is generated by the combined measures for the environment, for society, for the economy and for the ecology and who will benefit?

Strategies	Measures
large-scale water storage and raising of the water level in the landscape	2 3 4
reducing heat stress	1 2 3 4
reducing the effects of periods of drought	1 2 3 4

Climate adaptive measures



Creation of added value



6.8
A journey through climate proof Rotterdam

In 2025, if we cycle through Rotterdam we will see a climate proof delta city that makes the best use of all the characteristics that the water has to offer. The outer-dike areas on either side of the river Nieuwe Maas have varied characters and a variety of buildings. Outer-dike urban areas such as Feijenoord and the Noordereiland are waterproof and are popular places with attractive quays. Many of the premises are, in their own individual and characteristic way, protected from the flooding that occasionally occurs. It is easy to board the waterbus from the low quays.

The waterbus brings us to the city harbours where experiments are still being carried out into living on and with the water. A fisherman casts a line from a jetty in the tidal park. From the plateaus of the new residential and office buildings there is an impressive view of the harbours in transition. The new harbours of the Main Port Rotterdam lie further away towards the sea. They are, as always, extremely safe and well protected from storm tides.

We continue our cycle ride over the robust green dike towards the inner city, with magnificent views on either side. Fortunately, inner-dike Rotterdam is still well-protected. In addition to being a pleasant route, the dikes form an inextricable part of the city. We pass the 'district on the dike' and the dike park. Nature too, with the green banks along the river Meuse, is playing its part in protecting the city from flooding.

In the densely populated inner-city, the number of inhabitants has increased considerably over recent years. This has led to a lively centre with comfortable and attractive public areas. The compact city centre is greener, with less concrete and many trees lining the boulevards and streets, and with parks, gardens and water squares that provide cooling for the many visitors. The buildings too, with their green roofs and climate façades, also contribute to making the inner-city climate proof.

We then cycle through the 19th century urban districts. Here the 'hard', concrete city of olden times has been replaced by 'softer' areas rich in flora, which help both in times of intensive rainfall and during long periods of drought. Adventure and wilderness playgrounds, vegetable gardens, local parks and façade gardens all function as a sponge. The streets too are intelligently designed to collect water during heavy downpours and to allow it to gradually infiltrate through to the groundwater.

Our journey takes us to the post-war districts of Rotterdam. These are pleasant places in which to relax on hot summer days and the attractive lakes and wide waterways provide opportunities for recreation and water storage. Blue corridors are inviting, guarantee fresh water during periods of drought and link the city to the surrounding areas. We cycle back towards the centre of Rotterdam for a refreshing drink on one of the many terrace cafés overlooking the Meuse.

7

Getting started!

Rotterdam is actively preparing for climate change. This is being done in such a way that added value is created for the environment, for the ecology and economy of the city and port and for the Rotterdam community. The Rotterdam Climate Change Adaptation Strategy indicates which measures can be implemented in the various parts of the city in order to combat the effects of climate change and discusses where opportunities lie. In short, the Rotterdam Climate Change Adaptation Strategy can be summarised as a number of key decisions, which together form the basis for the implementation of the strategy.

These decisions reaffirm Rotterdam's aims to actively anticipate the effects of climate change and to provide guidelines for coping with them. The way in which these decisions are followed up depends on the implementation approach. A number of instruments are available to support the implementation.

View of the construction site for the Benthemplein water square (winter 2012). The largest and deepest pool is already visible. This is intended to function as a space for sports, theatrical performances and events.

7.1
Instruments

Instruments

A number of tools have been developed to support the implementation and development of the adaptation strategy. These form the first steps to creating a tool box which will be useful for implementing the strategy and for devising action perspectives for the various stakeholders. These tools can also be used by other (delta) cities and much interest has already been shown. The development of these instruments, frequently in cooperation with SMEs, is a good example of using climate change adaptation to create (economic) added value.

Interactive Climate atlas

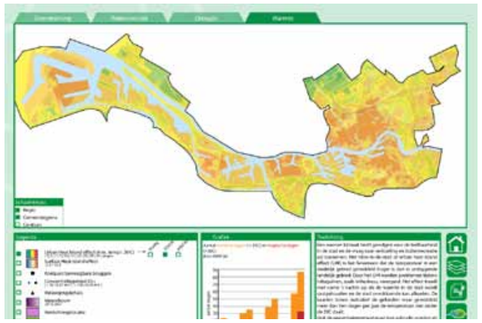
The interactive climate atlas presents a digital overview of the climate. The atlas is a collection of diagrams and graphs providing general information about climate change, climate scenarios and the consequences for Rotterdam and vulnerable areas and buildings. The atlas makes it possible to compare the consequences of various climate scenarios with each other. In this way, a wealth of information about the city and region can be easily accessed. The atlas can be used by various stakeholders to improve insights into area-specific consequences of climate change. This provides a good basis on which choices concerning climate proof urban design can be made and priorities set.
Producer: Climate Adaptation Services Foundation (CAS).

Climate adaptation barometer

The climate adaptation barometer provides an insight into the various phases that need to be carried out in order to devise an adaptation strategy and to actually make the city climate proof. This is an excellent tool to help the City Council structure the adaptation strategy and keep track of how far along we are in the process. It is less suitable for specific project monitoring; tools for this purpose will be designed and developed as part of the implementation approach. Other delta cities at the forefront of their own adaptation process are already showing an interest in using the barometer.
Producer: City of Rotterdam

Climate adaptation tool box

The climate adaptation tool box is an aid for spatial designers and project managers. The tool box provides an overview of potential adaptation measures for various spatial scale-levels and aims. The aims may for example include limiting the likelihood of the occurrence of adverse consequences due to climate change (prevention), limiting any damage during flooding or accelerating the recovery after flooding. The climate adaptation tool box provides a 'menu' of measures and is a dynamic instrument. New solutions arising from research in for example the Knowledge for Climate programme will be incorporated in this tool box.
Producer: City of Rotterdam



Interactive Climate Atlas

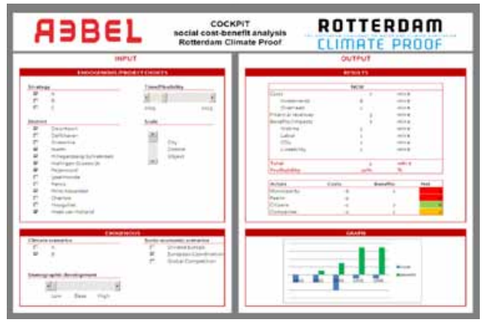
Climate adaptation tool box

Economic assessment tool: The Rotterdam Climate Societal Cost-Benefit analysis

This instrument provides an insight into the long-term social costs and benefits of various combinations of measures that may be selected. It also gives an insight into how these measures will contribute to making the city more climate proof. The flexibility of the instrument and the fact that this is the first tool to provide an insight into the societal costs and benefits makes it unique. In its current form it is a good tool to support strategic decision-making and justify choices of individual measures. Insights provided by this tool have made it clear that intelligently linking in with construction projects or maintenance programmes nearly always leads to a positive cost-benefit relationship. Furthermore, this frequently leads to the creation of added value!
Producer: Rebel Group Rotterdam

Rotterdam Climate Game Feijenoord

Rotterdam Climate Game Feijenoord is a serious game about climate proof area development. The modernisation of the Feijenoord district is used as an example. Feijenoord is a unique, partially outer-dike area in which 120 million euros will be invested over the coming years. This investment will lead to a much improved, climate-proof environment, both now and in the future! The assignment is characterised by a considerable number of stakeholders, each with their own specific interests. How will it be possible to divide the roles and get everyone to work together to implement the adaptation measures? This game gives a realistic visualisation of these interests, the mutual dependencies and the advantages and actual necessity of working together. The game focuses on issues that are universal and applies to a wide range of area development processes in which insights are needed into climate change adaptation, the effects of various measures and the interests of every other party involved.
Producer: Tygron



Economic assessment tool: the Rotterdam Climate Societal Cost-Benefit analysis

Rotterdam Climate Game Feijenoord

7.2
From strategy to implementation

Outline of the implementation approach

While the adaptation strategy sets the course to follow, the implementation approach proposes how Rotterdam should implement this strategy. This implementation approach will be devised in consultation with all parties working in and for the city. Our partners in climate change adaptation include municipal services, other government departments such as the water boards and Rijkswaterstaat, the citizens of Rotterdam and private organisations such as housing corporations, project developers, utilities and the Port of Rotterdam. This implementation approach is not a blueprint that lists measures to be implemented in each area. However, it does give an indication of the priorities, proposes links that can be made with the plans and projects of our urban partners who are working 'on Rotterdam' and discusses within which timeframe activities need to be carried out. These activities include the concrete implementation of adaptation measures as well as pilot projects, in-depth studies and mainstreaming adaptation into plans and procedures. The linking of climate change adaptation to economic and participative activities is explicitly discussed in its own right.
The key aspects of the implementation are as follows:

The implementation is in tune with the 'rhythm of the city'

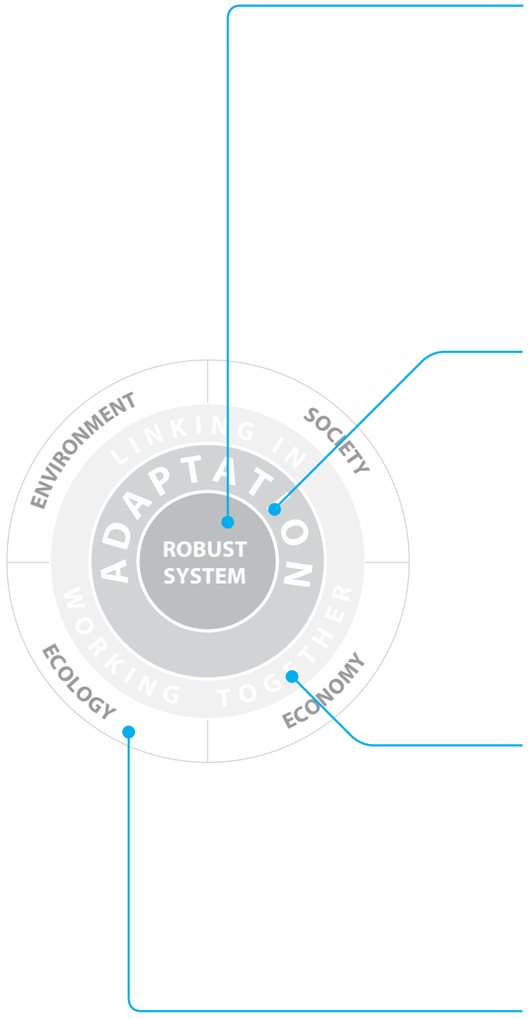
Climate change is a slow process in which the effects only gradually become visible. There is time to adjust. At the same time, the city is continually developing. Utilities and urban infrastructure are maintained, houses and offices renovated, outdoor areas redesigned and the city as a whole extended and compacted. At times the rate of such development is much reduced, such as in the current economic dip. Then, after a while new possibilities and new opportunities arise to enable the development of the city and improvement of the (living) environment to continue. The results of these activities are frequently long-lasting. Renovation or replacement of buildings and infrastructure occurs on average every thirty to fifty years and a lot of construction work is expected to last much longer. To govern is to foresee. Passively waiting to see what the climate change will bring could turn out to be very expensive for the city in the long run. Linking in with the city's development and maintenance activities is eminently sensible and with our current knowledge of climate change is also possible. The 'rhythm of the city' is the basis for the planning and implementation of activities that will make the city climate proof.

The implementation is area-specific

The vulnerability of various parts of the city to the effects of climate change has already been ascertained. There is also sufficient insight into the range of measures and activities that can be used to make the urban areas more climate proof. Those parties responsible for a specific location will have to determine which measures are most fitting and feasible for that area. In many instances the City of Rotterdam will not be in charge, but will define the framework, provide advice and stimulate other parties. It is essential that all activities link in with area plans.

The implementation will create added value

Activities will be devised to make Rotterdam more climate proof, reinforce the city's aims and create added value for the physical city, for the economy of the Rotterdam region and for the Rotterdam community. The implementation approach explicitly focuses on the creation of added value through the making of intelligent choices, such as where and how adaptation measures will be linked to construction and development projects in the city. Innovative designs and approaches will be adopted in order to attract businesses to Rotterdam and space in which to experiment will be provided, such as in the Aquadock at the RDM campus. Adaptation measures will be selected that will improve the living environment of the city, such as more plants and trees and more visible water, and the inhabitants and businesses will be involved right from the start. In this way, the city will remain an international example of a safe, ambitious delta-city that plans ahead and demonstrates leadership.



The basics in good order – key decisions
- Focus on maintaining and optimising the Maeslant storm surge barrier as an effective means of protection against the consequences of rises in sea level. This will be done together with the responsible administrators
- Link the specific urban area development to dike reinforcement in line with the strategic decisions in the Delta Programme
- Focus on maintaining and optimising the current urban water system: utilise the existing water infrastructure for as long as possible

Adaptive approach – key decisions
- Adaptive building and design, as part of a 'multi-level' approach, is key to the outer-dike area
- Focus on making use of the outdoor areas and buildings for water storage and 'intelligent' drainage (deep in the heart of the city) and link this to the specific urban development in the area; this creates more flexibility in the potential solutions and provides opportunities for improving the quality of the environment
- Actively encourage the incorporation of heatproof measures in the design, renovation and maintenance of buildings, outdoor areas and road and utility infrastructure

Working together and linking in with other projects – key decisions
- Actively provide information and action perspectives for citizens and businesses regarding the protection against river water, excessive rainfall, droughts and periods of high temperatures
- Work towards the joint responsibility of public and private property owners for the collection of excess rainfall

Creating added value – key decisions
- Actively stimulate innovation when implementing climate change adaptation measures
- Focus on incorporating more plants and trees in the city as a 'no regret' measure for improving the city's climate

The implementation involves working together

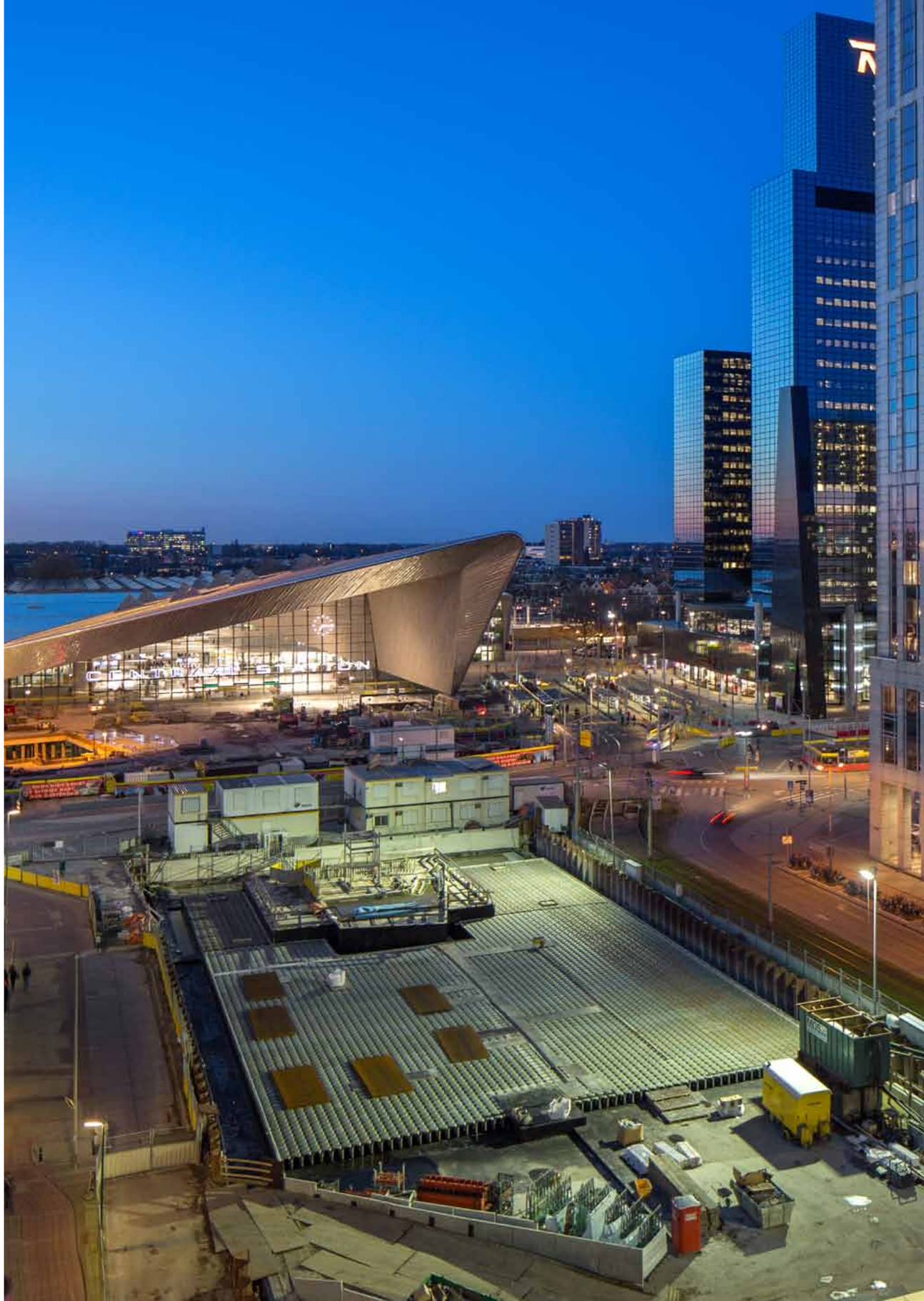
The effects of climate change will be seen in all areas of the physical city and the urban community. In Rotterdam many parties are working together according to their own responsibilities, ambitions and targets. It is impossible for the City of Rotterdam to create a climate-proof city on its own. The inhabitants too must also play their own part. Everyone must become involved in the climate change adaptation strategy. Discussions and agreements are an essential aspect of the implementation approach. We have already made a start and intend to continue in the same way. This adaptation strategy can form the basis of such discussions.

Climate change adaptation is already taking place

Various activities and plans already taking place in Rotterdam will contribute to making the city more climate proof. The Rotterdam water plan 2 and agreements with the water boards are examples of these. Concrete results include the creation of extra water storage and measures for improving the water quality. Such projects are frequently innovative and attract the attention of international governments and investors.

In addition to improvements to the urban water system, the climate change adaptation strategy focuses on other important functions of the city: essential utilities, infrastructure for traffic and transport and the environment. It is an integral strategy. The approach devised in the Rotterdam water plan will be extended to all areas that are important in a climate proof city. The adaptation strategy provides the framework and basis for discussions. The aim is to arrive at shared ambitions for climate proof urban development and to make specific concrete agreements about this. The City of Rotterdam will provide support for and give assistance to the urban partners and where necessary will take the initiative. The implementation approach will elaborate on this and outline concrete implementation practices.

Rotterdam is striving to become a climate proof city that will be safe and attractive to inhabitants, visitors and businesses, and will remain so in the future. A healthy delta city in which it is pleasant to live, work and spend leisure time.



Colophon

The Rotterdam Climate Change Adaptation Strategy is the responsibility of the Rotterdam Office for Sustainability and Climate Change

Management team of Rotterdam Climate Proof (RCP)
Corjan Gebraad (project manager), Arnoud Molenaar (programme manager RCP), Nick van Barneveld, Susanne Buijs, Daniel Goedbloed, Pieter de Greef, John Jacobs, Lissy Nijhuis, Chantal Oudkerk Pool, Hetty van Rhijn-Stumphius, Jos Streng, Peter van Veelen, Nicolien Wirschell

De Urbanisten
Dirk van Peijpe, Florian Boer, Jesus Hurtado, Jens Jorritsma, Eduardo Marin, Auke Wissing

Text
De Urbanisten in cooperation with Management team of Rotterdam Climate Proof (RCP)

Translation
Fennec Vertalingen, Rachael Fox

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De Urbanisten

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Rotterdam Climate Initiative
The Rotterdam Climate Initiative (RCI) aims to have reduced CO2 emissions by 50% and to have made the region 100% climate proof by 2025. The RCI is an initiative set up by the Rotterdam City Council, the Port of Rotterdam NV, DCMR Rijnmond environmental department and Deltalinqs, the umbrella organisation for Rotterdam industry. As a decisive and innovative international port, Rotterdam, together with its inhabitants, businesses and institutions is assuming responsibility for ensuring a sustainable future. By tackling both the causes and the consequences of climate change, improving the air quality and limiting noise pollution, Rotterdam is continually improving its sustainability. This unique approach is making Rotterdam an inspirational example to other cities. The aims and results in the field of the environment, climate, energy and water contribute to the creation of a greener, cleaner, healthier and economically stronger city and will make Rotterdam the most sustainable international port in the world.

Rotterdam Climate Change Adaption Strategy
The Rotterdam Climate Change Adaptation Strategy will set the course to enable Rotterdam to adapt to the changing climate. The target is to create a climate proof city for the people of Rotterdam, both now and for future generations. A climate-proof city that is also attractive and economically prosperous.

More information
www.rotterdamclimateinitiative.nl

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