Knowledge for Climate

Exploring Opportunities for Green Adaptation in Rotterdam

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Exploring Opportunities for Green Adaptation in Rotterdam

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Content

1 Summary

Worldwide, deltas are faced with an increasing demand on space, caused by sea level rise, freshwater and food scarcity, population pressure and land subsidence. Effects of climate change and population growth are expected to have the largest impacts in highly populated urban areas, often located in low lying deltas, vulnerable to floods. The awareness of the limitations of pure engineering (increasing the demand for limited space, negatively affecting long-term ecosystem functioning) has created an urgent demand from vulnerable delta areas worldwide for efficient integrated climate adaptation approaches that enable multi-functional use of available space.

Ecosystem functions and services can provide cost-effective, multi-functional adaptation solutions. Such so-called “Green Adaptation” solutions seek a balance between civil engineering and naturally functioning biological components, in order to make optimal use of potential ecosystem services and functions for the benefit of safety against flooding and freshwater availability.

In the Netherlands, Rotterdam is one of the most densely populated urban areas, relatively vulnerable to various climate impacts. Deltares, knowledge institute for water management, and the city of Rotterdam have formed a strategic alliance to explore how our Dutch knowledge and experience on Building with Nature / Green Adaptation can be optimally applied to the urban and regional delta system in Delta cities in general and the city of Rotterdam in specific.

This report investigates how Delta cities and as pilot the city of Rotterdam could make optimal use of such ecosystem services and functions in water management and (adaptive) building to adapt to climate change (inclusive water, nature, heat-stress, and land-use pressures), and how Green Adaptation measures could be effectively implemented in, or combined with, on-going policy plans and climate initiatives, in order to improve safety against flooding as well as environmental quality, while enhancing economic development (port activities) and citizen livelihoods (recreation, cultural heritage) in the city.

2 Nederlandse Samenvatting

Wereldwijd worden delta's geconfronteerd met een toenemende vraag naar ruimte, veroorzaakt door stijging van de zeespiegel, zoet water en voedselschaarste, bevolkingsdruk en bodemdaling. De effecten van klimaatverandering en bevolkingsgroei zullen het grootst zijn in dichtbevolkte, stedelijke gebieden, vaak in laaggelegen delta's die kwetsbaar zijn voor overstromingen. De bewustwording van de beperkingen van harde engineering (meer vraag naar toch al beperkte ruimte, en negatieve gevolgen op het functioneren van het ecosysteem) leidt wereldwijd tot een dringend verzoek op efficiënte, geïntegreerde klimaatadaptatie benaderingen. Kwetsbare deltagebieden maken zo multifunctioneel gebruik van de beschikbare ruimte.

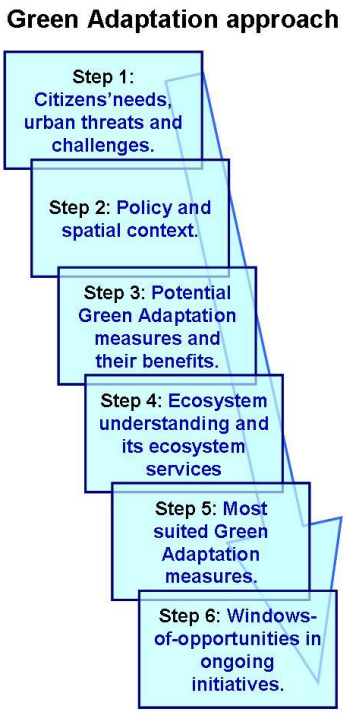
Ecosysteemfuncties en -diensten kunnen kosteneffectieve, multifunctionele klimaatadaptatie oplossingen bieden. Dergelijke zogenaamde "Green Adaptation" oplossingen zoeken een evenwicht tussen weg-en waterbouw en natuurlijk functionerende, biologische componenten. Hierbij wordt een optimale benutting van het potentieel aan ecosysteemdiensten en functies beoogd ten behoeve van de veiligheid tegen overstromingen en beschikbaarheid van zoet water.

In Nederland is Rotterdam is een van de meest dichtbevolkte stedelijke gebieden, relatief kwetsbaar voor verschillende klimaateffecten. Deltares, kennisinstituut voor waterbeheer, en de stad Rotterdam vormen een strategische alliantie om te onderzoeken hoe onze Nederlandse kennis en ervaring op Building with Nature / Green Adaptation optimaal kan worden toegepast op het urbane en regionale deltasysteem in deltasteden in het algemeen, en voor de stad Rotterdam in het bijzonder.

In dit rapport is onderzocht hoe deltasteden, met als pilot de stad Rotterdam, optimaal gebruik kunnen maken van deze ecosysteemdiensten en functies in waterbeheer en (adaptief) bouwen in het licht van klimaatverandering (inclusief deopgaven gerelateerd aan water, natuur, hittestress, en ruimtelijke ordening). En hoe Groene Adaptatie maatregelen effectief kunnen worden geïmplementeerd in, of gecombineerd met, lopende beleidsplannen en klimaat initiatieven om de veiligheid tegen overstromingen en kwaliteit van de omgeving te verbeteren, en tegelijk de economische ontwikkeling (havenactiviteiten) en leefbaarheid van de stad (recreatie, cultureel erfgoed) te verbeteren.

3 Extended Summary

Worldwide, deltas are faced with an increasing demand on space, caused by sea level rise, freshwater and food scarcity, population pressure and land subsidence. Effects of climate change and population growth are expected to have the largest impacts in highly populated urban areas, often located in low lying deltas, vulnerable to floods. The awareness of the limitations of pure engineering (increasing the demand for limited space, negatively affecting long-term ecosystem functioning) has created an urgent demand from vulnerable delta areas worldwide for efficient integrated climate adaptation approaches that enable multi-functional use of available space.



To reach these goals, we will follow a Green Adaptation approach defined within this project: a set of steps to identify the most (cost)-effective set of Green Adaptation measures for a certain area.

- step 1: identify urban treats, challenges and citizens' needs in an area,
- step 2: describe the policy and spatial context setting,
- step 3: know what Green Adaptation measures there are and what added benefits they have,
- step 4: know your ecosystem and the services it could provide,
- step 5: identify the best Green Adaptation measures for a certain area with a certain system with certain needs,
- step 6: identify opportunities to implement these measures in an integrated manner with on-going initiatives, the spatial context and policy programmes.

Ecosystem functions and services can provide cost-effective, multi-functional adaptation solutions. Such so-called "Green Adaptation" solutions seek a balance between civil engineering and naturally functioning biological components, in order to make optimal use of potential ecosystem services and functions for the benefit of safety against flooding and freshwater availability.

In the Netherlands, Rotterdam is one of the most densely populated urban areas, relatively vulnerable to various climate impacts. Deltares, knowledge institute for water management, and the city of Rotterdam have formed a strategic alliance to explore how our Dutch knowledge and experience on Building with Nature / Green Adaptation can be optimally applied to the urban and regional delta system in Delta cities in general and the city of Rotterdam in specific.

This report investigates how Delta cities and as pilot the city of Rotterdam could make optimal use of such ecosystem services and functions in water management and (adaptive) building to adapt to climate change (inclusive water, nature, heat-stress, and land-use pressures), and how Green Adaptation measures could be effectively implemented in, or combined with, on-going policy plans and climate initiatives, in order to improve safety against flooding as well as environmental quality, while enhancing economic development (port activities) and citizen livelihoods (recreation, cultural heritage) in the city.

We have selected several new or on-going projects that can provide opportunities for the implementation of Green Adaptation measures. The aim is to restore the ecosystem functioning again in order to make use of ecosystem services.

Rotterdam project opportunities	Urban needs for climate adaptation	Desired ecosystem service(s)	Additional ecosystem service(s)	Green Adaptation measure(s) (1)
Shores of the Schie and Rotte rivers (North)	Flood protection (2), Pleasant temperature (3)	Water storage, Wave attenuation, Heat stress reduction	Urban liveability, Urban nature, Water quality	Riparian wetland creation, Floating structures, Green roofs
Older neighbourhoods in the North (4)	Flood protection, Pleasant temperature, Salinisation prevention, Soil subsidence prevention	Water storage, Water infiltration, Heat stress reduction, Water supply	Urban liveability, Urban nature, Water quality	Green retention, Bioswales, Water purification by soils/organisms, Green roofs
The large regional parks in the North and South	Flood protection, Pleasant temperature, Drought prevention, Salinisation prevention, Soil subsidence prevention	Water storage, Water infiltration, Heat stress reduction, Water supply	Urban liveability, Urban nature, Water quality	Green retention, Bioswales, Water purification by soils/organisms
Spaanse Poort (North)	Flood protection, Pleasant temperature, Salinisation prevention	Water storage, Water infiltration, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Green roofs, Riparian wetland creation, Floating structures
Nassauhaven (South)	Flood protection, Pleasant temperature,	Water storage, Wave attenuation, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Green roofs, Riparian wetland creation, Floating structures

Zuiderpark (South)	Flood protection, Pleasant temperature, Drought prevention, Salinisation prevention, Soil subsidence prevention	Water storage, Water infiltration, Heat stress reduction, Water supply	Urban liveability, Urban nature, Water quality	Green retention, Bioswales, Water purification by soils/organisms, Green roofs
Brielselaan (South)	Flood protection, Pleasant temperature	Water storage, Water infiltration, Heat stress reduction	Urban liveability, Urban nature, Water quality	Bioswales, Water purification by soils/organisms, Green retention
Noordereiland (Rivercity)	Flood protection, Pleasant temperature	Water storage, Wave attenuation, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Riparian wetland creation, Floating structures
Rijnhaven (Rivercity)	Flood protection, Pleasant temperature	Water storage, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Riparian wetland creation, Floating structures
The Esch (Rivercity)	Flood protection, Pleasant temperature	Water storage, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Green roofs, Riparian wetland creation, Floating structures, Water purification by soils/organisms

The recommendations of this report are that:

- Urban delta regions (here Rotterdam) need a good Geographical Information System approach to analyse where all the climate adaptation measures must be and can best be implemented. The All London Green Grid can be used as an example of how to structure these maps.
- A clear picture of do and don'ts for the Rotterdam partners (project developers, builders, etc) who want to work with a GA approach or in the neighbourhood of GA zones and projects. We think of a tool.
- A shortlist of projects where the Green Adaptation approach could contribute significantly by aiming to address and integrate multiple urban needs in a multifunctional set of GA measures, would be:
  - Urban rivers the Schie and the Rotte
  - The Ring of older neighbourhoods through North and South
  - Making The Delta river
- It is important to get local stakeholder involvement and a clear view on the cost-benefits balance of the Green Adaptation measures.

4 Introduction

4.1 General Introduction

Worldwide, deltas are faced with an increasing demand on space, caused by sea level rise, freshwater and food scarcity, population pressure and land subsidence. Effects of climate change and population growth are expected to have the largest impacts in highly populated urban areas, often located in low lying deltas, vulnerable to floods. The awareness of the limitations of pure engineering (increasing the demand for limited space, negatively affecting long-term ecosystem functioning) has created an urgent demand from vulnerable delta areas worldwide for efficient integrated climate adaptation approaches that enable multi-functional use of available space.

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Rotterdam is a safe Delta city. Dikes, flood defensive works (fi. Maeslandtkering) and high leveled embankments protect the city against rising sealevels and make the Rotterdam harbour one of the savest ports in the world. In view of climate change Rotterdam wants to keep this quality on the same high level. Therefore, Rotterdam is working on flood defense within its climate adaptation program together with the Delta commission, local partners and Rotterdam Mainport.

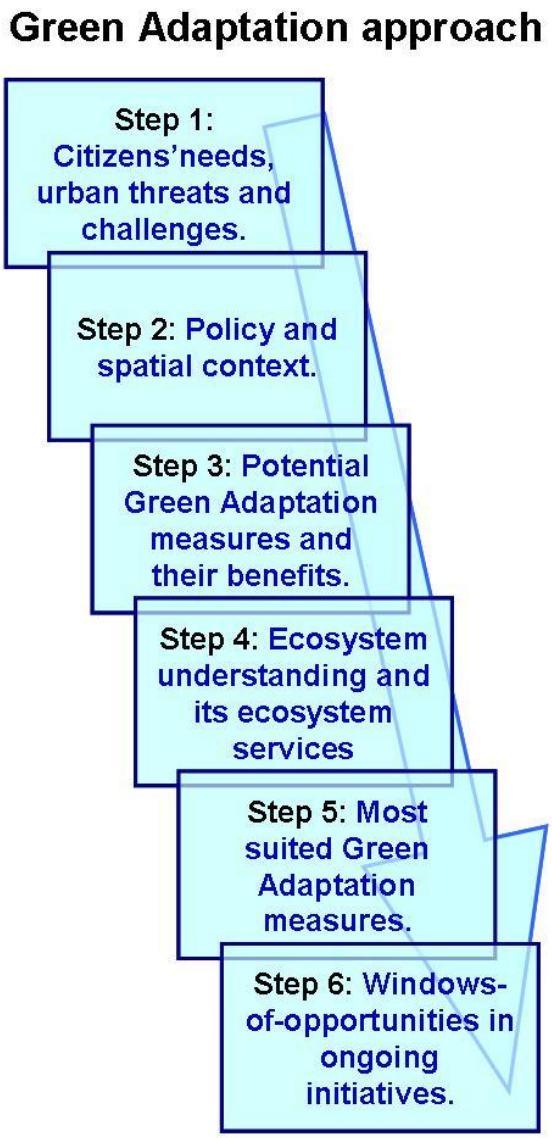
This report investigates how Delta cities and as pilot the city of Rotterdam could make optimal use of such ecosystem services and functions in water management and (adaptive) building to adapt to climate change (inclusive water, nature, heat-stress, and land-use pressures), and how Green Adaptation measures could be effectively implemented in, or combined with, on-going policy plans and climate initiatives, in order to improve safety against flooding as well as environmental quality, while enhancing economic development (port activities) and citizen livelihoods (recreation, cultural heritage) in the city. So, the focus of ecosystem restoration is not on its ecological values but on its services that contribute to climate adaptation.

The overall goals of this report are to:

1. *Explore applicability of the existing 'Green Adaptation'-solutions for water management and heat-stress in the field of climate adaptation in an urbanized (and industrialized) delta region, in this case the Rotterdam region. The proposed measures should enhance the adaptive capacity of the Rotterdam water system and make optimal use of ecosystem services like safety against flooding, water purification, heat stress reduction and liveability.*

2. *Provide recommendations for the Rotterdam Adaptation Strategy (RAS), based on lessons learned from Green Adaptation explorations in this study. The most promising Green Adaptation measures are identified and described for implementation at Rotterdam.*

To reach these goals, we will follow a Green Adaptation approach defined within this project: a set of steps to identify the most (cost)-effective set of Green Adaptation measures for a certain area.



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- step 6: identify opportunities to implement these measures in an integrated manner with on-going initiatives, the spatial context and policy programmes.

We will first describe the urban climate context of Rotterdam (Chapter 5) to give an overview of the threats and pressures that Rotterdam is faced with in

light of climate change, to indicate how Rotterdam has dealt with these pressures through various policy programmes and climate initiatives. This Rotterdam climate context then provides a framework in which Green Adaptations opportunities should fit (step 1 and 2 of the Green Adaptation approach).

We will then explain how ecosystem services and functions can aid in adapting to various climate related pressures, as well as economic- and population pressures. We will identify potential Green Adaptation measures in an urban setting (Chapter 6), and describe how they can improve flood protection, water storage, water quality and the general urban quality of living.

By identifying the different needs of the various city networks, we arrive at what type of measures could be effective to implement in certain areas in Rotterdam (step 3 of the Green Adaptation approach) to address area specific needs.

As Green Adaptation measures make use of services that an existing ecosystem (potentially) could deliver, the effectiveness of implementation of such measures therefore depends strongly on the (type, state and health of the) existing ecosystem in an area. Chapter 7 will explore how the Rotterdam ecosystem, could be used and strengthened in order to effectively deliver adaptation services, using the Rotte river catchment system as an example. The current state of the Rotte, its needs and requirements, and the ecosystem services it could (potentially) deliver are addressed. (Step 4 of the Green Adaptation approach).

To address step 5 of the Green Adaptation approach, Chapter 8 will describe the results of a workshop session with the aim to explore which, where and when Green Adaptation measures could be most effectively implemented in North and Historic South. The Chapter will describe potential Green Adaptation measures for those areas and also identify the most promising opportunities (new projects, area developments) for implementation of Green Adaptation measures (step 6 of the Green Adaptation approach).

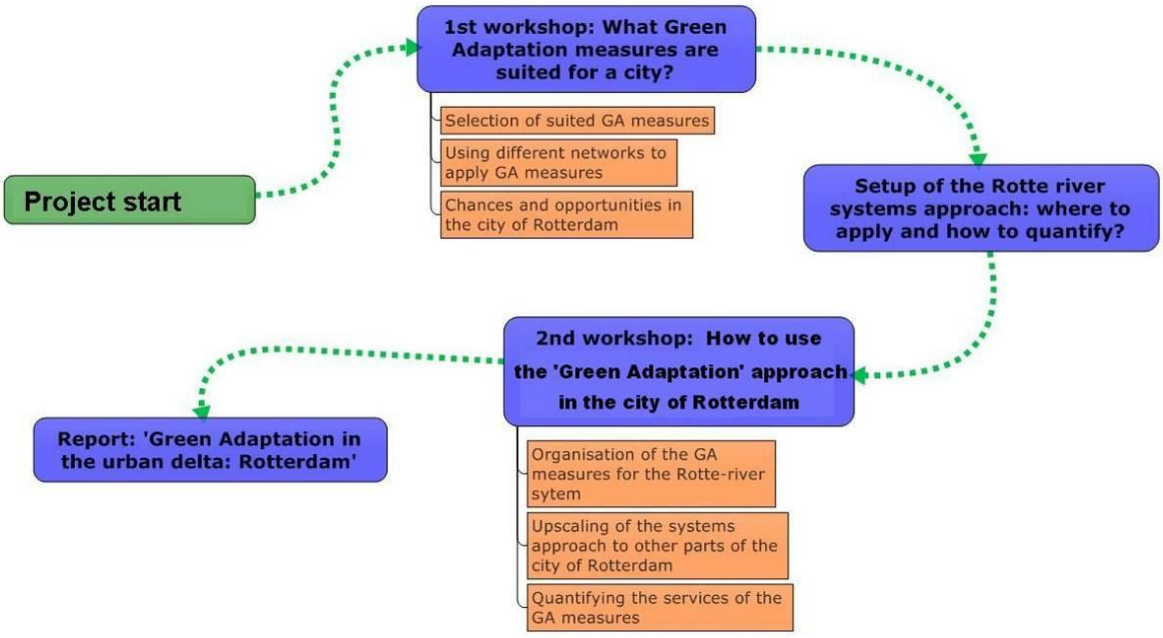
Chapter 9 will provide conclusions and recommendations for further exploration of potential Green Adaptation implementation for the City of Rotterdam, and for other comparable Delta cities.

4.2 Project route

In this study, the application opportunities of Green Adaptation concepts in the urban delta of Rotterdam was explored and discussed with the hotspot

coordinators, specialists of Rotterdam (water management, urban development, ecology, climate adaptation) and research institutes working in the 2nd tranche of the Knowledge for Climate Programme (KvK). In the urban environment it is of utmost importance that climate adaptation measures contribute to the attractiveness of neighbourhoods for the citizens. It becomes clear that ecosystem functioning provides valuable ecosystem services that contribute to climate adaptation.

Two workshops were organised during this study to discuss the Green Adaptation approach and explore Green Adaptation possibilities for Rotterdam. The first workshop introduced the Building with Nature solutions and a Green Adaptation approach. In the same workshop an inventory was made of opportunities for implementing specific measures in Rotterdam. In the second workshop the Green Adaptation approach was applied to two areas in Rotterdam, together with city planners, designers and engineering specialists of Rotterdam.

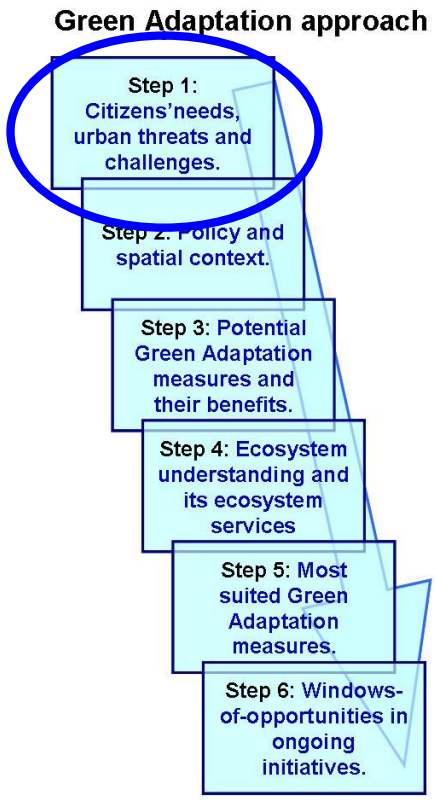


5 Setting the urban climate context for the City of Rotterdam

5.1 Introduction

Rotterdam is the Netherlands most important and relatively vulnerable Delta city, despite its ongoing search for innovative solutions for flood defense. The large harbour city is recognizing the limitations of traditional flood defence strategies: not flexible, mono-functional, affecting natural dynamics of the water system, and very costly. Therefore, the main challenge for Rotterdam and the Rotterdam region is to develop measures that adapt to future threats and additionally contribute to an economically strong, environmentally friendly and attractive urban area. This requires multi-functional measures that integrate various functions.

The city of Rotterdam has recognized the need for a multi-functional approach to climate adaptation, and has taken up various climate initiatives to address this need. In order to draw a complete policy framework in which Green Adaptation measures would have to be incorporated, this chapter will address the various climate, water and nature policy programmes and initiatives that are being implemented in Rotterdam. This chapter also provides an overview of Rotterdam adaptation measures that are already shown to be effective.



5.2 Climate issues for the city of Rotterdam

The two main climate issues for the City of Rotterdam are the challenges related to water and to heat stress. In this paragraph we carry out step 1 of the Green Adaptation approach: Identify citizens' needs and urban threats and challenges.

5.2.1 Water challenges

The City of Rotterdam expects the largest water challenges to be in the next decades:

- higher water levels due to sea level rise
- increased frequency and intensity of extreme rainfall
- higher demands for an improved water quality
- increased soil subsidence in the polders
- higher salinity in river and groundwater
- more heat and drought in the summer

Water safety

The increase in sudden extreme rainfall events can already be noticed, and the problem of groundwater level rise is becoming more and more frequent, resulting in regular flooding and overflowing of basements and cellars, tunnels and even entire parts of the city. For instance, the quaysides of the Noordereiland (the large island in the Meuse river) are occasionally completely flooded. Especially outer areas (areas outside of the dike ring) will flood more frequently. Urbanization has significantly reduced flexibility in the water system to cope with expected higher peaks in rainfall.

The City of Rotterdam is protected by dunes along the sea and by dikes alongside the main and the urban river basins. Storm surge barriers have been implemented on the main rivers of Rotterdam region: Maeslantkering, Hartelkering en Hollandse IJsselkering. However, within the urban region of Rotterdam, more localized measures are required to at least maintain, but rather enhance safety levels against flooding.

For the City or Rotterdam, the main water safety challenges are:

- strengthen the dikes of the main rivers where necessary
- strengthen the secondary dikes
- extra water storage areas in all districts
- maintain and strengthen the urban water canal system
- innovative measures in older neighbourhoods
- risk management on a spatial level

Rotterdam has a dike maintenance programme to make sure dikes comply with the new national climate standards. The dikes along the urban rivers are peat dikes, which can be unreliable in dryer periods (Wilnis 2009). Peat dikes can then lose their natural stability, which can be disastrous for urban polders.
The dike maintenance programme has found that the dikes along the main rivers and along the small city canals are parts not up to future safety standards, especially in Rotterdam North. The dikes in the South are within safety stand-

ards. Apart from the standard dike-reinforcement measures advised by the regional water boards and the Rijnmond commission, the City of Rotterdam is also looking into more innovative solutions.

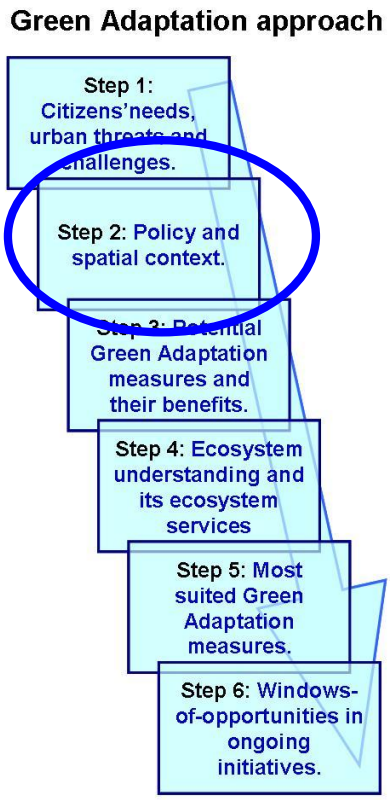
Water quality
Water safety is the main challenge but water quality is also important for an attractive city. Clean water can be used for recreational activities and will generate a more natural water system. Farming and drinking water facilities are not helped with brackish water. Rotterdam developed an instrument for its water quality ambitions.

5.2.2 Heat stress

In periods of high temperature, the highly urbanized areas in Rotterdam can be faced with a heat island effect, resulting in heat stress, despite its close location to the sea. City temperatures are expected to further increase, which will increase the urban heat effect. In Rotterdam, temperature differences up to 10 degrees can be observed, but the average difference during the day is 2-5 degrees. Heat stress can negatively affect the health and productivity of citizens, and in general can reduce general living comfort (liveability).

Highest temperatures are recorded in the city centre and Rotterdam Zuid, reflecting the highest concentration of buildings. The urban heat island effect creates differences in exposure within cities due to specific neighbourhood characteristics; factors of influence are: the percentage of impervious surface, water, sky view factor, albedo, traffic area and leaf area index (LAI) and in night-time also: soil adjusted vegetation index (SAVI), and wind. As an adaptation measure, trees function well during the day, flat green areas better during the night (Knowledge for Climate mid-term results August 2012).

5.3 Policy and urban planning programmes



Rotterdam wants to be an attractive and economically healthy city for their citizens, company's and other partners. Various policy plans and urban planning programmes in Rotterdam implement numerous measures to enhance safety against flooding (climate policies), improve the liveability (green policies) and to enhance the water quality (water policies). Green Adaptation approach and the potential measures must communicate with these plans to be most effective and to have the best chance of becoming realistic. In this paragraph Step 2 of the Green Adaptation approach is carried out: describing the policy and spatial context.

5.3.1 Climate

Rotterdam Climate Initiative

One of Rotterdam's' most important and elaborate climate initiatives is the Rotterdam Climate Proof Initiative. With this initiative, the city of Rotterdam has developed a climate adaptation plan, based on a multi-functional and multi-disciplinary approach. By involving local stakeholders, the city worked together on climate issues with climate measures that must be profitable for, or positively affecting citizens, companies and visitors.

The Rotterdam Climate Initiative (RCI) launched in 2007, is a joint initiative by The Rotterdam City Council, the Port of Rotterdam, DCMR and Deltalinqs. The

RCI focuses on the basic measures designed for tackling climate problem for Rotterdam and the Rijnmond region. To prepare for inevitable, considerable changes in the urban climate, Rotterdam needs to invest time and money to safeguard wellbeing and security of the population, to prevent damage and to increase the return on investments. Making Rotterdam Climate Proof (RCP) is one of the main goals of the RCI. Main themes for the RCP programme are: water safety, adaptive building, city water system, city climate and connectivity. In the climate proof programme, Rotterdam invited other public and private parties to come up with innovative contributions, in alliance with national and international climate programmes. Rotterdam is also seeking to secure a firm position on the international stage in the field of urban delta technology, through learning by doing and focusing strongly on knowledge development.

Rotterdam Climate Adaptation Strategy

The Rotterdam Climate Adaptation Strategy (Programmabureau Duurzaam, 2012) is to provide insight in on-going and planned initiatives, and provide an overview of all possible effective and affordable adaptation measures that can be implemented in Rotterdam. The strategy has to be adjusted periodically, to adapt to changing circumstances and gained knowledge about the expected midterm and long-term climate change impacts. The strategy follows actual national and regional knowledge and decisions made with impact on the Rotterdam water or climate system.

The Region of the City of Rotterdam already developed a regional toolbox for climate adaptation. It supplies measures which can be taken by the local governments in the region. It is an inspiration for project managers and its give an insight in what can be taken as precaution to climate change effects. It is not a standard but it is meant to turn the wheels to start implementing climate adaptation in running projects and developments.

Step by step, the City of Rotterdam is gaining insight in more detailed factors and interrelations between climate issues. It will lead to more trust and concrete measures for the Rotterdam Adaptation Strategy. However, there is a long way to go still and international change of knowledge is valuable for Rotterdam. As the national climate programme of the Netherlands has identified Rotterdam as a Hotspot, a lot of projects have been initiated in alliance with Dutch and European institutes.

Water management

In the last couple of years, the City of Rotterdam has been improving her water management approach to focus on multifunctional use of space. With the publications Waterstad ('Water city') 2035 and Waterplan 2 (Municipal of Rotterdam 2007) the City of Rotterdam outlines this new, integrated way of water management. These plans led to concrete results already: water plans have

been or will be developed for all city districts and new development areas such as Stadshavens (= City harbour) and Polder Schieveen. Together with the water boards, Rotterdam managed to improve the water quality of singels and lakes within the city and in the region. Also a numerous climate adaptations measures have already been implemented that carry multi-functionality and make use of ecosystem services to a degree.

The City has ambitious plans for the construction of city quarters that are entirely floating. In these floating residential areas, people will live, shop, work and recreate on the water. Floating urban areas are the ultimate form of adapting to climate treats in low-lying and especially unembanked areas, but depend highly on the surrounding parameters, technological capacity and the willingness of governments. This measure is a good example of climate adaptation, however, most of it is not a nature-based or a green adaptation measure.

Greening the city

In 2009 Rotterdam a new Green vision was developed on how to combine all the new trends in relation to green areas within the city: climate, water, child friendly neighbourhoods, ecology and social projects and initiatives around green schoolyards, urban gardening and management of green public space by volunteers. Green areas can play an important role in innovative combination of measures on mitigation and adaptation. More than open water areas, green areas can contribute to a cooler, healthier and cleaner city. Rotterdam wants to emphasize the social and health effects of green areas in the city.

5.4 Urban planning

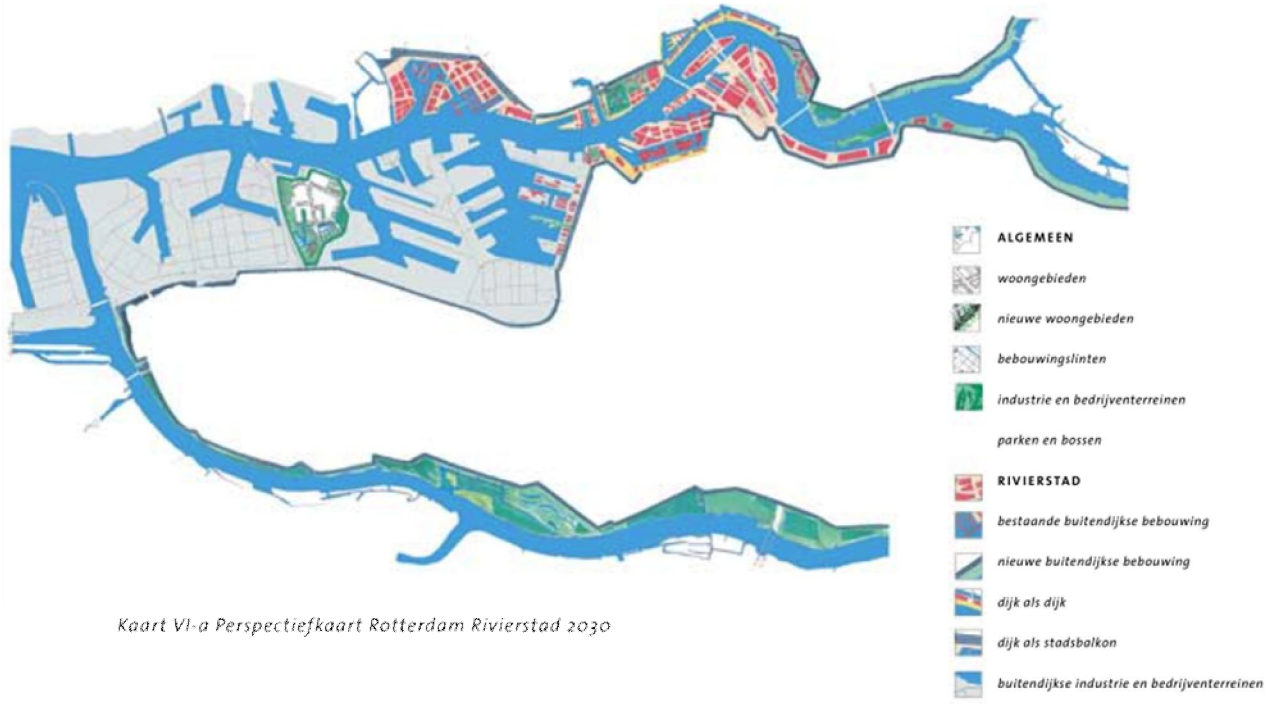
Currently, the Rotterdam Green Policy ('Groene opgave'; requirements for nature quantity and quality), the Rotterdam Water Policy ('Water opgave'; urban requirements for water quality and management), Deltaprogramme plans and spatial plans are interpreted and implemented in a predominantly separate manner. All these policy plans and initiatives have slightly different primary goals, but might overlap with their secondary goals. For example, the Green Policy, the Water Policy and the Deltaprogramme all advise on water retention measures, but with a different aim. This means that similar measures could be implemented in a parallel manner, leading to a large, expensive and not cost-effective set of measures being implemented throughout the city. Waterplan 2.0 and Rotterdam Watercity 2035 already emphasize the common interests between the various policy plans, and recommend an integrated approach.

This leads to the question of how to combine the Green Policy, the spatial plans and the Water Policy, in a way that the City of Rotterdam can come to a cost-effective, optimal set of measures that addresses multiple needs and provides various benefits, and assure that Rotterdam remains a safe, climate-proof, pleasant, green and healthy place to live, work and recreate. And how can we approach this integrated thinking, while crossing borders of city areas, municipalities and regions?

Rotterdam has four main districts (City visions):

Rivercity

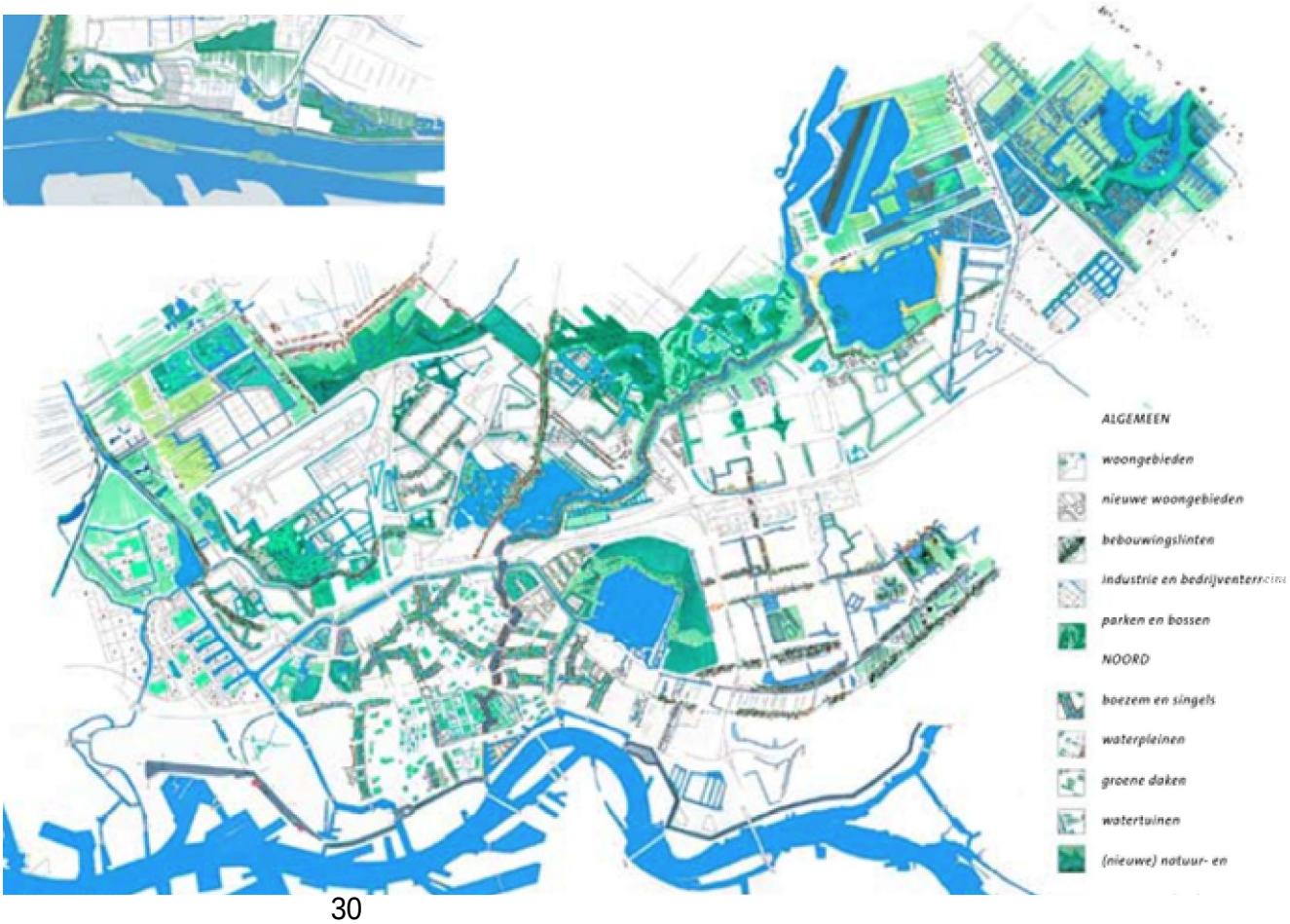
The river is a connection between the city, the harbour, the sea and the hinter-land. The waterfront is characteristic in historical sense and forms the main habitat for the newly developing areas of the city like Lloydkwartier and Stadshaven.



Kaart VI-a Perspectiefkaart Rotterdam Rivierstad 2030

Historical North

North has to upgrade neighbourhoods with the majority of the citizens, the central city area, and the most beloved parks of town: Kralingse Bos, the Park and Vroesenpark, and the oldest canals (Dutch = singel) with their beautiful mansions. Rebuilding of the older city parts, upgrading and condensing the center of the city, is at stake for many years already. Hoek van Holland is part of the North where two peat rivers are the basics of the watersystem. Of one of them, the Rotte river, Rotterdam originates its name.



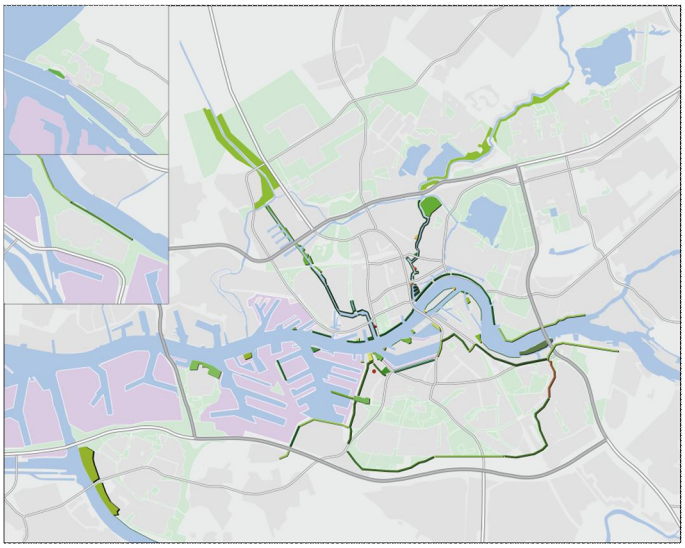
Gardenly South

It contains neighbourhoods built in the fifties and sixties in former polder areas and lots of green space. These neighbourhoods are loved by elderly people and families looking for quiet surroundings. The dikes are still intact and used as routes to connect the neighbourhoods. In the South district, the garden districts are currently being restructured. The Zuiderpark has been transformed to serve as an important city park. And the 'blue route' is planned as a better connection with the Oude Maas for a better water quality in South.

In the South of Rotterdam region the province of Zuid-Holland and local governments (including Rotterdam) are working on development of nature and recreational areas that connect urban districts with landscape and farming surroundings Part of these areas are climate buffers for rainwater to use in dryer seasons. So that farmers and nature can profit from fresh water also when the Oude Maas is becoming siltier. Nature organizations are involved to develop and maintain the climate buffer areas. The Blue route will bring this fresh water to the southern departmenst of the city of Rotterdam (buijtenland.nl, ark.eu). In Rotterdam Noord the city has similar projects only the climate buffers cannot be realised (www.vanrottetotschie.nl) due to the safety regulations for the Rotterdam-The Haque airport. So, Rotterdam is working on cool recreational areas around the city and green bicycle paths which connects the urban networks with the outer landscape.

The Green surroundings

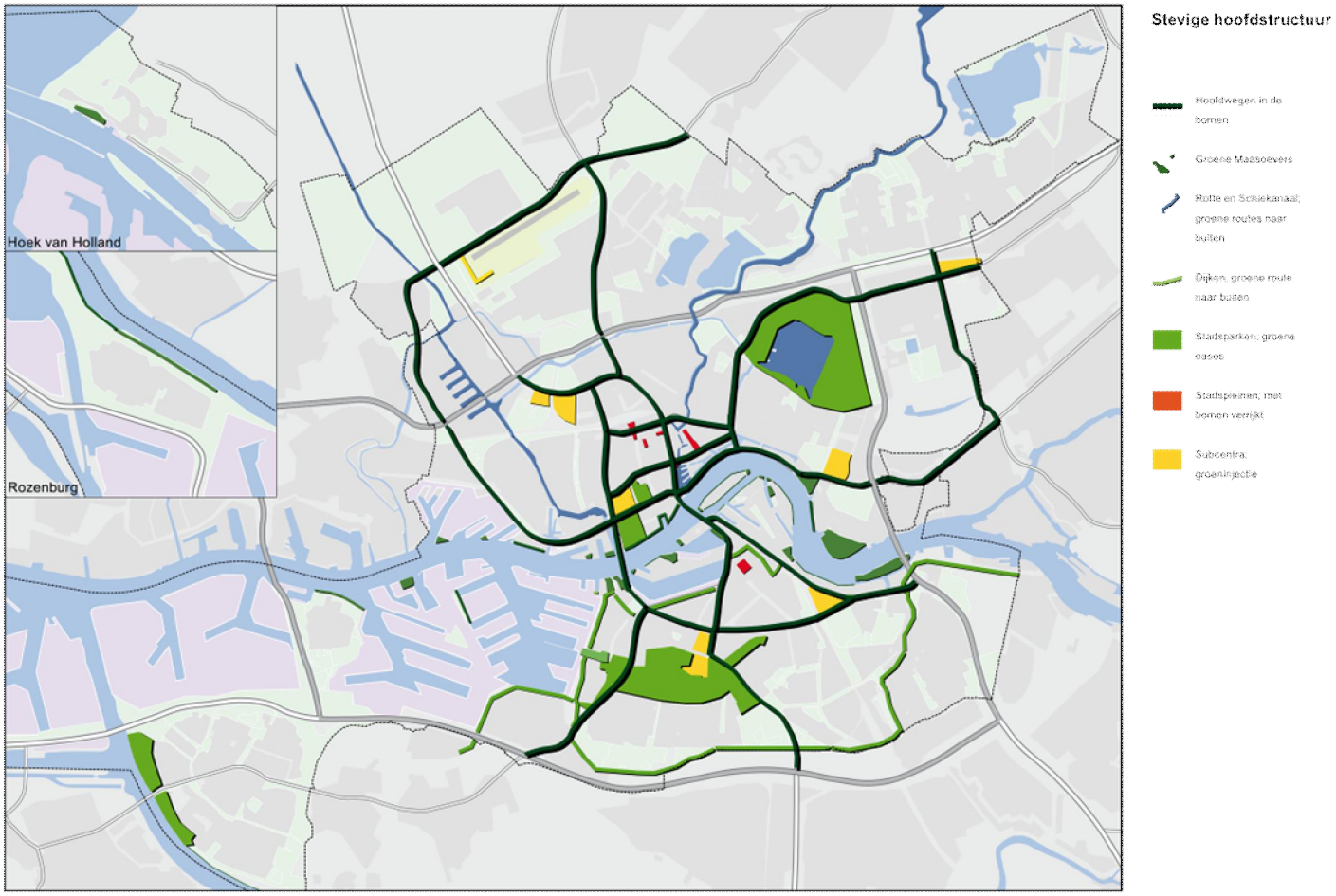
The green surroundings are around the city. They are mainly former agricultural land but restructured recently into natural and recreational areas for the citizens of Rotterdam. A lot of attention is given to water management aspects in combination with continuing farming activities. The North consists of polder areas part of the Green heart of The Netherlands and the South consists of polder areas and embankments of the Oude Maas river.



Green urban routes towards surrounding regions.

The network of the city can be drawn by (Rotterdam style):

- main public space structure on city level
- outer dikes areas
- river dikes
- bosom and polder dikes
- singles (historic urban water ways)
- public space structure on neighbourhood scale
- historical landscape structure



Above: *Challenges in the four districts.*

In all these districts, Rotterdam has been working on:

- restructuring neighbourhoods;
- realizing new neighbourhoods and high buildings;
- improving the quality and liveability of the inner city centre;
- opening up the green belt around the city for citizens;
- improving water and nature quality.

With the financial crisis hovering over Rotterdam, a stronger focus is required on economic efficiency in work and projects. Since the financial crisis began in 2008, the City of Rotterdam has been forced to focus its investments in certain priority areas. On the short and mid term the City Council decided in June 2011 that Rotterdam will focus her investments in developing:

- the inner city centre
- Rotterdam South
- Stadshavens ('City harbours').

For the long term there has been a proposal (Horizon Rotterdam May 2012) that a strategic focus will be given to:

- the inner city centre
- the older neighbourhoods on South (Nationaal Programma kwaliteitssprong Zuid) and North
- accessibility of the harbour and other economical hotspots
- the delta city.

Urban developments in Rotterdam will be focused on better quality and strategic small scale projects. Due to this prioritisation, tunnel developments can no longer be realized, and nature projects are scaled down.
Developments in the neighbourhoods in the North will continue, as the North is considered to be important for the financial strength of the city centre. The cultural and creative sector can fulfil a role in developing attractive urban areas in and around the centre. New measures on noise and air quality are necessary. Rotterdam South developments continue within the context of the national program. The Delta landscape and the Harbour landscape will gain innovative and economically attractive projects which will have a stronger relationship with the city.

5.5 Realised climate projects

Projects and measures for Water management and Greening the city
The credo for Rotterdam, as in the Netherlands is: collect-storage and slowly drain to the rivers. The spatial vision is close to the practical opportunities of existing water systems and non functioning urban areas. For an overview see appendix 4 of this report.

Projects and measures for water safety and water storage

- Heightening main infrastructure (city scale) (inventarisation where heightening is needed):

- Heightening dikes alongside urban rivers (city scale) (inventarisation and risk management)
- Heightening lowest fields (neighbourhood scale), (all new developments have adjusted field levels)
- Heightening edges of side walks (street scale) (all new developments have adjusted side walk levels)
- Emergency water storage areas (regional and city scale) Eendrachtspolder; Zuiderpark),
- Seasonal water storage; climate buffers (city/regional scale) (Buytenland, Polder Schieveen)
- Extra water storage areas (neighbourhood scale (Tjalklaan, Lepelaarsingel, Museumparkgarage, Hordijkersingel and Parc de Swaen).
- Innovative water storage at squares, green areas or underground (water level district),(Vierhavenstraat, Bellamyplein, Kleinpolderplein)

Project and measures to improve water quality

- Separated sewer system in newly developed areas where possible.
- Direct rainwater flush when possible
- raise the water levels to prevent brackish groundwater in agricultural and recreational areas (Polder Schieveen)
- Dredge program all urban water systems
- Restoring the Singels (historic urban water ways)
- Improving ecosystem services in the Bergse Plassen and Kralingse Plas

Projects and measures for greening the city

- More and more thick and older trees, and more different species on the main structure of public space (Bomenstructuurvisie).
- Shift from a mainly built and paved neighbourhood to a more mixed area with (more) green public spaces for children, recreation opportunities and shaded streets (Vergroeningsopgave 2011-2013: ten neighbourhoods have already implemented 'green' projects).
- A new standard for child friendly neighbourhoods, in which green areas play an important role (Kindvriendelijke Wijken).

Projects and measures for water management in combination with other urban functions

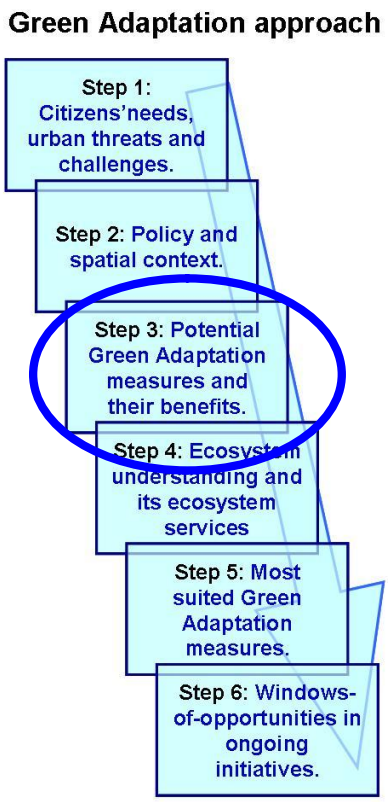
- Flexible buildings and road (adaptable), when problems occur you can alter to different use or management (studies)
- Multifunctional dikes (study, 1 price IGWR contest: technical innovations)
- Strengthening the identity of Rotterdam as a port and a delta city (climate buffers and the studies from WNF/Bureau Stroming)
- Water and greenery can be complementary. Green can store water. Green close to water can compensate to slower cooling down effect of

water in the night. (Toolbox Green and Climate, Green roof programme)

- Soil subsidence can cause groundwater problems. Setting up groundwater levels can stop soil subsidence (Polder Schieveen)
- Developing attractive neighbourhoods and port activities with climate proof measures: adaptive building, building with nature and heath prevention (Stadshavens, Watercentrum, Vergroeningsopgave, Park de Zwanen Groot IJsselmonde).

6 Potential Green Adaptation Measures for Urban Settings

This chapter will answer the following questions: What are ecosystem services and how can we make use of them for our own benefits? What are the principles behind Green Adaptation measures? How can they contribute to improving flood protection when using ecological processes or habitats in an urban delta system? How can we optimise water storage by improving the ecological function of urban areas? How can green adaptation measures in water management also contribute to an improvement of the urban living quality? Finally, this chapter gives an overview of how six promising types of Green Adaptation measures can contribute to addressing climate adaptation needs in various areas (networks) in the City of Rotterdam.



Ecosystem services are services that an ecosystem provides when these services are being used by people or organisms. Green adaptation is a directed way of making use of these ecosystem services for the purpose of climate adaptation.

This chapter can be regarded as step 3 in the Green Adaptation approach (on the right). It is about understanding possible Green Adaptation measures and their benefits.

6.1 What are ecosystems and ecosystem services?

Ecosystems are communities of organisms (plants, animals and microbes) in relation with the nonliving components of their environment (air, water and mineral soil). They interact as a system and can be regarded on different scales. Begon et al. (1986) defines it as the biological community together with its physical environment. Here, the biological community consists of species populations that live together in space and time. The environmental components are linked together through nutrient cycles and energy flows.

For example, the shore of a river can be seen as an ecosystem with typical plant and animal communities, interacting with the physical environment like the water level dynamics, water quality and soil quality. The present vegetation here, is providing a niche to certain animal communities, while the animal communities can influence the present vegetation again by destruction of or herbivory on it. Also, animal communities can bring in nutrients that influence vegetation, soil quality and water quality again. A complex map of interactions between biological community and physical environment can be drawn up.

Looking at a larger scale, the river itself can also be regarded as an ecosystem. Even the whole catchment or the whole world can be regarded as an ecosystem. However, it is obvious that the larger the scale the more complex the map of interactions. For practical reasons, ecosystems are used for systems that comprise areas with more or less similar environmental components or flows and a biological community that can be overseen. Like a deciduous forest, a fresh water lake, or a ditch. People will try to divide a river or a catchment into comprehensible sub-ecosystems.

Figure 6.1 Ecosystem services according to the Millennium Ecosystem Assessment (picture is a cropping from the original).

These ecosystems provide services like food, water and timber. Ecosystem services are the benefits that people obtain from nature (Ranganatan, 2008) and might be either goods or services. These include *Provisioning services* such as food, water, timber, and fibre. But also *Regulating services* such as the regulation of climate, floods, diseases, wastes, and water quality. It includes *Cultural*

services such as recreation, aesthetic enjoyment, and spiritual fulfilment and a group of *Supporting services* such as soil formation, photosynthesis, and nutrient cycling.

The use of natural processes or organisms for other functions then nature itself can be seen as isolated ecosystem services. When a degraded ecosystem is restored, its ecosystem services will grow again. For example, in a polluted pond many fish die and the population will not recover by itself. Here, the ecosystem service like fish for food (provisioning), regulation of mosquito population (normally eaten by the fish) and enjoyment of nature (recreational; people are disturbed by the explosion of the mosquito population) are effected.

The ecosystem services that a green roof can supply are very useful in urban areas. In the provisioning group it can supply food (in case of vegetable gardening, beehives, etc.), or fuel (when crops are used for generating energy). Very interesting, in the scope of this study, are the regulating services, like possibilities for water quantity regulation (temporary storage of rain water surplus), climate regulation by evaporation through vegetation, and water purification (when surface water is pumped onto the roofs). On a larger scale, a network of green roofs can supply primary production or sufficient amount of habitats that support other more complex services or in larger quantities (like cultural: recreational sun roofs in natural environments, or regulation of biodiversity). Natural shores of water ways can provide for instance extra water storage capacity, increase in water purification capacity, enhance biodiversity, habitat provisioning, heat stress reduction through vegetation and increase attractiveness housing areas.

The concept of ecosystem services is the base for sustainable development. After the United Nations report on The Economics of Ecosystems and Biodiversity which focus on the economical aspects, the concept is rapidly attracting interest from environmental policymaking, management and science arenas.

6.2 What is Green Adaptation?

Green Adaptation seeks a balance between civil engineering and naturally functioning biological components, in order to make optimal use of occurring ecosystem services and functions for the benefit of safety against flooding and freshwater availability. Ecosystem-based or ‘Green’ approaches embed natural functions and services (wave attenuation, sediment fixation, flow reduction, water retention, water purification, freshwater availability, biodiversity and fisheries) in land and water use planning.

Green Adaptation is an adaptive way of water management integrating natural processes and ecosystem services with human interventions and to sustainably manage water services and related climate risks. Ecosystem-based or 'Green' approaches can contribute to adaptation strategies through the following (Worldbank 2007):

- Maintaining and restoring natural ecosystems and the goods and services they provide
- Protecting and enhancing vital ecosystem services, such as water flows and water quality
- Maintaining coastal barriers and natural mechanisms of flood control and pollution reduction
- Reducing land and water degradation by actively preventing, and controlling, the spread of invasive alien species
- Managing habitats that maintain nursery, feeding, and breeding grounds for fisheries, wildlife, and other species on which human populations depend
- Providing reservoirs for wild relatives of crops to increase genetic diversity and resilience.

Green (ecosystem-based) adaptation complements other responses to climate change in two ways. First, natural ecosystems are more resistant and resilient to climate change than 'hard' solutions and they provide a full range of goods and ecosystem services, including natural resources such as water, timber, and fisheries on which human livelihoods depend. Second, natural ecosystems provide proven and cost-effective protection against some of the threats that result from climate change. For example, wetlands, mangroves, oyster reefs, barrier beaches, and sand dunes protect coasts from storms and flooding. Such ecosystem-based approaches can complement, or substitute for, more expensive infrastructure investments to protect coastal and riparian settlements (World Bank 2009). The green adaptation approach has been applied in regional settings mostly and is taking its exploratory steps in an urban setting (this study, and Green Adaptation in Indian cities, in press).

More adaptive ways of living are still found in local rural communities in transition countries. In parts of the Mekong Delta in Vietnam, communities are completely adapted to the natural dynamics of the water system, as river floods are essential for maintaining productivity of their rice fields. However, these traditional approaches tend to be neglected in developments and spatial planning on larger scales in these countries. It can be difficult to project such dynamic adaptation strategies on urban areas in Europe (like Rotterdam), as centuries of water management and urbanisation have been aimed at *reducing* such natural dynamics of the water system in highly populated areas.

Possibilities for incorporating natural processes into functional urban planning are explored only recently. Below we show a box with the key principles of Green Adaptation that ultimately might be applied in urban settings.

Key principles of Green Adaptation:

- Making optimal use of the ecosystem, its functions and its dynamics: work with what you've got - make nature work for you
- Making multi-functional use of space: work to integrate all functions in an area
- Meeting underlying societal goals: work with people's needs! Make it a win-win situation for all stakeholders
- Multi-disciplinary cooperation among key players: work together with different disciplines
- Involving stakeholders in early stages of projects: work together from the start

6.2.1 Benefits of Green Adaptation

Besides the multiple ecosystem services, the green adaptation measures can also be regarded as more resilient, and more cost-effective than traditional hard (concrete) solutions. In the studies of Building with Nature (Ecoshape) and Innovation programme of Rijkswaterstaat (Zachte werken met Harde trekken, in press) benefits of BwN concepts have been defined, however, the valuation of these is very situation specific. In the following paragraphs we have tried to sum the benefits with the measures that are used in the text.

6.3 Green adaptation measures

A vast amount of knowledge and experience in the field of Green Adaptation is available worldwide. Water managers all over the world increasingly apply green adaptation measures to combat climate change, in various forms.

6.3.1 Types of Green Adaptation measures

Generally speaking, we can identify three main types of Green Adaptation measures: those that are aimed primarily at increasing flood protection in coastal and river areas, those that are aimed primarily at optimizing freshwater quality and quantity, and those that are aimed primarily at improving the quality of living. It should be noted that many Green Adaptation measures are a combination of these types, as ecosystems generally provide multiple services.

Text Box 6.1 Overview of the main types of Green Adaptation (Modified after "Green Adaptation – making use of ecosystems services for infrastructure solutions in developing countries" Hulsman et al. 2011).

Flood protection in coastal and river areas	
Determined by:	wave loads, currents, river discharges, precipitation and erosion
How ecosystem services aid:	wave attenuation, current velocity reduction, sediment retention, water retention.
Example GA Approach:	willow forests retain sediment thereby preventing erosion, and reduce wave action thereby increasing flood protection.
Fresh water quality and quantity	
Determined by:	river discharges, precipitation, erosion of soils, salinity, purification capacity.
How ecosystem services aid:	water retention and storage, soil and sediment retention, filtration and oxygenation of water
Example GA Approach:	reed wetlands have a strong water retaining and filtration capacity, thereby improving water quality, and influencing water quantity downstream.

Quality of living	
Determined by:	suitability of an area for living, tourism and recreation; ecosystem health; water and air quality; biodiversity
How ecosystem services aid:	improving water and air quality, regulating temperature, improving water run-off, creating possibilities for recreation and tourism, increasing water availability
Example GA Approach:	Developing parks in urban areas to retain water, improve air quality, reduce heat stress and improve spatial quality - multi-functional use of space; strengthening nature reserves to improve tourism and recreation function of an area;

6.3.2 Green Adaptation: from man-made to natural

In any type of system (natural, urban), there are opportunities to make use of natural functions and ecosystem services. They can result either from designing an ecosystem (focusing on ecosystem service creation, for example water purification by helophytes), recognizing 'forgotten' services from existing ecosystem(-parts) (ecosystem service awareness, for example air cooling of vegetated gardens), or recognizing 'forgotten' ecosystem services within the creation of an ecosystem (ecosystem service awareness, for example biodiversity increase with green roofs). However, the extent to which we can actively manage ecosystems for sustainable use of their services depends on the occurring situation (environmental, economical, political and social) and the boundary conditions resulting from this. The general assumption is that the more a Green Adaptation measure makes use of the ecosystem and its self-designing and self-sustaining capacity, the more effective the measure will be. In cases where a natural ecosystem is still present only small efforts may suffice for successful management and maintenance of the natural system. However, in rural or urban environments where space is limiting it will be considerably harder to adopt a Green Adaptation solution without disturbing the primary function of the area. Therefore, measures have been developed to restore or (re-) construct ecosystems (see Figure 6.2 below).

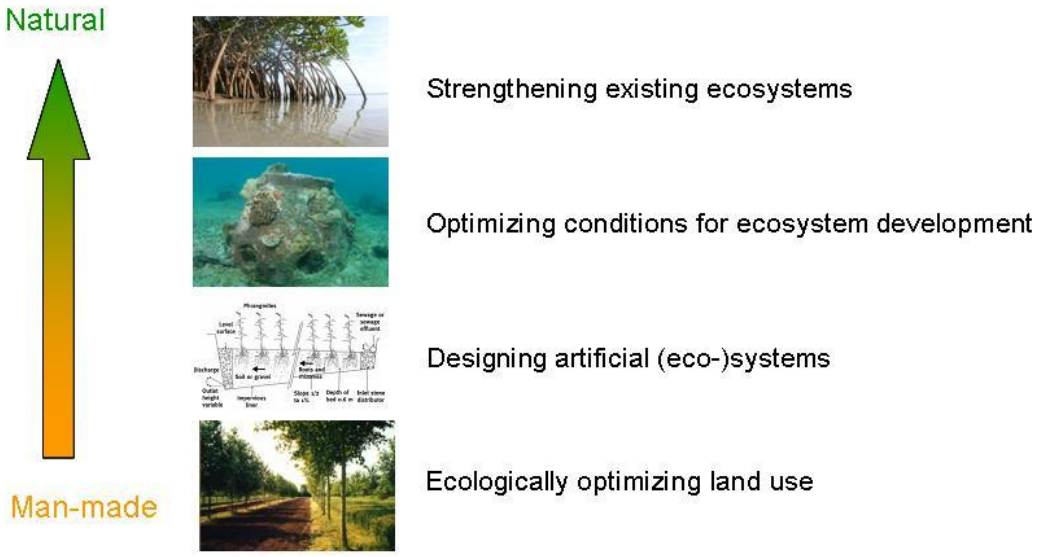


Figure 6.2 An overview of the different categories of Green Adaptation methods (from Hulsman et al. 2011).

6.3.3 Development of Green Adaptation measures

The Worldbank report 'Convenient solutions to an inconvenient truth – ecosystem-based approaches to climate change' provides a first, though still limited overview of various coastal and riverine climate change adaptation measures that make use of ecosystem functions, or aim at restoring ecosystem functions. However, for most coastal ecosystems in the report, the function of carbon sinking and storing is explained, while functions like coastal defence, protection against extreme weather events, trapping sediment and providing nutrients and nurseries for coastal fisheries are only referred to. It points out that these other functions or ecosystem services are being uncovered since recently (Hulsman et al. 2011).

Research and development programmes worldwide have aimed to address specifically these other functions and services, and develop measures to incorporate them in infrastructure solutions. The Dutch Building with Nature programme is one of the front runners in this field. The 'Building With Nature' (BwN) innovation program, coordinated by Project Bureau Ecoshape, has developed a variety of highly promising Green Adaptation approaches.

A unique concept of Building with Nature is the Sand Engine. A huge nourishment of 20 million m3 of sand will be deposited in front of the Dutch Delfland coast, after which wind, waves and sea currents will naturally disperse the sand. This will contribute to the coastal safety in the long term and additionally

create areas for nature and recreation. In this approach, maintenance costs are drastically reduced compared to traditional coastal defence structures, as natural coastal processes are being used.

Concepts like the Sand Engine are, for obvious reasons, not suitable for an urban environment. Though, within the Building with Nature programme, various approaches have been developed that could be implemented in urban areas. Key examples of this are: 'Diverse Dike' (ecological optimization of hard dike structures), 'Noordwaard' (wave attenuation through a vegetation in front of the dike), Wetland Restoration (erosion reduction through sediment fixation by wetlands), and 'Hangende Structuren' (structures to facilitate mussel growth to improve water quality in harbours) (Rijkswaterstaat 2009, 2012 in press).

6.3.4 Urban Green Adaptation

Most Green Adaptation measures have been developed for rural or natural areas; and these measures are difficult to implement in an urban environment (with lack of space, lack of dynamics). However, various pilots, case studies and small-scale applications of Green Adaptation have already been successfully developed in urban areas. Knowledge and experience on worldwide application of Green Adaptation approaches is increasingly being developed into manuals and guidelines, to enhance broader application.

Most of such urban measures are aimed at increasing water retention and water infiltration in urban areas. The American Society of Landscape Architects developed a large database of "green infrastructure" techniques that collect and process rainwater naturally before it flows into receiving waterways as polluted runoff (http://www.asla.org/ContentDetail.aspx?id=31301). All of their published projects with green adaptation measures recognize the enhanced quality of living for users and stakeholders. Some examples are: green roofs (vegetation on roofs to enhance water retention and facilitate a more gradual runoff), roadside plantings (vegetation to enhance runoff and infiltration), rain gardens (enhancing water storage and infiltration), and bioswales (wadi systems; vegetated ditches aimed at filtrating surface water from silt and other pollutants).

The city of Rotterdam has been a front-runner in the Netherlands in implementing adaptation measures that are generally focused on enhancing nature values and quality of living. Measures such as green roofs, bioswales and helophyte filters have already been implemented throughout the city. In Rotterdam, the adaptation focus is now also shifting to flood management and heat stress-reduction: in predominantly paved and concrete neighbourhoods, the

city aims at implementing more trees and greenery (Climate Proof Cities, KvK 2010-2012).

To identify the most promising Green Adaptation measures and to assess where and how they can be best implemented in the city of Rotterdam, it is necessary to identify the specific climate adaptation needs in the city. The main networks in a city (grey, red, blue and green) each have their own specific challenges and needs.

The following sections will identify the key needs of the various networks (paragraph 6.4) and how various ecosystem services (through Green Adaptation measures) can address these needs (paragraph 6.5).

6.4 Identifying city networks with need for ecosystem services

A city is made up of four major networks: blue network (water, canals, rivers, ponds), green network (nature/vegetation, parks, grassland), grey network (roads, lanes, squares, parking lots) and the red network (buildings, including accompanying gardens) (Pötz & Bleuzé 2012).

The networks face different challenges and therefore have different climate adaptation needs, Different networks can also potentially provide different ecosystem services (green and blue networks more than grey and red networks). The crossings of networks can be regarded as hotspots of urban needs and potential ecosystem services. The local situation and the types of crossing networks decide the final form of the measure.

Figure 6.3 Examples of network crossings: green, blue, red and grey network.

The green network we describe as nature or gardens, mostly vegetated areas. They can either cross with a. the blue network (open water), b. the red network (building area) or c. the grey network (hard infrastructure).

The blue network is described as open water, like canals, ponds, ditches, lakes, etc. The network can cross with a. the green network (nature/gardens), d. the red network (building area) or e. the grey network (hard infrastructure).

The red network consists of houses, industrial building, office buildings, etc. and can cross with b. the green network, d. the blue network and f. the grey network.

The grey network consists of hard infrastructure, like roads, side-walks, railways, hard shores, squares, etc. It can cross c. the green network, e. the blue network, and f. the red network.

In an urban setting with lack of space the measures will become more successful when linked as a chain through different scales in the city. For example: buildings with green roofs connecting to bioswales on a street level, to green water retention spots in the neighbourhood, to helophyte filters near or in open water areas. The potential of these chains should be emphasized in a follow-up study. Chaining of measures leads to the up scaling of the water retention capacity as well as the water purification capacity. These ‘green chains’ can also function as green routes or networks for walking, cycling or urban nature.

Within the scope of climate adaptation linking of the networks will benefit several aims in the city as arranged in the figure below.

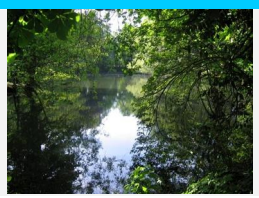
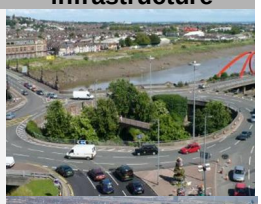
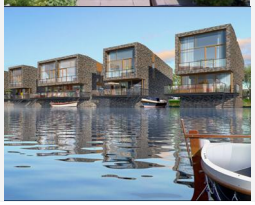
	Green: nature/garden	Blue: open water	Red: building area	Grey: hard infrastructure
Green: nature/garden				
Blue: water	**Water storage** **Reduction of erosion** **Wave attenuation** **Water quality improvement** **Natural values** **Recreation**			
Red: building area	**Water storage** **Water drainage** **Water quality improvement** **Liveability** **Reduction of heat stress** **Urban agriculture**	**Flood protection** **Soil stability** **Wave attenuation** **Water quality improvement** **Reduction of maintainance**		
Grey: hard infrastructure	**Water storage** **Water drainage** **Water/soil quality improvement** **Liveability** **Reduction of heat stress** **Air quality improvement**	**Flood protection** **Reduction of shore erosion** **Wave attenuation** **Water storage/drainage** **Reduction of maintainance** **Soil stability** **Air quality improvement**	**Flood protection** **Connectivity** **Air quality improvement** **Liveability** **Reduction of maintainance**	

Figure 6.4: the blue, green, red and grey urban networks with their combined needs and services.

The green network may provide heat stress reduction (via evapotranspiration), wave attenuation (semi-aquatic or aquatic vegetation), water storage, etc. On the other hand, the green network needs fresh water in the summer to survive urban heat and connectivity for natural resilience. While the blue network can provide water quantity regulation and heat stress reduction (via evaporation). In the figure below we have made an overview on the needs a certain urban network might have and the overlap of that between the networks. Especially these overlaps are interesting, because they can be provided by a single green adaptation measure serving two (or more) networks at the same time and will result in different forms of a specific measure when applied. Different forms of specific Green Adaptation measures are able to provide multiple services to address those needs (heat stress reduction, flood safety, recreation, nature, environmental quality, etc.)

Water storage, water drainage, heat stress reduction and improvement of the general living quality can be seen as the most important needs in the city of

Rotterdam. The next section will then investigate which Green Adaptation measures are best suited to address those needs, in an integrated manner.

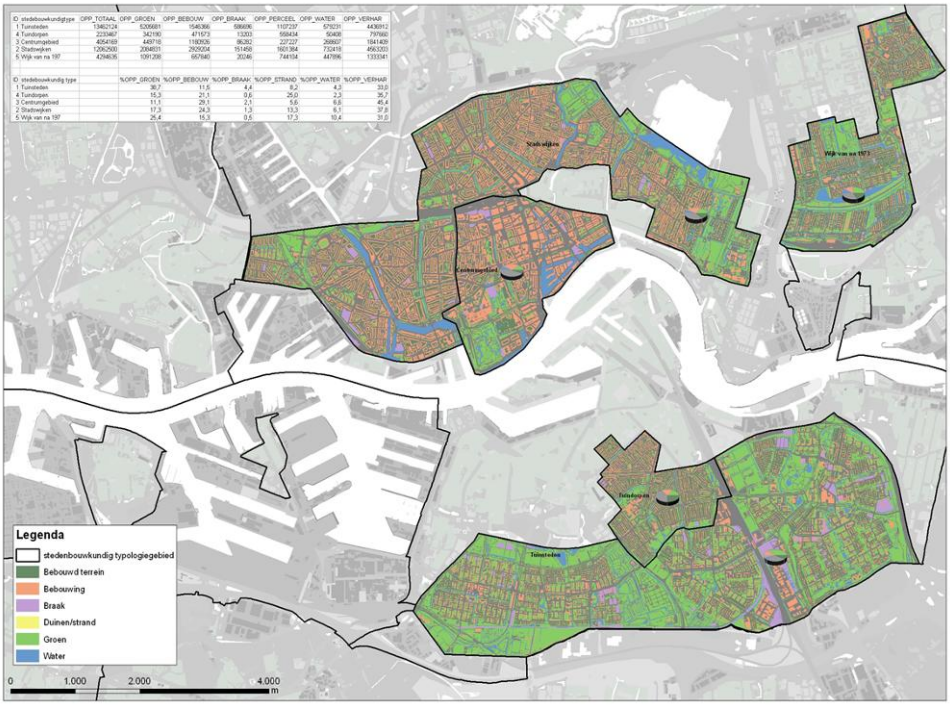


Figure 6.5 City quarters in North Rotterdam and South Rotterdam with their red, green, blue and grey networks.

6.5 Which green adaptation measures are suited for Rotterdam?

As said, numerous climate adaptation measures have been implemented in Rotterdam that have, in one way of another, made use of ecosystem services. The point is that many green measures supply ecosystem services that are not yet recognized as such. Each square meter of vegetation is increasing the capacity to reduce heat stress, is fixating CO_2, potentially produces biomass for energy/fibers, and is increasing local biodiversity. These square meters of vegetation become more valuable with the awareness of the services they supply. Chapter 5 has indicated that the City of Rotterdam is aiming to gain an overview of all possible climate adaptation measures, in order to develop the most effective and fully integrated plan of attack in the coming years. The on-going economic crisis affects potential budget for climate adaptation plans, forcing the City of Rotterdam to make smart choices and aim for sets of measures that are cost-effective, multi-functional and that can be incorporated with on-going urban developments, infrastructure and housing projects. The network analysis addressed above can be useful to optimise the effectiveness of small adaptation measures on specific locations in certain areas.

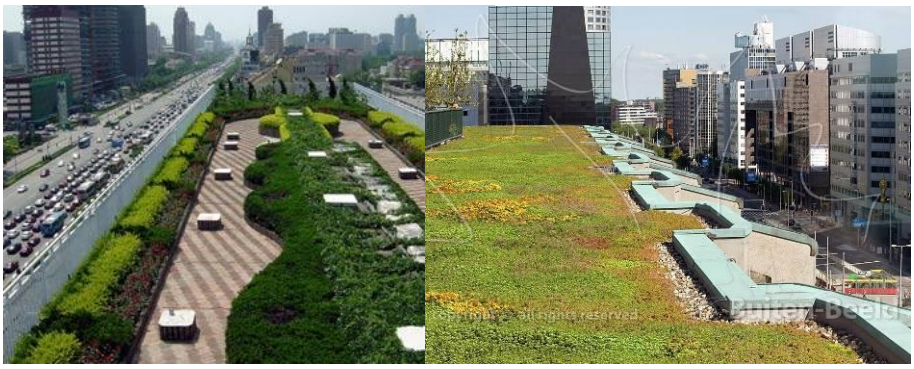
We have selected the six most suitable types of green adaptation measures for application in Rotterdam, based on the criteria that they:

- address Rotterdam's climate adaptation needs by generating multiple ecosystem services, contributing to an attractive an economically strong city,
- can be practically and cost-effectively implemented on an urban scale,
- are not hampered by lack of space and reduced dynamics of natural ecosystems, and
- can be incorporated in or linked to on-going development and maintenance projects in the City of Rotterdam.

Bioswales: Vegetated green strips in paved (grey) areas with a curly water stream. They function as infiltration areas, filter water form garbage and sediments, help reduce heat stress and have a water storage capacity. They are highly multi-functional because they can improve 'green feeling' in the city and provide new habitat for insects and birds, and ecological connectivity..
Where & effectiveness: all over the US, throughout Europe, but also in Asia (Singapore), small scale bioswales help regulate river discharge and reduce sewage discharge. Often they are part of a chain of measures to treat waste water, runoff water of surplus of rain water..

Green/blue roofs: Vegetated flat roofs are multi-functional because they can improve water retention in urban areas, reduce rainwater discharge to the sewage system, improve water and air quality, regulate temperature and increase overall quality of living. When these roofs are connected whole parks can evolve, smal scale production of vegetatbles, fruits and honey is proven to be effective.

Where & effectiveness: In Rotterdam, small to large-scale vegetation on flat roofs throughout the urban area increases overall water retention capacity and air quality. They can be combined with measures for water purification by soils/organisms and may provide ecological connectivity for birds and insects.

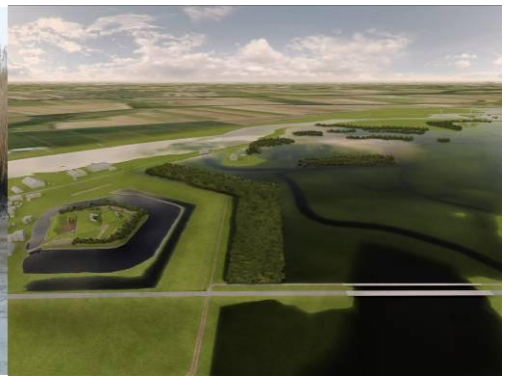


Floating structures: Floating structures on or in surface water are multi-functional because they can contribute to safety against flooding by attenuating waves and reducing erosion. Also, they can strengthen water quality by attracting filtrating organisms, and improve food availability by serving as nursery habitats, strengthening biodiversity and productivity.

Where & effectiveness: Floating reed islands in canals serve as wave attenuation buffers and reduce bank erosion (Randmeren Ijsselmeer, The Netherlands), floating ropes with mussels provide wave attenuation and water purification services in the Rotterdam harbour and is proven to be effective. They have not yet been applied in urban waterways.

Creation of riparian habitat: Riverbanks or dikes lined with (native) vegetation are multi-functional because they can contribute to flood protection in coastal and river areas through wave attenuation, reduce current velocity, increase sediment retention, reduce heat stress and increase water storage. They are a crucial part of the river functioning and next to that supply high ecological value.

Where & effectiveness: Coastal and estuarine wetlands are being restored all over the world to restore or enhance their flood protection function. In Rotterdam there is an initiative to restore the old, vacant harbours into estuarine habitat.



Water purification by soils or organisms: (water purifying) soil and associated organisms are multi-functional because it can support water storage, water purification in all kinds of settings and increase bio-availability (through vegetation cover). Water purification on the spot will increase water quality of the river but will release the high peak pressure on the sewage system.

Where & effectiveness: Bioretention areas and helophyte filters are being applied all over the world, especially in the US. The water purification potential depends mostly on the nutrient removal capacity of associated organisms. Often it is applied in combination with bioswales or green retention areas. In combination with floating structures (floating marsh) it can provide water purification of isolated water bodies.

Green water retention: Infiltration areas with specific vegetation are multi-functional because they not only enhance water retention in some areas, but increase water infiltration, increase biodiversity, reduce heat stress and produce biomass. They can increase the urban 'green feeling'.

Where and effectiveness: It is often applied in the US, but more and more in Europe as well. It consists of rain gardens, water storage in parks, water storage in vegetated roundabouts. Often, exisiting green areas are converted into green retention areas.

The table below displays an overview of the potential services that these six measures can deliver. The dark green colour refers to the expected magnitude of the ecosystem services for a specific measure, and the light green colour refers to a relative lesser magnitude of the service to be expected. The scales are Region, City, Quarter, Street, and Building, indicated with the first letter. It is to be expected that the effect of the measure can be expected mostly on the scales that have a dark orange colour. Creating riparian habitat potentially delivers 7 strong services and 8 services to a lesser extend. Water purification by soils/organisms, bioswales and green/blue roofs are the measures that are mostly effective on a smaller urban scale (streets or buildings).

Potential services of Building with Nature in urban deltas	**Creating riparian habitat**	**Water purification by soils / organisms**	**Bioswales / Wadis**	**Green/blue roofs**	**Floating structures**	**Green water retention**
Scale	R C Q S B	Q S B	Q S B	Q S B	C Q S	R C Q S B
Potential service						
Enlarge water storage capacity						
Prevent erosion/wave reduction						
Prevent drought						
Increase water quality (health & experience)						
Increase water quality (KRW)						
Re-use of water						
Reduction of water pollution						
Reduction of watershore maintainance						
Create & improve habitat quality						
Increase connectivity						
Recreation						
Increase city/quarter liveability						
Climate control (heat)						
Reduction of soil & soilwater pollution						
Increase air quality & availability						
Production (timber, food & energy)						

Table 6.1. Potential services delivered by the main types of urban Green Adaptation measures. Coding RCQSB aims at the scale at which a measure is applicable: Region, City, Quarter, Street, Building.

The implementation of these measures is highly dependent on the cost-benefit balance. Benefits must be larger than the costs, however, it is difficult to monetarise all benefits (think of recreation, biodiversity, ecological connectivity, etc.). In The Netherlands we work with a system of prefixes of cost-benefits for all kinds of measures. Green Adaptation measures have not been included yet.

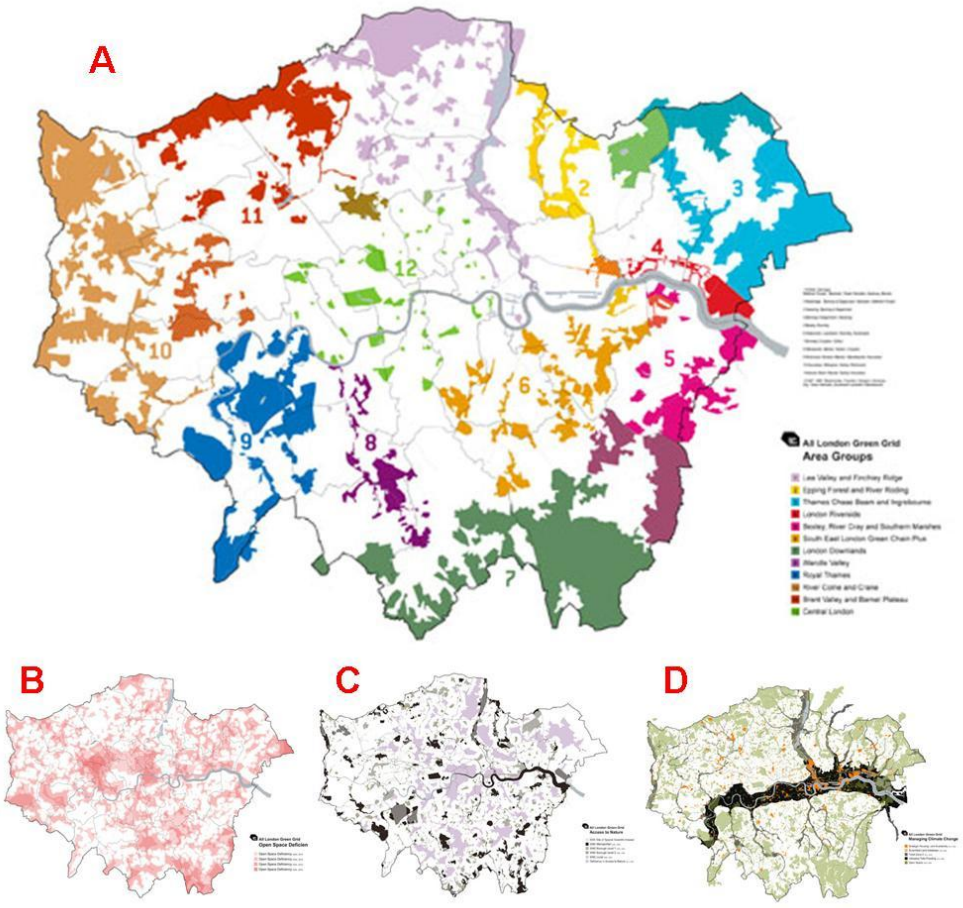
6.6 An ecosystem approach to implementing Green Adaptation measures

In the last sections, we've identified the large variety of needs in different city networks. Six main types of Green Adaptation measures have been identified that can significantly address such needs, that make multi-functional use of space, provide also additional benefits, and can be applied on different scales in an urban setting. The idea is not to identify THE best Green Adaptation measure, but to assess which set of measures could be implemented, and how, to reach the most effective climate adaptation in certain urban areas. The above sections indicated that different measures could be more effective in different city networks, and on different scales. To examine the potential of Green Adaptation measures in Rotterdam, it would be necessary to assess which measures should be implemented, and where they should best be implemented. The above sections also indicated that the effectiveness of Green Adaptation measures (the extent to which they can provide ecosystem services) depends largely on the occurring water system, whether the water dynamics and ecosystems are intact and healthy. In order to give an indication of where implementation of (a set of) measures could be most (cost)effective, it is therefore necessary to assess the water (eco)system of an area. Such an approach to examine the potential implementation of Green Adaptation measures could be called an ecosystem approach.

A programme that applies a similar approach is the All London Green Grid programme, developed in London UK. The ALGG aims to design urban plans by making use of networks to enhance the multifunctional use of green measures while regarding the city as one (eco)system. We have added the case of the ALGG as an example how to use the urban networks for the Green Adaptation approach. On the next page there is a textbox on the ALGG.

The ALL LONDON GREEN GRID

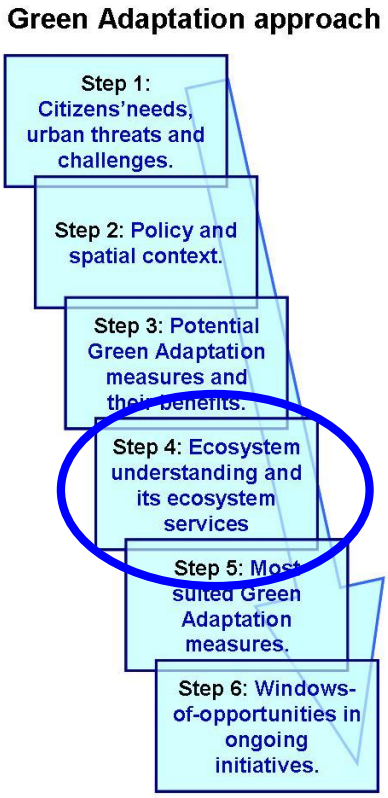
The All London Green Grid (ALGG) is basically a simple idea of connecting needs and functions throughout the city by overlaying different maps on the same scale. The English expect it will promote a shift from grey to green infrastructure combining environmental, social and economic services. It might also be seen as a tool for bringing together experts of various disciplines with various technical languages.



The All London Green Grid (Greater London Authority, 2011) Some maps are shown, A. Overview of London map with city areas, B. Need for open space, C. Space for nature, and D. Buffer areas for flood control.

The ALGG can be used to find hotspots for the implementation of measures that reinforce a sense of place, improve health and well-being, boost environmental resilience and make the English capital a more attractive and prosperous city. It provides a network of well designed and multi functional measures (green adaptation) and open spaces that secure the city to cope with the environmental challenges of the 21st century. Their objective is to plan strategically and manage networks of natural and designed landscapes and open spaces to conserve ecosystem functions and provide a range of benefits for people.

7 An Ecosystem view on the City of Rotterdam



In the next two paragraphs (7.1 and 7.2) we will explore how the Rotterdam ecosystem, specifically the Rotte river catchment, is working and what the current state is. It will inform us on the current and potential ecosystem services. The current state of the Rotte, its needs and requirements, and the ecosystem services it could (potentially) deliver are addressed. This can be regarded as Step 4 of the Green Adaptation approach.

7.1 Why look at the ecosystem?

As Green Adaptation measures make use of services that an existing ecosystem (potentially) could deliver, the effectiveness of implementation of such measures therefore depends strongly on the (type, state and health of the) existing ecosystem in an area. The functioning of an area's local ecosystem and the hydrological system it is based on, is of vital importance to be able to adapt to climate change effects in that area. Generally speaking, we can say that the climate buffer capacity of a hydrological system can be improved with restoration of ecosystem health and hydrological dynamics.

This chapter will explore how the Rotterdam ecosystem could be used and strengthened in order to effectively deliver adaptation services, using the Rotte river catchment system as an example.

Knowing which services the Rotte ecosystem could deliver will lead to a more cost-effective implementation of climate adaptation measures, while also strengthening the natural value and general quality of living in the Rotte area. The chapter addresses the current state of the Rotte, its needs and requirements (how can we restore ecosystem health and hydrological dynamics?), and the ecosystem services it could (potentially) deliver (how can

we strengthen the water retention function?). As the focus is not on specific areas, but on entire river catchments, Delta cities like Rotterdam could optimize their set of climate adaptation measures to serve multiple purposes in an urban area, across borders of city quarters, municipalities and regions.
The Rotte example can be used for other parts in Rotterdam (Rotterdam Noord and Rotterdam South, see chapter 8).

Restoration of the Rotte system functioning
To strengthen the climate adaptation capacity of the Rotte system, restoration of its natural values is not our ultimate goal, but rather the restoration of its functioning: to store rainwater from the surroundings, to discharge the water to large rivers downstream, the possibility of the river to flood adjacent areas, and by doing that, improving water quality along the way.. In other words, the hydrological and ecological functions of the Rotte river catchment should be restored in order for the Rotte to function as a climate buffer again.

The potential extent of restoration depends strongly on the level of urban development and alteration to the water system in the catchment area. In the more natural, green areas of the Rotte catchment, where hydrological dynamics are still somewhat intact (floodplains can flood), and water buffer function is already established, it is easier and more cost-effective to enhance its climate buffer capacity by strengthening these functions. Though in these rural, more upstream areas, the climate adaptation needs are somewhat less urgent. In the highly developed urbanized areas of the Rotte catchment downstream, the need to address heat stress, low storage capacity and low retention time is large, but the restoration potential of the hydrological and ecological system is limited. Here lies the challenge for green adaptation.

In the rural parts of the Rotte river catchment it is easier to apply large scale measures, while in the urban parts the emphasis would be on the medium and small scale measures. Therefore we must find opportunities for small scale green adaptation measures that can be applied across the city, quarters and streets that together form an optimal restoration of the catchment hydrology and ecology.

The major aim would be to restore the natural water dynamics that are characteristic for the Rotte river catchment. If we can do that with green adaptation measures that also provide ecosystem services as heat stress reduction, biodiversity increase, recreation, purification of water and air, and biomass production, then a major step forward is being made.

7.2 Applying an ecosystems approach: Rotte river catchment

7.2.1 Characteristics River and Catchment Hydrology

The Rotte is the main river within the region of Schieland and is used as a water storage and as an in- and outflow for the surrounding polders. It is also an important nature and recreational area. The source of the Rotte river lies in Moerkappelle, from which it flows in southern direction towards the city of Rotterdam, where it ends in the Haagse Veer. It is approximately 22 km in length and the water system has a surface area of around 200 ha (KASSA report).

It is a former peat river and is quite shallow, with depths varying from 80 cm up to approximately 1 meter (Website Anglermaps). Within the city of Rotterdam, the water is about 40 m wide and 2 m deep. The Rotte becomes wider around Bleiswijk; the Rottemeren area, where the width is about 80 m (Website Anglermaps). Because of soil subsidence (peat area), the areas adjacent to the Rotte river have been lowered, either by peat removal or peat oxidation. As a result the hydrological flows of the river become complex and un-natural.

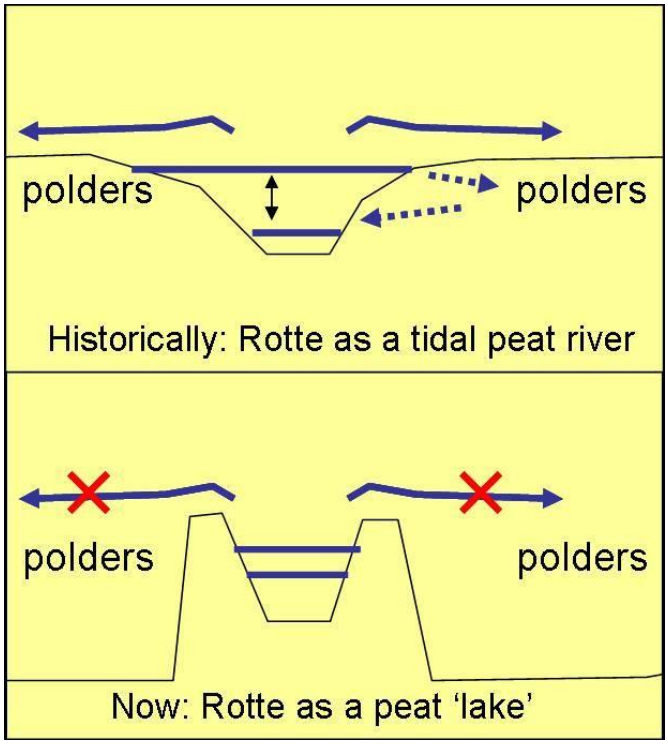


Figure 7.1 Alteration of hydrological dynamics in the Rotte river catchment.

Historically, the Rotte river catchment used to be a small tidal peat river, though it has been shut off from tidal influence in the year 1270. Additionally, the Rotte river catchment has been highly altered by the development of the city over time: natural floodplains have been paved or built on, seasonal flooding is restricted; groundwater flow directions have been altered (mainly because of soil subsidence (See figure above); water quality has deteriorated, shores have been hardened, etc.

The Rotte river catchment hydrology has been disturbed in a way that infiltration and retention capacity in the catchment has been decreased dramatically. Rain water will either be drained by the sewer system or will flow off as surface water. Both directions give problems when an extreme event occurs, with unwanted flooding in the streets as a result. The surplus of water should be delayed towards the Rotte river.

Water quality

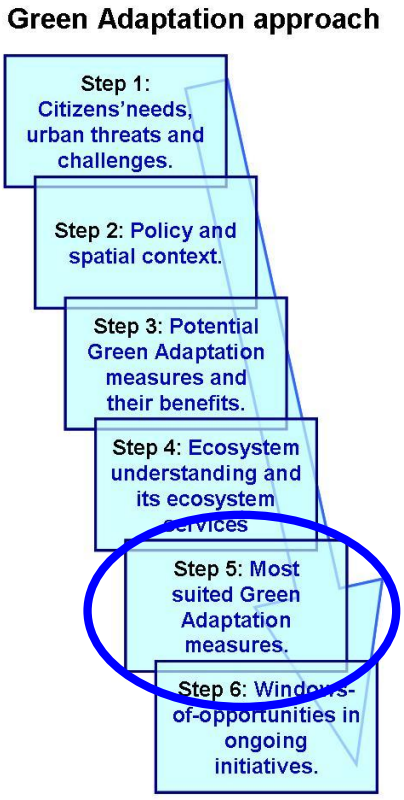
Within the European Water Framework Directive (WFD), the Rotte storage basin is characterized as M14: a shallow buffered lake, in which the Rotte is characterized as a heavily modified water body (KRW factsheet Rotte). Testing of the water quality by STOWA demonstrated that the organic load in the water is too high. According to the WFD, the Rotte and Bergse Plassen need to achieve Good Ecological Potential in 2027, which will require implementation of an elaborate set of measures.

Characteristic species

The Rotte provides habitat for a range of organisms, some of which are very rare. Along the banks of the Rotte and the Lange Vaart, the Desmoulin's whorl snail (*Vertigo moulinsiana*), a protected species under the Flora and Fauna bill, is present. Fish, such as bream, minnow and karp can also be found in the Rotte. In the Bergse Plassen more rare species like the bitterling and bullhead pike are present (Website Anglermaps). Other interesting species for anglers include pike (mainly in the Bergse Voorplas), roach, rudd, tench and perch.

The recreational area Rottemeren harbours around 75 species of nesting birds, including species from the warbler family (Website Rottemeren). The areas in which the forest is more mature, habitat is created for forest species such as the Eurasian hobby, the European green woodpecker and the Eurasian golden oriole (GRO202011 report). In the Zevenhuizerplas area birds like the Western marsh harrier, water rail, bearded reedling and bluethroat nest.

7.3 Addressing the Rotte adaptation needs by strengthening its own ecosystem



In this paragraph we give an example of how to restore the ecosystem functioning of the Rotte river cachment in order to realise climate adaptation via combined Green Adaptation measures. Which ecosystem services could be used and strengthened in order to effectively deliver adaptation services. This can be regarded as Step 5 of the Green Adaptation approach.

The Rotte catchment needs

What are the needs for ecosystem services in the Rotte river catchment (from Bleiswijk to Haagse Veer)?

Let us try to couple the climate adaptation needs with the ecological functioning, or rather the requirements to restore the Rotte river catchment as an ecosystem. The Rotte river catchment has the following needs in which services provided by the Rotte ecosystem can play a key role:

- Water storage at surges;
- Freshwater availability in times of drought;
- Improved water quality and ecology;
- Attractive living environment, recreation;
- Reduce heat stress in the urban areas.

Strengthening the Rotte ecosystem by implementing Green Adaptation

By looking at the Rotte river catchment, not as independent fractions, but as an entire system that provides ecosystem services, we can assess what kind of Green Adaptation measures (and in which combinations, on which locations,

and on which scale) can be effective to strengthen these ecosystem services, and address multiple needs.

With the smart implementation (optimal scale, location) of Green Adaptation measures that:

- Create shallow water (by restoring already occurring shallow riparian wetlands);
- Provide sheltered areas (providing species with shelter of floating structures);
- Capture sediment (slow down rainwater runoff through local vegetation in bioswales);
- Create water storage (create floodplains, allow areas to flood);
- Improve water retention (apply green roofs on buildings);
- Improve infiltration (redesign the green (park) areas to form water gardens.

Not only the storage capacity and retention capacity will increase of the entire area, but the entire Rotte river catchment becomes greener, gains an improved water quality and biodiversity (as measures also have water purification-, nursery- and shelter functions) and will be more sustainable for climate change effects.

Measures like 'Floating Structures' in the water itself and Riparian Wetland Restoration along the water bodies are valuable measures to enhance biodiversity and to attract more rare species; their effectiveness depending on the occurring ecosystem. Floating structures provide new habitat in water bodies that may lack shelter habitat or feeding habitat. Local biomass increases when floating ropes with water filtrating mussels are attached, which attracts feeding species. Application of floating structures depends on the type of surface water (space required), the type of use of the area (traffic?) and citizens preferences (not in my back yard?). The effectiveness in terms of wave attenuation and water purification depends on the naturally occurring organisms in that area.
The restoration of riparian wetlands (wetlands adjacent to rivers and subject to sporadic or seasonal flooding) attracts many different species (water birds, insects, fish and mammals) because of the provision of feeding, spawning, and shelter habitats. The extent to which riparian wetlands can be implemented, depends on the occurring ecosystem and the level of development: application of wetlands in hard, concrete environments will be a lot less effective than strengthening, enlarging wetlands in areas where softer, green shores (and the associated vegetation) are already present.

Below a figure with a schematic overview of the Rotte river catchment hydrology with the implementation of our selected green adaptation measures.

The riparian wetland creation will ensure the increase of water storage capacity, as well as the green retention areas (they are noted in the figure with 1). These measures have direct effect on flood protection. While green roofs, bioswales and areas for water purification by soils/organisms have an indirect effect on flood protection. They delay the surplus of rain water that would normally cause the river to flood, instead of this, water is temporary stored in subsurface either released to the groundwater or evaporated (they are noted in the figure with 2). Floating structures have primary a water purification function, but can attenuate waves during high water when shipping causes waves (noted in the figure with 3). All together they restore the functioning of the ecosystem for its hydrological cycling.

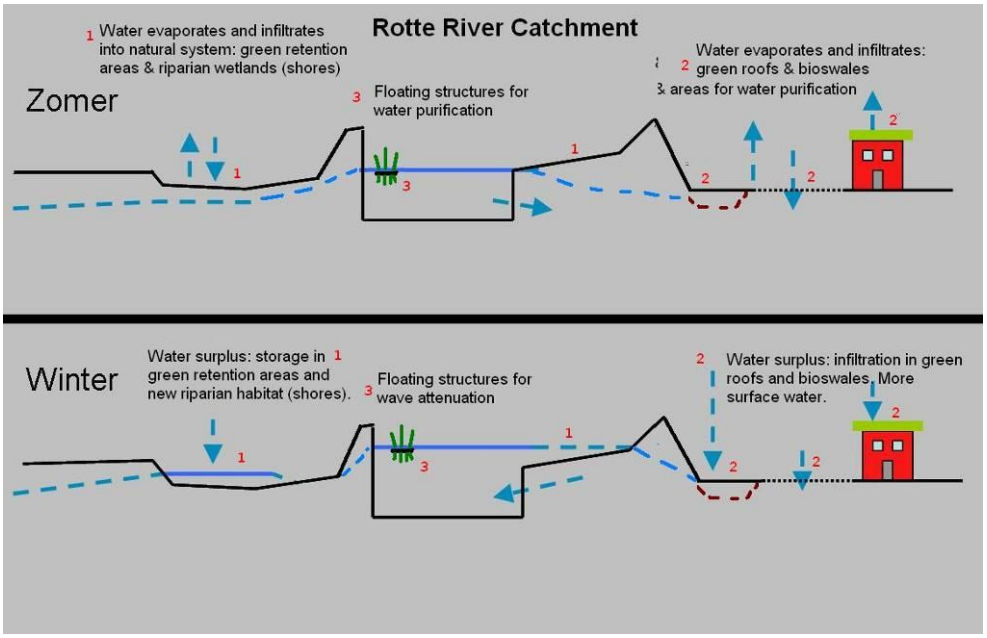


Figure 7.2 Schematic view of the Rotte river catchment with the implementation of green adaptation measures to restore its functioning.

<u>Which Green Adaptation measures should be implemented where for the best impact?</u>

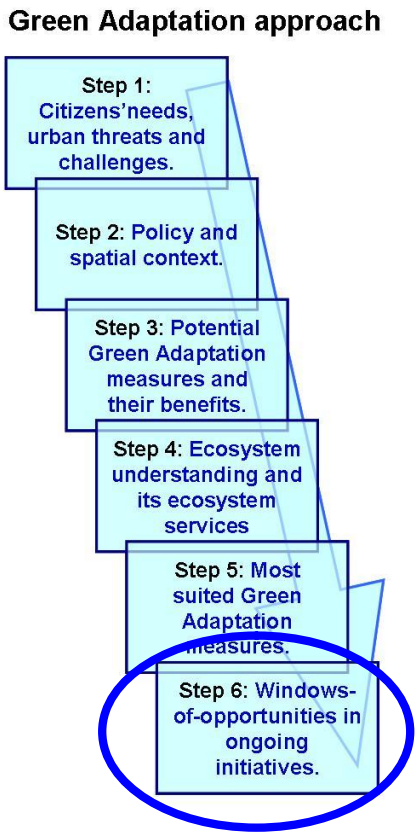
To gain understanding of which, where, what scale and to which extent we should best implement Green Adaptation measures so that it contributes to as many policy needs as possible, an overview is required where all ecosystem services, gained from the implemented green adaptation measures, per type of area are quantified. Some services are hard to quantify, either because data is unavailable or the services are too site-specific. Increasingly, quantified data is available for various types of adaptation measures. With information on the quantification of the ecosystem services of adaptation measures (for example, total water retention capacity of a square meter of green roof), and information on the area in which implementation is feasible (for example, total sur-

face of flat roofs that could be covered with vegetation), it is possible to play with the amount of potentially implemented measures per area, to arrive at a cost-effective set of measures (i.e., in areas where implementation potential of water gardens is large, it might be more cost-effective to implement water gardens rather than focus on green roofs). This can give some insight in which type of areas are best suited for which measures and which type of areas can contribute most to the restoration of the hydrological and ecological system of the Rotte river catchment.

For further studies, we recommend that such a conceptual model is further developed, to optimize sets of adaptation measures, in order to optimally address various policy needs in Delta cities. In the regional parts of the Rotte river catchment a large project has been set up, Eendragtspolder (www.eendragtspolder.nl). It concerns a polder where a rowing track for recreational benefit has been designed together with open water and wetland areas that provide climate adaptation benefits. It is a good example of completing the ecosystem functioning (water storage, water redundancy and sanitation) where climate adaptation, recreation and urban liveability, and nature is served. Other chances are along the golf court, below an artist's impression of a tidal side river as riparian wetland creation.

Figure 7.3 Artists impression of a tidal side river along the Rotte river.

8 Exploring Green Adaptation in Rotterdam areas



In this chapter we discuss the results of the second Knowledge for Climate – Green Adaptation workshop, where we explored and discussed the possibilities of a green adaptation approach for the city of Rotterdam. The workshop was organized with the Rotterdam and Green Adaptation experts. Two areas in Rotterdam were analyzed conform the spatial context introduced by Stadsvisie Rotterdam and continued in Waterplan2 and the new Horizon for Rotterdam (2012). See appendix 1.

As already mentioned in chapter 4 we have set up a Green adaptation approach for the exploration, and ultimately implementation, of green adaptation measures. It consists out of 6 steps. This chapter can be regarded as Step 6 of the Green Adaptation approach.

8.1 Rotterdam needs, spatial and policy program per city area

Rotterdam is a powerful delta and harbour city. It's an urbanized landscape of rivers and polders that has developed into to one of the biggest harbours in the world. With the building of Maasvlakte 2, Rotterdam will redevelop the last harbours in town into modern and innovative parts of the city. Due to the worldwide financial crisis, Rotterdam will focus predominantly on restructuring of pre- war and post-war neighbourhoods within the city, giving the public space a more green and blue (climate adaptation) character and making better connections with the surroundings (the surrounding landscape). The investments of the city itself will be concentrated on: the inner city centre, Stadshavens ('City harbours'), the older neighbourhoods on South (Nationaal Programma kwaliteitssprong Zuid) and North, accessibility of the harbour and other economical hotspots, and Rotterdam as the delta city.

Rotterdam is a city with huge profiles for infrastructure and public space. Traffic can easily access the city and park there. Pavements and squares are broad but hard structured. Rotterdam wants to transform these hard structured areas into more green or blue areas and routes. This is also inspired by the fact that Rotterdam has the most square meters greenery per citizen, while this is little noticed. Rotterdam has a positive image of a modern, hard working city, with special architecture, where summer and annual events occur regularly. The city has a growing creative young urban group of citizens. Rotterdam also has a negative image of a growing group of unemployed and poor citizens, a high number of nationalities, an unhealthy city full of traffic and industrial areas around, an 'urban city' (and not a landscape city).

The main challenge for Rotterdam is therefore to develop attractive living areas for young and creative citizens and the different nationalities and social groups and to develop a basis public space structure that's more healthy and attractive (green) for citizens and visitors.

In chapter 5 we introduced 3 main areas in the city of Rotterdam (North, South and the Rivercity). They form the spatial context of the city named in the Stadsvisie and the Waterplan and are therefore also chosen as the context for green adaptation measures. Challenges and opportunities for the implementation of green adaptation measures throughout these areas can be structured as opportunities in new projects (appendix 3), opportunities per network (appendix 5, 6 and 7).

The Rotterdam Adaptation Strategy is connected to the Green Adaptation measures with their beneficial services in the following tables.

Table 8.1 Rotterdam Adaptation Strategy, Green Adaptation measures and their beneficial services for urban rivers and embankments.

	Urban rivers and embankments
Urban climate /Heath stress	*'Green' also cools at night, water not* • Green Islands • Preserving and restoring estuarine areas • Green fore banks • Green dikes • Green Parks • Tidal Nature / banks (quay remove / reduce) • Climate / season buffers *Combine with:* • Floating living and work • Living / working in / with nature • Leisure and recreational routes • Fish and salt / brackish water animals catch and harvest • Reed cultivation • Education • Horeca
Urban Watersystem	*Runoff capacity and improve space for collecting peak discharge and sea level rise* • Large banks and floodplains • Climate / season buffers *Combine with:* • Connections between river and urban water system: connections for migratory fish between river / urban river / polders • Connections for recreation on the water and along the water • Water sports: rowing / aquatic • Cane Cultivation • Fish farming and fishing
Soil maintenance	*Utilizing open ground for water* • Overflow rivers and embankments green green calamity polders and from there connect to disaster area / polder make *Combine with:* • Biodiversity of the Delta region and city • Use riparian vegetation / crop • Trees Diversity: wetland vegetation management
Flood defense	• Space for the water • Tidal retain and use in estuarine environments and tidal parks • combined with lower places behind dikes or dams and embankments. • Emergency Salvage linked to river: outer dike climate buffers along rivers draining. *Combine with:* • Multifunctional dikes • Bathing and recreation • Floating living • Living in waiting and watchtowers • Economic activities linked to water safety: water transport, over the dike bring agent: wild nature excursions and routes, bird hides management, research in the Delta.
Accessibility	• cool routes and parking: trees, green verges, green pergolas / facades • keep green shoreline development outside traffic route • prevent underwater sliding of green banks along major routes
Salinisation	• visualization of fresh-salt differences / transition with natural vegetation *Combine with:* • stimulate economic activity in salty locations • develop salty residential environments

Table 8.2 Rotterdam Adaptation Strategy, Green Adaptation measures and their beneficial services for urban waterways.

	Urban waterways
Urban climate /Heath stress	*'Green' also cools at night, water is not* • Green banks • Green dikes • Green / Wetlands accessible and hold (water buffer zones, riparian zones, dykes: cool areas) *Combine with:* • Living / working in / near shore / nature • Fishing and farming • Leisure and recreational routes • Catering and retail associated with water
Urban Watersystem	*Runoff capacity and improve space for collecting peak discharge* • Climate / season buffers • Rainwater (from buildings) infiltration in banks *Combine with:* • Connections for migratory fish between urban river / polders • Connections for recreation on the water and along the water • Water sports: rowing / aquatic
Soil maintenance	*Utilizing open ground for water* • Overflow rivers and embankments green green calamity polders and from there connect to disaster area / polder make *Combine with:* • Biodiversity of the Delta region and city • Use riparian vegetation / crop • Trees Diversity: wetland vegetation management
Flood defense	• Space for the water • Emergency storage of water linked to river: outer dike water buffers along urban rivers: puddles, ponds and canals *Combine with:* • Recreational dikes • Bathing and recreation • Hanging living (at quays, dikes to, to walls) • Living on water
Accessibility	• cool routes and parking, trees, green verges, green pergolas / facades • no main traffic routes on green dikes

Table 8.3 Rotterdam Adaptation Strategy, Green Adaptation measures and their beneficial services for urban polders.

	Urban polders
Urban climate /Heath stress	*Green, water and open soil provides cool air and space for wind transit* • Contiguous or chain of green areas at different scales (green wedges) • Open water between the buildings (windbreaks) • Parks and recreation within walking distance • Neighbourhood Green spread through the neighbourhood and especially in locations with many elderly and children • Green streets / routes *Combine with:* • Green living environments • Green playgrounds and climbing gardens • Sports and games • Urban Agriculture
Urban Watersystem	*Increase water storage capacity and nature, and if urban rivers are present catch off overflow* • Water retention and infiltration in the open areas (green, water, gardens, verges, embankments) • Robust open water with low level differences and natural banks: lake mountains verges significantly more water • Chain of infiltrating water storage and measures: green roofs, infiltration around buildings, water plazas, water wales in public space, neighbourhood parks, boulevards with banks, parks, rivers bosom • Parks and gardens decorating as overflow and infiltration area *Combine with:* • Water and sport & games • Water Transportation • Design, design and architecture where GA measures are integrated and designed • Floating living • Water purification • Use rainwater for irrigation of greenery and trees in dry times
Soil maintenance	*Utilize water storage, cooling and production power of open ground* • Surface soil wide open account at district and neighbourhood level: ratio soil / water / green 25% compared to buildings and pavement • Infiltrate where possible • Water level surface water uphold prevents settling • Water storage in open soil areas and banks • Water storage in buildings for use in drought • Urban agriculture and gardening • Green schoolyards with edible crops, harvest gardens, school gardens *Combine with:* • Multiple use of space to make room for open ground to maintain: stacked parking, double parking industrial (day / evening) • Stacked and floating structures • Integrated (urban) agriculture: in wet seasons other use
Flood defense	• Parks and public spaces that can serve as emergency storage *Combine with:* • Build high-level (above ground or input), underground parking floors instead • Temporary use for water recreation, sports and games • Temporary nature • Species diversity: species that can handle varying water levels.
Accessibility	• cool routes and parking, trees, green verges, hedges, green pergolas / facades • no main traffic routes on green, recreational trails and green wedges • bioswales for water infrastructure along permeable paving • water storage under slow traffic routes
Salinisation	Maintain high water level will prevent seepage
Soil subsidence	• water uphold prevents settling • robust watersystem so that in larger units water levels can go up

8.2 Plans as windows-of-opportunity for the implementation of Green Adaptation measures

8.2.1 Rotterdam North

The upcoming years the older parts of the city are restructured, as well as the city centre. Most of the long term plans are already there, but there is room for concrete measures still to be embedded in neighbourhood specific plans:

- Centre: Binnenstadsplan and Green plan
- Old West: Spatial Plan
- Old Mathenesse: Spatial vision and IWAP
- New Crooswijk: Masterplan and Urban development Plan
- Old North; Spatial vision and IWAP
- Delfshaven: Spatial vision and Green plan.

Of course the measures and the context differ in each neighbourhood but the focus is on restructuring the houses and modernizing the public space areas: to give them a higher and greener standard and make them useable for modern recreational activities. The pressure on public space will maintain and even will be bigger because of funding for expensive underground building structures is under considerable pressure. All the areas are densely built so innovative combinations of functions still have to be designed.

Figure 8.1 Green roof park Vierhavenstraat Delfshaven Rotterdam

8.2.2 Rotterdam South

Neighbourhoods Gardenly South

The neighbourhoods built in the fifties and sixties, with lots of green space, are all going to be restructured in the Gardenly South: houses and buildings will be demolished, restructured and new apartments will be built. Currently, the green areas consist of low quality vegetation: large lawns with fast growing trees. There is room for improvement of the areas with water and green. De color groups in these neighbourhoods are yellow and green which means that the greenery must be tidy, as well as useful for children and elderly.
There are a few themes which fits the South of Rotterdam:

- public health (hospital Lombardijen);
- sports (Feijenoord, Varkenoord);
- gardens and agriculture (the garden cities).

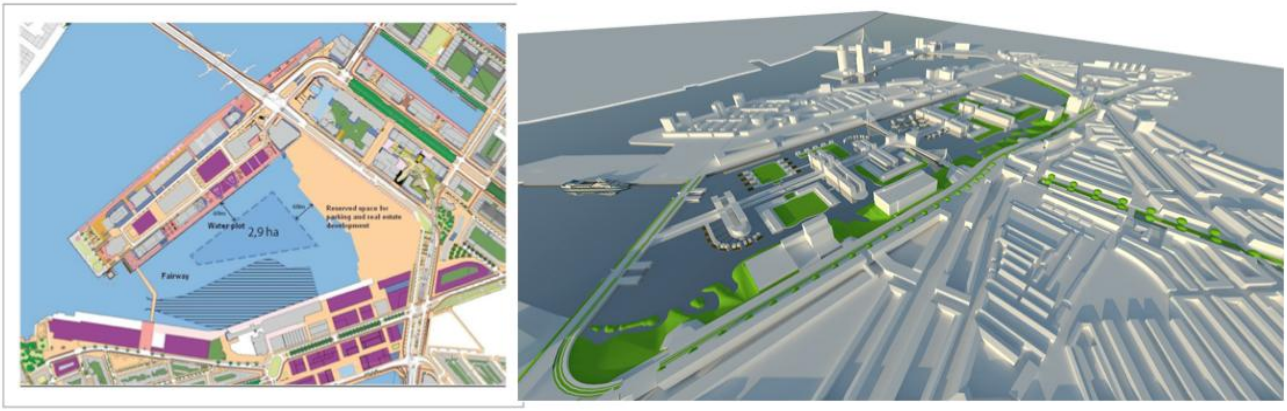
Neighbourhoods New South

The Kop van Zuid ('the Head of South'), the connection between south and north, is recently built and is accentuated by the Erasmusbrug. The pre-war neighbourhoods bordering the Kop van Zuid will be restructured in the following years. Charlois, Agniessenbuurt, Tarwewijk, Carnisse, Bloemhof and Hillesluis have already been partly restructured in the 80's, but there are many problems left which have to be solved in the next coming years. Better housing, improved public space and more green areas are necessary. The areas are densely populated. Vreewijk is an exception, a pre-war garden city. Rotterdam has started a development programme for these areas.

The heart of the South will be one of the first projects to work on. It forms the center of south with a big shopping mall and huge events (Ahoy). The city park Zuiderpark borders this area and forms a promising starting point, to connect or to extend the green areas around it.

8.2.3 Rotterdam Rivercity

The waterfront forms the habitat for the new development areas of the city like Lloydkwartier, Katendrecht and Stadshaven, and older parts like Waterstad, next to the city centre. These are all outer dike areas, but all located high above sea level with a stony, hard structured quay to protect the areas from tidal influence (tidal difference can be up to 1,5 meter). Rotterdam wants to make use of the river to gain experience with adaptive building.



Rijnhaven *Maashaven*

8.3 City of Rotterdam as a whole

Windows-of-opportunity

The financial crisis is noticed in town:

- focus is on economical development that fits in the identity of Rotterdam: harbour and delta;
- high standards for restructuring and newly built areas: more pressure on public space and care for the quality that characterizes Rotterdam;
- more public initiatives, participation from citizens and partners in making and managing the city (green public areas fi.) and gentrification.

Out of a Green Adaptation perspective, it is important that Rotterdam will concentrate on the following Green Adaptation strategies. A few instruments are very helpful.

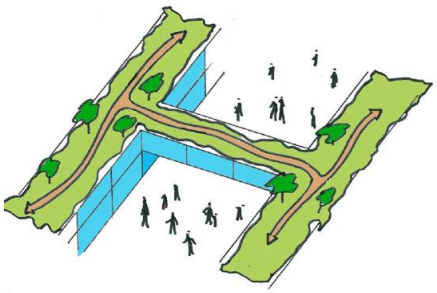
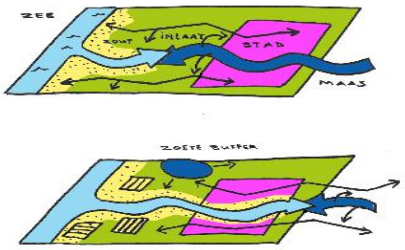
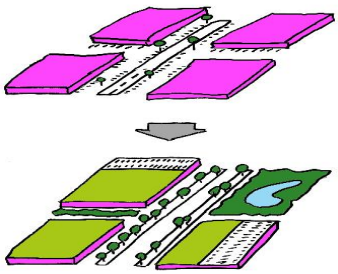
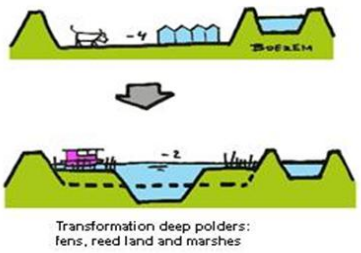
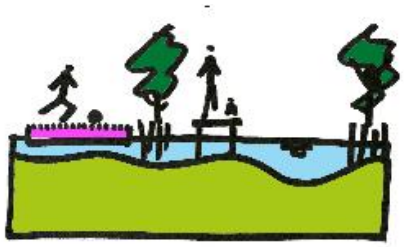
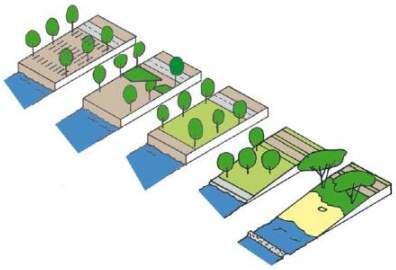
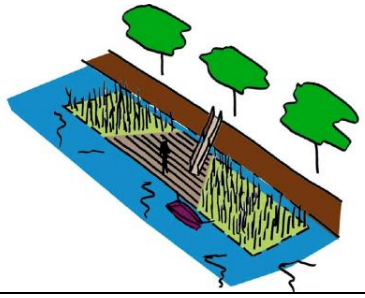
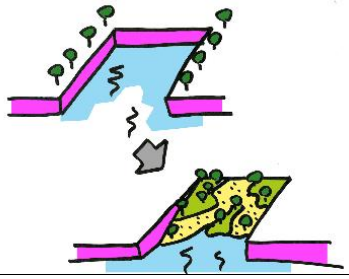
Green adaptation strategies and instruments

- Restore ecological processes in the river systems (main and urban);
- Restore polder systems and combine them with the sewer systems and the river system, make chains of measures through all the urban scales, combine with heat stress measures;
- Improve water quality of water storage places, singels and urban rivers to make them more suitable for recreation;
- Bring focus on the Delta identity of Rotterdam and stimulate Delta economics (fisheries, biofuel etc.);

- Use the infrastructural networks and interconnections for Green Adaptation measures;
- Large green areas are important for cool fresh air during the night on a city level. Green lanes are important for heat on the neighbourhood level. Green recreational areas become more important when temperatures are rising; a green network on the neighbourhood level is especially necessary for the different ages of citizens (child, sport and elder people);

In Table 8.4 (next page) some examples are shown of putting Green Adaptation measures in a chain to increase effectiveness. Also it shows the options for river system restoration in urban settings (North with urban rivers, South and North with 19th century neighborhoods, South with green and blue network conection, and restoration of the Delta rivers Nieuwe Maas and Oude Maas).

Table 8.4 Integration of Green Adaptation measures within urban circumstances, either in a chain of measures or to restore ecosystem functioning.

Chain of GA measures in polder and neighbourhoods for cooling and water storage. Supporting restoration of urban rivers	Restoring the Delta rivers
Green roof park 	Water storage fresh water (riparian wetland creation, green retention, bioswales, green roofs) 
Green business areas (green roofs, bioswales, green retention) 	Peak storage (riparian wetland creation, green retention) 
Green Neigbourhood park (green retention, water purification by soils/organisms) 	More natural shores (riparian wetland creation) 
Floating structures (whole embankment) 	Tidal water park (riparian wetland creation) 

Below is an overview of some of the new projects in Rotterdam that provide an opportunity to implement Green Adaptation measures with the accompagnied ecosystem services.

Table 8.5 Project opportunities within the city of Rotterdam where Green Adaptation measures can supply desired and additional ecosystem services.

Rotterdam project opportunities	Urban needs for climate adaptation	Desired ecosystem service(s)	Additional ecosystem service(s)	Green Adaptation measure(s) [1]
Shores of the Schie and Rotte rivers (North)	Flood protection [2], Pleasant temperature [3]	Water storage, Wave attenuation, Heat stress reduction	Urban liveability, Urban nature, Water quality	Riparian wetland creation, Floating structures, Green roofs
Older neighbourhoods in the North [4]	Flood protection, Pleasant temperature, Salinisation prevention, Soil subsidence prevention	Water storage, Water infiltration, Heat stress reduction, Water supply	Urban liveability, Urban nature, Water quality	Green retention, Bioswales, Water purification by soils/organisms, Green roofs
The large regional parks in the North and South	Flood protection, Pleasant temperature, Drought prevention, Salinisation prevention, Soil subsidence prevention	Water storage, Water infiltration, Heat stress reduction, Water supply	Urban liveability, Urban nature, Water quality	Green retention, Bioswales, Water purification by soils/organisms
Spaanse Poort (North)	Flood protection, Pleasant temperature, Salinisation prevention	Water storage, Water infiltration, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Green roofs, Riparian wetland creation, Floating structures
Nassauhaven (South)	Flood protection, Pleasant temperature,	Water storage, Wave attenuation, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Green roofs, Riparian wetland creation, Floating structures
Zuiderpark (South)	Flood protection, Pleasant temperature, Drought prevention, Salinisation prevention, Soil subsidence prevention	Water storage, Water infiltration, Heat stress reduction, Water supply	Urban liveability, Urban nature, Water quality	Green retention, Bioswales, Water purification by soils/organisms, Green roofs
Brielselaan (South)	Flood protection, Pleasant temperature	Water storage, Water infiltration, Heat stress reduction	Urban liveability, Urban nature, Water quality	Bioswales, Water purification by soils/organisms, Green retention
Noordereiland (Rivercity)	Flood protection, Pleasant temperature	Water storage, Wave attenuation, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Riparian wetland creation, Floating structures
Rijnhaven (Rivercity)	Flood protection, Pleasant temperature	Water storage, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Riparian wetland creation, Floating structures
The Esch (Rivercity)	Flood protection, Pleasant temperature	Water storage, Heat stress reduction	Urban liveability, Urban nature, Ecological connectivity, Water quality	Bioswales, Green roofs, Riparian wetland creation, Floating structures, Water purification by soils/organisms

[1] Green Adaptation measures as described in Chapter 6.

(2) Flood protection, by means of direct and indirect water management measures (storage capacity, water containment, and water redundancy).
(3) Pleasant temperature, by means of heat island prevention.
(4) Highly suitable for the connection of the Green Adaptation measures in order to have a chain of measures, combined with water plazas.

9 Conclusions and recommendations

9.1 Main Goals

The main goals of this study were:

1. *Explore applicability of the existing 'Eco-engineering'-solutions for water management and heat-stress in the field of climate adaptation in an urbanized (and industrialized) delta region. The proposed measures should enlarge the adaptive capacity of the Rotterdam water system and profit from ecosystem services like water safety, water purification, heat stress reduction and liveability. Rotterdam is a Delta city and by looking at Rotterdam this study can also be useful for other Delta cities.*

2. *The results lead to concrete input for the Rotterdam Adaptation Strategy, strengthening it and enriching it with a new approach. The selected green adaptation measures are described and prioritised for the intended implementation in the Rotterdam hotspot.*

The eco-engineering solutions are defined as Green Adaptation measures. Green adaptation is making use of natural processes to cope with climate change effects. When these measures are multifunctional (provide more than one ecosystem service) they have the best chance to be implemented and maintained in an urban context. Ecosystem services can be improved, emphasized or restored in a sustainable way by restoring the ecosystem as a whole. When using different urban networks, resembling the different needs within a city (housing, infrastructure, water and nature), clusters of needs can be detected. These hotspots are the most ideal location for a green adaptation measure. So, there are two sides when approaching the determination where to apply climate adaptation measures: 1. Where would the multifunctional character of the measures be used most efficiently (urban networks) and 2. Where will the measures contribute to the completing of the ecosystem as a whole in order to make the ecosystem services that contribute to climate resilience more sustainable? Note that it is not the goal to restore the ecosystem for nature value purposes, but for sustainability purposes of the water storage, water retention, water purification, heat reduction services, that can also improve general quality of living.

In this study we have come to a Green Adaptation (GA) approach for urban areas. The GA approach consists out of six steps that will give the user a guideline to identify opportunities for the implementation of Green Adaptation (GA) measures in a city. This report has explored the application the GA approach in Rotterdam.

It is important to identify citizens' needs and the urban threats and challenges in the future (Step 1), because GA measures have to serve those needs, threats and challenges, and preferably all together. Next (Step 2) is a description of the policy and spatial context in which the GA measures have to be embedded. The policy and spatial context set out the borders of the playground for the implementation of the measures. Having inventoried the first two steps, a good understanding of potential urban green adaptation measures is needed (Step 3), in order to have a wide view on the local possibilities and the services that can be provided. (Step 4), historical or present ecosystem functions may be recognized as ecosystem services that connect to the inventory in the first step of this approach.

For Rotterdam we have considered the Rotte river catchment, where its historical functioning was supplying a flooding buffer (flooding areas, floodplains) and its catchment slowly released water back into the river (through infiltration, surface and underground storage). Step 5 is to identify the most suited GA measures (out of the inventory of step 3). Most suited are GA measures that fill in the missing, or insufficiently present, functions of the ecosystem described in step 4. For the urban situation those are: creation of riparian habitat, bioswale, green retention areas, green roofs, floating structures, and water purification by soils/organisms. They either supply more space for flooding in urban rivers, or withhold rain water longer in neighbourhood surroundings. Simultaneously, they provide other functions that make them more valuable to the city, like water purification, heat stress reduction, improving livability and increasing urban ecological values. The last step (Step 6) is to identify windows-of-opportunity to implement these measures. A clear view must be present on the on-going or future projects on urban developments, so GA measures can benefit from these activities and implementation is cheaper.

The city of Rotterdam has applied many climate adaptation maesures and rojects already, however, the ecosystem approach to benefit from as much ecosystem services as possible and the Green Adaptation approach have not been applied yet. For Rotterdam, the individual steps of the GA apporoach are familiar. Waterstad 2035's approach for watermanagement can be broadened and strengthened to a Green Adaptation Approach for Climate adaptation (watermanagement and heat stress management), with a special focus on ecosystem knowledge, in order to support the Rotterdam Adaptation Strategy.

9.2 Research questions addressed

What are the opportunities for improving flood protection when using ecological processes or habitats in the urban delta system?

Using GA measures for improving flood protection will provide not only the ecosystem service for flood protection, it can additionally provide heat stress reduction, water purification, increase in biodiversity, and increase in liveability. Because of the multi-functional character, the value of these measures are high and, therefore, GA measures might be cheaper , when seen from a societal perspective (as non-monetary can be included in financial considerations through a societal benefits cost benefit analysis) than hard solution to flood protection.

How can we optimise water storage by improving its ecological function?

Restoration of the hydrological system of catchments asks for more riparian wetlands (healthy river, side-effect is restoration of the ecosystem), but also for the GA measures like bioswales, green retention areas, water purification by soils and green roofs. All of these measures have a capacity to store water and, therefore, delay rain water input to the river system. All of these measures (apart and together) restore the hydrological system (providing ecosystem services simultaneously) will optimise the water storage capacity. In an urban context it is necessary to interlink green adaptation measures to help strengthen the natural ecosystem and hydrological dynamics of urban rivers, so that their climate adaptation potential can be improved.

How can green adaptation measures in water management improve urban living quality?

Green Adaptation improves urban living quality because: 1. they provide green space and reduce heat stress, 2. it is implemented in a way that the ecosystem as a whole benefits, which will increase biodiversity. A healthy catchment ecosystem needs all kinds of habitats and processes or flows (energy, nutrients, hydrological, etc.). The more complete an ecosystem the more robust it is for external threads and a network of vegetated habitats can also transport cooler air into the city.

How can we integrate green adaptation measures with other adaptation measures in the Rotterdam Adaptation Strategy?

We have selected six green adaptation measures, however, only bioswales and floating structures are not part of the Rotterdam Adaptation Strategy yet. The GA approach is interesting for the Rotterdam Adaptation Strategy. It will help

organize multi-functional measures at the right spots within the city while making optimal use of the ecosystems in place and the services they could provide.

9.3 Recommendations

Urban delta regions (here Rotterdam) need a good Geographical Information System approach to analyse where all the climate adaptation measures must be and can best be implemented. The Program office for Sustainability of Rotterdam expressed a desire to work with process-oriented maps as well. During the term of the project we have realized most Building with Nature concepts asks for a large scale application, while a better strategy in an urban setting might be to implement all kind of small scale measures that are enhanced through ecosystem functioning. In this way the Building with Nature vision is integrated with an urban setting with infrastructure, housing, offices and industrial buildings. It would then be necessary to monitor all the different measures linked to realised projects in a Geographical Information System approach. The All London Green Grid can be used as an example of how to structure these maps.

A next step would be a clear picture of do and don'ts for the Rotterdam partners (project developers, builders, etc) who want to work with an GA approach or in the neighbourhood of GA zones and projects. When it comes to realization of projects, the Rotterdam Adaptation Strategy must develop a list with rules and recommendations with GA measures on an operation level.

A shortlist of projects where the Green Adaptation approach could contribute significantly by aiming to address and integrate multiple urban needs in a multifunctional set of GA measures, would be:

- Urban rivers the Schie and the Rotte: river ecosystem functioning restoration with the combination of water storage (green retention and riparian wetland creation), floating structures and green roofs.
- The Ring of older neighbourhoods through North and South; chains of GA measures on hotspots of networks and in connection with restoring urban river functioning or poldersystem functioning (bioswales, green retention, green roofs, water purification by soils/organisms)
- Making The Delta river: estuarine habitats in harbours and on embankments of Nieuwe Maas en Oude Maas (riparian wetland creation, floating structures, bioswales)

Finally, for the implementation of these measures within spatial planning projects it is important to get local stakeholder involvement and a clear view on the cost-benefits that will result from them.

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Appendix 1: Overview of the setup of the two workshops.

Workshop 1 ESCAUR (24 februari 2012)

13.00 Welkom en Opening workshop door dagvoorzitter
Victor Beumer
13.10 Klimaatadaptatie in Rotterdam en doel ESCAUR
Arnoud Molenaar
13.20 Presentatie Building with Nature projecten in Nederland
Mindert de Vries
13.40 Inhoudelijke vragen en aanvullingen
Deelnemers
13.50 Presentatie Ecologische strategieen voor Rotterdam
Victor Beumer
14.10 Inhoudelijke vragen en aanvullingen
Deelnemers

14.20 Pauze

14.30 Presentatie Rotterdam in kaart: problemen, aanpak en kansen
Ronald Bakker
14.50 Inhoudelijke vragen en aanvullingen
Deelnemers
15.00 Werken in groepjes van 4 deelnemers
Deelnemers
Welke maatregel haalbaar, waarom en waar,
Wat nog nodig om uit te zoeken
Victor en Erica lopen rond, info op tafel
16.00 Presentatie meest kansrijke maatregel per groep
Deelnemers

16.20 Pauze

16.30 Conclusies
Victor Beumer en Erica Koning

16.40 Conclusies en advies voor vervolg
Arnoud Molenaar

17.00 Afsluiting wo werkzaamheden voor en aanpak van workshop 2
Victor Beumer

Deelnemers

1. Corjan Gebraad /PD Rotterdam
2. Arnoud Molenaar/PD Rotterdam
3. Erica Koning/ IGWR Duurzame RO Rotterdam
4. Ronald Bakker/ IGWR Landschap Rotterdam
5. Joop Zwiep/ GW Beheer Buitenruimte Rotterdam

6. Joke Klumper/ SO Landschap Rotterdam
7. Teus Blokland/ IGWR Waterbouw Rotterdam
8. Karel Hulshof/ IGWR Geotechniek Rotterdam
9. Olaf van Velthuijsen/ IGWR Ecologie Rotterdam
10. Susanne Buijs/ IGWR Stadsklimaat Rotterdam
11. Pieter de Greef/ SO RO Water en Landschap Rotterdam
12. Bas de Wildt/ GW Watermanagement Rotterdam
13. Mindert de Vries/ Deltares Building with Nature Delft/Zeeland
14. Victor Beumer /Deltares Landschapsecologie Utrecht
15. Helene Hulsman/ Deltares Watermanagement en Natuur Delft
16. Suzanne van der Meulen/ Deltares
17. Bregje van Wesenbeeck/ Deltares
18. Frans van der Ven/ Deltares Civeile Techniek
19. Arno Lammers/ Regio Haaglanden

Workshop 2 ESCAUR (24 mei 2012)

1 Welkom en rondje	Erica Koning	9.00-9.15
2 Resultaten 1e workshop	Helena Hulsman	9.15-9.25
3. Presentatie Rotte	Helena Hulsman	9.25-10.00
4. Aanvullingen en opmerkingen uit de zaal	Erica en Helena	10.00-10.25
Pauze		
5. Toelichting opgave	Erica	10.40-10.45
Inspirerende aftrap werkgroepen	Mindert	10.45-10.50
5. Werkgroepen		10.55-11.55
6. Presentatie resultaten en discussie		11.55-12.15
7. Eindconclusies	Erica en Helena	12.15-12.30
8. Afsluiting	Erica	12.30-12.35
Lunch		

Groepsindeling workshop 2

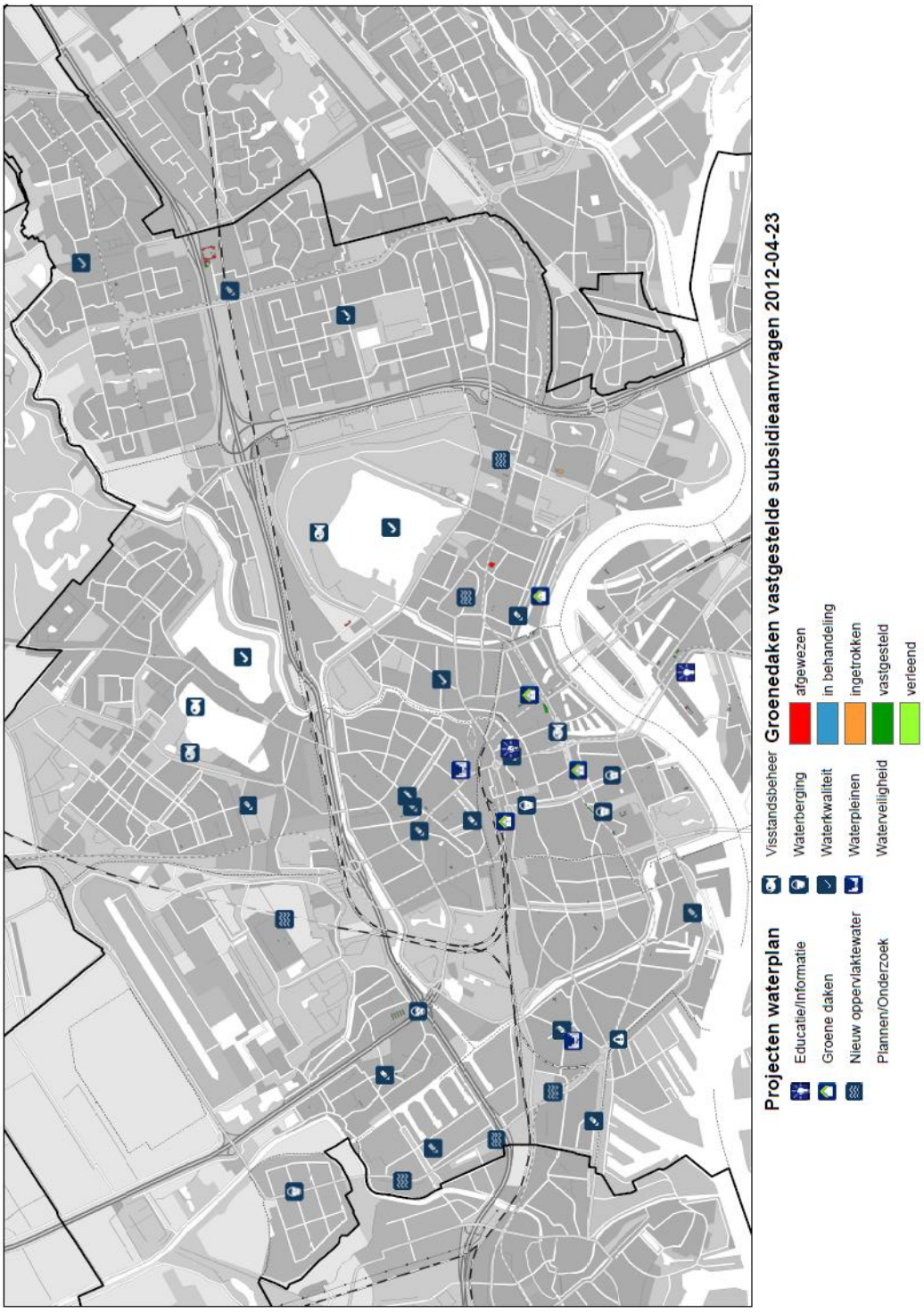
Rotterdam Zuid

1. Sandra de Bont senior landschapper Rotterdam Zuid
2. Helena Hulsman Deltares
3. Olaf van Velthuijsen ecoloog gemeente Rotterdam
4. Cor Jan Gebraad RCP Programmabureau Duurzaam
5. Kees van Oorschot opdrachtmanager buitenstedelijk groen
6. Arno Lammers regio Haaglanden
7. Lissy Nijhuis RAS coordinator gemeente Rotterdam
8. Bas de Wildt watermanagement gemeente Rotterdam
9. Toine Vergroesen onderzoeker KvK 2e tranche
10. Rens Labadie stagiar gemeente Rotterdam

Nieuwe Maas en Stadshavens

1. Mindert de Vries Deltares
2. Joep van Leeuwen adviseur Milieu & Ruimtelijke Ontwikkeling gemeente Rotterdam
3. Martin de Vries geotechnisch adviseur gemeente Rotterdam
4. Jarit de Gijt kade specialist gemeente Rotterdam
5. Ronald Bakker landschapper gemeente Rotetrdam
6. Marius Brants Wereld Natuur Fonds
7. Sander Klaassen senior landschapper gemeente Rotterdam
8. Arnoud Molenaar programmamanager gemeente Rotterdam
9. Susanne Buijs stadklimaat coordinator gemeente Rotterdam
10. Teus Blokland adviseur watermanagement havengebied gemeente Rotterdam

Appendix 2: Map with project opportunities in Rotterdam.



Appendix 3: New projects in Rotterdam, possibly supplying opportunities for GA measures.

North:

- Restore the Rotte with green shores and green quays within the city boundaries
- On the shores of the Schie, a chain of small lakes can function as water storage areas, ecological ponds and a green cycling route at the same time.
- The connection of the turban green areas can be improved and developed into big green zones (physical and communicational) for cool air, clean air and healthy play grounds for children:
- Zone 1 Bergse bossen, Bergse plassen, Kralingse Bos and – Plas, Ypenhof, Arboretum Trompenburg, Oude Plantage and the Esch;
- Zone 2 Polder Zestienhoven, Vroesenpark, Roel Langerak park, Heemraadsingel and the Park.
- Zone 3 Stationsplein, Park Oude Westen, Museumpark and the Park
- Spaanse Poort needs more green areas for heat stress prevention
- In transforming the older neighbourhoods on North, it would be beneficial to try to interlink watermanagement measures and make them profitable for the urban river system.

South:

- The Zuiderpark exhibits a good combination of ecology with green living experience and recreation. The urban system is connected with the park system. When the neighbourhoods are increasingly being connected by the singels and more green areas, it will increase the attractiveness of quarters in the South. It is necessary to increase green and blue areas in these quarters for a better future climate, and it will have a spin-off for other issues (social, economic). The idea should be to make a new singel(s) which connects with Zuiderpark and Nieuwe Maas. This will create an ecological and recreational connection between two big blue spines of South.
- The Brielselaan is a dynamic area where there is a confrontation between outer and inner dikes areas. It is planned to be renewed so this provides an opportunity for green adaptation measures focused on dynamic processes.
- The Nassauhaven is a project with options for natural estuariene vegetation. This type of vegetation can improve the area's atmosphere and identity, to attract new citizens.

- In Lombardijen, it would be good to examine if the poldersystem can be restored in combination with enhanced infiltration in green areas and a connection with the Oude Maas.

Rivercity:

- Noordereiland: estuarine habitats in combination with a quay for water safety will be constructed;
- Rijnhaven: estuarine habitats in combination with adaptive building or ships are explored;
- Quays of Nieuwe maas: plans for Regional and Urban recreational area with different city parks are being developed;
- The Esch : a plan for a huge city park with estuarine nature is being developed.

Appendix 4: Implementing Green Adaptation measures in Rotterdam

North:

- In the Rotte river catchment (see chapter 7) lakes and wetlands can function as water storage and natural areas. Rotterdam already started with Kralingse Plas en Bergse Plas, but they are more areas to go for.
- Large water areas when developed with marsh land and riverbanks can function as attractive new areas for living and or recreation. They can also be suitable for breeding of fresh- and brackish water fish. Local fisherman know a lot of the regional species who can live in these systems.
- Water storage can be created or enhanced in zones alongside infrastructure like the Tjalklaan.
- The singels can be enhanced to green walking and biking areas or parks. In this way, the single waterways could be broadened and given more room to overflow in wet seasons. These areas can be used for green and cool walking and cycling paths. And they can be inner ecosystems suitable for submerged plants and fish.
- Green areas can function for water storage when available open waters are too small or too few, in combination with sewer systems for flooding from extreme rainfall. These green areas must have vegetation that is adjusted to a dynamic water level. Green adaptation measures can be bioswales, green roofs and areas with water purifications by soils/organisms (see chapter 6).
- the Green roof programme can be intensified in areas with less green and a lot of stony, hard structured public space to prevent the heat island effect in warm summers. When green roofs contain flowering plants, they have even additional ecological functions (bees, butterflies).
- Greenery or lanes in industrial areas can reduce air temperatures, expected to rise in the future. The green zones of Rotterdam can be used for cooling and recreational activities on a city level.

South:

- Strengthen the poldersystem and the singel system for watermanagement. Developing more singels , enhance water connections.

- Water throughout the Rotterdam South area can and should be better interconnected so natural functions in the water system can also be used for purification of the water (flushing). It will generate other eco-system services, like opportunities for sport, fishing and recreation, as proposed in Waterstad 2035
- Water storage and water connections can be integrated in the main green structures. When linked with walking and cycling paths it can up-lift the recreational network on South.
- Improve the infiltration capacity of the green areas where possible.
- The Oude Maas can introduce water of a better quality to South. Buijenplaats will be given huge water basins and also the climate buff-er projects from WWF, with water that can be used in dry seasons in South.
- In South, a green roof programme is not possible due to a very small surface of flat roofs. Innovative green adaptation measures must be found on the ground level.
- Use the dikes and infrastructural zones for transforming into water and natural areas. When possible, combine this with new living quarters like for example De Zwanen in Groot IJsselmonde. The dikes then form a walking route through South.

Rivercity:

- Strengthening the robustness and flexibility of Rotterdam ecosystems;
- Strengthening the relation between the city and the region;
- Keeping a tidal influence in the Nieuwe Maas. Rotterdam is the only Dutch town with tidal influence visible in the city centre. Only with tidal dynamics, it will stay a characteristic river for delta areas and will keep the Rotterdam identity as a Delta city strong.
- When the connections are kept open and estuarine habitats are restored, various fish species will pass through Rotterdam to reproduce in smaller rivers or in the polders or vice versa, and therefore improve the region's biodiversity. This would be necessary for sustainable possibilities for small scale fisheries around Rotterdam.
- Developing estuarine habitats in the Nieuwe and the Oude Maas. Recycle soil and urban or harbour stony and limestone materials to make these habitats.
- Developing estuarine habitats in combination with urban parks as dynamic and flexible dikes. Estuarine habitats will help the dikes to withstand higher water levels and severe waves. Exact flow and wave paterns in the Nieuwe Maas river need to be investigated to identify potential locations in Rotterdam.

- Interaction between brakish and freshwater can create special habitats which can accentuate the Delta city.
- Make a connection for fish between Nieuwe Maas/Rotte and Schie and for South with Oude Maas/ Zuiderpark (trekvissen: polder, river, sea and vice versa).
- The outer dike embankments can form a park on a city level, when seen as a connected urban space. It provides space for innovative developments and riverine nature, aqua-building, innovative dikes which emphasizes the identity of Rotterdam as a Delta city. It will also bring cool areas for hot nights.
- Using the Oude Maas river for run-off (Delta commission) is a good option. In the South there is space for wetland development which can function as extra water buffers. In the North this space is not available, due to the localization of the Rotterdam Airport, which prevents new big water and wetland areas in the region.

Appendix 5: Possibilities in urban networks, north.

Blue network:
The North has two urban rivers and a lot of urban water canals. Sewer systems have been introduced in the past for a better water quality and as a surplus to cope with heavy rainfall. However, the system is expected to fail in the future (Waterplan2 Rotterdam). New measures for water management already have been implemented but the urban river system of the North could be enhanced more effectively by using an ecosystems approach.

The Rotte river
The last ten years, many designers have investigated ways to give the Rotte a more prominent place in the city. It serves as a route to the outer, green landscape. On Sundays, the Rotte near the Rottemeren is full of bikers and hikers. But within the city it could be used more intensively and it has too little identity for such a important river, which has given her name to the city. A few nice projects have already been realized. Measures have made the border between the high city and the low river more accessible. People can sit or walk more closely to the water surface. The route along the Rotte is marked more clearly, and the surrounding public space is enhanced and made more attractive with design shops and events for the local community.

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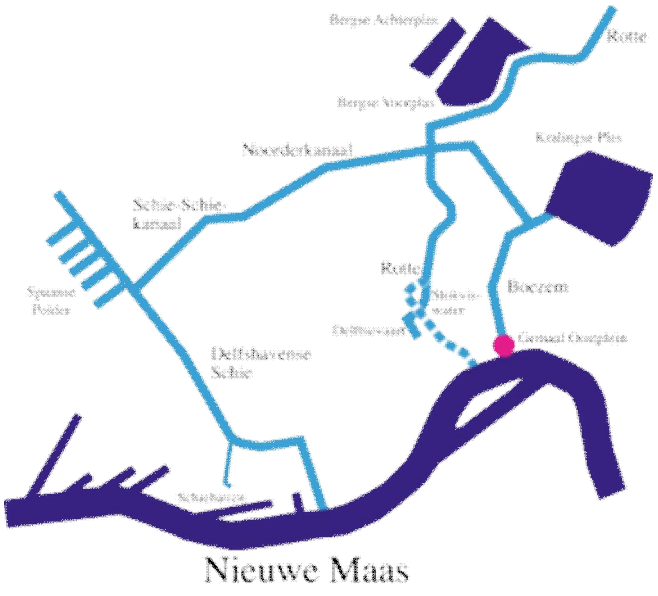


Watersystem Rotterdam North

Still there is space for more recreational activities, a pavement alongside the river, more alignment and perhaps an innovative way to facilitate living on water. There are some houseboats in the north of the river, but they are lying

next to a big green cemetery. Perhaps these boats could be relocated to a better place along the Rotte, so there is space available for a natural habitat in connection with the cemetery.

The Schie river

The Schie has a fascinating history, but nowadays in Rotterdam only the Delfthavense Schie is left. De Schie is used for transportation and recreational boats. It makes a connection with de Nieuwe Maas at Parkhaven, near Coolhaven -eiland and Lloydkwartier. The Schie has a lot of green and public space along the river, especially near Overschie. Housing only occurs at a great distance. The green areas are not heavily used up to now. This could serve as a great opportunity for green adaptation measures.

Alongside the Schie there is a modern cycling path which leads you up to Delft, passing beautiful farmland and natural areas. Green adaptation could emphasize the identity of this route as green and recreational and attractive.
Within the city boundaries, there is less space and other types of Green adaptation measures should be used, less focused on restoring the original ecosystem dynamics, but enhancing the potential local urban ecosystem services. Local, small-scale measures could well be introduced on conjunctions of urban networks.

Green network:
In the North, we can distinguish 4 layers:

- the large parks and green zones on a city level
- the city infrastructure lines
- the department infrastructure
- some historical dikes and lines

Rotterdam is not a green, stretched city. But there are zones in the North which can be considered like that:

- Bergse bossen, Bergse plassen, Kralingse Bos en – Plas, Ypenhof, Arboretum Trompenburg, Oude Plantage and de Esch.
- Polder Zestienhoven, Vroesenpark, Roel Langerak park, Heemraadsingel and the Park.
- And in the city centre: Stationsplein, Park Oude Westen, Museumpark and the Park

In the North, the green areas can be more natural. People who live here appreciate nature or innovative green design, like green roofs or green facades.

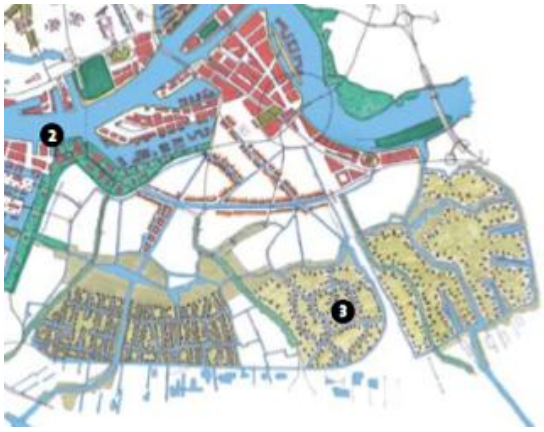
Red network:
De Spaanse Poort ('Spanish gate') is one of the industrial sides of Rotterdam. It has harbours which are connected to the Schie. It will be restructured the upcoming years.

Appendix 6: Possibilities in urban networks, south.

Blue Network:
The South of Rotterdam has no urban rivers or large water storages areas, except for the human made Zuiderpark. It is mainly a polder with dikes and has a lot of green space. Therefore it is a better option to focus on combinations of green and blue networks in the South and make more effective use of the soil system (underground water storage).

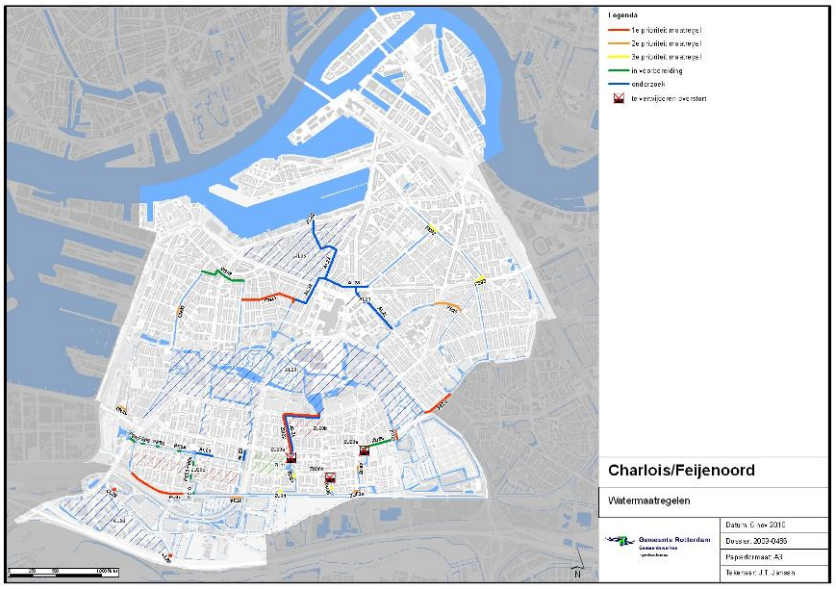
The future challenge is to organize a water system with a high water quality, because ground and surface water may become more saline by the inlet of Nieuwe Maas river water. The Blue route in South and the water system of the Zuiderpark are already good examples of water management measures for water quality improvement . However, the Blue route will not be sufficient for the South and more connections to the Oude Maas river are required.

Waterstad 2035 sketches a vision of big waterways to flow through all the neighbourhoods so that the people from South can visit each other by boat. Up to now this idea is not been realized.



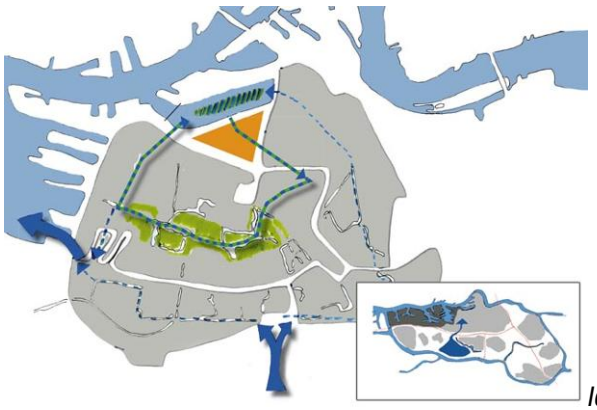
Waterstad 2035

In the nearby future, the Deelgemeentelijk Waterplan focuses on increasing the open surface waters, establishing different connections and realizing the blue connection with the Oude Maas river.



Deelgemeentelijk Waterplan Charlois Feijenoord.

- In Feijenoord there is a lack of space and development projects. The water challenge can only be realized by broadening up existing water channels and implementing green adaptation measures in the green structure.
- In Charlois there are projects at hand. There, it is possible to introduce a bigger area for water storage in combination with the new houses to be built.
- In the north of Feijenoord, Bloemhof, Afrikaanderwijk, Hillesluis, innovative measures are needed.
- New innovative ideas for the South already brought up: to strengthen and uplift the watersystem in combination with adaptive building and other new innovative habitats and or recreational areas.



Idea for a new watersystem Rotterdam South in connection with newly build Maashaven

FIGUUR 17 Voorkeursalternatief uit de MER voor het Landschapspark Buytenland.

Idea for climate buffers along side the Oude Maas: Buijtenland van Rhoon en Climatebuffers WWF en Stichting Ark (not realized yet). The dikes in Rotterdam South are still intact and are planned to be designed as a specific route to connect all the neighbourhoods, with high quality vegetation and trees. It is not necessarily to strengthen and heighten them to a higher level As these dikes meets the common standards for dikes in the Netherlands.

Green structure:
On the South, it's possible to consider a large green zone:

- Zuiderpark, Valkenierswijde, Groene gordel Lombardijen, Park de Twee heuvels;
- Zuiderpark, Zuiderbegraafplaats, Koedood zone en Polder Buytenland;
- A15 and old harbour railway zone.
- Embankments Oude Maas en Blue route

Zuiderpark has been restructured 10 years ago. It is now an important city park with a modern view on combining a park with water storage, with using natural processes (helofyte filters) to improve good water quality. It is also the park end point for the 'blue connection'. The blue connection brings water from the Oude Maas into South to improve and guarantee a better water quality in all the neighbourhoods. This water of an improved quality will also be used for swimming and other recreational activities like canoeing and rowing.

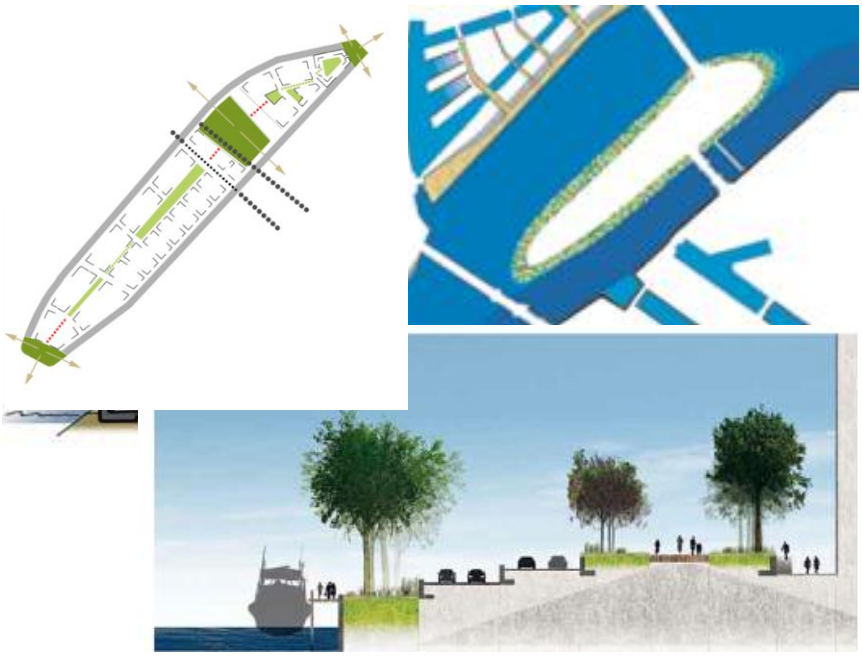
Appendix 7: Possibilities in urban networks, rivercity.

Blue network:
It is necessary to find a solution for rising sea- and riverlevels (Deltacommission). In the advice of the Delta commission, the peak in river water is to be transported southwards via the Oude Maas, so the Nieuwe Maas will only have to be protected against higher sea levels. The river system is presently a system where the Oude Maas river and the Nieuwe Maas river are interlinked, but plans are prepared to create a division. In the North, there are several dikes which must be heightened to apply to the new standards for dikes in de Dutch Delta.

Rotterdam wants:

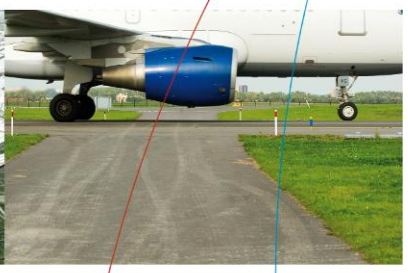
- More dynamic and flexible dikes so people can use them for urban functions, or develop them in time without having to destroy too much;
- Dikes bordering open land : strengthening dikes on the land side;
- Dikes Stadshavens: strengthening dikes on the water side;
- Noordereiland, Scheepvaartkwartier and a part of Feijenoord: a completely new dike;
- Waalhaven en Merwehaven: new urban quarters in, and in interaction with the river.

The river is brakish up to the Erasmusbridge and will become more saline with climate change impacts. It is expected that saline waters will come with in reach of the Hollandse IJssel. It is planned to shift some intake points of river water to the east to guarantee good (fresh) water quality for agriculture.



The Nieuwe Maas river provides a connection with the sea and is the only open connection left in the region. Closing off this connection will reduce the ecological quality of the river drastically by deteriorating natural dynamics of the system, causing a loss of biodiversity and bio-productivity, and a loss of estuarine habitats. With rising sea levels, a lot of estuarine habitat is expected to disappear.



To develop the scientific and applied knowledge required for Climate-proofing the Netherlands and to create a sustainable knowledge infrastructure for managing climate change.

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