Thesis Landscape Architecture
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WETLANDSCAPE

ADAPTATION TO CLIMATE CHANGE ON THE ISLAND OF IJSSELMONDE

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Thesis Report
Master of Landscape Architecture

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PREFACE

From March 2009 till November 2009 I focussed on the island of IJsselmonde, its landscape, its water system, its problems and its opportunities. In these months, different viewpoints and focuses passed by, and many choices have been made, resulting in this booklet.

I would like to thank my tutor Rudi van Etteger for his guidance during the last half year. His focus on the research part was helpful for the structuring of arguments, problems and story-telling. For advice during the design I would like to thank Cees van de Veeken from LOLA Landscape Architects in Rotterdam. His critical view helped me with being critical myself, making choices and made me sometimes 'kill my darlings'. Furthermore I would like to thank LOLA for providing information about the island IJsselmonde and its history of building dikes and polders.
I would like to express my thanks to Jelle Vervloet and John Mulder, for their time and their information about the historical origin of the region, the geological underground and the cultural history. The conversation with these bright men made me 'understand' the place, and with that understand its problems.
Furthermore I would like to thank the experts on different themes in this thesis, who communicated their knowledge to me. Jannekee van Herreveld-Brand from the Waterboard Hollandse Delta gave me insight in the water system of IJsselmonde. Vincent Kuypers and Barry de Vries from Alterra provided information about possible measures for adaptation to climate change. Frank van Dien from Ecofyt in Oirschot helped me with his knowledge about helophyte filters and wetland purification.

ABSTRACT

This thesis is a research to the resistance to climate change of the island IJsselmonde, as a part of the Dutch south western delta, and a landscape adaptation plan for 2050. Before projecting expected changes in the future on the region, the present state of affairs is made clear by a research to the historical landscape development and the 'functioning' of the current landscape and water system.

The island IJsselmonde is situated in the middle of the Dutch delta, which makes the region strongly influenced by external processes of sea and rivers. However a delta system is naturally a dynamic water system, the water system of Ijsselmonde lost its dynamics as a result of urbanisation, mainly by the city of Rotterdam. An historical development of eras of humans restricting the water system, by embanking, draining and discharging led to many problems and an unattractive landscape today.
Firstly, the regional water system of IJsselmonde is dependent on pumping and letting in water. Pumping is difficult with high water levels outside the dike-ring, and with extreme rainfall. On the other side, letting in in dry periods is difficult with low water levels. Salt water is reaching Rotterdam which makes inlet ever more difficult.
Secondly, clean rain water is pumped out in wintertime, while relatively polluted water from the Rhine is let in during summertime. This leads, together with a hardly circulating water system on the island, to a poor surface water quality.
Thirdly, the urban water system exists mainly of the sewage system. All rainwater is discharged via this system of underground pipes. Extreme showers can not be processed by the system, resulting in sewage overflows in the canals. This leads to a poor water quality and in extreme cases to water problems in streets and houses.

Maeslantkering
(Ticone-photos- Het Keringhuis)

By the expected climate changes (KNMI ') all existing problems will increase. Reliance on the principle water system by pumping and letting in water will be more difficult because of sea level rise, land inwards shifting salt water and changing river discharges. Furthermore, the distribution and intensity of precipitation will change. Less precipitation in summer will increase water shortage problems, while more precipitation in winter will increase water surplus problems. More extreme rainfall will especially increase the load on the urban water system and with that lead to a more often overflowing sewage system.

The plan for adaptation to climate change in 2050 proposes a 'wetlandscape'. Instead of pumping clean rain water out, it should be retained in new, circulating urban water system, stored in storage basins and cleaned by natural wetland purification. The stored water can be used for inlet in the urban and regional water system in periods of water shortage. The adaptation measures contribute to a more attractive landscape, with more possibilities for recreation and living. The wetland purification zone is designed as a 'watermachine'; the process of water cleaning is made comprehensible and attractive for visitors. Furthermore, a new water park provides opportunities for swimming, walking, sunbathing and sailing. The park offers attractive places for living in floating houses, which makes the developments more profitable. In the plan, the neighbourhoods Zuidwijk and Pendrecht in the urban district of Rotterdam south have a new surface water system for rain water retention. The developments make the neighbourhoods more attractive, provide better routes from the city to the new park, and result in an attractive transition zone from city to water storage lakes in the form of a boulevard with beach.

CHAPTER 1

INTRODUCTION

1 INTRODUCTION

Adaptation to climate change, on the island of IJsselmonde
The first part of this subtitle, adaptation to climate change, implies that our climate is changing, and that adaptation of the landscape is necessary to avoid problems. This is a very bold statement, since climate changes, as well as changes in society, technique, economics, landscape and all other future developments are very uncertain. Although the extent to which climate will change is uncertain, the fact that it will change is sure.

Al Gore's Inconvenient Truth made the world aware of this. He showed the effect of the emission of greenhouse gasses on sea level rise. He also showed the scary image that, if we continue our consumption behaviour, the Netherlands will possibly disappear under the sea.
Our country is not accidentally chosen as an example in his movie. Half of the land is situated one to five meters below the sea level! And this land has to discharge the water of three big rivers into the North Sea. Al Gore was right to recognise the Netherlands as very vulnerable to changes in the climate...

The second part of the subtitle says 'on the island of IJsselmonde'. The image above shows that IJsselmonde is an island, because it is surrounded by rivers. The 'Nieuwe Maas' (New Meuse) in the north, the 'Oude Maas' (Old Meuse) in the south, and the 'Noord' (the North) in the east discharge the water from the river Rhine. Via the 'Nieuwe Waterweg' in the west the water is discharged into the sea.

Aerial view IJsselmonde (Bing-maps)

The Dutch delta

The location is chosen for adaptation to climate change because it is situated in the delta region of the Netherlands, called the 'Zuidwestelijke delta' (south – western delta). This is the place where the rivers meet the sea. Originally, a delta system is one of the most dynamic natural systems. The interaction between rivers and sea result in a continuous process of growth and loss of land. Floods would be normal, the line between water and land would never be the same. Climate change would not be a problem at all!

However, the island of IJsselmonde is not part of a natural delta anymore. The island is for the larger part covered by the city of Rotterdam, the rivers are dammed and restrained by the harbours. Urbanisation has turned the region in one of the most fixed and un-dynamic places. This makes the urbanised delta very vulnerable to changes in the natural system of rivers and sea. From the many facets of climate change, water is the most significant one for the delta of the Netherlands. In the thesis research on IJsselmonde, it will become clear that in the past, in the present and in the future, water is the determining factor in development of landscape and cities. In the past, water brought along problems and danger. The disaster of 1953 when many people where killed by floods in the south western Netherlands is still fresh. But water also brought economical chances for the area. The downstream harbours close to the sea gave Rotterdam the strongest trade position. Water has always been an attractive factor, it 'gives a special experience that attracts people'. (Tjallingii et al, 2007). This thesis shows that water in the present still causes many problems and danger for the area, and that

Het verdronken land van Saeftinge - Zeeland (Vildaphoto)

this, without intervention, will get worse in the future. However, this thesis also shows that water is still a chance for the island. By working together with water, the region will be safer, healthier, more attractive and prepared for future climate change!

In chapter 2 the thesis statement and the research questions will be explained. After that, the research questions will be answered in different chapters, following each other like a story. The story starts with a retrospective view on the historical development of the landscape of IJsselmonde, which is explained in chapter 3 'Landscape development'. After understanding how the landscape has been evolving, it becomes clear how the current landscape ' works'. This insight shows that many current problems are connected to water and water management. Therefore, chapter 4 takes a closer look to the water system. In chapter 5 the impacts of climate change on the landscape and on the water system are described. In chapter 6 a vision for the future is developed. It is translated into design goals, which lead to a concept for the island of IJsselmonde in 2050. The concept is explained in chapter 7.

For one part of IJsselmonde it is worked out how the concept can be implemented on a local scale. For this purpose, a design is made for the area between Rotterdam South and the highway A15, including the two southern most neighbourhoods Pendrecht and Zuidwijk. Chapter 8 contains an introduction and analyses of Pendrecht, Zuidwijk and surroundings, followed by the design in chapter 9. In the final chapter 10, it is concluded to which extent the objective of the thesis and the goals for the design are achieved.

River Meuse through Rotterdam (Aerophoto)

The rivers around Rotterdam once were a natural, dynamic delta system of waterways meandering through wetlands. Today, the system is totally restrained and fixed by urbanisation...

CHAPTER 2

THESIS

Skyline Rotterdam
(www.flickr.com - Leo Roubos)

2 THESIS

Thesis statement:
By transforming the current artificial and un-dynamic water system of IJsselmonde to a more natural and dynamic system, the landscape will be resilient to future climate changes, and more attractive.

2.1 RESEARCH CONTEXT

The Netherlands have had a defensive, offensive and finally a manipulative approach towards water (see chapter 4). In the 21st century the insight came that the traditional way of pumping out water and building dikes may not be the best way. We realized that we are pumping ourselves deeper and deeper below the surrounding water levels, which brings along flood risks and increasing consequences of a possible flood. Currently different policies and strategies are focusing on more sustainable ways to deal with water.

One scenario is to keep on raising the river dikes. Higher dikes are fixing the rivers even more, with as a consequence higher water levels between the dikes which can cause problems downstream. Stronger pumps

High water in the river Waal. As a result of raising the dikes and restraining the rivers for ages, the rivers in the Netherlands are fixed and have not enough space to process extreme amounts of water. If no more space will be given to water, the water will take more space by itselve...

would be necessary to discharge the water, a measure that works contrarily when the land is already declining.

A new approach towards water comes forward from the 'Vierde Nota Waterhuishouding' (Fourth Policy Document on Water management). The new approach towards water is among many others described in 'Remaking "Nature": The Ecological Turn in Dutch Water management' (Disco, 2002). The following shifts in the way of thinking can be distinguished:

- For the coast: Transition from statically defensive to dynamical coastal management

- For the rivers: transition from dike raising to 'Room for the River'

- For creeks: transition from straightening to re-meandering creeks

- For polders: from pumping out and letting in water to retention of water

- For urban areas: from fast discharge to retention of water

(Tjallingii, 2007)

Many national and international agreements and plans came forward from the new approach towards water, with intentions ranging from improving water quality to giving more space to water. on the next page the most important Policy Papers are shortly described:

WB21

The Dutch water policy of the 21st century breaks with the tradition of pumping out and discharging as fast as possible. A new sustainable strategy is developed in WB21, in which is described that water should be retained as long as possible. For this new water management an order of three steps is developed:

1. water retention
2. water storage
3. water discharge

Room for the River

The Dutch parliament has developed this new strategy on a political level, with the objective to deal with the increasing river discharges. The strategy breaks with traditionally raising the dikes. Instead, storage areas or overflow areas are developed to increase the capacity of a river. In rural areas many Room for the River projects have been implemented, often successfully combined with other functions as nature and recreation (Dutch Ministry, 2000)

Delta Plan II 'Working together with water' (2008)

The second Deltaplan is an advice for the Dutch parliament, from the Delta commission led by the Dutch politician Cees Veerman. The advice is about dealing with climate change and increasing river discharges, on the scale of the Netherlands. The vision for the year 2100 combines an adaptive strategy towards water for 'normal' situations, with an offensive strategy for extreme situations. An adaptive strategy means working together with water, and implies allowing more water inland, and adapting to such circumstances by means of living in floating houses or on higher places. The offensive strategy consists of storm surge barriers, through which the open sea arms and river estuaries can be closed off in case of extreme high water levels and storms. (Veerman, 2008)

KRW guidelines water quality (Kaderrichtlijn Water)

Many Dutch waterways are polluted with nutrients and heavy metals. The KRW is a European guideline, developed to make sure that all European surface water and ground water is of sufficient quality in 2015 (EU, 2000).

2.2 RESEARCH GAP

Many adaptations of the water system and the landscape have been implemented in rural areas. However, in urban areas this development stays behind. While exactly in urban areas the problem is extra urgent, because the water system is strongly fixed and restrained, and flows through a higher population density. For that reason the economical, but also personal, consequences of a flood are often bigger in the city.

There are reasons why not many adaptation projects have been implemented in urban areas. First of all, it is more difficult to implement transformations in the urban tissue. Buildings form a fixed structure, and people are living there. The sewerage system is an underground structure often situated under buildings and under streets. It can not be changed without shutting off streets, or demolishing buildings.

A second reason is a more strategic one. Projects like Room for the River give more space for water upstream, to prevent problems downstream. For that reason adaptations in rural areas can solve problems in urban areas. But the urban areas can not totally depend on transformations in rural areas. Especially a region like Rotterdam, where influences from the sea play a major role. Next to this, extreme rainfall increasingly appears to be an important cause of problems. This problem can not be taken away by upstream measures.

The aim of the research is to analyse the consequences of climate change in the urbanized area, and develop strategies for adaptation.

2.3 OBJECTIVE

Developing a strategy for the landscape of IJsselmonde, to solve existing problems, prepare for climate change, and make the landscape more attractive.

This objective will be translated to different scale levels. On the regional scale of the island of IJsselmonde a concept will be developed to solve the existing and the expected problems. In a design for one part of the island, the concept is implemented on a local scale. This scale shows that the landscape can be more attractive while at the same time water problems are solved.

Overflow space for the Rhine near Pannerden (www.members.chello.nl)

2.4 RESEARCH QUESTIONS

The following research questions and sub-questions are formulated to fulfill the objective:

1 How does the landscape of IJsselmonde ' work'?
  - How did the landscape develop in time?
  - Which existing problems does the landscape have?

2 What are the impacts of climate change on the landscape of IJsselmonde?

3 Which adaptations of the landscape are necessary to solve the existing problems and to prepare for climate change?

In the chapters one to five, the research questions one and two will be answered. This part goes into the origin of island IJsselmonde, its development through time, existing problems and expected problems for the future. The research questions have been answered by analysing maps, talking to experts, reading about the area and fieldwork.

From chapter six onwards, a vision for the future is explained. In this part, the third research question is answered by 'research by design'. It results in measures for adaptation to climate change. In the final chapter, the design, the measures developed as an outcome of the third research question will be implemented in a specific area on the island of IJsselmonde. In the design I strived to combine the necessary adaptations in the landscape with a more attractive landscape (see objective).

CHAPTER 3

LANDSCAPE DEVELOPMENT

This chapter describes the historical development of the landscape of IJsselmonde, and its occupation by humans. The development of the landscape of IJsselmonde has always been connected to water, and men's attitude towards water. For that reason, this chapter will slightly focus on water, and the ever evolving relation between man and water. The following journey through time is specific for the island IJsselmonde, but is more or less characterizing the whole south western delta region of the Netherlands.

3.1 GEOLOGICAL UNDERGROUND

To obtain insight in the landscape and the attached water system of IJsselmonde, it is crucial to go further into the geological underground of the area. It turns out that the pre-historical development of the geological underground has been determining for the evolvement of the landscape, the water system and the human occupation of the area. In this paragraph, the most important geological processes follow. First, the situation of the underground in the Pleistocene, starting point for the geological development of IJsselmonde in this thesis, will be described. After that, the processes that took place in the following period Holocene will be described. These processes formed the current landscape.

3.1.1 Pleistocene (11.800 – 1.800.000 years ago)

The geological underground of the Netherlands of today, is formed in the Pleistocene. In the first hundred thousands years of the Pleistocene banks were formed, caused by sediments deposited by the sea. Later, the rivers from the east deposit their sediments on these marine banks. These fluvial sediments consist of sand and gravel and are therefore water-permeable. Till today, groundwater is still transported through these layers. On and around the island of IJsselmonde these Pleistocene underground is formed by sediments of Rhine and Meuse (Formation of Kreftenheve). This underground consists mainly of coarse sand and very coarse sand. The upper side of these sediments is -12m to -20m NAP (Vervloet et al, 1985).

In the Pleistocene, the Netherlands has known three important glacial periods. Each of them has its specific influence on the landscape. In the first ice age, which started around 400.000 years ago, the ice caps of Europe were firmly expanding. A lot of water was captured in this ice sheets, and as a consequence the sea level lowered. The North sea was pulled back and finally became dry. In intermediate warmer periods the ice caps melted, through which the sea level rose again (National Museum of Natural History).

The next to last glacial period (180.000 – 130.000 years ago) has had the biggest influence on the landscape of the Netherlands. Huge ice sheets were pushed from Scandinavia in southern direction, behaving like a giant glacier. The moving ice sheets transported masses of stones and gravel to our country, and created ice pushed ridges. The ridges of the Veluwe are still remains of this process. The ice sheets didn't get past the line Arnhem – Utrecht, therefore they didn't have an impact on the underground of IJsselmonde.

In the last glacial period (110.000 – 10.000 years ago), the Netherlands were not reached by ice caps. At the time, the country appeared to be a tundra or pole desert, with cold and harsh winds transporting huge amounts of sand. As a result, new layers of sand were deposited on the older layers of sediments. In the western part of the Netherlands, these layers are again for the largest part covered by sediments in the Holocene. On the island IJsselmonde, the Pleistocene wind laid deposits are recognizable as 'donken' (small sandy hills) on a few places. These places are to be found east and south-east of Rotterdam. The 'donken' around Rotterdam are ridges, originating from river sand, blown by the wind out of periodically drying out river-beds (Vervloet et al, 1985). Only the highest parts of these dunes were prevented from being covered by younger sediments or peat growth in later periods.

In the Pleistocene period, human beings had not enter the south western delta region yet. Human occupation in the Netherlands was restricted to the higher river banks along the Meuse in Limburg and the higher sandy grounds in the east of the country. Until the Pleistocene, the western part of the Netherlands was a natural teamwork between climate, soil and water, in which forest and swamp ecosystems succeeded each other.

At the end of the Pleistocene the climate starts being warmer again. The ice caps melt, the sea level rises, the

A possible, north west European Pleistocene landscape (www.bbc.co.uk)

coast line moves eastwards. This is when the Holocene starts.

3.1.2 Holocene (today - 11.800 years ago)

This period is the period in which human beings are, in the beginning gradually and exhausting, taking over the natural system. All over the world peoples end their roaming existence and settle on permanent places.

In the Holocene period the Dutch coastal zone was formed under the influence of sea level rise. As a consequence of temperature rise, big amounts of ice water from Central Europe flowed through the Netherlands into the North Sea. These streams formed the basis for the current rivers in the Netherlands and have a very dynamic character. Braiding and meandering the water went the way of the least resistance, thereby often periodically inundating big surfaces of land. By deposition of the transported fluvial sediments, the land surface was rising along with the rising sea level. The south-western delta of the Netherlands started to take shape. In the dynamic play of flooding, sedimentation and water stagnation a continue process of water transforming into land took place. This is called hydrosere (verlanding). Hydroseres are communities in which pioneer plants invade open water, evolving into swamp forests and eventually forming some kind of soil such as peat or muck. However, vegetation was often being swept away by high water levels in wintertime and floods. Sediments and peat from this period are classified as the 'Westlandformatie' (Vervloet et al, 1985).

In a later stadium of Holocene, Atlanticum (around 3000 AD) dunes came into existence. Behind these dunes large

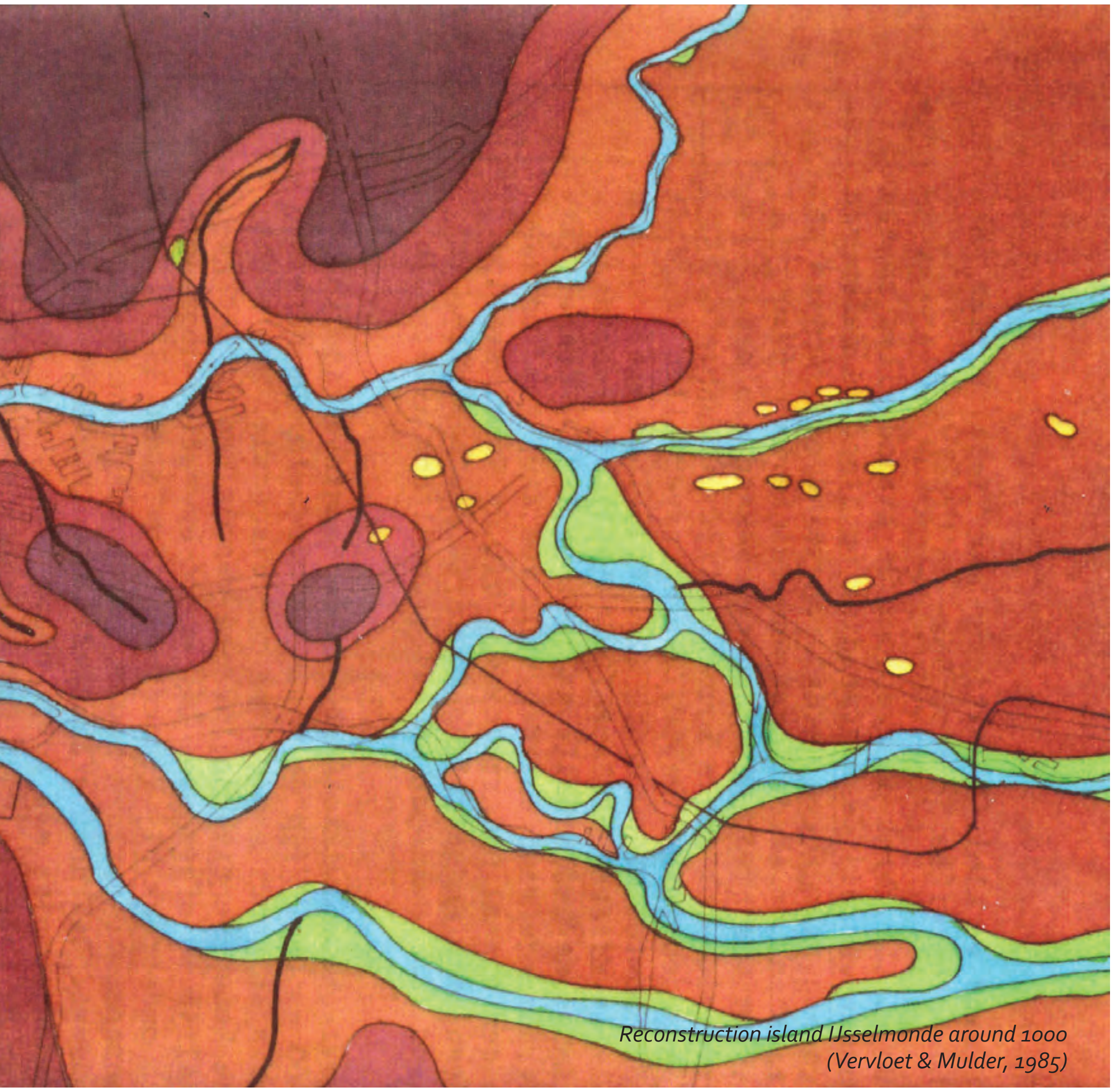
Het Verdronken Land van Saeftinge' - Zeeland (www.maps.google.com)

amounts of peat were formed. Due to this peat growth, the surface of the earlier Netherlands was rising above sea level. This comfortable situation is however changed into an uncomfortable one, by human interference in later phases of history.

In the eastern part of the delta the rivers were depositing sand and clay along their banks, so higher river banks came into existence.

On IJsselmonde arose mainly swamp forests existing of alder, birch, hazel and willow trees. The forests were rather proof against floods and dehydration.
In the Holocene the first inhabitants settled in the delta. Even before the Roman Empire, with the Old Rhine or Limes as northern border, the river area was occupied by humans. In Poortugal and Rhoon remains of Roman farmhouses and grain storage sheds are found (Stichting Oude Kern Rijsoord).

Since the water was free to go its own way, human beings couldn't do else then accept the water system as it was, and adapt to the circumstances. That made him dependent on higher places and he settled on the Pleistocene ridges (donken), and on the higher banks along the rivers. Interventions in the natural water system haven't been done yet. Except from some farm houses on these higher areas little permanent settlement took place.



Reconstruction island IJsselmonde around 1000
(Vervloet & Mulder, 1985)

sphagnum peat
cyperacea peat
swamp forest peat
river clay
sea clay
sand
water

In the holocene, IJsselmonde probably looked like the present 'Verdronken Land van Saeftinge' in Zeeland. Around the year 1000, IJsselmonde consists of peat bogs from where water courses and streams flow towards the rivers. Clay can be found directly along the rivers. Sea clay is dominant on both sides of the Meuse estuary, with Poortugaal as eastern most border.

The dunes are visible in the north western corner. Around 1000 the coastline was situated more westwards.

Landscape changes on IJsselmonde have always been connected to man's attitude towards water...

Natural delta system:
growing of peat; process of hydrosere

Het Verdronken Land van Saeftinge' - Zeeland (Google Earth)

1000

Acceptance of circumstances

Dikes, dams and ditches:passive drainage

Topographical map IJsselmonde 1850 (Municipality Rotterdam)

1500

Defensive attitude towards water

3.2 HUMAN OCCUPATION AND DEVELOPMENT

Till around 1000 AD mankind accepts his minor position to the will of the water. From about 1000 onwards he is not content with this anymore and humans get a growing influence on the landscape, and the water system. Therefore the period after 1000 will be described more detailed and subdivided into different phases, resp. 1000-1500, 1500-1850, 1850-today. After that the current era will be described, with its new insights for the future according water management, landscape and urban development.

3.2.1 1000 – 1500: Draining and embanking

This period is characterized by passive drainage and the protection of settlements against the water by the building of dikes and dams. Reclamation and cultivation of the land was done from the higher places, especially from the banks of water courses and rivers. The first settlements of this area were probably the old centre of Riederkerk which had a church in 1064 already, and IJsselmonde, that carried the name of Islamunda in 1076. From these places the peat swamps were cultivated for the purpose of agriculture (Vervloet, 1985).

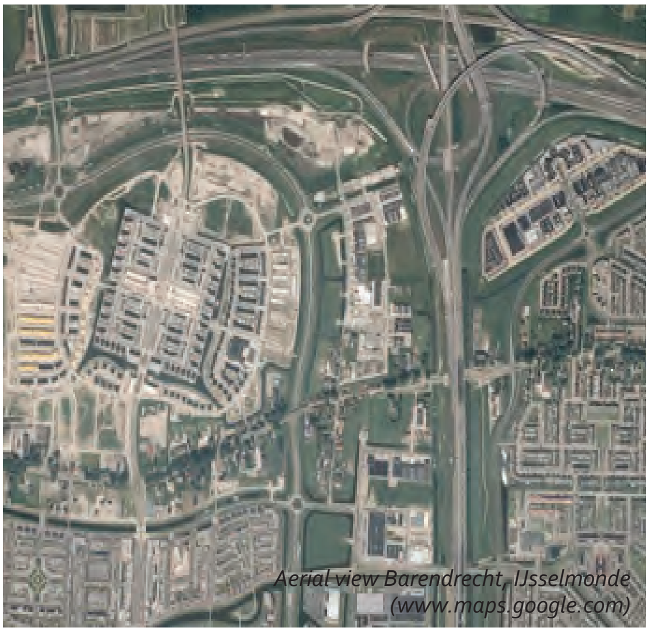
The peat swamps and wetlands were drained by ditches, and discharge of the water took place by gravity. At low water levels the water could be discharged naturally into the river. The land reclamation was characterized by a strip formed parcelling, stretching from the river banks. The reclaimed areas were protected by

Windmills and steam pumps for active drainage

1850

Offensive attitude towards water

Urbanisation:
water system taken over by sewerage system



2009

Manipulation of the water system

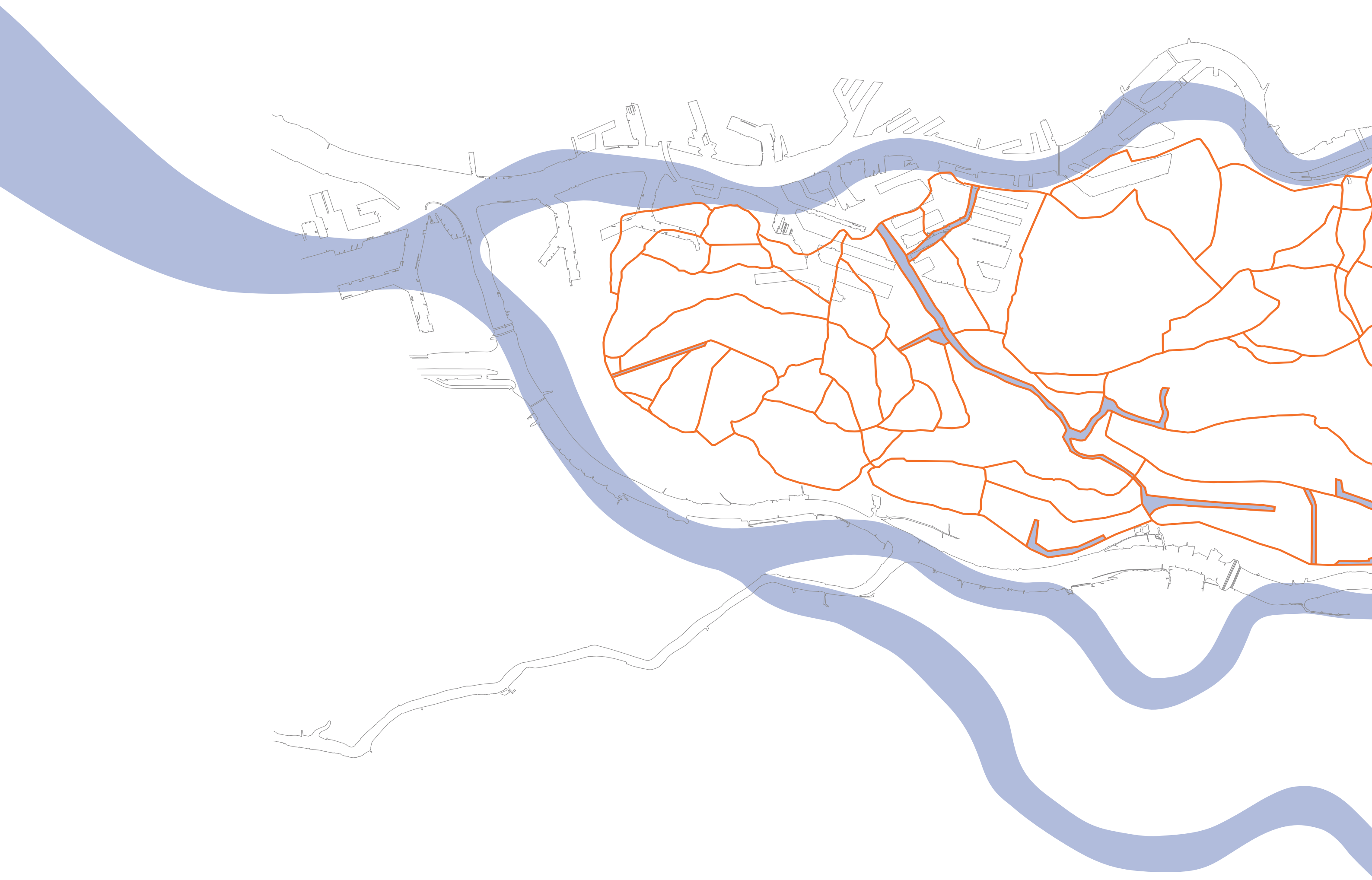
a dike-ring. In this way the polders were developed one after the other.

The drainage of the peat areas resulted in oxidation of the peat, and as a consequence subsidence of the soil. Before reclamation, the peat areas were situated one to three meter +NAP. As a consequence of human influences and natural subsidence, the (former) peat areas declined to one to two meters -NAP.

In the 14th and 15th century many large floods from sea distressed the area now called island IJsselmonde. As a consequence, the land has been under water for a long time, through which the parcelling disappeared for the largest part. Many of the 10th and 11th centuries settlements were washed away by the water. After a flood, it often took more than ten years to reclaim the land again. Original parcelling has often been changed in a new parcelling in an other direction.

The first large flood in the 14th century was 1314 / 1315. The earlier 'Zwijndrechtse Waard' was under water for a long time, and first in 1325 is attempted to repair the dikes.

The next flood came in 1373 and 1374 and had a huge impact on the landscape. Especially the earlier 'Riederwaard' was severely affected. New channels came into being, and the middle part at 'Koedood' was under water for a long time. The first banking after the flood worked out in 1404 (polder 'Oud-Reyerwaard). From the east side as well as from the west side the polders were constructed one after the other. First around 1650 the island of IJsselmonde got its present-day form.



Finally, the St. Elisabeth flood in 1421 has been disastrous. An extreme western storm caused failing of many dikes, and large parts of South Holland and West Brabant were under water. The stream of the rivers changed. The current Biesbosch south of Dordrecht still reminds of the force of the water of that time.
Since the 14th and 15th century one succeeded in keeping the water out of the polders. The today's IJsselmonde landscape first came into being in this period. Remains of the reclamations and parcelling from before the big floods are hardly visible, sometimes rectangular on the current parcelling.

The western part of IJsselmonde, 'Het Land van Poortugaal', was protected by dikes since around 1180. Pernis has its own dike-ring since before 1250.

The period between 1000 and 1500 in the Netherlands was characterised by an enormous loss of land. For a long time, it is believed that this was due to sea level rise and the increasing of storms and floods. However, G.P. van de Ven concluded that human occupation was cause number one. The biggest reason for the increasing influence of the sea and resulting loss of land was the subsidence of the soil, caused by drainage of the land. As a consequence, bigger and bigger dikes were needed to resist the danger from the sea (van de Ven, 2003).

The struggle against the water and the loss of land, polders and reclamations is characterising the period 1000 till 1500. The inhabitants continuously fought against the water, playing a game of giving and taking of land. The political structure of the water boards came

The original dike- and polder structure, for the greater part ready in the 15th century.

into being in this period. The traditional Dutch attitude against the water probably relates to the fight fought in this period (van de Ven, 2003).

3.2.2 1500 – 1850: Human domination over water

In this period an offensive strategy against water becomes usual. Windmills were introduced to drain the declining polders, for urban development or agriculture. Pools and wetlands as well as sedimented grounds outside the dikes were actively drained and embanked. A large gain of land at the expense of water is the result (Schuetze, 2008).

Since the 15th century passive drainage became hardly possible. Due to the subsidence of the soil the ground water level got extremely high in periods with a lot of rain. Despite the many ditches and canals the drainage and discharge of water from the reclaimed areas became more difficult. Often it was not possible to discharge in the river, because the river level was higher than the level in the ditches! In such situations, polders were periodically under water. This happened even in the summer months.

The solution for this problem was drainage with windmills. Since the 16th century this new technique was adopted in a large scale. The first windmill however dates from 1408 in Alkmaar. The fourth Dutch windmill was built on island IJsselmonde in 1422.

In the period 1500 till 1850 the influence of human beings on the landscape and the water system increases. Drainage techniques improve, and in 1643 it is possible to pump up the water up to 4 meters by the use of wind energy. In 1776 the first steam pumping station is used for drainage of the polders. Power and control over the water increase again..

As a result, the number of floods decreased drastically, and more land could be used (prolonged) for living and agriculture. Man had now control over the water, however the consequence was less space for the water, and less resiliency in the water system.

From 1600 till 1800 the western Netherlands had the Golden Age, a period of great prosperity. In Rotterdam this resulted in many developments in the harbour, which transformed from a herring harbour to an international transhipment for bulk materials and luxury goods. The employment in the city increased, and the population of Rotterdam grew enormously. The concentration of people in the city however resulted in environmental problems, as water pollution and a scarcity of green. At the end of this period one started to work on a healthier city, with clean water, fresh air and a lot of green space.

3.2.3 After 1850: Industrialisation and urbanisation

Around 1850, the history of the landscape is legible anywhere on the island. IJsselmonde consists of a sequence of polders and dikes, farms and houses situated on or attached to the dikes and on the higher places. From 1850 onwards technical, spatial and economical changes have been occurring faster and faster. The industrialisation that started in this period had a big impact on the relation between city and countryside. People from the countryside become more dependent on employment in the city (de Greef, 2006).

New techniques make it possible to manipulate the water system on a larger scale. With steam engine pumps, and later with electrical pumps, deeper polders and peat pools could be drained. The current polder landscape of the western Netherlands is still dependent on this manipulative water management.

In the last 150 years, the urban area existing of harbours, industrial areas and residential areas has been increasing drastically. Especially since the fifties urbanisation has been a fast process. The island of IJsselmonde has been chosen for urban expansions for Rotterdam and surrounding municipalities, because after the disaster of 1953 lots of salt remained in the soil. That made the area less suitable for agriculture and horticulture. While the city was expanding, the countryside was degenerating in economical sense.
The today's landscape is an urbanised landscape, with only fragments left of a long history.

1850
Around 1850 the landscape of IJsselmonde looked a lot like the landscape of ages before. The inhabitants were mainly living of agriculture and horticulture, for which the fertile and well drained clay soils were very suitable.
North of the New Meuse in Rotterdam the 'Singelplan Rose' is implemented, with new canals and waterways for flushing of the city with fresh water from the river.
Between 1865 and 1872 the 'Nieuwe Waterweg' (New Waterway) is constructed, providing the Rotterdam harbours with a perfect accessibility. From this moment on the harbours expanded faster and faster.

1920
The harbours expand to an important transhipment, whereby the Meuse is restrained by means of relocation, embanking and expansion of the transhipment platforms outside the dikes. In the city many canals and waterways are filled up, to make way for the increasing car traffic. The disappeared open water is almost everywhere replaced by a sewerage system, existing of underground pipes. In the countryside stronger steam engine pumps allow more control over water levels, and even in winter time the land can be kept dry. "All in all, the water is ever more restrained and regulated." (de Greef, 2006).

The city of Rotterdam expands in southern direction, on the island of IJsselmonde. Over the island the new rail connection between Rotterdam and Dordrecht is constructed, for the transport of goods from the harbours to the hinterland.

1940
On the map of 1949 a further expansion of the harbour in western direction is visible. As a result of this development, the city of Rotterdam expands in southern and eastern direction, and loses its link with the harbour. The shifting of harbours in western direction is due to space and logistics. Big sea ships and tankers become bigger and need a deeper fairways. This process is continuing till today.
In 1930 the curves of the river Meuse are cut away, for faster access of the harbour. Dams and transhipment platforms make the river even smaller at Rotterdam, resulting in a bottleneck.

1960
The disastrous floods of 1953 had a big impact on the area. Spring-tide in combination with north-western storm pushed up the water of the North sea. Big floods in Zeeland, West Brabant and Zuid Holland (and IJsselmonde) killed more than 1800 people. After 1953 a new awareness of the ever dangerous water arose. The decision was made that such a thing may never happen again, and the delta commission was established. This commission drew up the 'deltawet' (delta law) in 1958, and develops the Deltaplan. After that the biggest civil technical operation ever done in the Netherlands is implemented: the 'Deltawerken' (Delta Works), large storm surge barriers that close of the sea arms of the delta. First finished structures are the Storm surge barrier Hollandse IJssel (1958) and the Haringvlietdam (1972).

1850

1920

1940

Urbanisation processes since 1850: The harbours expanded more and more to the west, while Rotterdam grew in southern and eastern direction

In the sixties the harbour and industrial area Europoort is developed. In 1962 Rotterdam is the biggest port of the world.

1980

Around 1970 the Europoort was not big enough anymore, and the new expansion Maasvlakte is being built. In 1973 this harbour expansion in sea is finished. The implementation of the Delta Works continues, and in 1988 the Oosterscheldekering is finished.

A change in attitude of man towards environment occurs. "In this period the attention shifts from mainly quantity to quality, from growth to development and transformation." (Rotterdam Waterstad 2035). During the construction of the Delta Works attention for ecology arises. Despite this development, no more space to water is given, and the water system is still further restrained.

The highway A4 and the dominant A15, cutting through the island from west to east, are realized. Also the impressive nodes Vaanplein and Ridderkerk appeared. The large shunting yard Kijfhoek is constructed in the south eastern part of IJsselmonde.

Below the development of built up space on the island IJsselmonde since 1850 is visualised:

open space

built up space

1960 *1980* *2009*

Maasvlakte II, the newest harbour expansion ready in 2033 (DSV Rotterdam)

2009

The current island IJsselmonde is transformed to a complex whole of infrastructure, residential areas, commercial areas. The landscape is almost totally urbanised, resulting is a relatively large amount of paved surface. As a consequence, the water system is based on drainage and discharge of water.

After the Europoort, also the Maasvlakte appeared to be too small. Therefore, in 2008 a start is made with the construction of the second Maasvlakte. This harbour expansion will consist of 2000 hectares of land reclamation in the sea, is will be ready in 2033.

Other new developments are the big infrastructure networks HSL and Betuwelijn. The HSL, a high speed train connection between Amsterdam, Rotterdam, Brussel and Paris cuts through the island IJsselmonde is the direction north – south. The Betuwelijn, a freight railway between the Rotterdam Maasvlakte and Germany, cuts through the island in the direction west – east.

3.3 TODAY'S LANDSCAPE

Thousand years of landscape development led to a complex and interesting landscape anno 2009. The landscape of today will be unravelled with the help of the layer approach, used in the National Spatial Strategy (Nota Ruimte) by the ministry of VROM. This model uses three layers, differing from each other in transformation time.

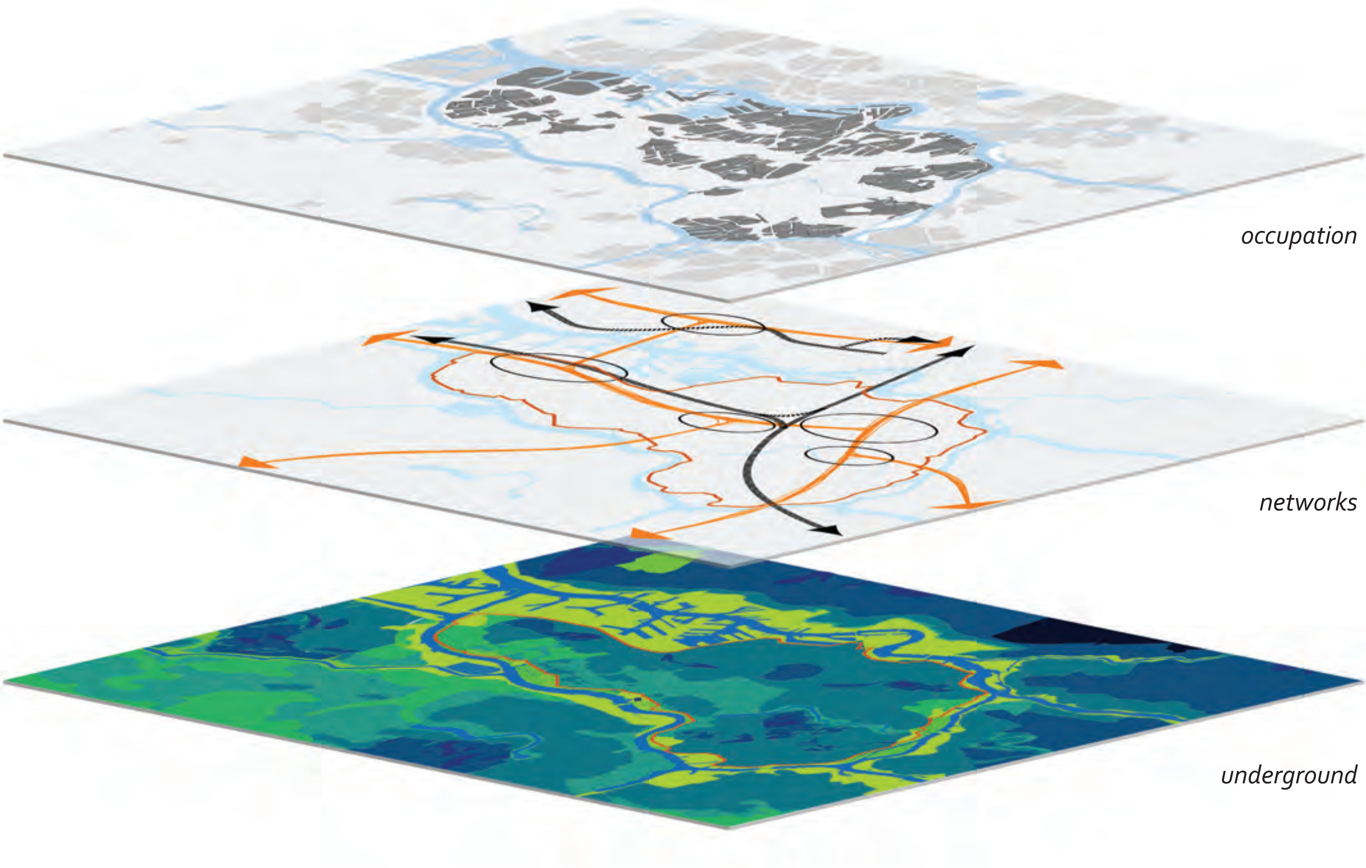
The model of three layers:

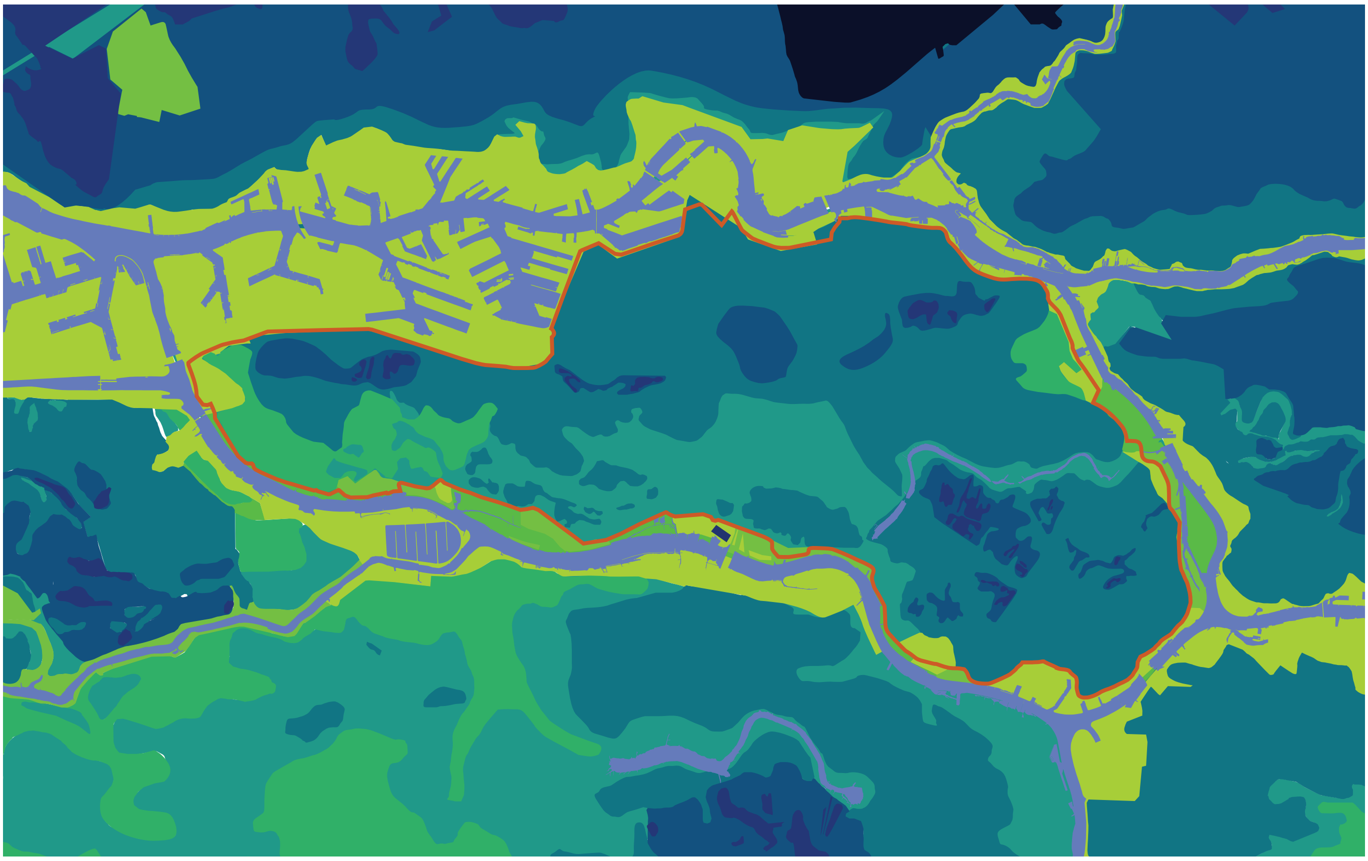
3 *Occupation:*
- *high-dynamic spatial filling in*
- *transformation time 10 – 40 years*

2 *Networks:*
- *middle-dynamic spatial filling in*
- *transformation time 20 – 80 years*

1. *Underground:*
- *low dynamic spatial basis*
- *transformation time > 100 years*

(VROM, 2004)



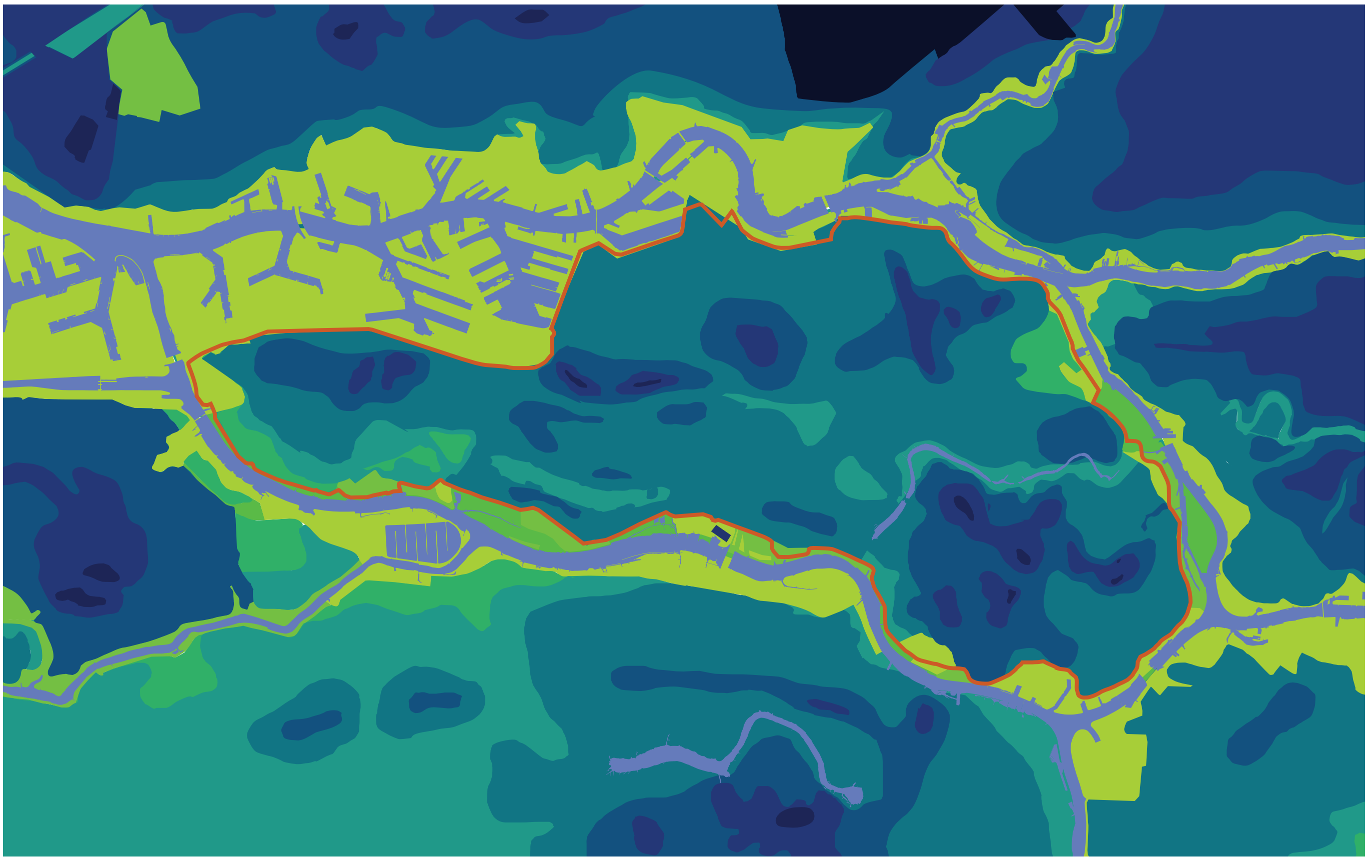


3.3.1 Underground

The natural underground of IJsselmonde consists of clay. The peat on top of this clay that once grew dozens of meters above the sea level, has been dug away. In the foregoing part about the landscape development till today, it became clear that people have been draining the land since they occupied it. This process of draining and discharging the water had its consequence for the clay soils, namely that it has been sinking ever since human occupation. The results is showed on the altitude map on the following page. The ground level within the dike-ring of IJsselmonde varies from about 0 meters NAP to – 2.50 m NAP.

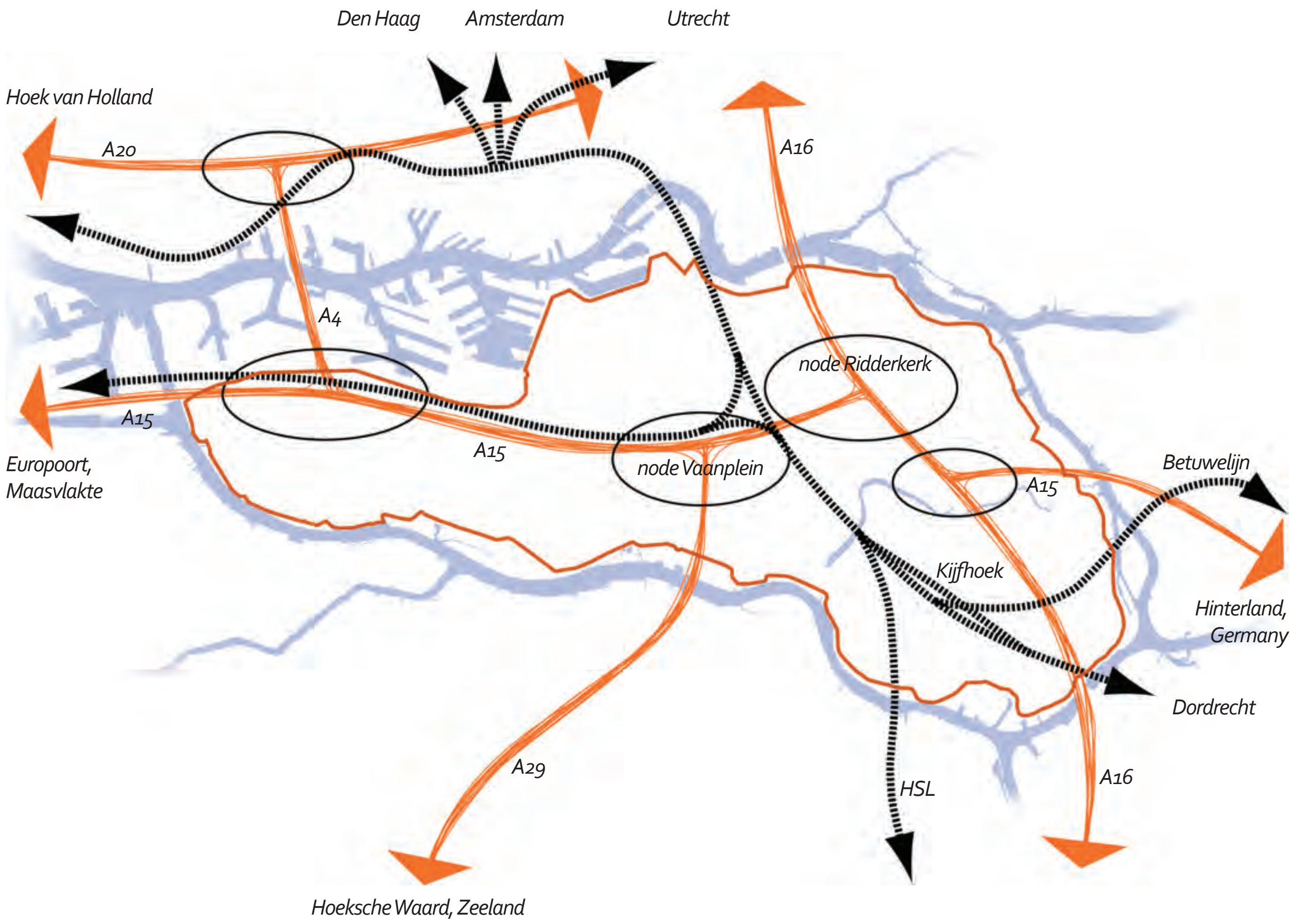
However, the process of subsidence of the ground is still going on. Due to settlement of the IJsselmonde clay, and to tectonic subsidence of the western part of the Netherlands, IJsselmonde sinks every year up to 1.5 centimetres per year! In 2050, some parts of the island will be 40 – 60 centimetres lower than today! In appendix 1 the subsidence map for 2050 is attached.

The map on top of this page shows the current altitude of the island IJsselmonde. On the map on the next page, the manipulated altitude map for 2050 is showed. The current altitude is extrapolated by data of subsidence of the soil. Drawn it the 'relative' altitude, that means the altitude compared to NAP. An expected sea level rise of 20 cm is included in the manipulated map, which makes the relative subsidence extra big. The soils that contain more peat, sink the fastest.



	> 300
	+300 / +150
	+150 / +75
	+75 / 0
	0 / -75
	-75 / -150
	-150 / -225
	-225 / -300
	-300 / -400
	-400 / >-500

Approximation altitude in meters NAP (GIS & www.ahn.nl)



3.3.2 Networks

The layer of networks is a very important layer in the region of Rotterdam, which connects the area to many parts of the world. This makes the island of IJsselmonde to an important international node. The networks that cross IJsselmonde are mainly highways and rain connections, as showed on the map below.

From west to east, the highway A15 and the rail connection Betuwelijn are important. These great infrastructures connect the Rotterdam harbours Maasvlakte and Europoort to the hinterland and to Germany. From north to south the highway A16 and the HSL are significant. These infrastructures connect the Rotterdam region to Amsterdam in the north, and to Antwerp and Paris in the south.

A consequence of the position of IJsselmonde on internationally important routes, is a fragmented landscape, cut into pieces by enormous infrastructures. The infrastructure causes sound- and air pollution, and makes the landscape visual unattractive. The highways attract offices and industrial buildings, which adhere themselves on both sides of the road. The result is a chaotic landscape, perceived by inhabitants as 'ugly' / 'messy' (RPB 2006).


Betuwelijn between Rotterdam south and Barendrecht


Highway A15 and Betuwelijn between Rotterdam south and Barendrecht


Node Ridderkerk
(www.skyscrapercity.com)

3.3.3 Occupation

The first artefacts of occupation were the dikes, surrounding the old polders to keep out the water. The original dike structure, as showed in paragraph ... does not exist anymore. What's left of it are just remains, it is not a connected structure anymore. Some parts have been erased by storms and floods, and have never been repaired. Other parts have been removed on purpose, to make space for urbanisation or to construct cables from the harbours to the city. (Kuijpers, 2009. Verbal communication). However, the old dikes are still the backbones for the cultural history of the island. Along the dikes one can fine old farmhouses and dike houses on or attached to the dike.

In different urban periods, different ways of dealing with the old dikes have been adopted. In some periods the dikes have been removed, in other periods the dikes have been preserved and are now recognisable as green zones through the urban districts.

The map above shows the main contents of the occupation layer, built up space and recreational park space. It shows that the biggest part of the island is urbanized, and that only a few polders in the south and the south east are still open landscape. As in the rest of the province of South Holland, there is little open space, caused by 'malignant' and 'messy' urban growth. IJsselmonde has little green space, and little opportunities for recreationa (van der Veeken, 2009 - verbal communication).

Recreational areas are developed, and often planted with forest. As a result, the original landscape is becoming less legible due to 'green projects', as well as due to 'red projects' (LOLA Landscape Architects, 2008).

3.4 CONCLUSION

The island of IJsselmonde has been through a booming development. From a totally natural, dynamic delta system of a few thousands years ago, the landscape transformed into an urbanised landscape regulated by men. The landscape came into existence from the struggle against the water, from the fear for a storm. However, in the last 150 years, urbanisation erased almost all remains of this 'original' landscape. Most dominant features of the current landscape are the highways and railways, the lifelines of the Rotterdam harbour and with that of the Netherlands. The reverse side of this important connections is a fragmented landscape, with a messy appearance.

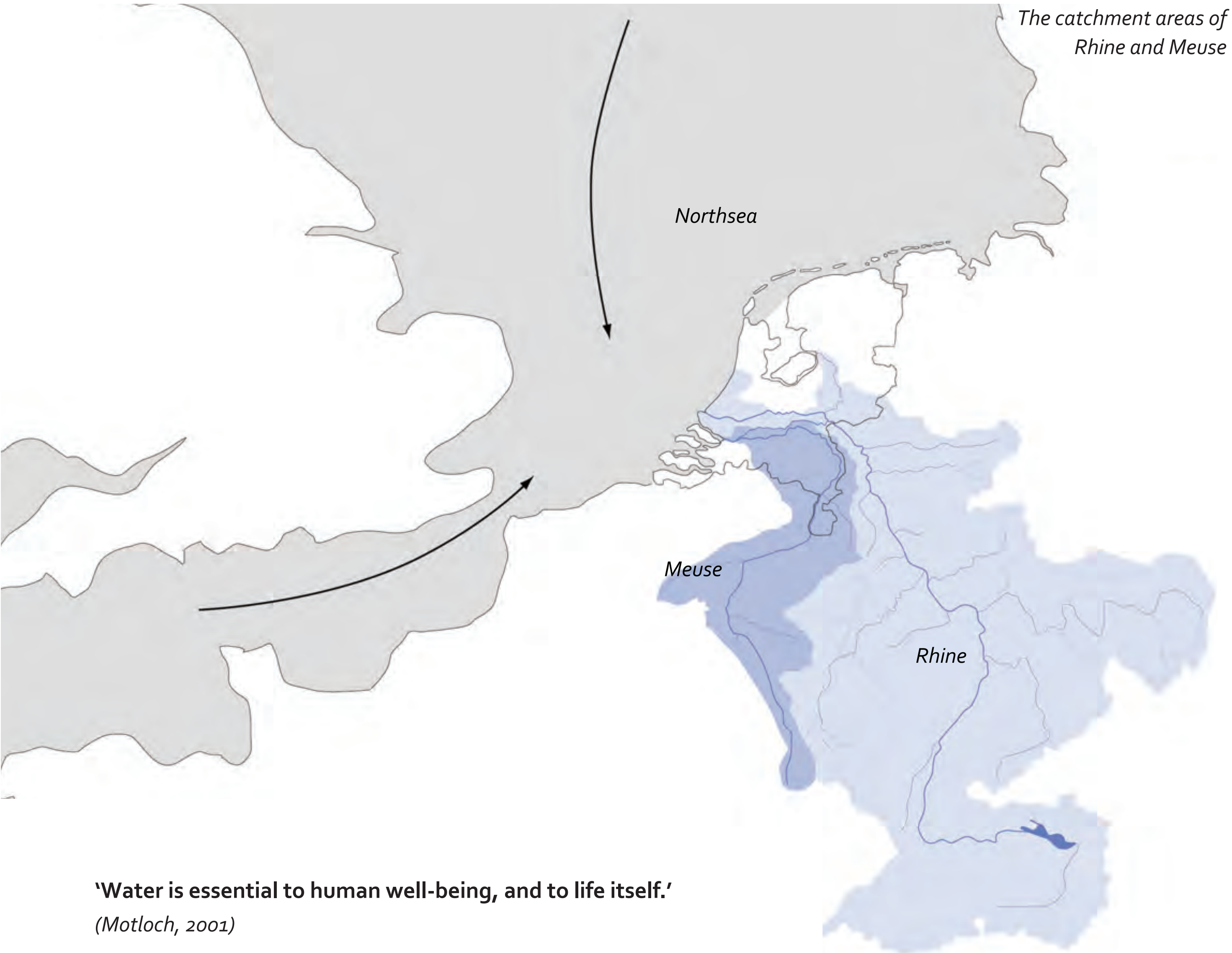
IJsselmonde's landscape development has always been connected to water, and its manipulation. The relation between men and water has changed drastically during the landscape development of IJsselmonde. Once the landscape was a toy of the dynamic water system, today it is a fixed entity dependent on human control. By all men's attempts to increase safety and control over the water, in a thousand years the water system is totally restrained and regulated. The result for the urbanised landscape is great loss in flexibility. The system is not resilient anymore. However, climate and water will always remain dynamic factors...

From the story of the landscape of IJsselmonde can be concluded that a closer look to the functioning of the water system is essential before continuing with a research to the impacts of climate change. Only by knowing exactly how the current water system works and what the existing problems are, it is possible to create a realistic vision for the future...

CHAPTER 4

THE WATER SYSTEM

'Het Waaltje'
(Google Earth - Wim Punt)



The catchment areas of Rhine and Meuse

‘Water is essential to human well-being, and to life itself.’
(Motloch, 2001)

Because the water system of IJsselmonde is a very complex whole, a distinction is made between the principle water system of sea and rivers, the regional water system of the island and the urban water system (de Greef, 2006).

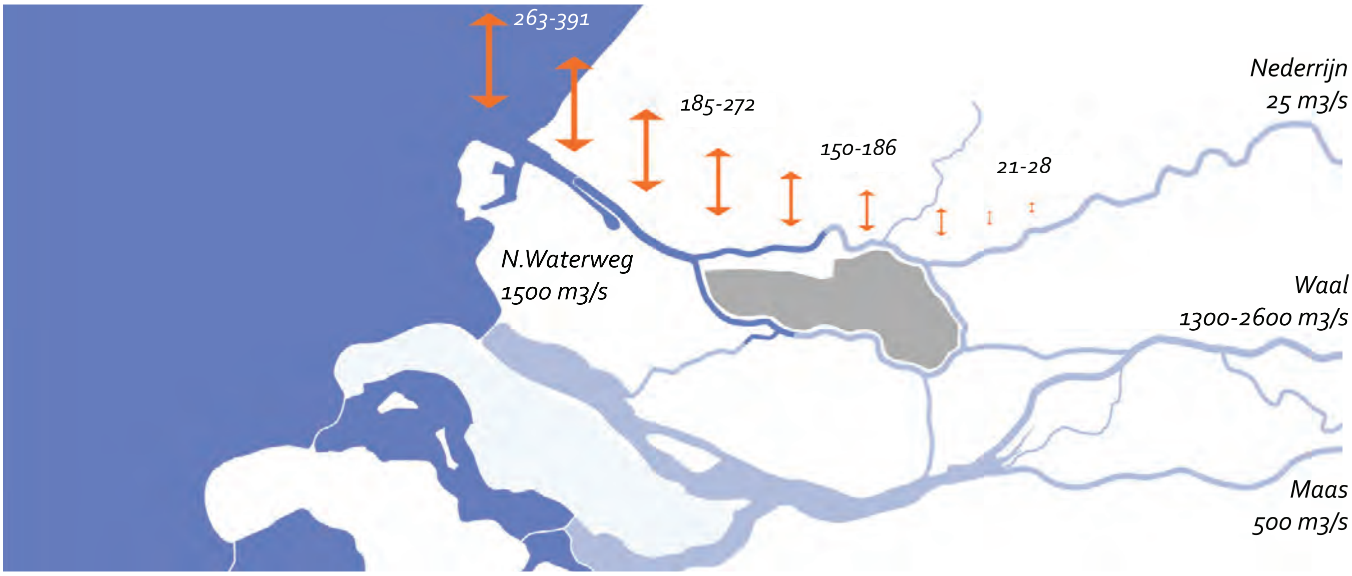
The water system of IJsselmonde is dependent on the principle water system for different reasons. The first reason is that the island is situated below the water level of the principle water system. The level of the water outside the dike-ring is in turn dependent on external processes like rainfall in the mountains or storms on the sea. At high water levels a higher flood risk occurs, however the island is well protected by a delta dike and the storm surge barrier Maeslantkering. Secondly the island depends on the principle water system for the inlet of water. Therefore not only quantity but also the water quality is of major importance.

4.1 THE PRINCIPLE WATER SYSTEM

In the delta around the island IJsselmonde the catchment areas of the rivers Rhine and Meuse flow into the North Sea. The image above shows the catchment areas of Rhine and Meuse.

The hydraulic regimes in the delta are very much dependent on external, upstream processes. The Rhine is mainly fed by ice water from the Alps, and reacts because of that quickly on temperature changes. The Meuse is a rain river, for its water mainly dependent on rainfall in the Belgian Ardennen.

Water levels
IJsselmonde is situated in the downstream part of the delta. The water outside the dike-ring is therefore more



The Island of IJsselmonde is situated between influences of rivers and sea. River discharges from Rhine, Waal and Meuse are described in m3/sec. for an average situation. Tidal influences as well as salt influences from the Northsea decrease land inwards. (levels are tidal differences in cm, for neap tide and spring. the darker blue colour is salt water.)

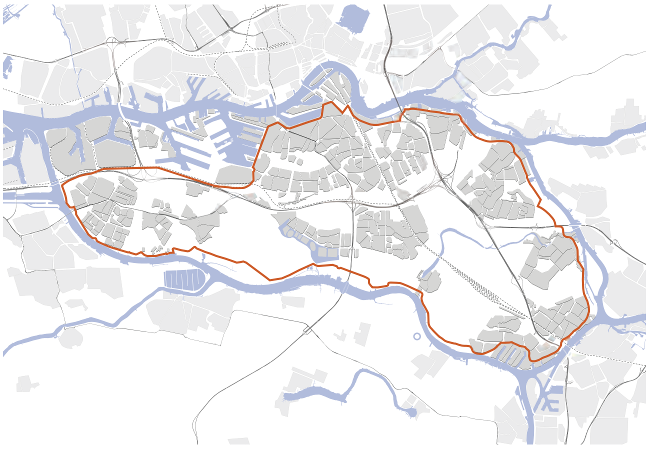
influenced by the sea than by the rivers. The New Meuse at Rotterdam knows an average tidal difference of 1.71 m. The tidal influences decrease land inwards, however the tides are still recognizable at Gorinchem. The twice daily variation between low and high tide, caused by the situation of the sun and the moon, is of crucial importance at spring tide and neap tide. At neap tide the difference between low and high tide is smaller, at spring tide the difference is bigger! As springtide comes together with a south western storm on the North Sea, extremely high water levels occur on the Dutch coast and in the downstream parts of the rivers.

Salt influences

Caused by the influences of the sea water, the water in the downstream part of the rivers is salt. The image on top of this page shows the average transition from salt to fresh water. However, in periods of low river discharges and under the influence of sea level rise this transition shifts further land inwards. This process already causes already problems for the fresh water supply of agriculture and horticulture in the province of South Holland.

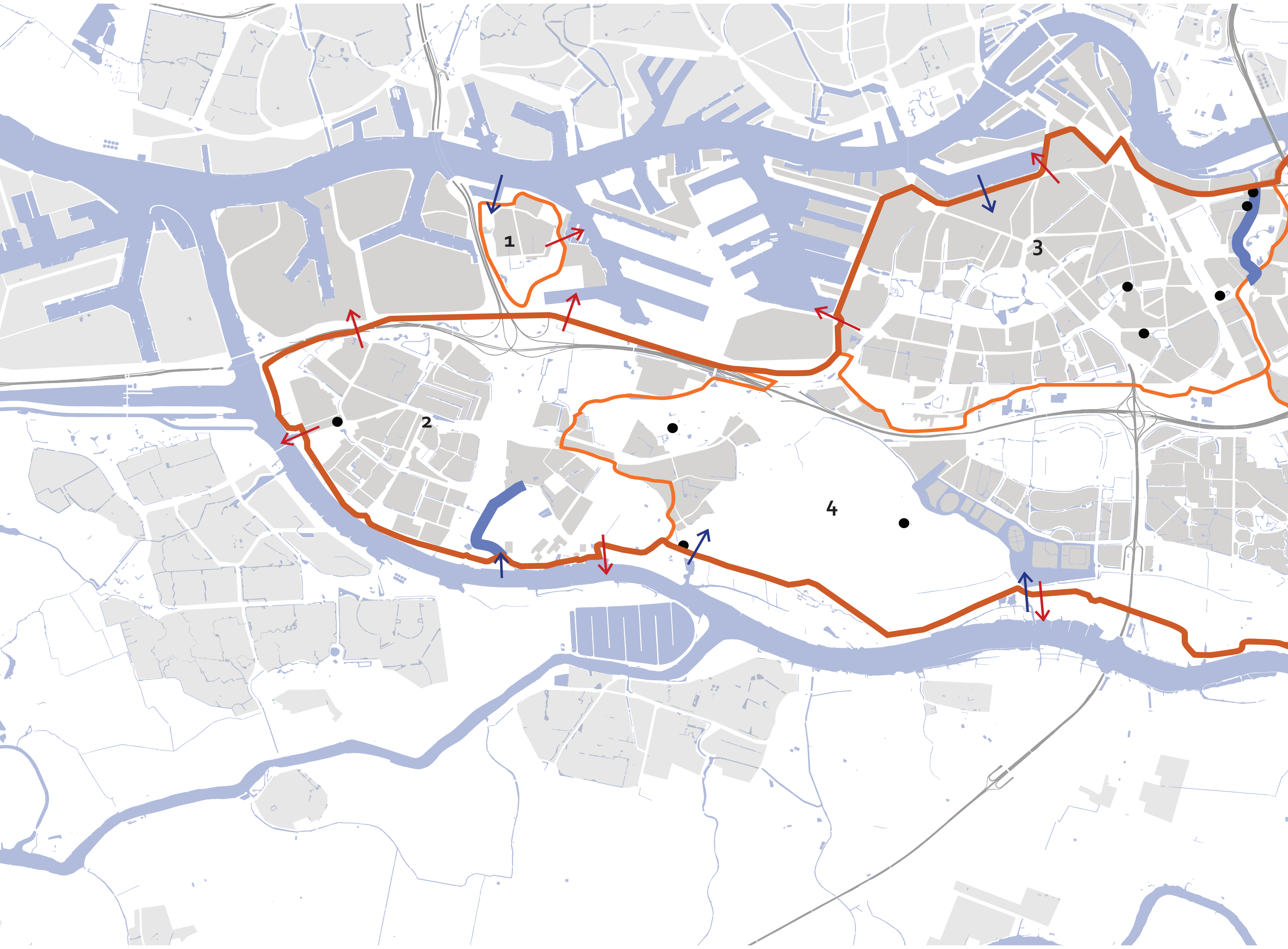
Safety

The island of IJsselmonde is protected by a strong dike-ring of 4,5 to 5 meter +NAP. The height of the dike is calculated on a safety level of 1:10.000, which means a flood risk of 1/10.000. However, when the water level in Rotterdam Centre rises above 3.10 meter +NAP, the New Waterway is closed by the Maeslantkering. This storm surge barrier serves than as an extra protection against the sea with a height of 6.00 meter.



A strong delta dike -ring around the island provides safety

The harbours and industrial areas are outside the dikes. These areas are built on elevated platforms, and because of that dry during high tide. However, with a rising sea level these areas are increasingly fragile for floods.



4.2 THE REGIONAL WATER SYSTEM

IJsselmonde is situated one to two meter below the level of the water outside the dikes and is therefore for its existence dependent on the delta dike-ring surrounding the island. As a result, the water system within the dike-ring is completely artificial and regulated. The natural dynamics of a water system are undesirable, and because of that there is always a situation of either water surplus, or water shortage.

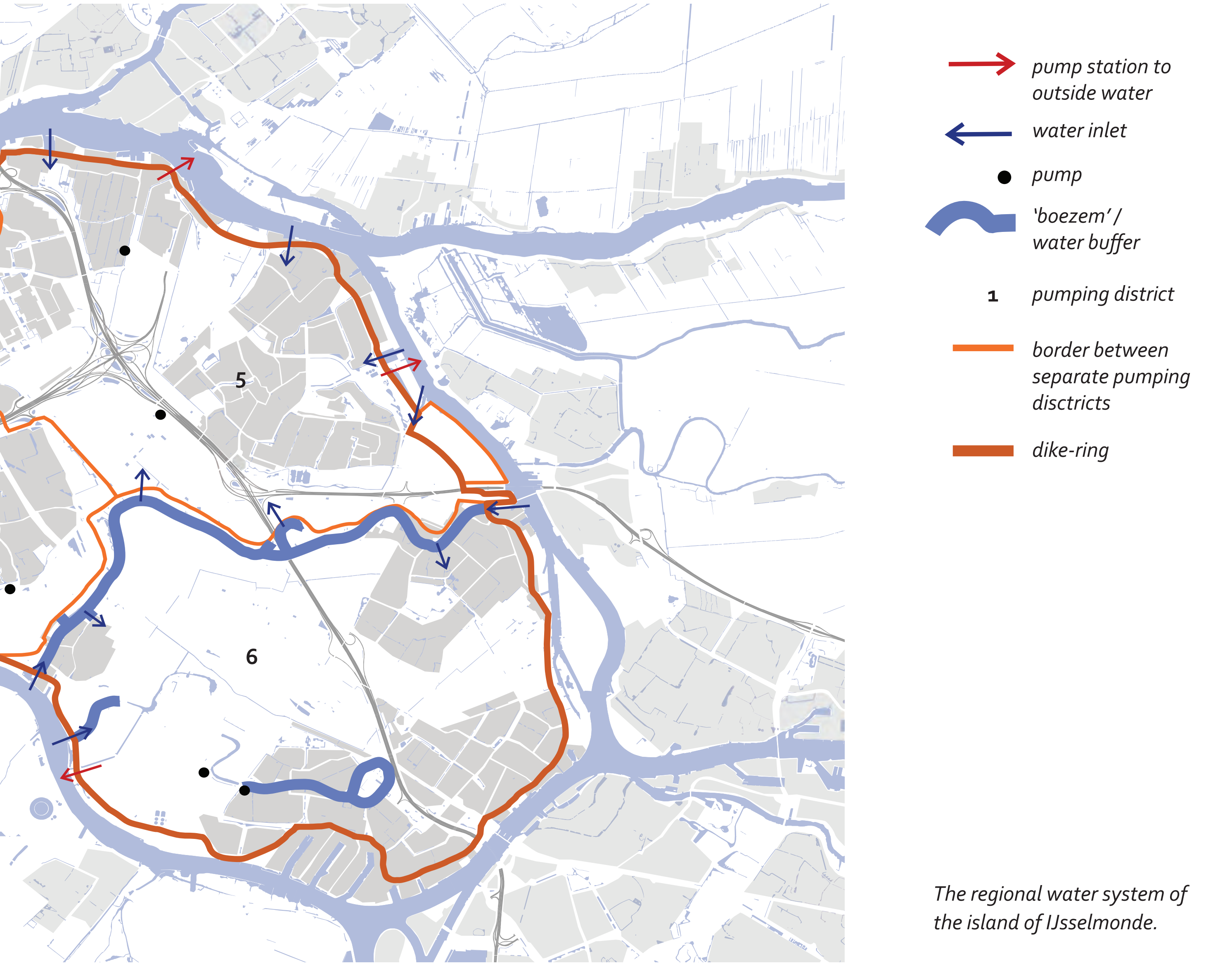
The map shows that IJsselmonde is separated in six different pumping districts. In each district the discharge and inlet of water is managed autonomously. Furthermore the map shows the places where water is pumped out by electrical pumps, the places for inlet, and the delta dike ring. (Waterschap Hollandse Delta, 2009 - personal communication)

Water surplus

For the biggest part of the year the regional water system knows a precipitation surplus, and therefore a water surplus. Especially at extreme rain showers or long periods of rain continuously pumping is necessary. As a result of the low lying land, seepage forms an extra input of water with an average pressure of 0.50 – 0.75 mm / 24h. Because IJsselmonde is an island, the pumped out water can be discharged into the rivers immediately.

Water shortage

In dry periods the evaporation surplus causes quickly a water shortage in the regional water system. This water shortage leads to unhealthy and smelling water, but more important is a lowering ground water level. When the ground water level lowers too much, the dikes can get unstable with an increasing risk of dike burst as a

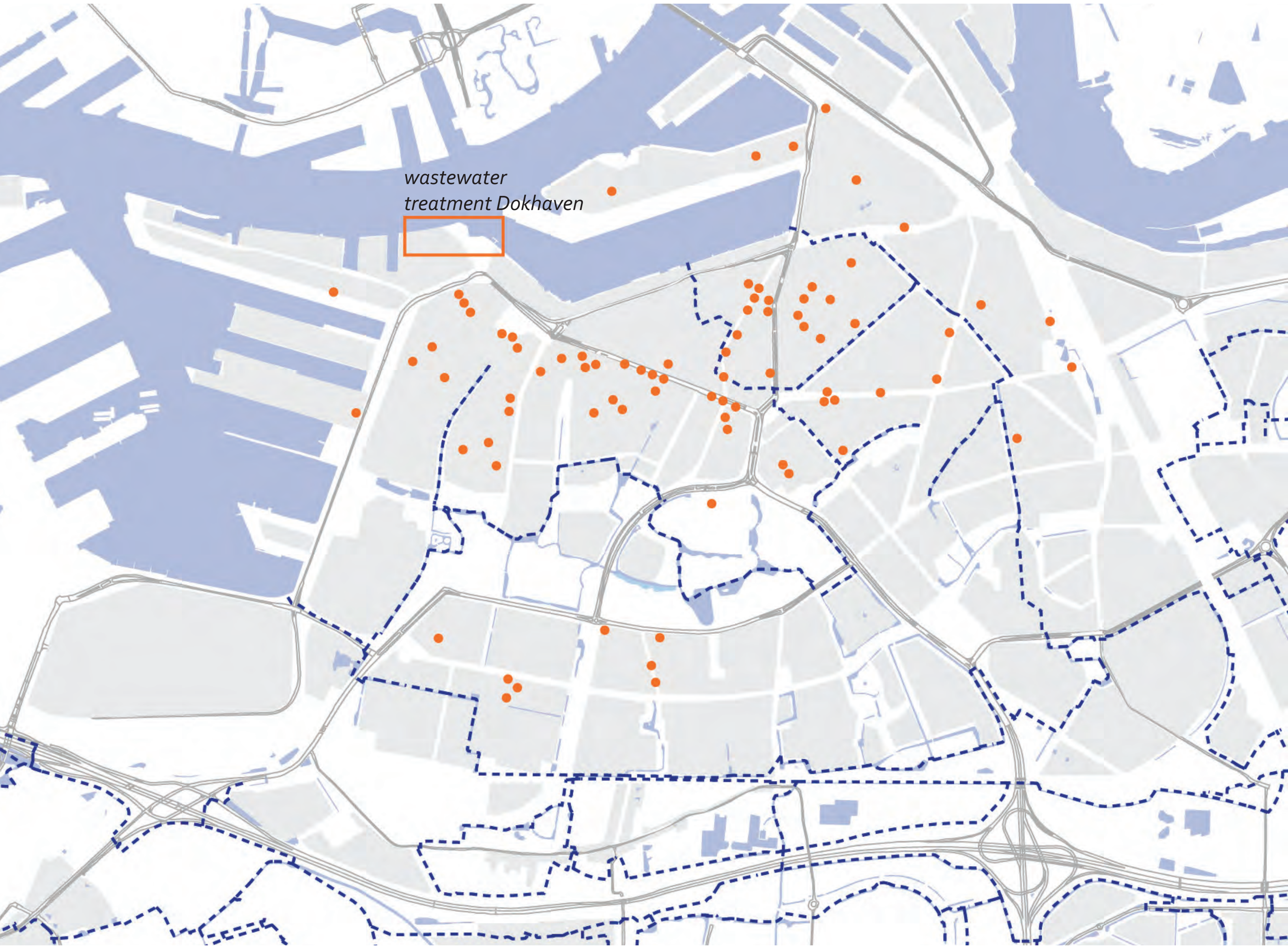


The regional water system of the island of IJsselmonde.

consequence. This process is especially dangerous for dikes built out of peat, like the dike burst in Wilnis in 2003 that was caused by dehydration of the dike. However, also for the dikes of IJsselmonde dehydration can be dangerous and therefore it is of major importance to keep the ground water level on sufficient height (Waterschap Hollandse Delta, 2009 - verbal communication).

In dry periods 'Het Waaltje' in the eastern part of IJsselmonde serves as a substantial fresh water supply. In this water body fresh water is stored during the winter period, and is used for let-in in times of water shortage. The amount of water is not sufficient for the whole island, but can only supply pumping district 6 attached to 'Het Waaltje'. For the biggest part of IJsselmonde inlet water from the river is used. This means relatively polluted water is let in the water system.

Water inlet is done by a siphon system. In times of low river discharges it is not possible to use the siphon system, and in some cases emergency pumps have to be installed to make it still possible to let in water (Waterschap Hollandse Delta, 2009 - verbal communication).



4.3 THE URBAN WATER SYSTEM

The main function of the urban water system is the discharge of wastewater and rainwater. It is a complex whole, where open water and underground waterways intertwine. However, the main part of the urban water system is the underground sewerage system, open water plays a minor role (Rotterdam Municipality, 2007). The discharge of waste- and rain water is dependent on an underground pipe system, mostly dimensioned in the fifties, sixties or seventies, and fixed on discharges from this period. However, current changes and peeks in water supply cause problems for the discharge of water, showing the vulnerability of the system. The interdependence and the complexity of the over- and underground systems makes adaptation to changing circumstances very difficult.

The rain water in the city is collected by drains and street gullies, and discharges via the sewage system. This means that relatively clean rain water is mixed with sewage water and transported to the wastewater treatment plant. On IJsselmonde this is treatment plant Dokhaven, an underground purification plant at the southern bank of the New Meuse. From Dokhaven the purified water is pumped out into the river.

The vulnerability of the water system in the city has to do with the little or no open water in most urban districts. There is little (temporary) storage capacity for rain water. Especially some after-war neighbourhoods in Rotterdam south are for drainage totally dependent on the underground pipe system.
After extreme showers the vulnerability of the system becomes visible. The city has a large amount of paved

Urban water system, over- and underground. It is clearly visible that the city of Rotterdam has only very little open water.

area and roofs, so that rain water can not be stored temporarily in or on the ground, but flows directly into the sewerage system. However, the system has a limited capacity and is not able to process all the water at once. In such cases the water is discharged into the open water of the city via sewage-overflows. Grey water (waste-water mixed with rainwater) flows than into the canals and waterways of the city, which get very polluted. Because most waterways are not connected, there is no circulation and only little refreshment of the water. As a result of high phosphor levels in the water, algae and duckweed are blooming.

Apart from this being a disaster for the water quality, there is a quantitative problem as well. Because there is just a minor amount of surface water, the storage capacity is very limited. After a sewerage overflow the level of the surface water can rise very fast, and results often in water troubles in the city. The map showes reports at the fire departments because of water troubles in 2001 (de Greef, 2006).

In many cities overflow sewerage systems are being transformed into a separated system, whereby rainwater is discharged through a separate pipe without mixing with waste water. A transformation to a separated system is very radical and expensive, and especially in the old neighbourhoods in Rotterdam south hardly possible. A transformation to a separated underground sewerage system in Rotterdam will not be realized (Waterschap Hollandse Delta, 2009 - verbal communication).

In the past Rotterdam had more open surface water, mainly canals. In the 'Singelplan' (canal-plan) of Rose

The urban water system: combined discharge of waste water and rain water with an overflow on the surface water. (Paul Maas, Stichting RIONED Tilburg)

in 1854 Rotterdam is built up from a system of canals, which made the surface water the basis for the urban water system. The system was based on regular sluicing with river water from the New Meuse. Fresh water was let in the city, and pumped out into the river again from a place more downstream.
Over the years, most canals have been filled up to make space for buildings or car roads. As a consequence, the water system is shifted to the underground, and became with that less and less resilient.

4.4 CONCLUSION

The water system of island IJsselmonde is managed according to the Dutch 'polder system': In winter time the relatively clean excess water is pumped out into the rivers. In summer time the water shortage is solved by the inlet of relatively polluted water from the principle water system. The once self-regulating water system is now totally dependent on artificial management. There is only little surface water, and with that hardly any buffer capacity for water, resulting in many problems in periods of extremely much or extremely little water. If the system can not cope with the natural circumstances today, how can it cope with it in the future? And how does this relate to climate change?

Water problems in the centre of Rotterdam
17 March 2009 (www.nu.nl)

CHAPTER 5

CLIMATE CHANGE

Our climate is changing. Sea level is rising, winters are becoming wetter, summers are becoming drier, rain will more often come down in extreme showers. Moreover, the discharge of the big rivers Rhine and Meuse will change. Expected are an increasing winter discharge, and a decreasing discharge in summer.

Chapter 3 about the (historical) landscape development of IJsselmonde showed that the climate in western Europe has been changing a lot of times in the past hundred thousand years. It is a natural phenomenon. The current global warming however has a human cause, that is practically undisputed. “The biggest part of the increasing of the global average temperature since the mid twentieth century is ‘very likely’ caused by the increasing of anthropogenic greenhouse gasses.” (Dorland & Jansen (red.), 2007). ‘Very likely’ has according to the probability terminology defined by IPCC (Intergovernmental Panel on Climate Change) a probability of >90%.

The current climate change differs from ‘natural’ climatic changes in time scale. The past climate changes described in chapter 2 were long term changes, they took thousands of years. The current changes seem to take place in a relative short term, impacts are visible in ten to hundred years!

The foregoing chapters expressed that human being has ever been fixating the water system, and that less flexibility in the system is left to cope with natural dynamics. The process of restricting the current water system started in the Middle Ages already, and is predominantly focused on climatic circumstances, water levels and land use from former times. Especially the civil engineering approach of the past fifty years determined the current situation for the larger part. Without a thousand years of human interference, the Netherlands would look totally different. Rivers would be broader, the coastline would be somewhere around Utrecht. Now the climate is starting to change, the consequences of our operations are starting to stand out.

5.1 DEALING WITH CLIMATE CHANGE

To deal with climate change, different strategies can be applied. Anyhow, dealing with uncertainty plays a mayor role.

5.1.1 Uncertainty

Apparently the current climate change has a human cause, that is very likely. But to which extend the changes are going to happen is very unclear. The climate system is so complex that predictions can never be done with 100% accuracy.

On the one hand this is caused by incomplete knowledge of the complex processes of the climate system, incomplete measurements and the limitation of climate models. On the other hand uncertainty about climate change is caused by uncertainty about future emission of greenhouse gasses, which is is turn related to future development as population growth, and economical, social and technological developments.

To deal with uncertainty, the KNMI (Royal Dutch Meteorological Institute) has developed four climate scenarios. The four scenarios together form a base of probability. Common characteristics of the four scenarios are:

- Temperature will continue to rise. Mild winters and hot summers will become more common;

- on average, winters will become wetter and extreme precipitation amounts will increase;

- the intensity of extreme rain showers in summer will increase, however the number of rainy days in summer will decrease;

- the calculated change in wind is small compared to the natural fluctuations;

- the sea level will continue to rise.

(KNM, 2006)

5.1.2 Anticipation

Anticipation on climate change is twofold. On the one hand we have to deal with the causes of climate change, that is mitigation. Mitigation means to reduce the emission of greenhouse gasses as much as possible, for example by using renewable energy. On the other hand it is essential to prepare for the consequences of climate change, this is adaptation (Dessai & van der Sluijs, 2007). Global warming has impacts on our living environment, and these impacts will increase the next decades, with or without mitigation. Oceans and ice caps react slow on changes in the atmosphere, through which sea level will continue to rise for hundreds of years.

Though we are unsure of the extent to which climate is changing, we know for sure that it will change. Climate effects will continue to increase, even if we stopped the output of greenhouse gasses today.

The objective of this thesis is to research the possibilities of adaptation, that is to adapt the landscape the consequences of climate change. Therefore this chapter will mainly deal with the consequences of climate change on the landscape and the city. For processes behind the causes of climate change will be referred to the reports of IPCC and KNMI.

5.1.3 climate scenarios KNMI '06

To deal with uncertainty about future changes, the KNMI produced new climate scenarios for the Netherlands in may 2006, called KNMI '06. These scenarios are consistent and plausible images of a possible future climate. The scenarios do not show every possible development, but show a certain margin in which the future climate will probably develop.

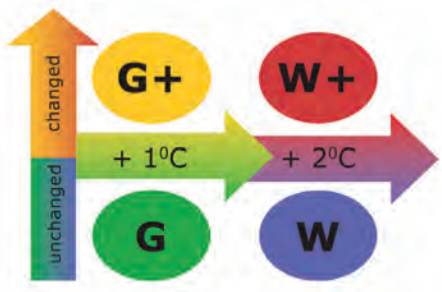
The four KNMI scenarios are developed on the basis of different degrees of temperature rise, and with or without the occurrence of changes in air circulation patterns. These principles lead to four combinations, four scenarios: G, G+, W and W+.

The occurrence of changing air circulation patterns is presented by a + behind the character.

A summary of the KNMI '06 scenarios is included in appendix 2.

The KNMI presents the KNMI '06 scenarios as follows:

Air circulation patterns



Global temterature in 2050 compared to 1990

G *(average)*
1 °C temperature rise on earth in 2050 compared to 1990
No change in air circulation patterns in Europe

G+ *(average, with changes in air circulation patterns)*
1 °C temperature rise on earth in 2050 compared to 1990
+ milder and wetter winters due to more westerly winds
+ warmer and dryer summers due to more easterly winds

W *(warm)*
2 °C temperature rise on earth in 2050 compared to 1990
No change in air circulation patterns in Europe

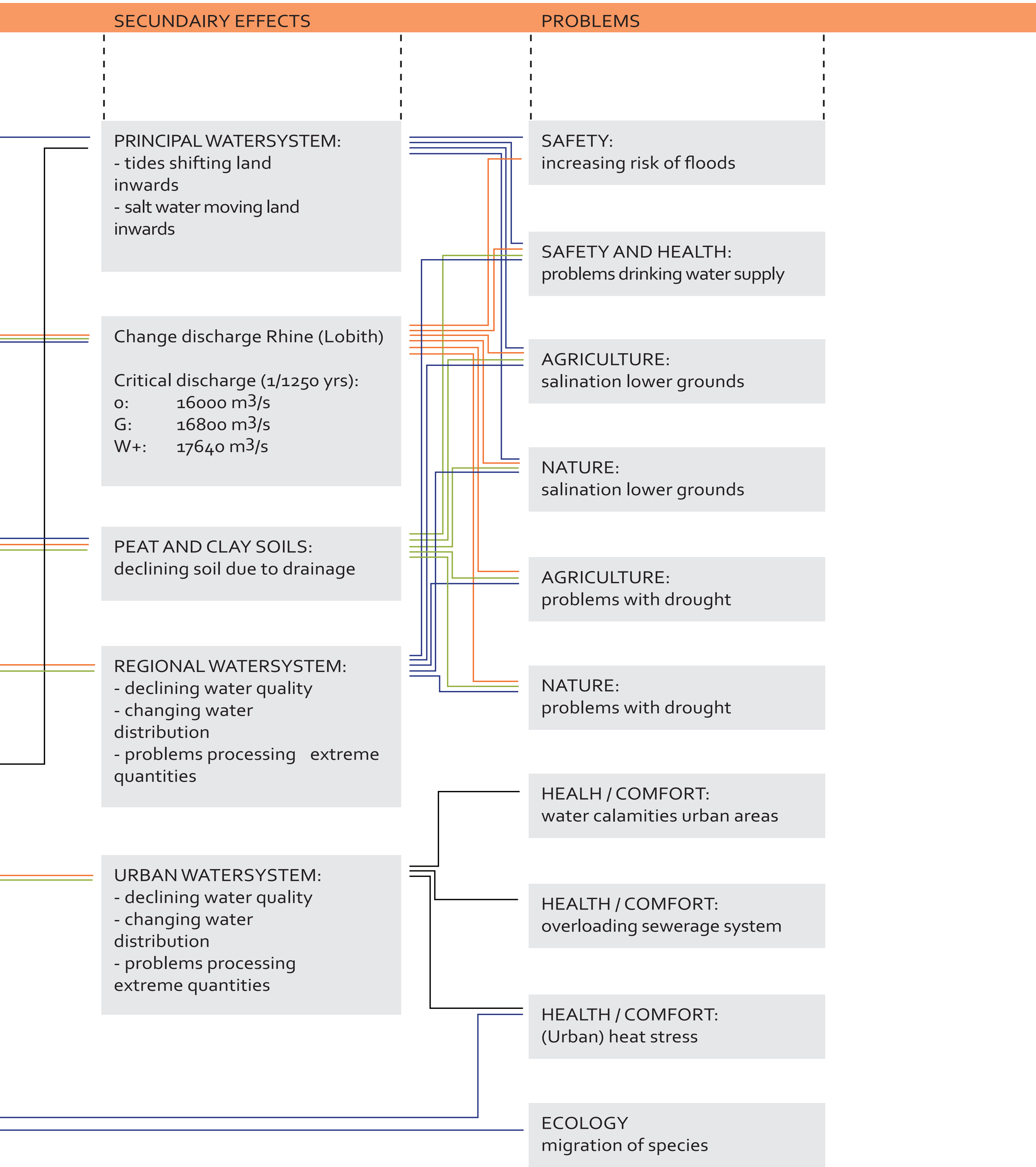
W+ *(warm, with changes in air circulation patterns)*
2 °C temperature rise on earth in 2050 compared to 1990
+ milder and wetter winters due to more westerly winds
+ warmer and dryer summers due to more easterly winds

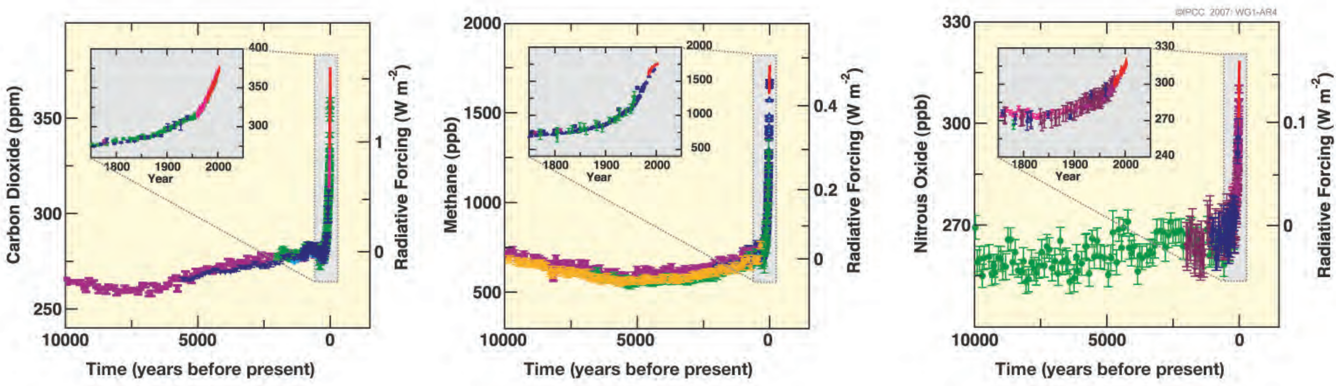
In this thesis, the W / W+ scenarios will be used as a starting point, with focus on 2050. The choice for the most extreme side of the range is made because in this thesis climate change will be the basis of spatial adaptation landscape and city, which are long term processes. As the graph above shows, the W scenarios in 2050 are equal to the G scenarios in 2100. That means the factor time can be seen the variable factor. Plans will be made for the extreme W scenarios in 2050, if the climate turn out to change less quick, this results into more time for implementation: 'Prepare for the worst, hope for the best.'

5.2 THE IMPACTS OF CLIMATE CHANGE

CAUSE	CONSEQUENCE	PRIMARY EFFECTS
Emission Greenhouse gases: - Carbon Dioxide - Methane - Nitrons Oxide	Temperature rise G: +1°C W+: +2°C	Sea level rise G: 15-25cm W+: 20-35cm
		Precipitation More and more extreme showers expected G: +4% winter +3% summer W+: +14% winter -19% summer
		Potential evaporation G: equal W+: +8/+15%
		Wind storms G: no change W+: slightly increasing No significant changes

Consequences, effects and problems resulting from climate change. The scheme is specific for the Dutch south western delta region, based on KNMI '06 expectations for 2050


SECUNDAIRY EFFECTS
PROBLEMS
PRINCIPAL WATERSYSTEM:
- tides shifting land inwards
- salt water moving land inwards
Change discharge Rhine (Lobith)
Critical discharge (1/1250 yrs):
0: 16000 m3/s
G: 16800 m3/s
W+: 17640 m3/s
PEAT AND CLAY SOILS:
declining soil due to drainage
REGIONAL WATERSYSTEM:
- declining water quality
- changing water distribution
- problems processing extreme quantities
URBAN WATERSYSTEM:
- declining water quality
- changing water distribution
- problems processing extreme quantities
SAFETY:
increasing risk of floods
SAFETY AND HEALTH:
problems drinking water supply
AGRICULTURE:
salination lower grounds
NATURE:
salination lower grounds
AGRICULTURE:
problems with drought
NATURE:
problems with drought
HEALH / COMFORT:
water calamities urban areas
HEALTH / COMFORT:
overloading sewerage system
HEALTH / COMFORT:
(Urban) heat stress
ECOLOGY
migration of species



5.2.1 Emission of greenhouse gasses

Since the industrial revolution the emission of CO2 and greenhouse gasses has been increasing enormously. It is proofed that the emission effects global warming.

"The global atmospheric concentrations of carbon dioxide, methane and nitrous oxide are clearly have been increasing as a consequence of human activities since 1750 and exeed to a large extend the pre-industrial values as determined from ice observations of the last many thousands of years. The global increase of carbon dioxide is mainly the consequence of the use of fossil fuel and changing land use, the global increase of methane and nitrous oxide is mainly caused by agriculture." (IPCC 2007)

The graphs below show the explosive increase of carbon dioxide, methane and nitrous oxide:

The concentration of carbon dioxide in the atmosphere is increased from 280 ppm (parts per million) in 1750 to 379 ppm in 2005.
The concentration of methane in the atmosphere is increased from 715 ppb (parts per billion) in 1750 to 1774 ppb in 2005.
The concentration of nitrous oxide in the atmosphere is increased from 270 ppb in 1750 to 319 ppb in 2005.

5.2.2 Temperature rise

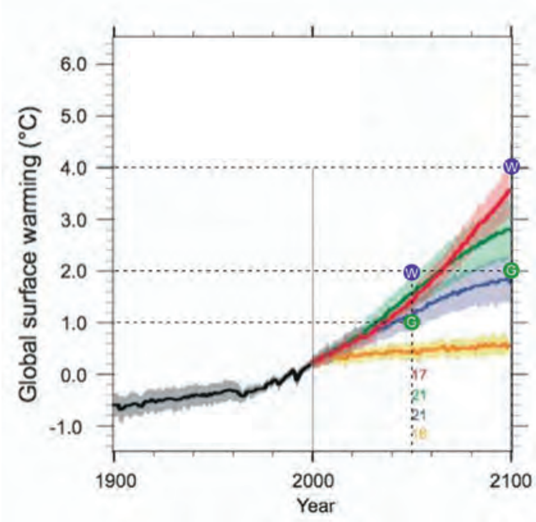
The KNMI predicts for the Netherlands a temperature rise of 1 – 2 degrees in 2050, and 2 – 4 degrees in 2100.
Temperature rise depends not only on the global emission of green house gasses, but also on changes in atmospheric circulation like the direction of the wind. Therefore changes in temperature are not equal on the World. The temperature in the Netherlands has been rising faster than the average temperature on the World.

As the scheme on the former page shows, global temperature rise has impact on sea level rise, changing precipitation patterns and changing River discharges. Next to these indirect consequences of temperature rise, problems with warmth as a direct consequence increase.

5.2.3 Sea level rise

The KNMI predicts for the Netherlands a sea level rise of 15 – 35 cm in 2050, and 35 – 85 cm in 2100.
The sea level reacts on temperature rise as a consequence of the expansion of the water, the melting of the glacier and small icecaps, and the sinking of the big icecaps on Greenland and Antarctica.

The KNMI and the IPCC use the same models for predictions about sea level rise. Still they do different predictions. The IPCC calculates a global sea level rise during the 21st century of 18 to 59 cm compared to 1990. KNMI predicts for the Netherlands a sea level rise of 35 – 85 cm in 2100 compared to 1990, as mentioned above. The differences are derived from the calculation of two extra effects. First effect is the accelerated melting of the edges of the icecaps of Greenland and the west-Antarctica icecap, observed between 1993 and 2005. IPCC does not include this information in its scenarios. KNMI does take this extra rising into account in its KNMI '06 scenarios because of the significant importance of



The global temperature rise calculated by IPCC. KNMI and IPCC based their predictions about temperature rise on the same sources.

To show the relation, the KNMI scenarios for 2050 and 2100 are added to the figure on the left. This figure shows only temperature rise, which means that G stands for G as well as for G+, and W stands for W as well as W+.

sea level rise for the Netherlands.
The second difference comes from the effect of regional expansion of sea water,

The second difference it that the KNMI does include the regional effect of expansion of sea water. Climate models pronounce a slow decreasing of the warm golf stream in the 21st century. Due to that the current difference in level of 60 cm between the equator and the north east of the Atlantic ocean will slowly disappear, and cause an extra sea level rise at the Netherlands of 0 – 15 cm.

The most extreme situations are not included in the KNMI scenarios. Scenarios exist in which the sea level rises with 1.5 m in 2100. On the long run the possibility exists of total melting of the Greenland icecap, which will cause 6 – 7 meters of sea level rise. According to IPCC, this process will take a few ages till thousands of years.
The relative sea level rise in the Netherlands is bigger as a consequence of oxidation of peat areas and subsidence of the (clay) ground.

5.2.4 Precipitation

In the next century the amount of precipitation will increase with 4-14%, and more extreme rain showers will be common. Moreover, the + scenarios of KNMI '06 predict drought in summers in the Netherlands (towards 19% less precipitation in summer).

The increasing of extremes will have direct consequences for water discharges in the Netherlands. KNMI '06 predicts an increasing of 4-14% of periods with a lot of rain, like the extreme 10-days winter precipitation. This scenario directly leads to increasing Rhine discharges and consequently higher water in the delta. But also on local level, especially in urban areas, peek discharges will cause problems.

5.2.5 Changing River discharges

The predictions about future River discharges show a clear image. Winter discharges will increase and, particularly for the Rhine, summer discharges will decrease. The average winter discharge of the Rhine is currently 2900 m3/s, and will increase towards 3090 – 3400 m3/sec in 2050. The summer discharge of 1600 m3/s will decrease in the W+ scenario to only 1030 m3/s in 2050 (RIZA, 2007). However, to determine the safety level, more important than the average discharge is the critical discharge. The critical discharge is the maximum discharge on which the height of the dikes is calculated. In the Dutch regulation on dikes (Wet op de waterkeringen) is determined that we accept a change of 1/1250 that an higher discharge than the critical discharge occurs. The current critical discharge for the Rhine is 16000 m3/s.

With an increasing discharge, the critical discharge will have to be raised as well. In Deltaplan 2 the advise is a critical discharge for the Rhine of 18000 m3/s in 2100 (Veerman, 2008). To prepare for a higher critical discharge, means to increase the discharge capacity of the river. Such developments are expensive and often radical interventions, because the river basis is tied up between dikes, carrying infrastructure and houses.

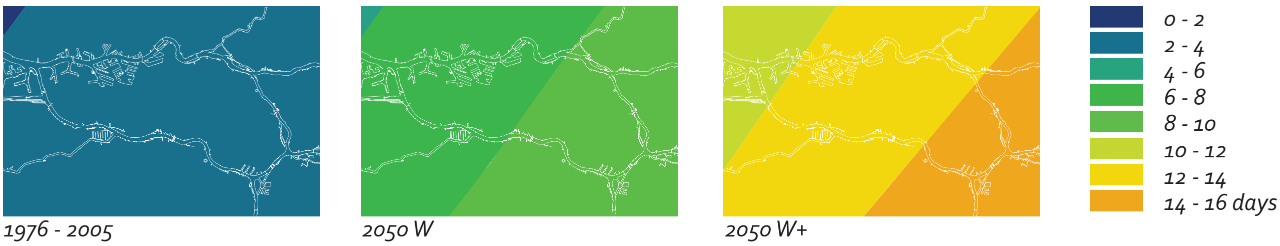
5.3 SECONDARY EFFECTS: CONSEQUENCES FOR THE ISLAND IJSSELMONDE

"Global climate change would disturb the Earth's physical systems and ecosystems; these disturbances, in turn, would pose direct and indirect risks to human health."

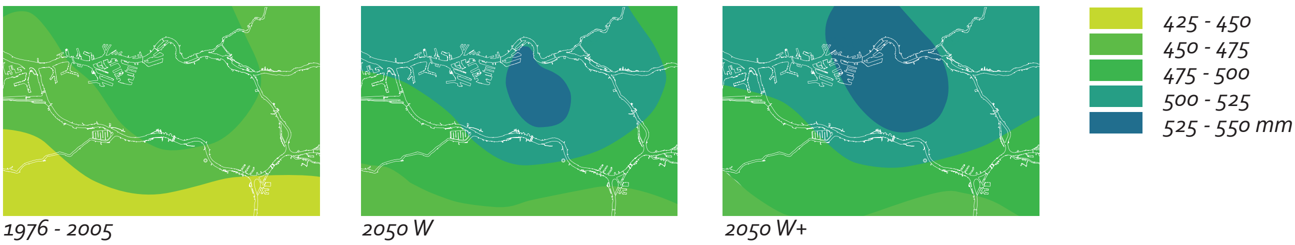
(Cohen & Miller, 2001)

In the section on the page on the right the consequences of climate change for the island of IJsselmonde are presented. Almost all effects for this urban landscape in the delta concern water. From four sides the area has to deal with a future change of water inflow. This situation is different for summer and winter periods. In wintertime the water surplus will increase, in summertime the water shortage will increase.
The figures below show the consequences of the KNMI climate scenarios for the area of IJsselmonde, and compare the situation of today (1976-2005) and the situation in 2050. The KNMI '06 scenarios W and W+ are worked out. The figures are made on the basis of information on climate effects on the province of South Holland (Province of South Holland, 2008)

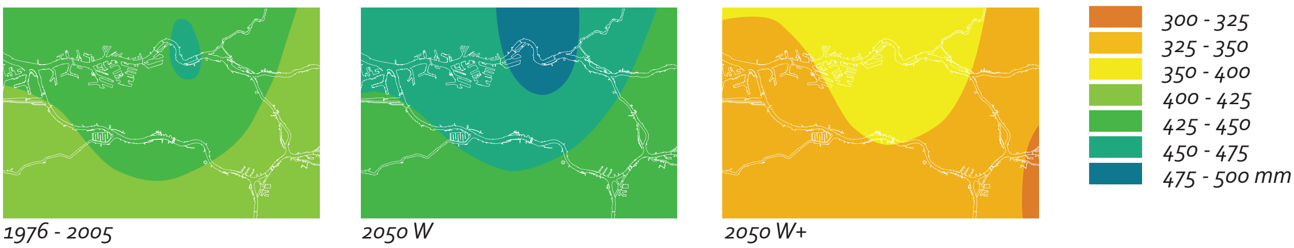
Tropical days / year



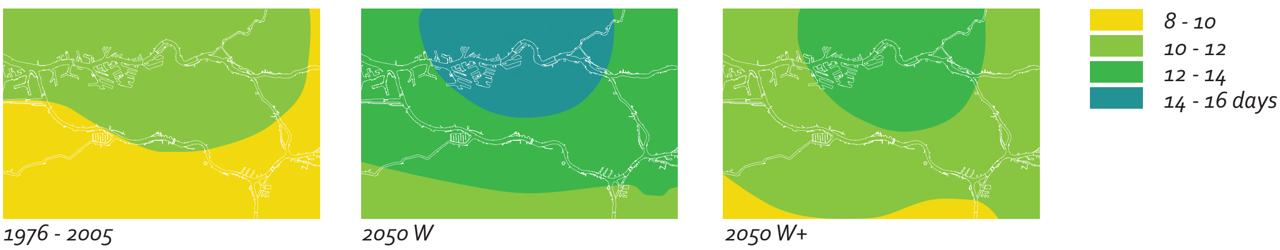
Average precipitation winter half-year

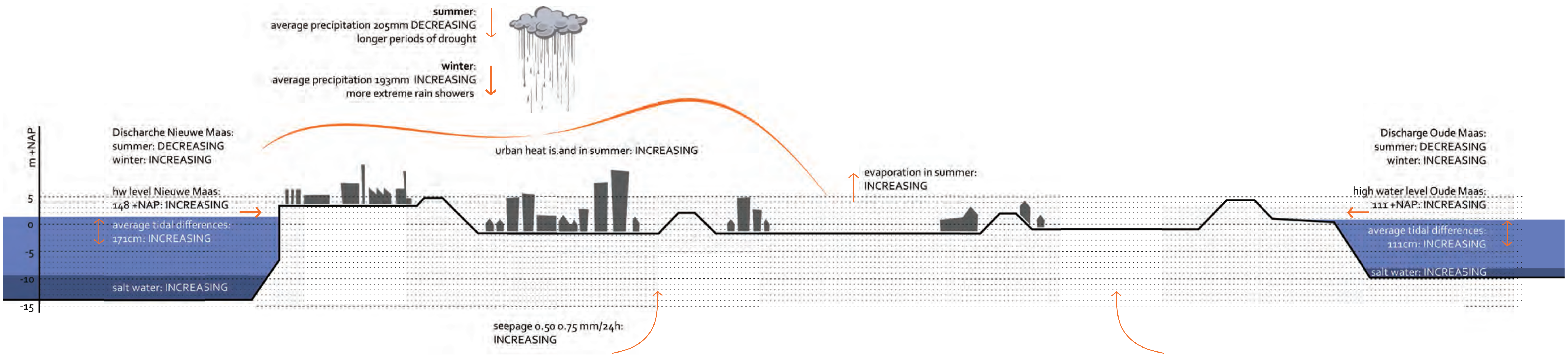


Average precipitation summer half-year



Extreme precipitation: >15mm / day




summer:
average precipitation 205mm DECREASING
longer periods of drought
winter:
average precipitation 193mm INCREASING
more extreme rain showers
m +NAP
Discharche Nieuwe Maas:
summer: DECREASING
winter: INCREASING
urban heat is and in summer: INCREASING
evaporation in summer:
INCREASING
Discharge Oude Maas:
summer: DECREASING
winter: INCREASING
hw level Nieuwe Maas:
148 +NAP: INCREASING
high water level Oude Maas:
111 +NAP: INCREASING
average tidal differences:
171cm: INCREASING
average tidal differences:
111cm: INCREASING
salt water: INCREASING
salt water: INCREASING
5
0
-5
-10
-15
seepage 0.50 0.75 mm/24h:
INCREASING

5.3.1 Higher water levels outside the diked area

The section on the former page shows that, in 2050, the average water level around island IJsselmonde will be 15 – 35 cm higher due to sea level rise. Next to this there will be higher peek discharges of the Rhine, mainly in wintertime. When extra high seal levels due to western storm and springtide occur in combination with extremely high river discharges, this will lead to a raising water level at the place where river and sea meet. Island IJsselmonde is situated at this place, where the urban landscape of Rotterdam turned the river area into a bottleneck for the water. Congestion of the water due to wind will raise the water level even higher.

Due to this process the risk of flooding increases. Although the chance of a dike breach is small (IJsselmonde has a strong dike ring with a safety level of 1:10000 and the protection of the Maeslantkering and the Hartelkering), the possible consequences of a flood are disastrous. The calculated damage as a consequence of a flood in IJsselmonde in huge. The dike-ring IJsselmonde has a damage calculation of 20,2 billion Euro, which is the fourth highest damage calculation of all 53 dike-rings in the Netherlands (MNP, 2007).

The risk of flooding increases when the above described circumstances of the combination of western storm and high river discharges occur. When the Nieuwe Maas in Rotterdam centre reaches the level of 3.10m +NAP, the Maeslantkering will be closed. This storm barrier reduces the impact of western storm from the sea significantly. On the other hand it closes the connection between river and sea and therefore stops the Rhine from discharging its water. Long lasting storms in combination with high river discharges will than still lead to ever increasing water levels around IJsselmonde. When the Maeslantkering is not closed or not working, high water levels around IJsselmonde occur due to sea influence. In short, there are two dangerous situations:

1: High sea level: Maeslantkering open. Result: high water level around IJsselmonde caused by sea

2: High sea level + high river discharges: Maeslantkering closed. Result: high water levels around IJsselmonde caused by rivers.
(Theunissen, 2006)

5.3.2 Water surplus problems inside the diked area

In combination with extreme rain showers there will be difficulties with pumping the water out of the dike ring. Especially in urban areas with high percentages of paved surface high amounts of water can be problematic.

The water system of IJsselmonde is mainly situated underground, and there is very little surface water in the city. The water system is lead through drainage tubes with a fixed width, and results therefore in a system that is not flexible. It is designed for a certain amount of water discharge, without taking into account possible future changes in the inflow of water (see paragraph 4.3, the urban water system).

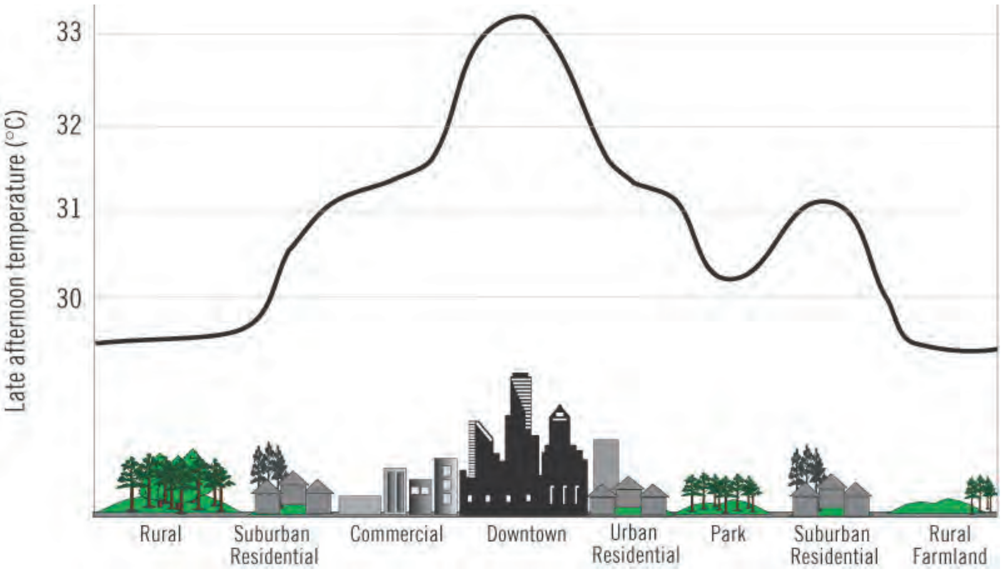
The sewage system is not able to cope with extreme rain showers, and overflows sometimes. The graphs on the previous page show that the amount of days with extreme rainfall will increase with two to four days per year in 2050 (two days extra for scenario W and four days extra for scenario W+). This will increasingly cause problems with discharging rainwater out of the urban tissue, with more often overflowing sewage system as a consequence.

5.3.3 Water shortage problems

Next to the water-surplus problems, there will be a water shortage problem in dry summer periods. The Rhine discharge possible decreases from 1600 m3/sec today to 1030 m3/sec in 2050 (RIZA, 2007), evaporation will increase with 3 – 15%, and precipitation in summer will decrease with a maximum of 19% (KNMI, 2006).

A lack of fresh water will cause problems for agriculture as well as for the city. A lack of fresh water in the (urban) water system leads to unhealthy and unsafe situations. Firstly, fresh water provides life for plants, animals and humans. Secondly, the urban tissue is built upon a fixed ground water level. Too much declining of the groundwater level will have instability for houses and dikes as a consequence (see chapter 4).

Today the water system is based on water inlet from the surrounding rivers in dry periods. The inlet of water works by means of a siphon system. At times of low river discharges and consequently low water levels in the head system, the siphon system does not work. Even today this results in problems with the inlet of water.



The urban heat island effect

(Climate Change Impacts and Adaptation: A Canadian Perspective - www.nrcan.gc.ca)

will increase in the future, when Rhine discharges will decrease during summer as a consequence of changing precipitation patterns.

A different threat for the inlet of water from the river is the eastwards moving salt water. With lower summer discharges, the Rhine will not have enough power to push away the salt water out of Rotterdam. The climate scenarios for 2050 show that the sea influence will move land inwards. In periods with a low river discharge, and a higher sea level, the salt sea water will reach up to Dordrecht and beyond! The inlet of fresh water from the Maas into island IJsselmonde will than not be possible. In combination with long periods of tropical days this can result in serious problems with drought and heat.

5.3.4 Heat

"Extreme warmth can lead to an increase of health problems like dehydration, fatigue, concentration- and respiration problems, sleeping problems and allergies. (…) In 2003 and 2006 in the Netherlands, between 1000 and 2200 people extra died as a consequence of heat waves, compared to an average year."
(Kuypers, 2008)

The problem occurs in urban areas like IJsselmonde, where temperatures happen to be more than ten degrees higher than in rural areas. This is caused by the concentration of traffic, and by the absorption of warmth by dark and paved surfaces, like buildings, roofs and asphalt. Because of this cities absorb during the day more warmth than they can discharge during the night. This results in an urban heat island above the city.

Solutions for the heat island effect can be found in as well the architecture and materials of buildings, which means buildings are made less warmth absorbing, as in the morphology of the city. This means the urban structure is adapted is a way it provides more coolness. Possibilities are extending the surface of open water in the city, stimulating the inflow of fresh wind and air circulation, and providing more green space in the city.

Green in the city partly takes away the warmth absorbing effect. Trees and shrubs influence temperature by providing shade and by evaporation through its leaves. Cool, underground extracted moisture is brought into the atmosphere. As a consequence the humidity raises through which the temperature under the foliage drops. Different researches prove that trees in the city can reduce the temperature with five to twenty degrees.

Rotterdam is vulnerable for urban heat, due to high concentrations of buildings and paved areas. Green space in the city is concentrated in a few large parks like the Zuiderpark. Most neighbourhoods have a lack of green.

5.4 CONCLUSION

The main conclusion of this chapter about climate change, is that all existing problems concerning the water system will increase in the future. That means:

Due to sea level rise the water outside the dike-ring of IJsselmonde will rise. Pumping out will be more difficult in the future. Salt influences will move land inwards, which will make the inlet of water more difficult because of water quality reasons.

River discharges will change. More water will be discharged in winter time, and less water will be discharged in summertime. This makes pumping and letting in water more difficult, and it intensifies the effect of salt influences from the sea during low river discharges.

The distribution and intensity of precipitation will change. Less precipitation in summer will increase water shortage problems, while more precipitation in winter will increase water surplus problems. More extreme rainfall will especially increase the load on the urban water system and with that lead to a more often overflowing sewage system.

CHAPTER 6

DESIGN GOALS IJSSELMONDE 2050

Erasmus Bridge Rotterdam
(Pieter Musterd - www.flickr.com)

In the foregoing chapters it became clear that IJsselmonde already has a lot of problems, especially problems concerning the water system. It also became clear that the problems consider in particular the urban area of IJsselmonde, that is Rotterdam south. Chapter 5 explained that the current problems of IJsselmonde will increase with climate change. In the foregoing part I the research questions 1 and 2 are answered. Part II will go into research question 3:

'Which adaptations of the landscape are necessary to solve the existing problems and to prepare for climate change?'

6.1 SUMMARY OF EXISTING PROBLEMS

Below the existing problems, and the main impacts of climate change that can be concluded from the three foregoing chapters will be shortly summarised:

1 Urbanisation
In the past thousands of years the island of IJsselmonde is transformed from a natural, dynamic delta system into an urban landscape, regulated by men. The relation between man and water has been changing drastically, from a situation in which man accepted and adjusted to the natural system, to a situation in which men manipulated the natural system. As a result of this development, the water system is totally restrained and fixed, and the landscape of IJsselmonde is hardened and urbanized. The resilience disappeared out of the landscape and the water system, which leaves the area not flexible for changes in the water system.

2 The water system
On each level of the water system significant problems exist. Island IJsselmonde is for the management of its water system for the larger part dependent on the principle system, that is the river Rhine flowing into the sea. Nowadays, the (clean) water surplus is pumped out into the river, while (polluted) water is let in from the river in times of water shortage. This water management is problematic, because pumping out is difficult at high water levels in the river, while letting in is problematic at low water levels in the river. Next to quantitative problems, there is a qualitative problem because salt water from the North sea reaches Rotterdam. Salt inlet water would be inconceivable, and a disaster for agriculture and nature.
In urban areas, the urban water system with its overflow system leads to significant problems. The system can not cope with extreme rainfall, resulting in wastewater flowing into the urban surface water with extreme pollution and overflowing surface water as a result.

3 Climate change
The climate is changing. And it is changing into an undesired direction. As a result of this, all existing problems in the water system of IJsselmonde will increase. Due to higher temperatures, the distribution of rain- and river water will change into more extremely wet periods and more extremely dry periods. Furthermore, the water of the principle water system surrounding the island will increasingly be brackish or salt. This development attacks the weak point of IJsselmonde and the urban area of Rotterdam, and will lead to uncomfortable, unhealthy and dangerous situations. Furthermore, the rising sea level in combination with higher river discharges and western storm leads to dangerous high water levels in the delta. The flood risk for island IJsselmonde will increase.

4 Subsidence of the ground
IJsselmonde is declining due to tectonic subsidence as well as settlement of the clay soil. As a consequence of drainage the clay soil has been setting. The process is still going on resulting in a subsidence of 2 – 60 cm in 2050. The difference between the level of the land and the level of the water outside the dike-ring of the island increases, which in turn makes it more difficult to sustain the current water management of pumping out and letting in water.

5 Declining spatial quality
The landscape of IJsselmonde and Rotterdam is perceived as unattractive. The landscape is fragmented by great infrastructure, there is little green space and a lack of recreation possibilities.

6.2 DESIGN GOALS

On the basis of these existing and expected problems the design goals for IJsselmonde 2050 are formulated. But the objective of this thesis was not just to solve problems. The objective of this thesis is:

'Developing a strategy for the landscape of IJsselmonde, to solve existing problems, prepare for climate change, and make the landscape more attractive.'

The last goal of the following design goals comes forward from the last part of the objective, 'to make the landscape more attractive'.

Goal:

Make the regional and urban water system more robust, resilient, and self- reliant, to make it less dependent on the principle water system.

How?

separate stormwater from waste water, to reduce the load on the sewage system; urban stormwater discharge 100% via surface water

retain this water, clean it in natural way by wetlands, and store it in water storage areas

use this water in summer for inlet (flow through) in regional and urban water system, to improve a healthy living environment and provide coolness

improve water quality: reconnect waterways to bring back circulation in the water system

To combine with:

make a more attractive landscape, with more possibilities for recreation

new housing on the water, to make the interventions economically profitable.

Vision:

Water as a chance, not as a threat!

The design proves that water is not just a inconvenience, but a chance to create quality. It shows that different functions can be combined with water, and that water can contribute to a healthier, more sustainable and more attractive landscape.

In the future, rainwater will be the most important source of fresh water in the lower Dutch delta. River discharges will be lower in summertime and after all less predictable. Furthermore, the river basins in the western part of the delta will be increasingly salt by the increasing influence of the sea. If these developments continue, fresh water will become a scarce good in the future.

It is not sustainable to keep on pumping all the clean, fresh water out. It is important to transform our living environment in a way that clean rain water can be stored, and used in dry periods. It is a big challenge for urban regions and cities to become more self-reliant concerning fresh water. "It is crucial to develop a more independent rainwater management system in the polders. It should allow the fluctuation of the water levels inside the polders for seasonal storage and flood control." (Schuetze, 2008, page 1)

By using the opportunities of water, and combining new developments with recreation and housing, more sense will be given to the concept 'living with the water'. In a literally sense this will be done by the implementation of adaptive building, like floating houses. This strategy gives a multiple sense to adaptation to climate change. Firstly, the chances of a flood decrease because more water can be stored. Secondly, the consequences of a flood decrease because the landscape and the (floating) houses are adapted to the presence of water. Problems will be prevented, at the same time the values of water will be used. With that, a secondary goal is the creation of awareness about the ever nearby water.

Taking up the difficult and complex task of giving more space to water in the urbanised landscape, means (partially) healing of the natural water system. By giving back Rotterdam and its region some of the surface water that it once had, the water system will be more flexible and more sustainable.

The Maeslantkering closes the Nieuwe Waterweg when the water level in Rotterdam centre rises above 3.10 m +NAP

Maeslantkering (Panoramio)

6.3 ASSUMPTIONS

Before focussing on the concept for the island of IJsselmonde, it is essential to zoom out once again to the scale of the whole south western delta. On this scale level, an assumption has been made about dealing with flood risks in the future, concercing increasing river discharges and sea level rise. In the Dutch risk approach, the flood risk is calculated as follows:

Flood risk = probability x consequence

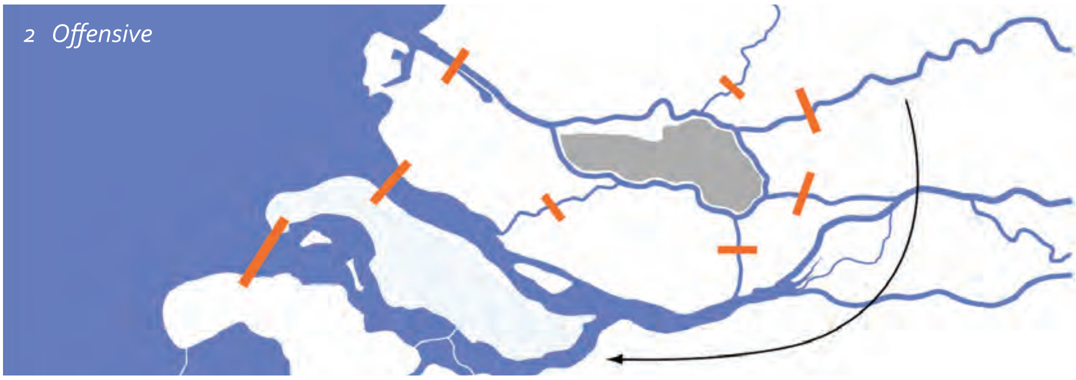
In the current discussion about this theme, three strategies can be distinguished to reduce flood risks: a defensive strategy, an offensive strategy and an adaptive strategy (based on: Pols, 2007).

In the concept and the design for IJsselmonde, it is assumed that in the future a combination of an offensive strategy and an adaptive strategy will be adopted to deal with increasing river discharges and sea level rise on the scale of the south western delta. The probability as well as the consequences of a flood will than be reduced. This assumption follows the advice of the Deltacommission. (Veerman, 2008)

Flood probability: ↓

Flood consequences: ↑

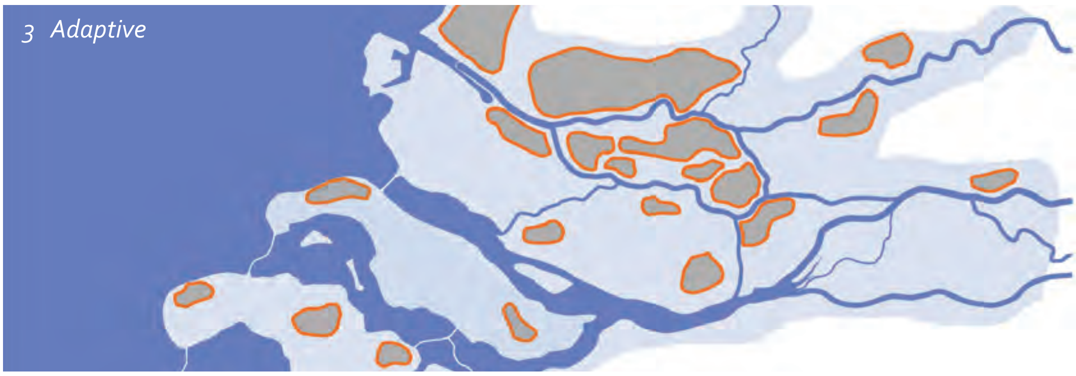
Continuing the traditional strategy of pumping out water, discharging it is fast as possible, raising the dikes and pushing the river water into a narrow channel elevated above the land. With this strategy, the current problems like subsidence of the ground and problems with fresh water supply, will keep on increasing. Furthermore, the strategy focuses only on decreasing the risk of a flood. But if a dike breaks, the consequences are disastrous.



Flood probability: ↓

Flood consequences: ↑

Closing the open sea arms and river estuaries with flexible storm surge barriers. In case of extreme weather or extreme river discharges the structures can be closed. The large quantities of water from the Rhine can probably no longer be discharged via the 'Nieuwe Waterweg' (New Waterway) west of the island IJsselmonde, but have to be discharged via the 'Haringvliet' and Zeeland. At the engineering structures probably bigger pumps are needed, to pump the river water into the sea.
This strategy is one of the scenario's of the Deltaplan II. ('Samen Werken met Water', Deltacommission, 2008)



Flood probability: ↑

Flood consequences: ↓

In this strategy, more water is allowed inland, in order to 'move with the water'. Smaller dike rings can be created, to leave more space for the water. By adaptive ways of building, like floating houses or houses on poles, living is possible outside the dikes. This strategy will need a revolutionary change in the way of thinking of the Dutch, but it can lead to a safer living environment. In this strategy the approach of risk is different that we are traditionally used to. The focus is not on the reducing the chance of a flood, but on reducing and preparing for the consequences of a flood.

CHAPTER 7

CONCEPT

A regional concept for the island of IJsselmonde in 2050 is developed, based on the design goals of chapter 6. In this chapter the surface of water storage is calculated, and different strategies to store water are discussed.

7.1 CALCULATIONS

The calculations for the amount of water storage are based on the precipitation shortage in summer 2050 (is evaporation surplus). Assumed is a possible fluctuation of the water level of 0.5 meters, with which data the surface of water storage area can be estimated. The complete calculations are attached in appendix 3.

Precipitation surplus in 2050:

- 13.000.000 m3 in summer
+ 40.500.000 m3 in winter

(calculations precipitation surplus are attached in appendix 4)

Water storage for inlet during summer based on water shortage in summer: 13.000.000 m3

Surface needed when a fluctuation of 0.5m is possible:

13.000.000 m3 / 0.50 m1 = 26.000.000 m2 (2600 ha.)

The calculations are based on a dry summer, with 80% of the year evaporation. Precipitation and evaporation data is modified by the most extreme KNMI '06 scenario W+.

Different ways of implementing the water storage concept have been taken into consideration. On the next page a range of possibilities is shown.

?

2600 hectares is a huge area. This image shows the island of IJsselmonde, with one connected area of 2600 ha.

?

The storage area of 2600 ha. can be implemented in many different ways. One option is to create one reservoir for each family...

?

An option is to create one pool for each district...

However, in the concept for IJsselmonde 2050 is chosen for one connected zone for buffering and storage with flexible 'overflow areas' attached to it, instead of separate water bodies. This is done with the purpose to create a resilient water system, which is robust and flexible (Pols, 2007 after: De Bruijn, 2005). A larger water body will longer remain clean and healthy in extremely dry periods, in contrast to small water bodies that become smelly and dehydrated.

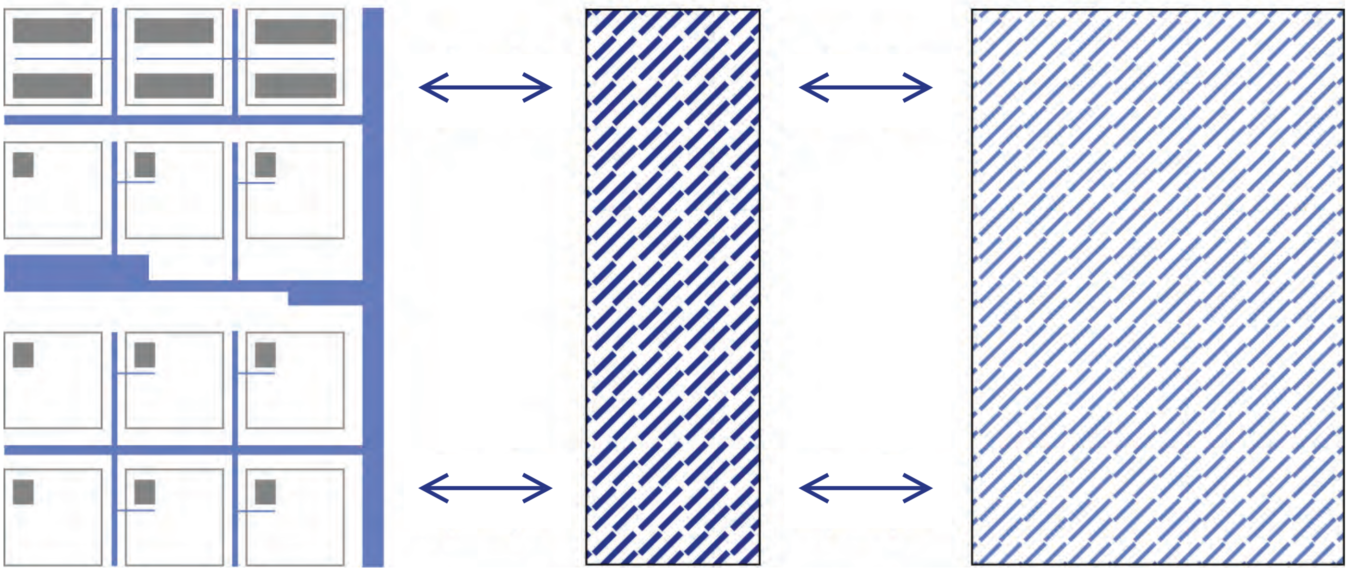
The location of the connected water storage body as showed on this image, is the result of specific analyses of the island. The three most important criteria are open space, altitude and the existing pumping districts (see page 60,61)

7.2 CONCEPT THE WATERMACHINE

From the analyses of IJsselmonde the concept 'Watermachine' is developed. The watermachine is a transformation of the rest space along the big infrastructure A15, into one connected zone for water buffering. Rainwater from the urban districts is separated from the sewerage system, collected by gutters and water ways, and led via this (new) surface water system into the watermachine. In the watermachine the water is kept clean by natural purification wetlands, so that water of good quality can be stored and used as inlet water in summer periods of water shortage.

The open polders in the south and south-east are flexible polders connected to the watermachine, which can overflow in periods of extreme rainfall. The old dike structure, still intact in this areas, function as embankments for the overflow areas. The flexible polders can also be used as extra buffer space when fresh water shortage increases in the future.

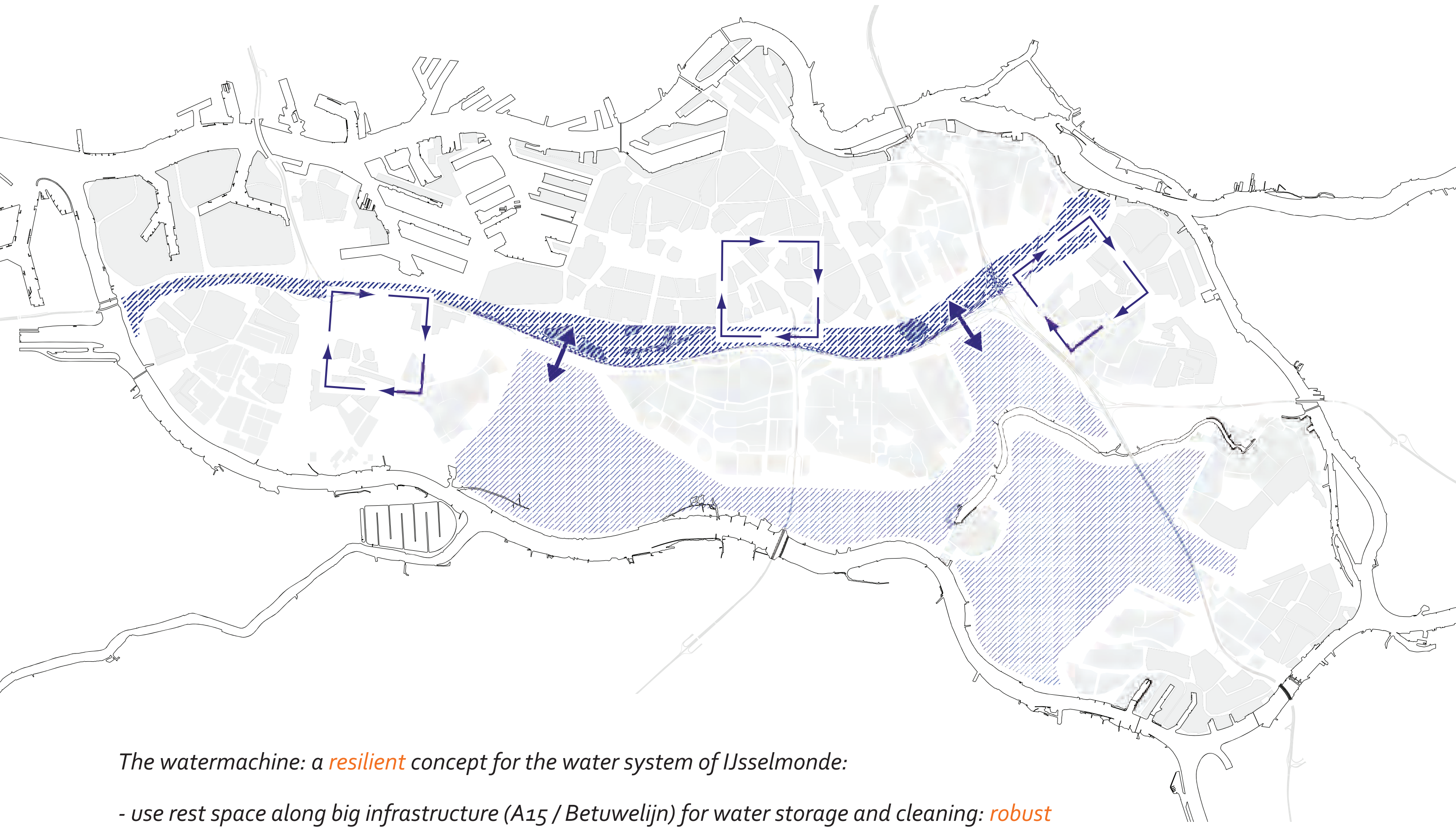
In urban districts on IJsselmonde the water system will be healed by re-connecting water bodies and canals, and bringing back circulation. The circulating urban water systems can connect to the water machine, so that surpluses or shortages of water can be buffered. Connected to the watermachine, the attached neighbourhoods will be provided with enough water of a good quality. For urban districts, especially some declining after-war neighbourhoods with social problems, the developments are great opportunities to combine with current restructurings, and to improve spatial quality.



'Rizome system'
('open, connected system' - Gilles Deleuze)

Watermachine

Flexible polders



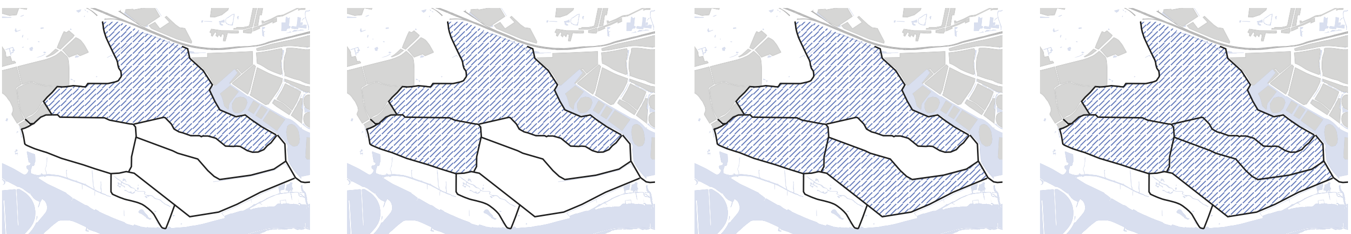
The watermachine: a resilient concept for the water system of IJsselmonde:

- use rest space along big infrastructure (A15 / Betuwelijn) for water storage and cleaning: robust

- transform this zone into a 'watermachine'

- connect urban water systems to watermachine through circulation (Tjallingii et al, 2007)

- use historical open polders as overflow areas for peak storage: flexible



The albranswaard polders in south IJsselmonde can serve as overflow area for peak storage or for more extreme situations beyond 2050. The old dike structure functions as compartmentalisation:

7.3 LOCATION WATERMACHINE

The location of the watermachine is based on the criteria open space, altitude and the existing pumping districts.

Open space

First of all, to store such an amount of water without demolishing houses, open space is essential. The map on the right shows that the (little) open space of island IJsselmonde is to be found in the open polders in the south and south east, and along the highway A15 cutting through the island from west to east.

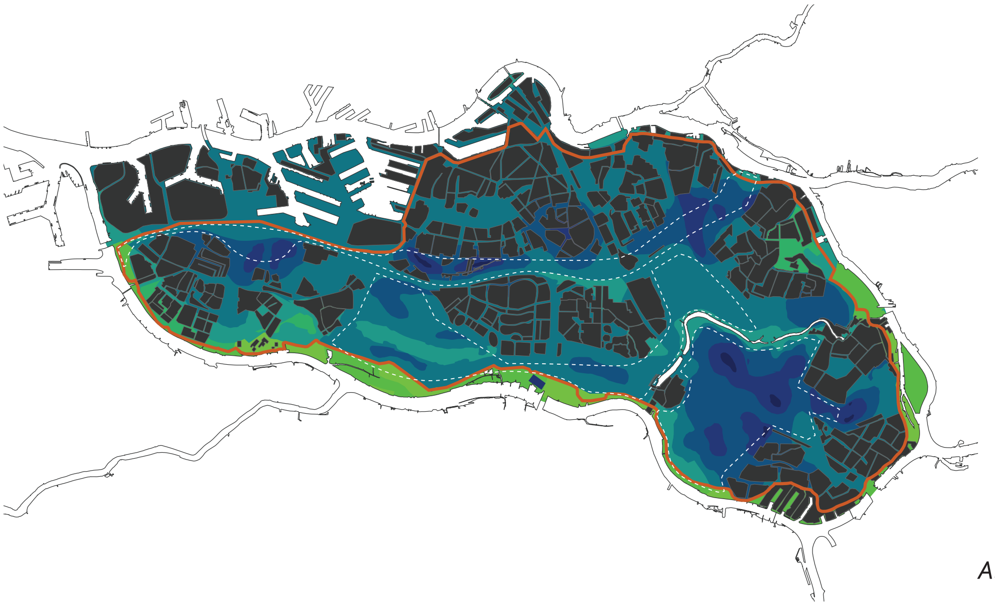
Altitude

Secondly, water runs to the lowest place. To get rain water from an extreme shower as fast as possible from the urban areas into the buffer areas, without being dependent on pumps, it is essential to chose the lowest location for the buffer areas. The manipulated altitude map of 2050 shows that the lowest places are situated along the A15, and partially in the open polders in the south and south eastern part of the island.

Existing pumping districts

The third criterion for the location of the buffer zone, is the existing water management of island IJsselmonde. On the right, the six pumping districts are showed. By connection the water buffer zone to all of the pumping districts, all districts can have benefit from the zone. That means that each district can discharge water into the buffer zone, and each district can let in water from the buffer zone. In the proposed location for the water buffer zone, the districts 1 to 5 are connected to it. The sixth is not, but this district does not need to be connected to the new water buffer zone. It uses the 'Oude Waaltje' as water buffer, which can be expanded in the future if needed (see paragraph 4.2).

Open space

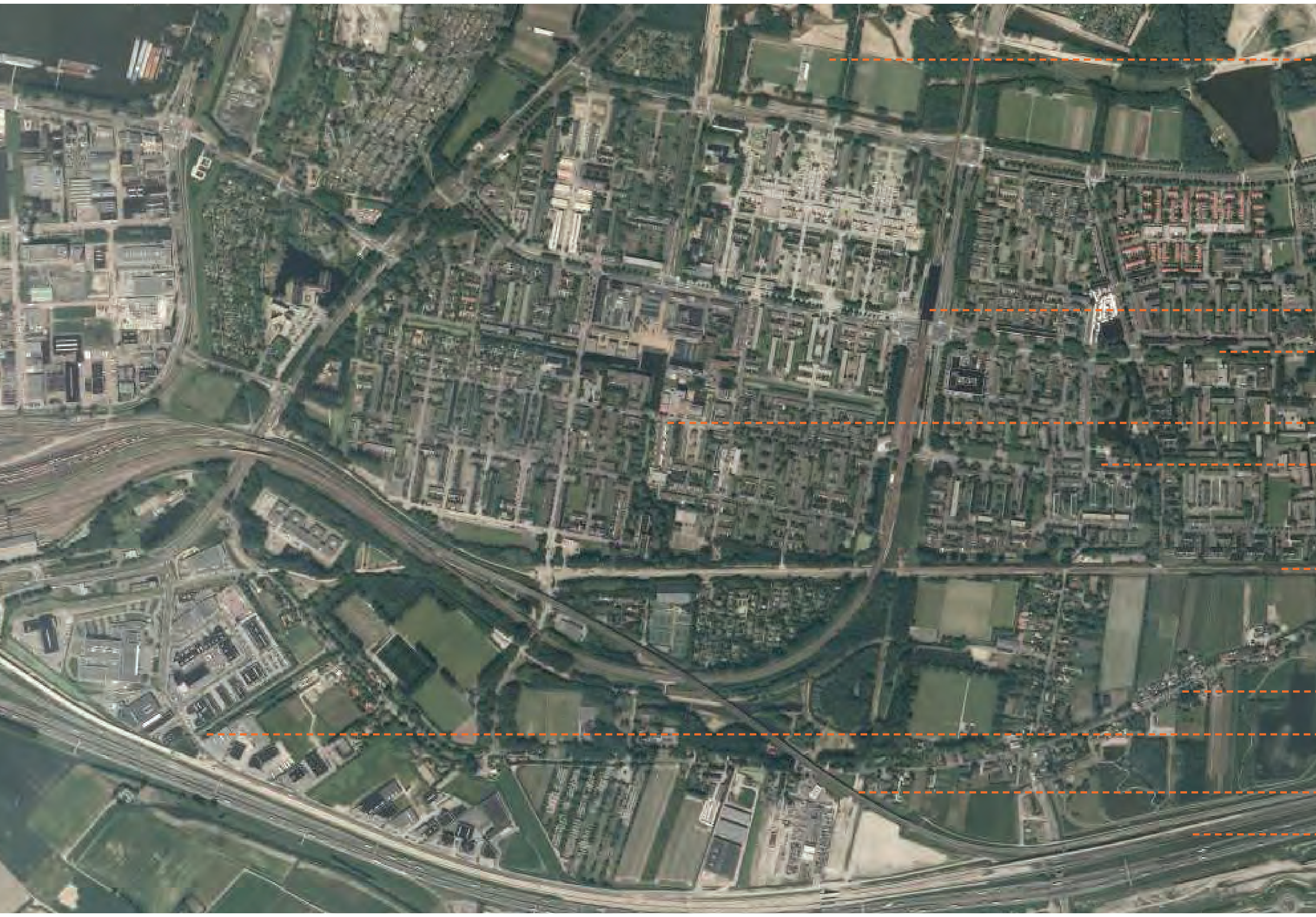


Altitude

Existing pumping districts

CHAPTER 8

ZOOMING IN ON ROTTERDAM SOUTH: PENDRECHT AND ZUIDWIJK



To show how the concept of the watermachine can be implemented in the local scale, one part of the island will be taken out. For this part, the zone between the highway A15 and the neighbourhoods Pendrecht and Zuidwijk in Rotterdam south has been chosen. It is an interesting zone, with two after-war neighbourhoods, attached to a 'green zone' between the highway and the neighbourhoods with mixed recreational use. The old 'Charloise Lagedijk' is a cultural historical ribbon through the area, unsubtly crossed by large infrastructure like the rail connection Betuwelijn.

8.1 ANALYSES PENDRECHT AND ZUIDWIJK

Pendrecht and Zuidwijk are the two southern most neighbourhoods of Rotterdam, and belong to the districts of Charlois and IJsselmonde. The neighbourhoods are build since 1951, according to the fan-structure of the 'Algemeen Uitbreidingsplan Linker Maasoever' (Official urbanization plan left Meuse banks) of Witteveen 1927.

The southern neighbourhoods are called the 'Zuidelijke Tuinsteden' (Southern Garden Cities), their urban design and intentions determined by the after-war building typologies with a lot of space and green. Furthermore, Pendrecht and Zuidwijk are developed according to the idea of the 'neighbourhood community', developed by Clarence Perry (1929). They belong to the first neighbourhoods which represent a clear connection between a sociological basis and the physical form of the 'unit' on the small scale. Perry believed that many social problems could be prevented by urban and architectonical design. The basis for this was the neighbourhood as a unit, autonomous and independent, where social interactions and community relationships

Aerial view Rotterdam South (Bing-maps)

could freely unfold (DSV, 2004).

A long study to different forms of urban structure has been done before building the new districts in south. Common theme was the stamp-like building masses organised around a community garden (DSV, 2004).

Pendrecht and Zuidwijk are divided by the Zuiderparkweg, in north–south direction. Furthermore, the neighbourhoods are divided in a northern and southern part by the Slinge, the main arterial road through the neighbourhoods. Metrostation De Slinge is situated on the crossing of the Slinge and the Zuiderparkweg.

The largest part of the housing stock in Pendrecht and Zuidwijk consists of three or four floored flats without elevator. Furthermore, many duplex houses, access gallery flats, one family houses and dwellings for elderly people can be found. Pendrecht has in total 6.400 houses, while Zuidwijk has in total around 7200 houses, of which 75% is social housing (KEI, 1995).

Till the eighties Pendrecht and Zuidwijk were popular neighbourhoods. Since the eighties however, the houses reached an aging state, the neighbourhoods suffered from impoverishment and young people migrated. Rotterdam south got more social problems and liveability problems. Due to the lowering housing prices Pendrecht and Zuidwijk became more popular for the low-income group of people. Today, around 12.000 people live in Pendrecht and 12.500 people live in Zuidwijk, of which the largest part has an foreign origin.

Aerial picture of Pendrecht (Archive Municipalty of Rotterdam)

Since the nineties many local shops in Pendrecht

In 1992 a start has been made for the urban renewal and restructuring of Pendrecht and Zuidwijk. The green character of the Garden city is to be strengthened and new buildings have been added to the existing urban structure. Goal is to reduce the amount of social housing from 95% to 54%. The urban intention is to replace cheap houses, which are mainly too old and too small, by private houses of higher price categories. Goal is to create differentiation in the housing supply, with more different types of houses and different price categories. Pendrecht and Zuidwijk should be more attractive for middle income families, and be a better alternative than the Vinex location Carnisselande.

In Pendrecht, more than 60% of the total housing stock is taken on. 1500 houses are or will be demolished and replaced by new buildings. 1200 housing units are being renovated (KEI, 1995).

In Zuidwijk more than 950 houses are being demolished, and replaced by private houses of a higher price category. The new ratio of rental / private houses will be 65% / 35% (KEI, 1995).

Efforts are being taken to improve the social structure of the neighbourhoods. A positive approach towards the inhabitants is adopted, and the focus is put on the dedication of the own inhabitants. To create more social cohesion and involvement by inhabitants, activities are being organised like theatre, expositions and debates.

An other mean to improve the living quality is to improve the green structure of the neighbourhood. The 'Zuiderpark' is already restructured. Ideas are circulating for the development of a park / pool on the south side of the district, in the A15-zone.


and Zuidwijk have been closed


Emptied plots for urban renewal in Pendrecht

8.2 CONCLUSION: SUB-GOALS FOR DESIGN

A great opportunity is missed by not connecting the restructuring of Pendrecht and Zuidwijk with a restructuring of the water system. Therefore, the current situation in Rotterdam south will therefore be an extra input for the implementation of the watermachine in this area. Three sub-goals for the design result from the analyses of Zuidwijk and Pendrecht:

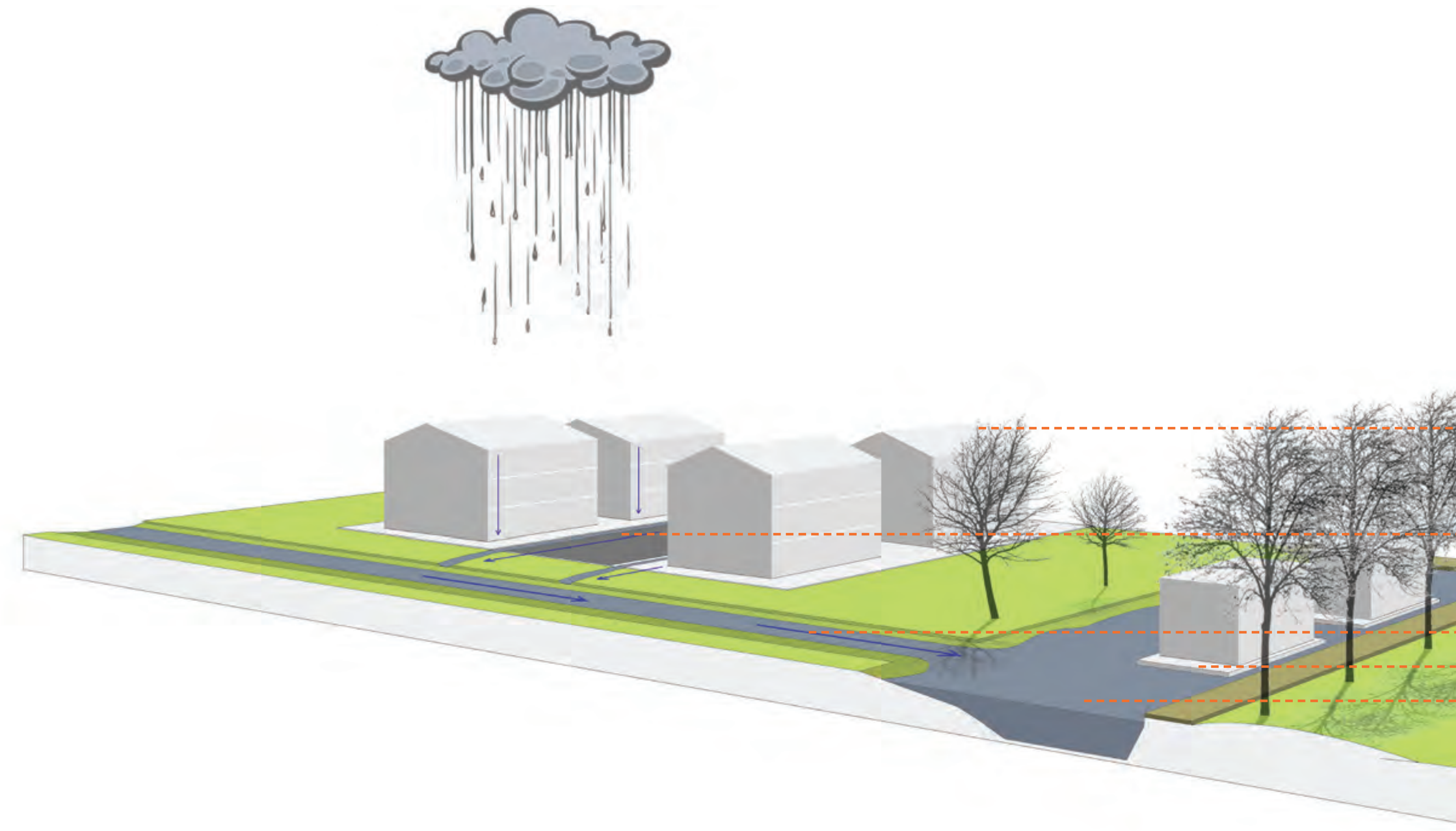
1
Use the new surface water system in urban areas as a chance to improve the spatial quality in the neighbourhoods. With that health and comfort for the urban population, and social cohesion can be improved.

2
Design the watermachine in the A15 zone by Pendrecht and Zuidwijk as a recreation area / park for the inhabitants of the neighbourhoods. Good north - south connections, and an attractive transition zone from the urban district to the park are essential.

3
Combine the new developments with new housing, especially floating houses. The combination with housing is necessary to make the interventions in the landscape economically profitable. Nevertheless, the combination with housing can contribute to a differentiation of housing types in Rotterdam south, to attract different kinds of people. Floating houses are desired because it contributes to people's awareness that the water is nearby. It also helps proving that 'living with the water' is possible and a desirable.

CHAPTER 9

DESIGN



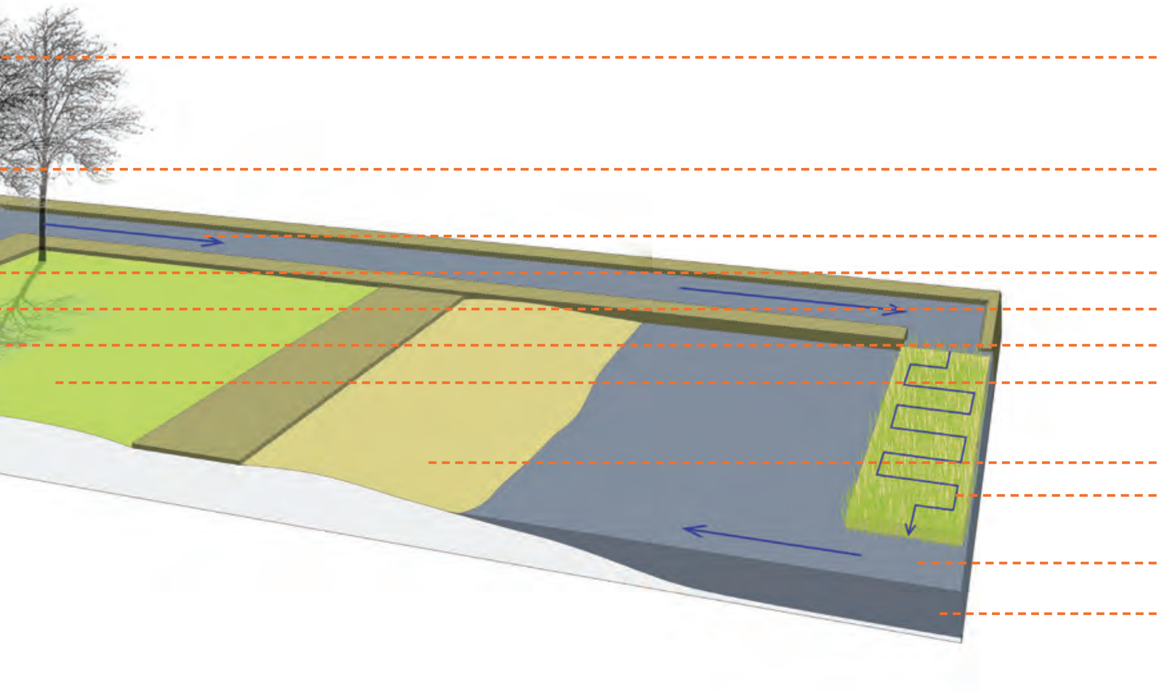
The concept of the Watermachine has been given form in a design for the A15-zone south of the after-war neighbourhoods Pendrecht and Zuidwijk. The design shows that an urban region can be self-relient in (rain-) water management, and that this improves the (spatial) quality on many different facets.

Calculations for the needed surface of water and wetland in this part of IJsselmonde have been made on the basis of specific data about Pendrecht and Zuidwijk, and data about precipitation and evaporation (KNMI).

Paragraph 9.1 explains the new water system. In 9.2 the design plan is showed and clarified. In the following paragraphs, successively the watermachine, the new park, the new boulevard, the new urban water, and the calculations are explained.

9.1 THE NEW WATER SYSTEM

The design makes circulation of the water system possible. From the urban district, water is led by gutters and small waterways from the buildings to new canals in north – south direction. These canals flow into the main water retention canal on the southern city edge of Pendrecht and Zuidwijk. From this canal the water flows in eastern direction into the watermachine. This is a wetland area where the water is led through a structure of mazes of in total more than ten kilometres long. Natural processes and the growth of biomass make sure that the outflowing water is clean. To simplify management and maintenance of the watermachine, the wetland area is divided in six compartments. The compartments can be closed or opened separate from each other, for example for the



cutting or the cultivation of the reed. As a result, six different inlet places and six different outflow places exist. After purification the water is pumped by small windmills from the watermachine into the storage basin. From the storage basin, the water flows to the Zuiderpark north of Pendrecht and Zuidwijk, and finds its way through the neighbourhoods back into the canal. Due to the pumping power, the machine keeps running, and circulation is brough in the water system.

The scheme above shows the principle of the new water system for Pendrecht and Zuidwijk, connecting the urban water system and the regional water system in the A15 zone south of the neighbourhoods.

9.2 DESIGN PLAN ROTTERDAM SOUTH

new urban water for rainwater retention
polluted water
clean water
shallow water
floating houses
park island and path
watermachine: wetland purification
boulevard
existing rail road
trees: 10-25m
bushes: 1-3m
0
100
500m

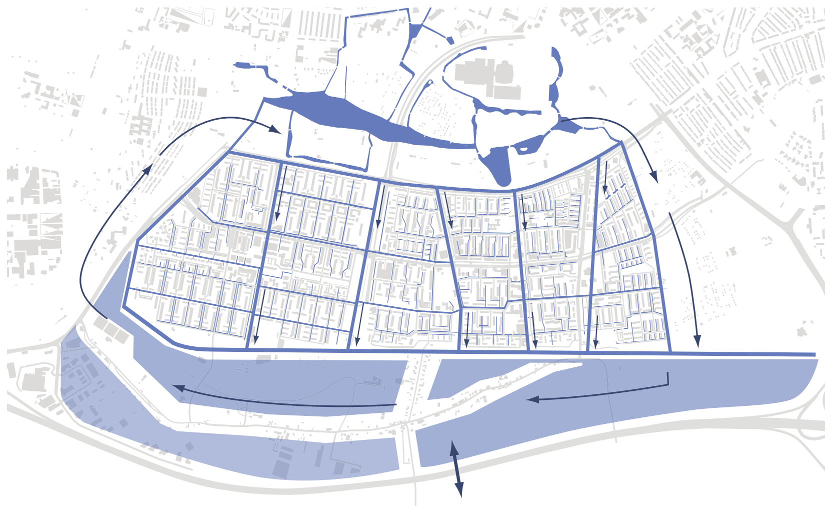
9.2.1 Healing of the water system in Rotterdam South

Situation around 1950:

Many connected ditches as a fine-grained system through the polders.

Situation 2009:

Only a few larger water bodies remained; the paved surface increased drastically.

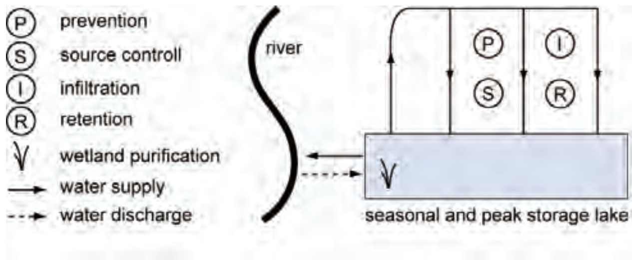


Concept 2050:

Healing of the water system: a fine-grained surface water system is brought back in the city, functioning as a ' rhizome-system'

Waterways are connected so circulation is possible.

'Circulation model'



In urban neighbourhoods the water system is adapted so that circulation is possible. The water passes a helophyte filter. The principle means that water in winter time is retained as much as possible, so that the inlet of water from the outside will be redundant. Storage can take place in lakes or ponds just outside the city. For circulation a pump is necessary. The principle is useful for after-war flat neighbourhoods on polder level, where relatively much open space is available.

(Tjallingii, 2007)

'Rhizome'

Rhizome (Jet Safi - www.flickr.com)

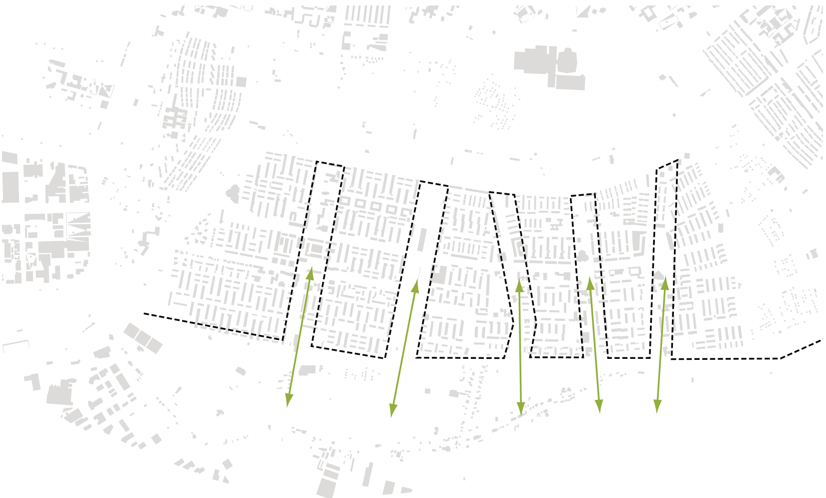
Rhizome is a figurative term uses by Felix Guattari and Gilles Deleuze in their book 'A Thousand Plateaus: Capitalism ad Schizophrenia'. Rhizome stands for open, non-hierarchical networks. According to Deleuze such systems, where many reciprocal connections are made, are stronger and more resilient than hierarchical systems. He compares a rhizome system with the roots of Common Yarrow, which are very thin but still form a very strong, almost immortal network.

(Deleuze, 1987)

9.2.2 Pendrecht and Zuidwijk connected to 'the green'

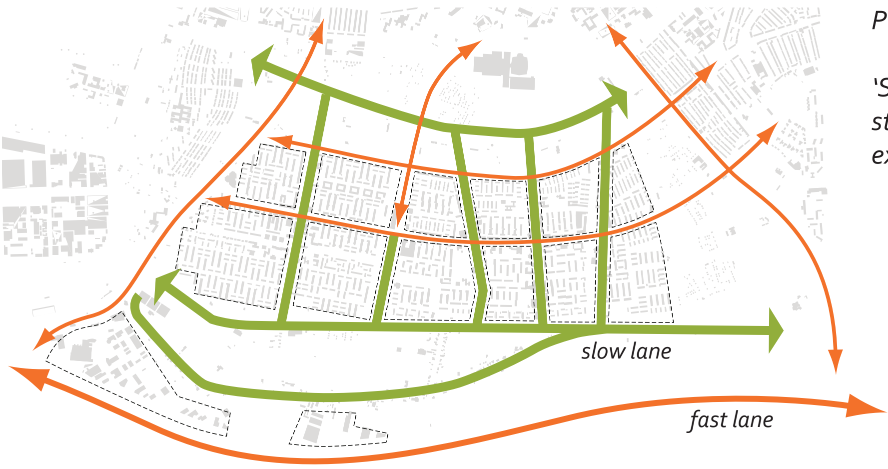
Situation today:

The city edge on the south side of Pendrecht and Zuidwijk is hard. No good connections from the neighbourhoods to the green zone on the south are made.



Plan 2050:

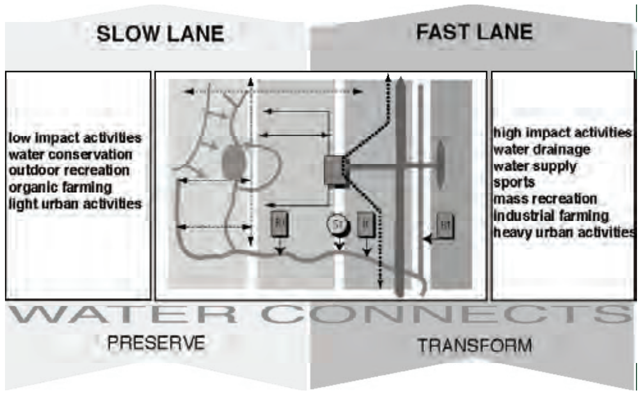
The new water structure through the urban districts connects the urban water system to the regional water system and the water storage areas south of the neighbourhoods. This structure also serves as connection for people from the neighbourhood to the new recreational area. The new water structure is a 'slow structure' to which other ' slow functions' can be connected (Tjallingii, 2007). The border line between urban and 'green / blue' is extended, more people live close to green / blue space. A more permeable city edge originates.



Plan 2050:

'Slow functions' connected to the water structure, 'fast functions' connected the existing traffic networks.

'Concept of two networks'



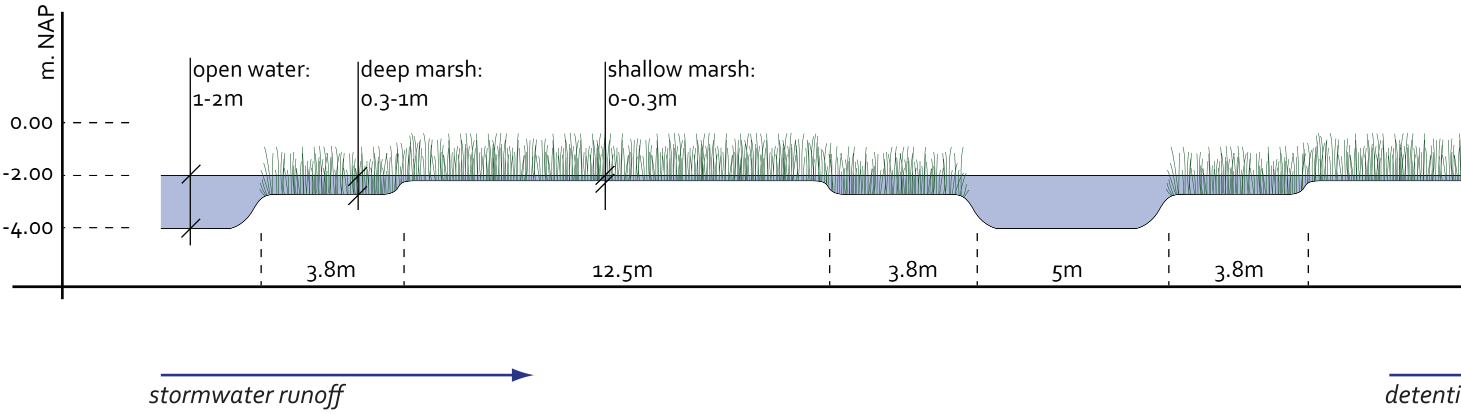
The strategy of two networks is a more general urban planning model, which can be used as a guiding principle to implement the foregoing principles into the urban space. The strategy introduces a spatial basis for urban developments, which is the distinction between two spatial networks. Firstly the traffic network (fast lane), secondly the water network (slow lane).

The distinction is based on dynamics. The essential spatial contrast between quiet zones and high dynamical zones is carried by the networks of traffic and water. The two networks are used to order and plan functions. That means a concentration of quiet functions and green, water, slow traffic and recreation along the slow lane network, and a concentration of high dynamic functions and fast traffic, work and production functions along the fast lane network. Ideal place for living is in between the two contrasting networks: green and quietness on the one side, dynamics and services on the other side.

A concentration of green- and water functions along the slow lane network improves the chances that retention and the keeping clean of the water will succeed. The bundling and concentration of traffic routes improves the flow through, and reduces the inconvenience that traffic brings along. Furthermore, the efforts to reduce nuisance can be bundled as well which reduces costs.

The two networks combine ecological and economical issues, and forms a sustainable and flexible framework for planning. This is necessary concerning the uncertainty brought along by the future.

(Tjallingii, 2007)



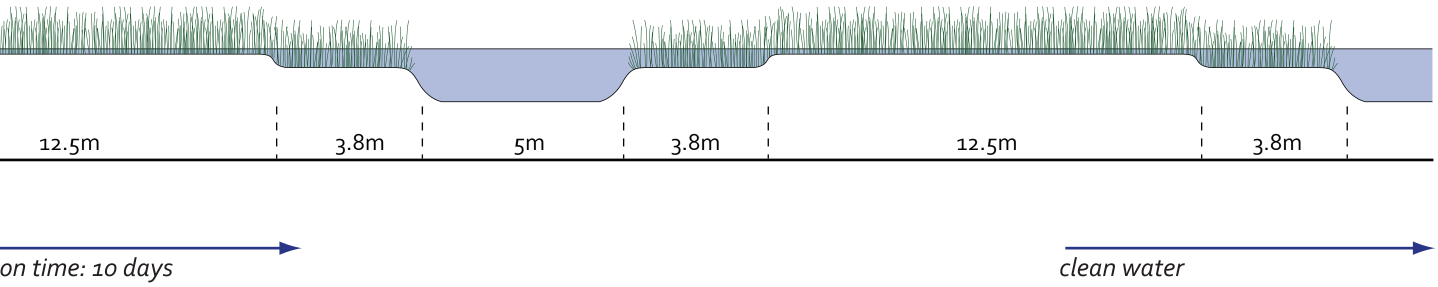
9.3 THE WATERMACHINE

The water machine has the main function of cleaning run off water from the urban districts Pendrecht and Zuidwijk, southern most neighbourhoods of Rotterdam. To serve this function, the water machine exists of waterways through wetlands, where water is naturally cleaned with helophytes.

It is necessary that the run off water from the urban area is cleaned before it becomes a part of the new circulating water system, and the recreation lakes. The 12.000 inhabitants of Pendrecht, 12.500 inhabitants of Zuidwijk, their cars, their gardens and their dogs cause a permanent nutritious load of the water system. Furthermore, sewage overflow water (today still very common) and inlet-water from the Meuse certainly don't meet the requirements of a healthy water quality.
Growth of algae and unclear water are the consequence. According to the WB21 water should be of good quality, and a clear sight through the water is a part of that. Next to this, in the plan for the water machine, the water will be used as swimming water.

The principle of wetland purification is cleaning by plants. In the watermachine different water depts are used, to stimulate the growth of specific plant species. 50% exists of shallow marsh, where reed will grow. 30% is deep marsh, where Common Club-rush will be the most effective plant. In the 20% open water plants like Canadian waterweed and Common Hornwort are active and provide oxigen to the water. The plants use nutrients in the water for their growth, and store in this way pollution of the water in their biomass. By removing the plants after the growing season (mainly cutting the reed), the pollution is removed out of the area. The cut off reed can serve different functions like roof covering or renewable energy production in a biomass power plant.

To stimulate the cleaning by plants, it is essential to



Total surface of watermachine:	*10 ha.*	*(100%)*
surface shallow marsh:	*5 ha.*	*(50%)*
surface of deep marsh:	*3 ha.*	*(30%)*
surface of open water:	*2 ha.*	*(20%)*

create as much length of waterfront as possible, that is contact zone between water and plants. In the design a mazes-like pattern is made, to create about 20 km of waterway in ten hectares of wetland.

9.3.1 Size of the purification wetlands

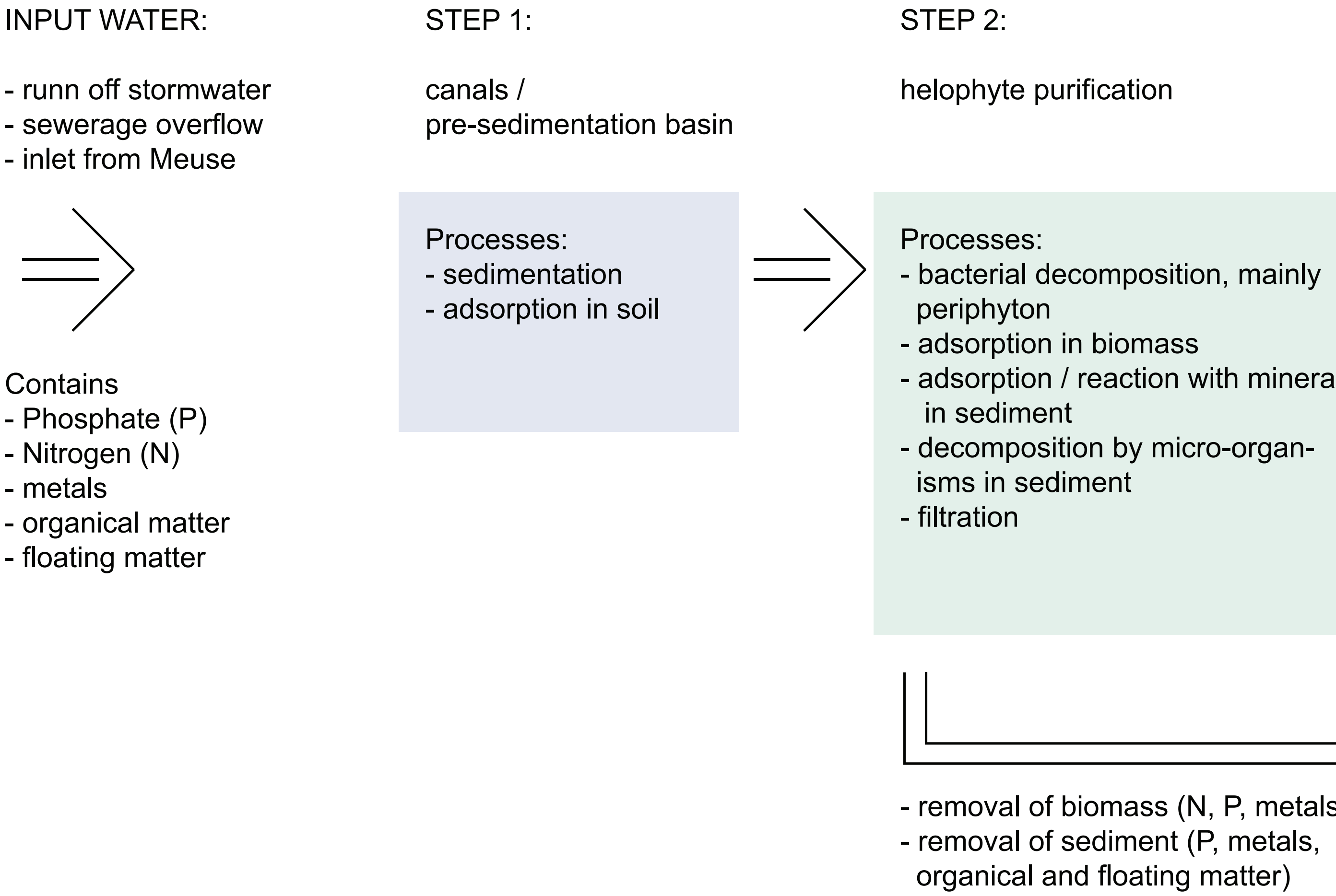
A guideline for the size of purification wetlands is:
Purification wetlands = 2-4 % of catchment area (France, 2002)

Catchment area = 248 ha (Pendrecht and Zuidwijk total)
0.04 x 248 ha is 10 ha.

The width of the waterways is determined on the basis of future maintenance of the wetlands. With a width of 5 meters of deep water (1-2 meters), it is possible to cut the reed from a small boat.

The length of the watermachine is approximately ten kilometers. This is length of waterway with a width of 5 meters that can be created in the design for the wetland area with a total surface of 10 ha.

A detention time of ten days would be the best situation for wetland purifications. To stimulate sedimentation and cleansing processes, and a good buffering of the water, a low flow through speed in necessary (STOWA, 2001). The flow through speed of the water through the wetlands is determined by the capacity of the pumps driven by wind energy. With a length of 2000 meter per compartment, and an ideal detention time of ten days, the water would flow very slow. It comes to a flow speed of 200 meters per day, which means that the pumps with a very low capacity would be sufficient.



9.3.2 The type of purification wetland

Four different types of water are suitable for cleansing with helophytes:

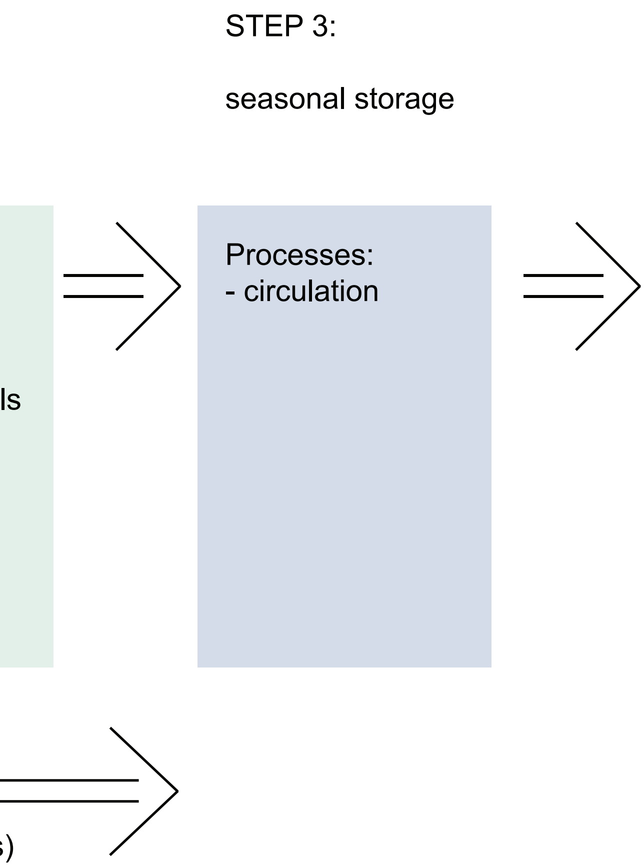
1. effluent of wastewater treatment
2. surface water inlet (from rivers) to compensate water shortage
3. rainwater discharge of paved surface, separated from the sewerage system
4. sewerage overflow water

(STOWA, 2001)

In the situation of IJsselmonde, the water sources 3 and 4 are input for the water machine. Further research could discover the possibilities of leading effluent of wastewater treatment and inlet water from the Meuse through the water machine. An efficient way for the cleaning of stormwater and sewage overflow water is the horizontal flowing purification wetland.

Different types of horizontal purification wetland and helophyte filters exist. The type that is used for the watermachine, is the ditch-system. The water is led through the ditches, which are parallel connected. 'In a ditch-system the flowing of the water can be better regulated than in a field-system, so that preferential lines of flow and short-circuiting can be prevented. The advantage of a parallel switched system compared to a serial switched system is in case of calamities one or more compartments can be closed.' (STOWA, 2001).

Before the water flows into the ditch system, it flows through a canal from the urban district to the watermachine. This waterway functions as a pre-



sedimentation basin, where coarse materials in the water can settle on the ground. A low flow speed is necessary. The polluting materials can be removed from the bottom of the canal (Van Dien, 2009 - verbal communication).

9.3.3 Cleaning processes in the watermachine

The most nutritious elements in the stormwater and sewage overflow water are phosphate and nitrogen. The main polluting elements are metals, which are mainly caused by car use. The removal of phosphate is important, because in the Dutch situation this element is the limiting factor for the growth of algae.

Purification by wetlands is based on the following cleansing processes:

1. Bacterial processing and decomposition
In the ground as well as in the water bacteria decompose and remove organic matter and nitrogen. The flow speed of the water, the temperature and the amount of oxygen in the water is determining for this process.

2. Absorption in biomass and periphyton.
Plants as well as algae absorb nutrients (phosphate and nitrogen), and pollution (metals) from the water. Reed is one of the most efficient plants for this process. Periphyton is a mixture of algae and cyanobacteria, that absorbes nutrients and pollution in the colder seasons, when the other processes are less active.
By removing biomass, nutrients and pollution is removed from the system.

3. Filtration, sedimentation, adsorption
In these processes, solid particles in the water are caught by water plants or in the soil. Essential is a low flow speed. Pollution can be removed by removing plants and the top soil layer.

4. Chemical reactions
Main chemical reaction is oxidation – reduction reaction. This influences the linkage of Iron and Phosphate. The process is more important for vertical helophyte filters, where often extra Iron is added to the soil. In the horizontal wetland principle that is used for the watermachine, no extra Iron will be added, which makes this process less important.

(STOWA, 2001)

Water plants in the open water will be added to stimulate the production of oxygen in the water.

9.3.4 Watermachine: formal language

To reinforce the concept Watermachine, the appearance of a 'machine' is given to the wetland area. One reason for this is to make the process of purification perceptible for visitors. Industrial forms with straight lines make the watermachine a comprehensible system.

The second reason for a slightly industrial formal language is the atmosphere of the region. Rotterdam has always been a 'work city', with functional and solid design mostly connected to harbour activities. This in combination with the infrastructure crossing IJsselmonde resulted in a landscape of strong lines and hard edges. A 'too soft' design would not fit in the landscape, and would maybe not be appreciated by inhabitants.

The straight lines of the watermachine follow the existing landscape structure, that resulted from reclamation of the land. The lines refer to ditches in the landscape for drainage and water discharge, however with a new function for the future.

To reinforce the industrial straight lines, some contrasting winding lines have been added in the form of a new park zone separating the watermachine from the storage basin, and in the form of winding boardwalks through the wetlands. From the boardwalk, the watermachine with all its different kinds of plants can be seen from close by.

The aim of maiking the processes and meaning of the watermachine clear for visitors, is raising awareness for water. The watermachine is made attractive and comprehensible, to show people how all rain water from the neighbourhoods is processed, cleaned and stored in their own living environment. This gives the watermachine an additional educational function.

9.4 A NEW PARK

The watermachine and the water storage basin are separated by a park zone built up from islands. From different outflow points, the clean, purified water from the watermachine flows into the basin, finding its way through the islands.
The islands have a park like appearance, some slightly slanting, with spread bushes and trees. The park offers attractive walking routes with a variety of paths; some going over islands, some going through the wetlands and some going over the higher islands. Furthermore, the new park can be used for swimming, sailing, and surfing.

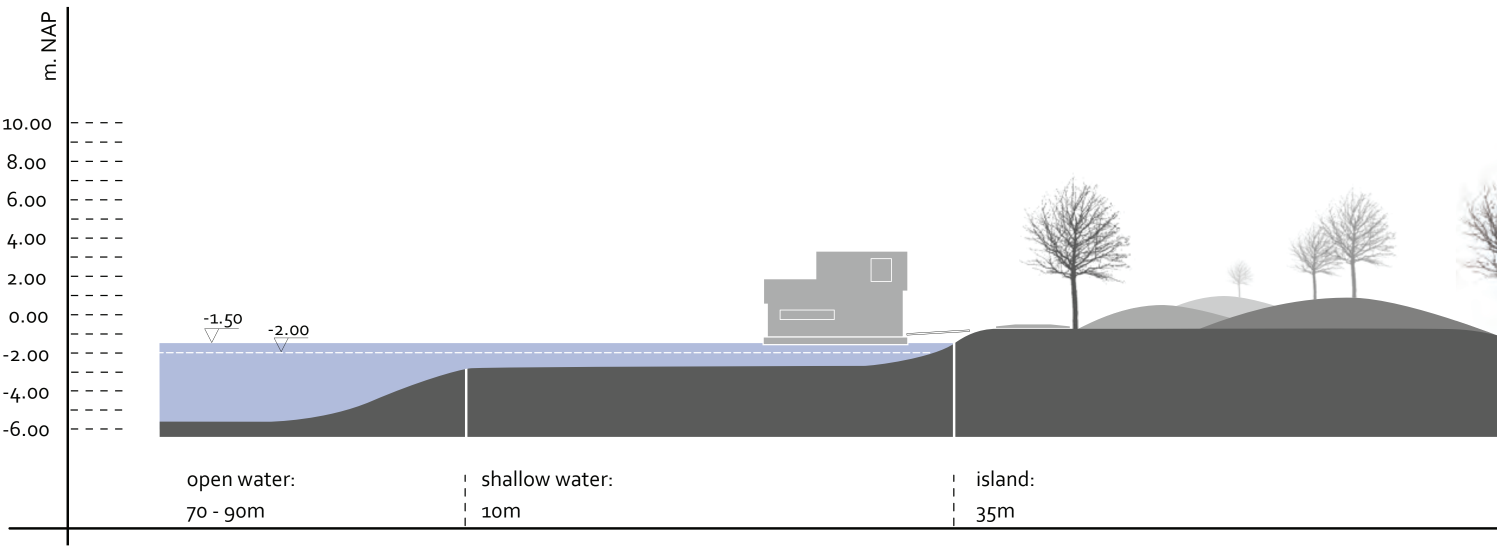
The eastern part of the park is a connection to the boulevard and the rain water retention canal. This part connects recreational routes as well as the circulating water system.

The structure of islands forms a great opportunity for living on the water. The waterways between the islands and the waterfronts on the north side are attractive places for floating houses, right next to the inflow of clean ' nature' water. Shallow parts of the water make the living environment safe for children, and the waterfronts suitable for paddling and swimming.
The islands are designed in a way that insight into the watermachine is provided, and the process of water purification is made intelligible. This gives the park an educational meaning, as well as the intention to raise awareness for the importance and presence of water.

The islands as a whole represent the waves of flowing water, moving in western direction.

Perception from the highway A15

However on some places the rail connection Betuwelijn closes the view from the highway A15, from other some places the watermachine is visible. The highway lies about 4 meters higher than the watermachine, so the perspective slightly becomes a view from above. A variation of groups of trees and groups of lower bushes creates alternately a blocked view and an open view from the highway to the wetlands. The rhythm repeats along the highway, resulting in an attractive 'highway panorama'. With that, the watermachine following the A15 counteracts the messy appearance of the IJsselmonde landscape, perceived from the highway.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8.00
6.00
4.00
2.00
0.00
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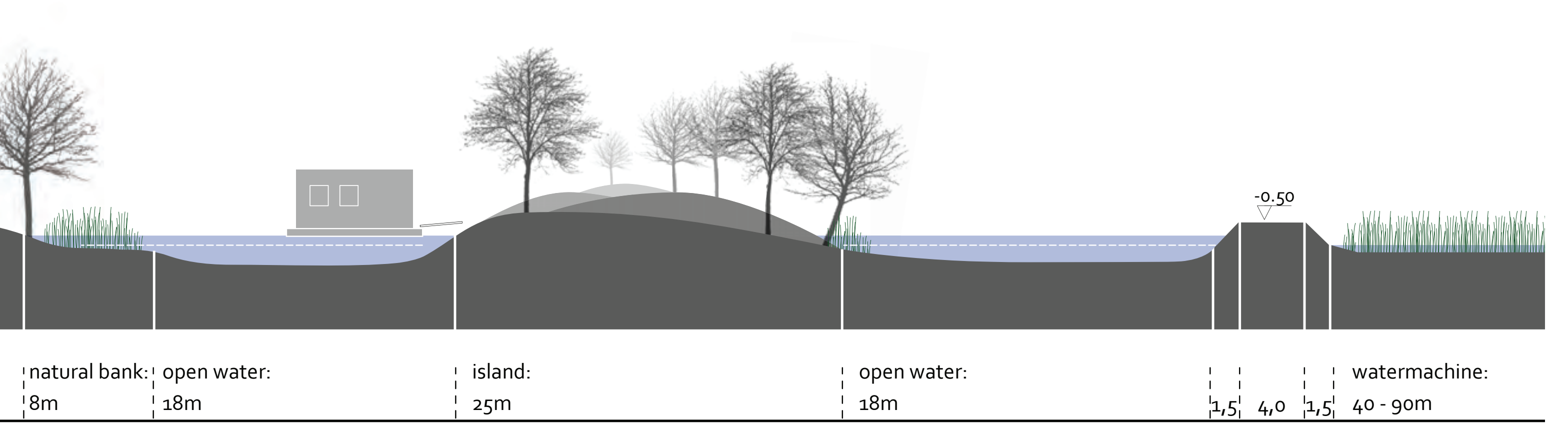
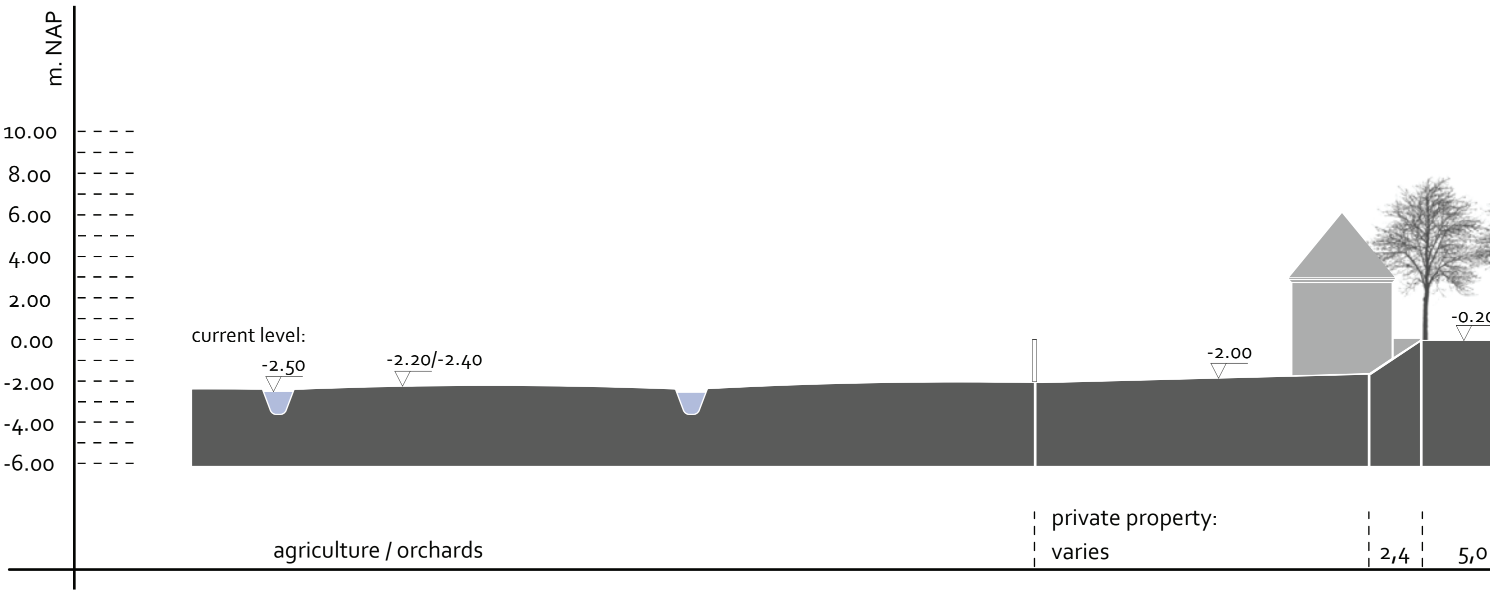
open water:
70 - 90m
shallow water:
10m
island:
35m



Section islands in new park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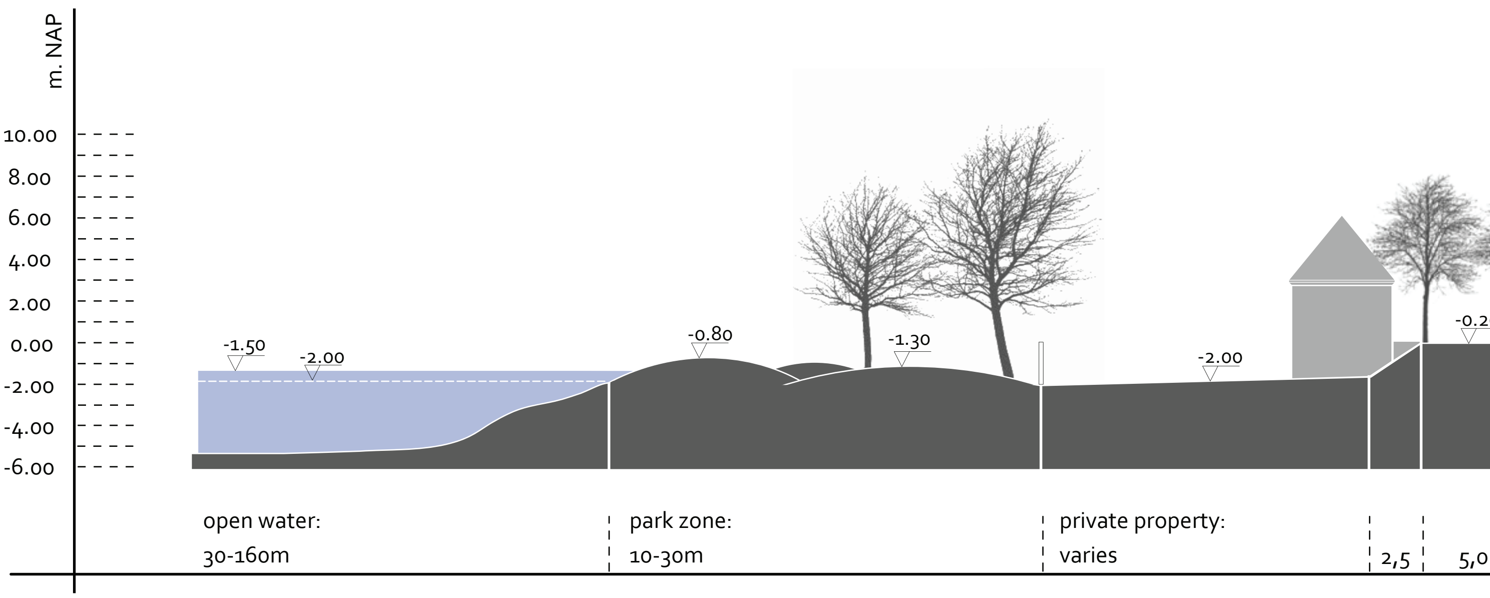
current level:
-2.50
-2.20/-2.40
-2.00
-0.20
agriculture / orchards
private property:
varies
2,4
5,0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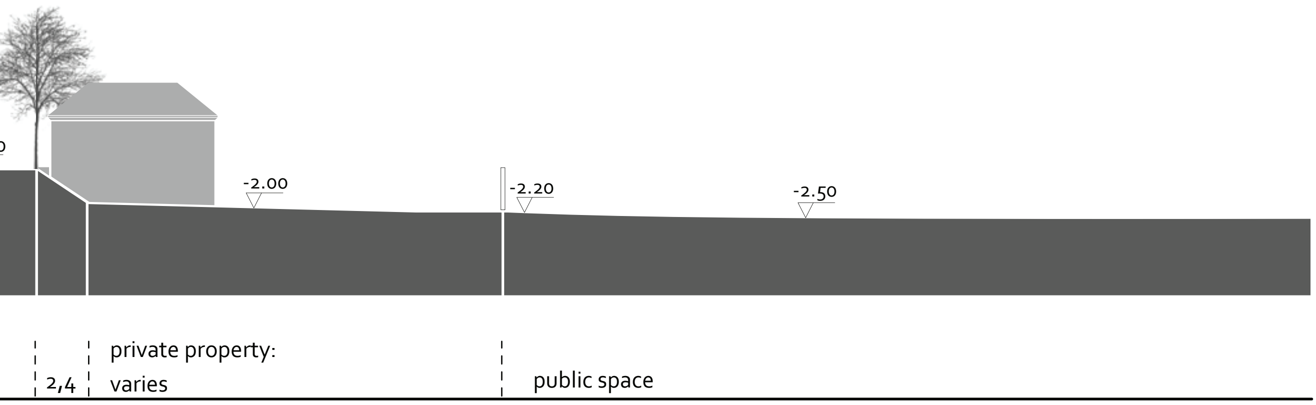
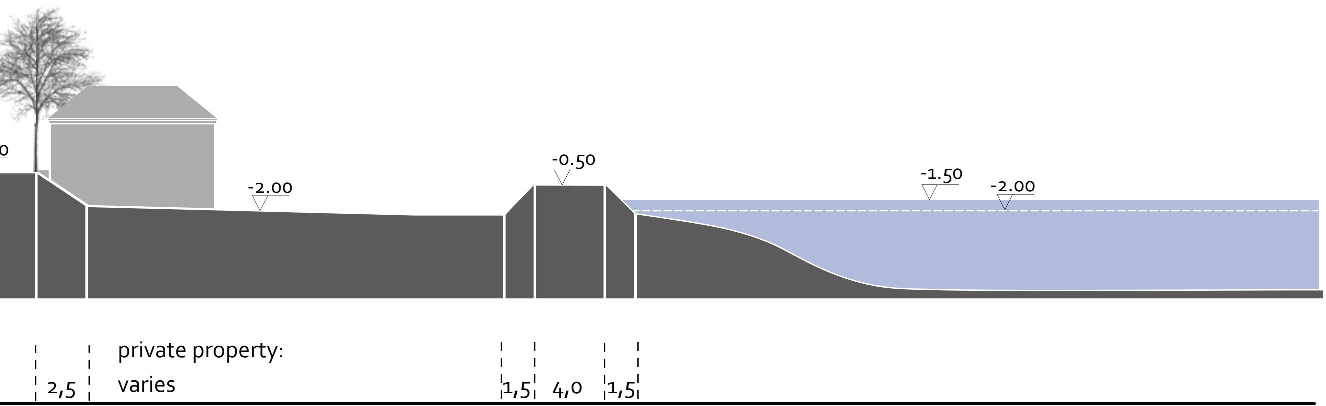
-2.00
open water:
30-160m
park zone:
10-30m
private property:
varies
2,5
5,0



Section Charloise Lagedijk current situation



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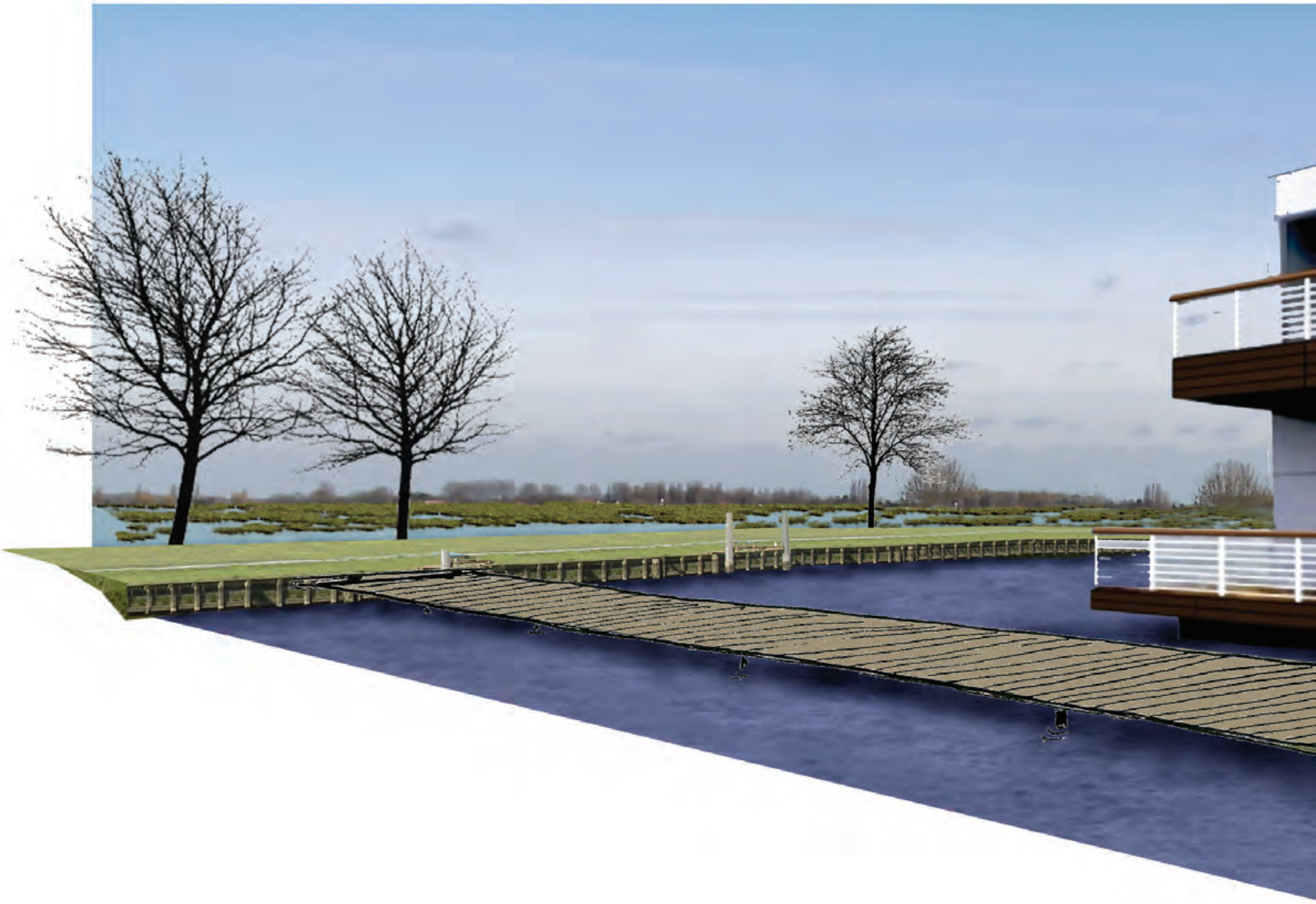


Impressions living on the water.

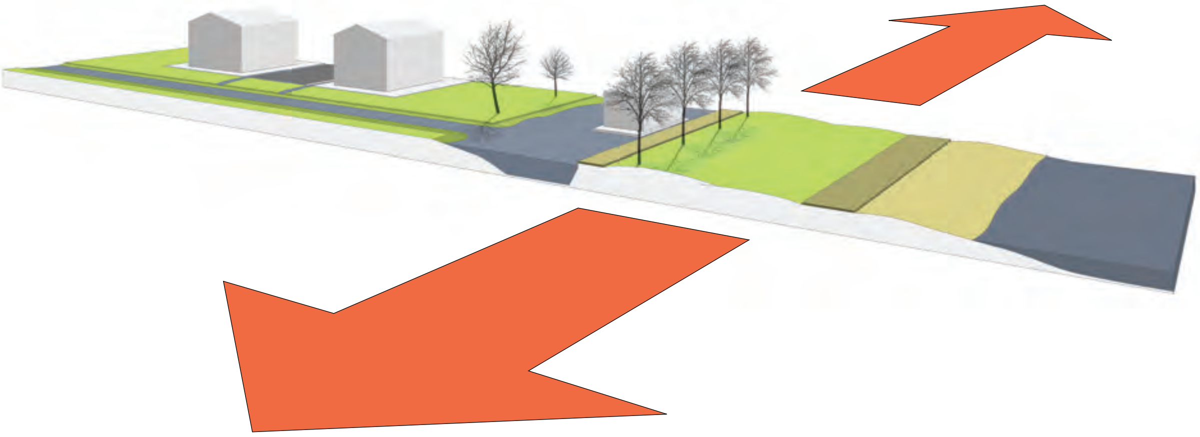
Impression of the islands in the new park. Connections between the islands are made with walking bridges.

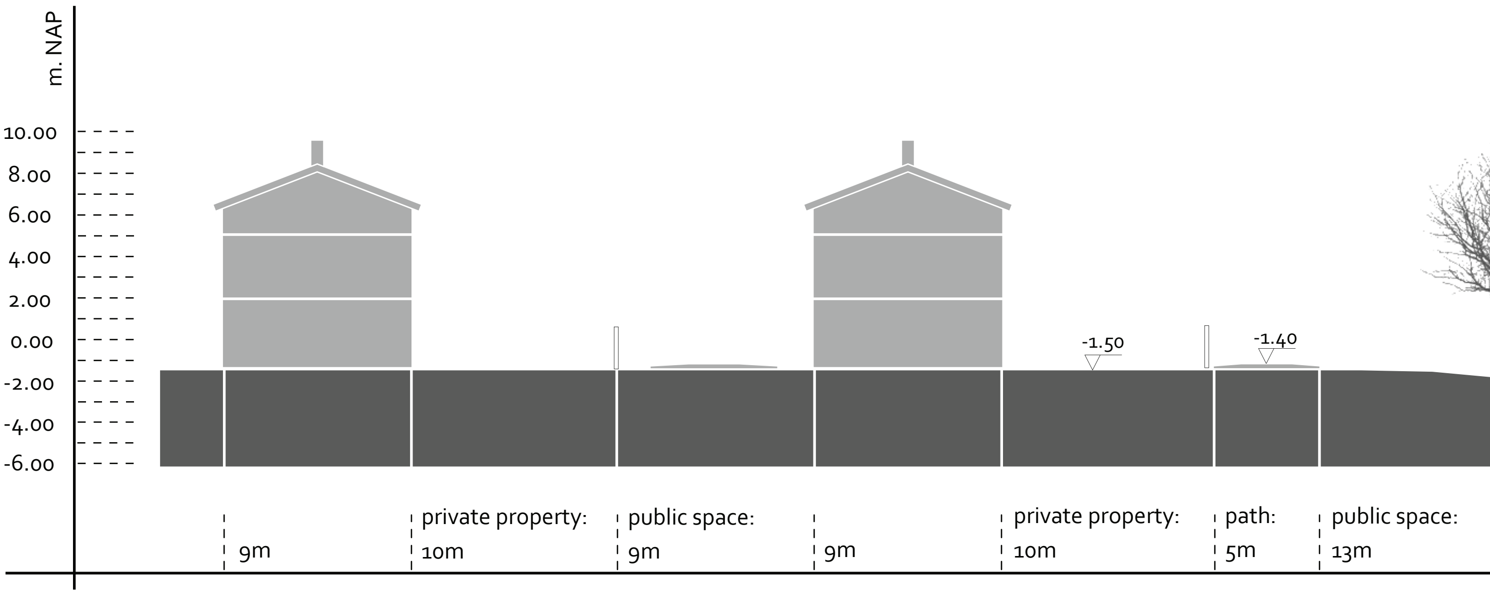
9.5 A NEW BOULEVARD

The southern city edge of Rotterdam was once constricted by a rail road. Last year the rail road is removed, which offers great opportunities.

In the plan Wetlandscape, the new water retention canal south of Pendrecht and Zuidwijk is combined with a new boulevard. This boulevard forms an attractive transition zone between the neighbourhoods and the water storage park. A beach makes the water accessible, and offers possibilties for sunbathing and swimming.

On the new canal floating houses with commercial and hospitallity businesses can develop. Great recreational opportunities turn the once dull and deadening city edge into an attractive linear park zone.

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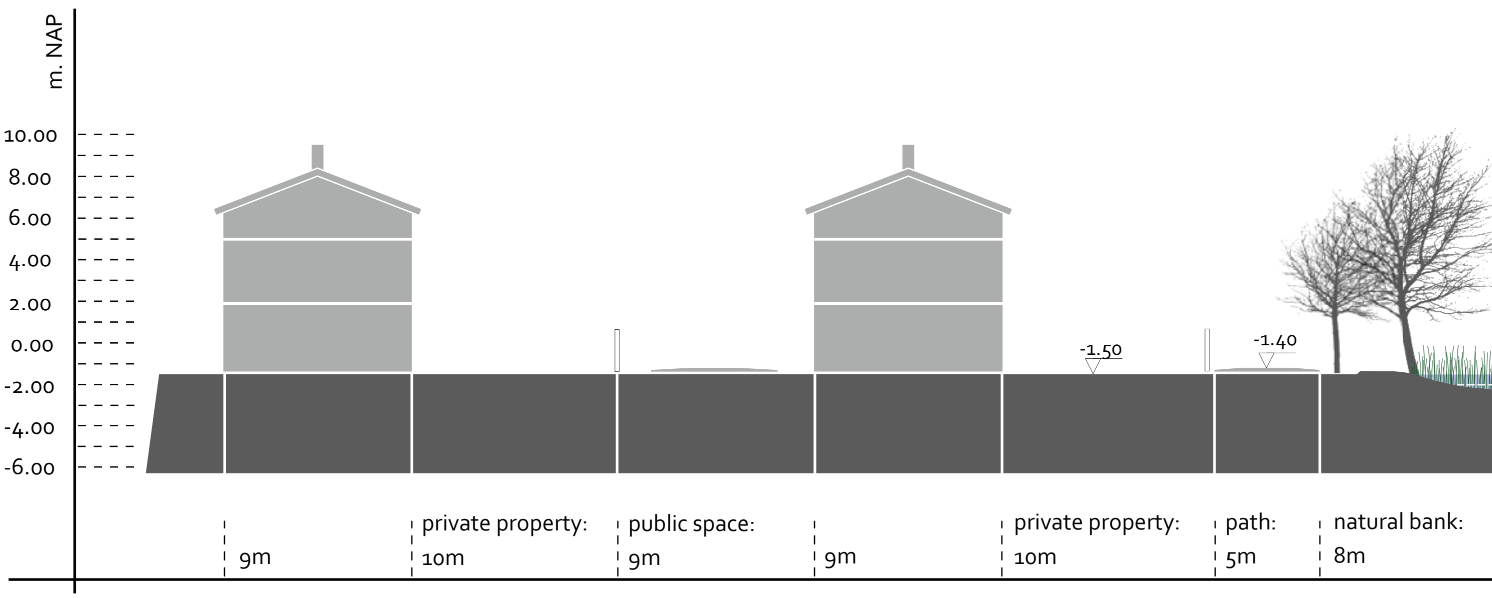
-2.00
-4.00
-6.00
-1.50
-1.40
9m
private property:
10m
public space:
9m
9m
private property:
10m
path:
5m
public space:
13m


m. NAP
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9m
9m
private property:
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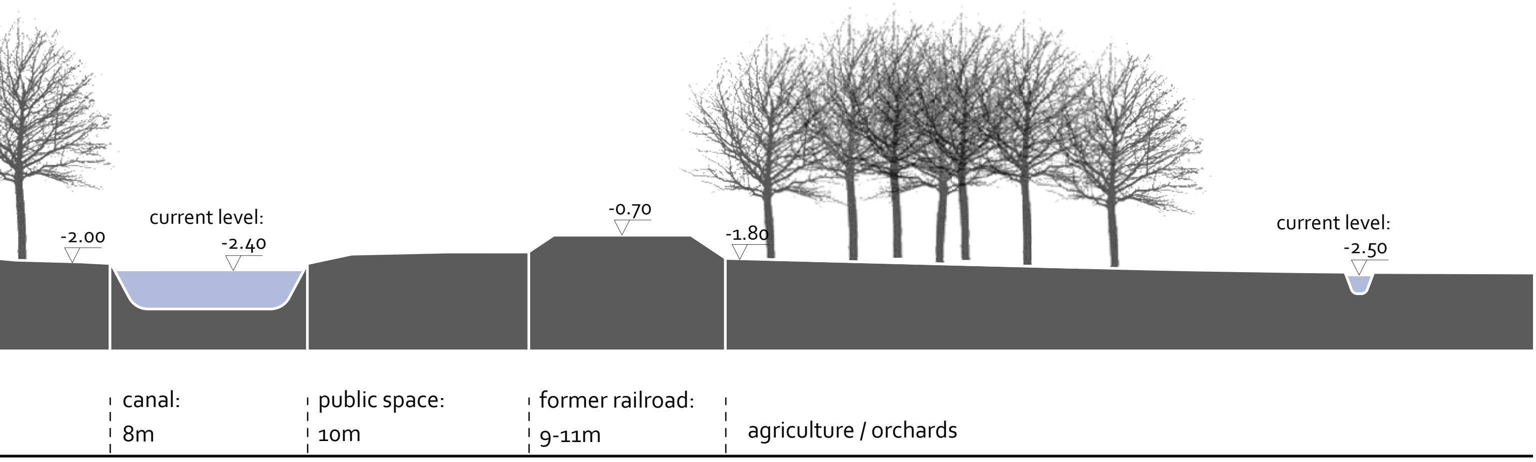
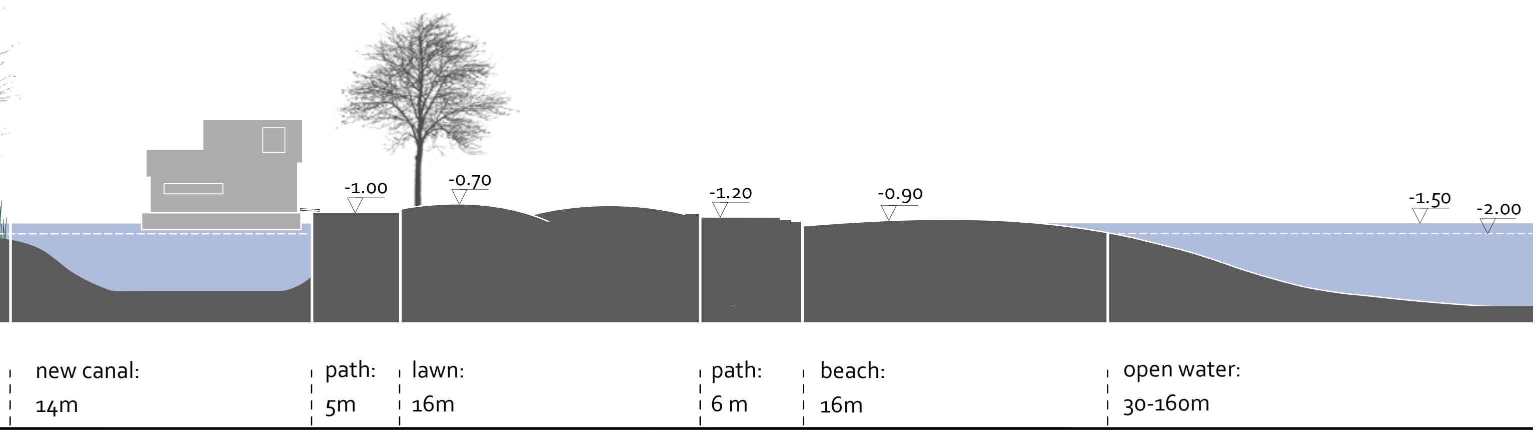
path:
5m
natural bank:
8m



Section southern city edge current situation



Section southern city edge with boulevard and park zone

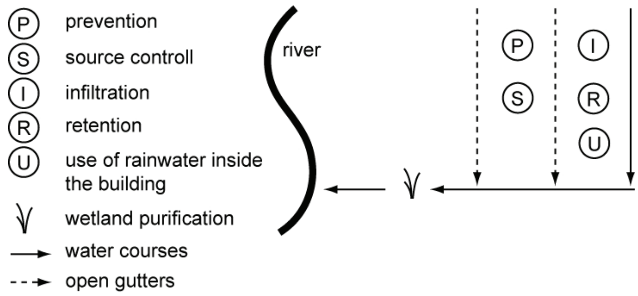
Impression of the new southern city edge of Pendrecht and Zuidwijk. With floating buildings on the new canal, the city edge can develop to a boulevard with park zone.

9.6 NEW URBAN WATER IN THE NEIGHBOURHOODS

The new north – south waterways through the neighbourhoods serve at the same time as bike- and pedestrian routes for inhabitants from the neighbourhood to the new boulevard and park. The connections form green / blue zones through the urban structure, which are great opportunities for combination with the current restructuring of the neighbourhoods. The spatial quality will improve, and more houses will be situated next to or close to green space. People without a garden have more opportunity to spend time outside, which brings along more chances to meet other people. With introducing green / blue connections the social cohesion of the neighbourhood can be improved.

Theory:

'Slow down model'



In this principle technical and spatial measures slow down the rain water in urban areas. Rainwater flows are disconnected from the sewage system, so that waste water and relatively clean rain water are not mixed. Rainwater is retained on roofs and small squares, then be led by open gutters into canals, and finally flow through a system of open waterways towards an helophyte cleaning system.

(Tjallingii, 2007)

9.7 CALCULATIONS WATER RETENTION AND STORAGE

The water machine will be an important part of the new water system of Rotterdam (south). The working of the water machine depends on water circulation. The water circulation is in turn depending on the average precipitation surplus (precipitation minus evaporation). Future precipitation surpluses, specific for winter (November – April) and summer (May – October), for the Rotterdam south district (Pendrecht and Zuidwijk) are calculated in this part.

Pendrecht and Zuidwijk:	
Total surface of neighbourhoods:	248 ha
Total surface of water:	3,6

Water storage surface
The calculations in appendix 3 show that the average precipitation surplus in the region of IJsselmonde is:

Summer 2050:	350 – 480 = -130 mm
Winter 2050:	525 – 120 = 405 mm

The winter surplus and summer shortage for Pendrecht and Zuidwijk (248ha.) in m3 amounts than:

Summer:	248 ha. x -130 mm = -322.400 m3 / 6 months
Winter:	248 ha. x 405 mm = 1.004.400 m3 / 6 months

It is clear that when the water surplus in wintertime would not all be pumped out of the area, there would be no water shortage in summertime.

The amount of water that is necessary for inlet to cope with the water shortage in summer time, is calculated on the basis of the precipitation shortage in summertime.
In summer time the water level will go down. The amount of surface water needed to provide enough water to deal with the water shortage of 322.400, is calculated on the basis of a fluctuation of 50 cm in the water storage basin:

322.400 m3 / 0.50 m1 = 644.800 m2 (64 ha.)
This means only with a water storage area of at least 64 ha. the water system of Rotterdam south can circulate the whole summer, without the inlet of water from the Meuse.

The average flow through
'possible normal situation 2050'

The average flow through of the watermachine is based on the precipitation surplus in winter time. During water shortages in summer the water circulation will be maintained by pumps working on wind energy. The average water inflow in winter time per day:

1.004.400 m3 / 182,5 days = 5500 m3 / day

Pumps on the end of the compartments of the water machine pump water up from the purification wetlands into the water storage basin. This pumping out of the water causes suction from the end of the water machine compartment, and as a result the water will flow through.

Water retention capacity
'Extreme cases'

Information on average precipitation is used to calculate the 'normal' situation and flow through of the water system. But to prepare for more extreme rain showers, information about average precipitation is not sufficient. In this part, it is calculated how much water retention space is needed to retain all rain water of an extreme shower, without discharging water to the sewerage system.

As data for 'extreme rain', the biggest rain shower calculated by KNMI will be used. This extreme situation occurred in 1976, with 101.4 mm of precipitation in 24 hours.

Increased by 11% for 2050, the determining rain shower will rise to:
11% x 101.4 mm = 112 mm

To retain all water after a rain shower, the amount of surface water in the urban areas has to increase. Significant for these calculations is the surface from where runoff flows directly into the open water, that is pavement, roofs and open water. For Zuidwijk and

Pendrecht this is 136 ha.

The total amount of directly inflowing runoff water is than:

112 mm x 136 ha. = 152.320 m3 (150.000 m3)

In the neighbourhoods Pendrecht and Zuidwijk, a water fluctuation of 30 cm is realisable. The surface of water that is needed to retain 150.000 m3 with a fluctuation of 30 cm is:

150.000 m3 / 0.3 m1 = 500.000 m2 (50 ha.)

It is not possible to create 50 ha. of water in the existing urban structure. Almost the whole water storage basin (60 ha) is needed to retain this extreme amount of water. That means that, from a certain amount of water, the water is flowing directly into the storage basin, without passing the purification wetlands of the water machine. Due to limited space, and the necessity of multiple use of space, (future) water management has to deal with priorities. From a certain amount of precipitation water quantity has priority above water quality.

Analyses of the urban structure of Pendrecht and Zuidwijk showed that with a transformation of the water system, and introduction of an hierarchic structure of water ways (concept page...), it is possible to create around 13 ha. of water retention space in the neighbourhoods. 7 ha. of open water already exists, that makes 20 ha. of open water in total.

20 ha. open water with a fluctuation of 30 cm, can store:

20ha x 0.30m = 60.000 m3 rain water.

This amount of rain is the amount of water that comes down on the critical surface of 136 ha. with the extreme storm of:

60.000 / 136 ha. = 44 mm

According to data of KNMI, a rain shower of 44 mm in one day occurs approximately once in eight years.

This means that rain showers smaller than 44 mm can be retained by the urban surface water, and can follow the 'normal' circulation and cleaning process through the water machine, before being stored in the storage basins. Rain showers extremer than 44 mm however, will be discharged into an overflow area south east of Zuidwijk, before being immediately discharged into the storage basin. This water will than not pass the purification wetlands. The water quality will go down a bit, however due to circulation the water will pass the water machine in a later stadium.

CHAPTER 10

CONCLUSION

10 CONCLUSION

The first five chapters of this thesis are a research to the resistency to climate change of the island of IJsselmonde, as a part of the south western delta of the Netherlands. In this part, research question 1 and 2 are answered:

1 How does the landscape of IJsselmonde ' work'?
- *How did the landscape develop in time?*
- *Which existing problems does the landscape have?*

Landscape changes on the island IJsselmonde have always been connected to water, and to man's attitude towards water. This makes the water system one of the most important systems of the landscape of IJsselmonde. Furthermore, urbanisation has been and is a determining process for the landscape of the island. It can be concluded that the water system has been restrained ever since human beings occupy the region, and that this process accelerated since urbanization started. This suppression of the water led to several problems:

The regional water system of IJsselmonde is dependent on the principle water system outside the dike-ring, and with that strongly influenced by external factors of sea and rivers. As a result, IJsselmonde is dependent on artificial management of pumping out and letting in water.

Pumping out water is difficult with high water levels outside the dike-ring, and with extreme rainfall.

The inlet of water is difficult with low water levels outside the dike-ring, and impossible when salt water from the North Sea reaches the inlet points of IJsselmonde.

Clean rain water is pumped out in wintertime, while relatively polluted water from the Rhine is let in during summertime. This leads, together with an hardly circulating water system on the island, to a bad surface water quality.

The urban water system exists mainly of the sewage system. All rainwater is discharged via this system of underground pipes. Extreme showers can not be processed by the system, resulting in sewage overflows in the canals. This leads to a bad water quality, and in extreme cases to water problems in streets and houses.

Even without including climate change, the current (mainly water-) problems that the region of IJsselmonde and especially the urban districts have to cope with, leave it no option to continue this way of dealing with water. The current water management is not sustainable, and not resilient for changes.

2 What are the impacts of climate change on the landscape of IJsselmonde?

The main answer on this research question is that all existing problems concerning the water system will increase in the future. That means:

Due to sea level rise the water outside the dike-ring of IJsselmonde will rise. Pumping out will be more difficult in the future. Salt influences will move land inwards, which will make the inlet of water more difficult because of water quality reasons.

River discharges will change. More water will be discharged in winter time, and less water will be discharged in summertime. This makes pumping and letting in water more difficult, and it intensifies the effect of salt influences from the sea during low river discharges.

The distribution and intensity of precipitation will change. Less precipitation in summer will increase water shortage problems, while more precipitation in winter will increase water surplus problems. More extreme rainfall will especially increase the load on the urban water system and with that lead to a more often overflowing sewage system.

The expected impacts of climate change will cause significant problems for IJsselmonde. A shift in the approach to water has to be made. From chapter six onwards, measures for adaptation of the landscape to climate change are proposed. This part answers the third research question:

3 Which adaptations of the landscape are necessary to solve the existing problems and to prepare for climate change?

To solve existing problems and to prepare the landscape of IJsselmonde to climate change, it is necessary to make the regional and urban water system less dependent on the principle water system of sea and rivers. Therefore the current system has to be more robust, resilient and self-reliant. Adaptations that have to be implemented between today and 2050 are:

Transformation of the urban water system to separate storm water from waste water, and to retain the clean rain water. Urban (surface) water systems have to be restructured, and connected to the regional water system.

Transformation of the regional water system, to clean the water surplus of the urban districts by wetland purification, and to store the water. This water can be used for inlet in dry summer periods.

Circulation is brought back in the water system to improve the water quality, by re-connecting waterways.

The design proofs that the thesis statement can be fulfilled:

Thesis statement:
By transforming the current artificial and un-dynamic water system of IJsselmonde to a more natural and dynamic system, the landscape will be resilient to future climate changes, and more attractive.

The design shows that the landscape can be more attractive by implementing the climate adaptation measures in a local situation. The 'messy' A15 zone is transformed to a water park, where urban rain water is stored. Even the most extreme rain showers can be retained and stored in the area. The new water system will have enough buffer capacity to sustain extremely wet and extremely dry periods, and will have a much better water quality than the current, fragmented water system.

The plan offers a more attractive landscape, with more possibilities for recreation that the current situation. Firstly the new boulevard, attached to the new water retention canal, turns the 'messy' urban fringe into an attractive transition zone between the neighbourhoods and the new water park. The new park is, next to a necessary adaptation to natural circumstances, a beautiful place for daily recreation. There are possibilities for walking, swimming, sailing, and surfing. Furthermore, the new park offers attractive places for living in floating houses.

The circulation of the water, and the cleaning processes in the watermachine, are made comprehensible by design. The new park with the watermachine raises awareness of the presence of water, and the importance of water for the city. This gives the watermachine an additional educational function.

Not only the park, but also the public space in the neighbourhoods Pendrecht and Zuidwijk is more attractive and healthy as a result of climate adaptation measures. The neighbourhood are totally self-reliant, and with that very special in itself. Moreover, more urban water upgrades the neighbourhoods to a more attractive living environment, with more variation.

REFERENCES

CHAPTER 1

Gore A. (2006) *An inconvenient truth*

Tjallingii S., Berendsen R. (2007) *Een Rijke Bron, een nieuwe rol van water in ontwerpen*. Techne Press, Amsterdam

CHAPTER 2

Dutch Ministry (1998) *Vierde Nota Waterhuishouding*

Disco C. (2002) *Remaking "Nature": The Ecological Turn in Dutch Water management* (Science Technology Human Values 2002; 27; 206).

Tjallingii S., Berendsen R. (2007) *Een Rijke Bron, een nieuwe rol van water in ontwerpen*. Techne Press, Amsterdam

EU (2000) KRW (European Water Framework Directive, EWFD)

Dutch Ministry (2000) *Ruimte voor de Rivier* (Room for the River)

Veerman C. (Delta Commission II) (2008) *Samen werken met water. Een land dat leeft, bouwt aan zijn toekomst. Bevindingen van de Deltacommissie 200*8. DELTACOMMISSIE

CHAPTER 3

Vervloet J.A.J., Mulder J.R. (1985) *Cultuurhistorisch onderzoek in het landinrichtingsgebied IJsselmonde*. Stichting voor bodemkartering, Wageningen

National Museum of Natural History. *Geologie van Nederland 'Een tijdreis van 500 miljoen jaar'*. (www.gelogievannederland.nl)

Stichting Oude Kern Rijsoord. *Vroegste geschiedenis van het eiland IJsselmonde* (www. oudekernrijsoord.nl)

Schuetze T. (2008) *Climate adaptive urban design with water in Dutch polders*. Delft University of Technology, Faculty of Architecture. Delft.

Greef P, De. (2006) *Rotterdam Waterstad 2035*. DSV, Municipality of Rotterdam, Rotterdam

Ven, G.P. van de (ed.) (2003) *Man-made Lowlands. History of water management and land reclamation in the Netherlands*. Matrijs, Utrecht

VROM (2004) Nota Ruimte

AHN, Actueel Hoogtebestand Nederland (2009) Het Waterschapshuis (www.ahn.nl)

Rijkswaterstaat (www.rijkswaterstaat.nl)

RPB (Ruimtelijk Planbureau Den Haag) (2006) *Snelwegpanorama's in Nederland*. Nai Uitgevers, Rotterdam

Kuijpers V. (2009) personal communication

LOLA Landscape Architects (2008) *Studie naar verrommeling en de kansen voor een groener en grootser Zuid-Holland*. Rotterdam

Veeken C. Van der (2009) (LOLA Landscape Architects) personal communication

CHAPTER 4

Motloch J.L. (2001) *Introduction to Landscape Design*, Second Edition. John Wiley & Sons, INC. USA.

Greef P, De. (2006) *Rotterdam Waterstad 2035*. DSV, Municipality of Rotterdam, Rotterdam

DSV Municipality of Rotterdam, Waterboard Hollandse Delta, Hoogheemraadschap van Schieland en de Krimpenerwaard, Hoogheemraadschap van Delfland (2007) *Waterplan 2, Werken aan water voor een aantrekkelijke stad*. Rotterdam

Waterboard Hollandse Delta, Herreveld-Brand J. (2009) personal communication

CHAPTER 5

IPCC Climate Change (2007) *Climate Change Impacts, Adaptation and Vulnerability*. Earthscan, London

KNMI (2006) *Climate in the 21st century: four scenarios for the Netherlands*. Royal Dutch Meteorological Institute, De Bilt

Dorland R., Jansen B. (2007) *Het IPCC-rapport en de betekenis voor Nederland*. Publication PCCC, De Bilt / Wageningen

IPCC Climate Change (2007) F*ourth Assessment Report. The Physical Science Basis*. Cambridge University Press

IPCC Climate Change (2007) *Fourth Assessment Report. Impacts, Adaptation and Vulnerability*. Cambridge University Press

IPCC Climate Change (2007) *Fourth Assessment Report. Mitigation of Climate Change*. Cambridge University Press

Cohen S., Miller K. (2001) *North America; in Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press

Dessai S., Sluijs J. Van der. (2007) *Uncertainty and Climate Change Adaptation - a Scoping Study.* Copernicus Institute, Research Institute for Sustainable Development and Innovation. University of Utrecht

Veerman C. (Delta Commission II) (2008) *Samen werken met water. Een land dat leeft, bouwt aan zijn toekomst. Bevindingen van de Deltacommissie 2008*. DELTACOMMISSIE

RIZA Rijkswaterstaat. Buiteveld H., Deursen W. van, Wit M. de (2007) *Klimaatverandering en de afvoer van Rijn en Maas*. Carthago Consultancy Rotterdam. Arnhem

Province of South Holland, Alterra, DHV BV, KNMI, VU. (2008) *Klimaateffectschetsboek Zuid-Holland*. Rotterdam.

MNP, Schrojenstein Lantman J.P. van (2007) *Overstromingsschade in Dijkring 14, Een koppeling van het Hoogwater Informatie Systeem aan de Ruimtescanner*. Bilthoven

Theunissen R.P.G.J. (2006) *A probabilistic flood risk assessment and the impact of compartmentation*. Delft University of Technology. Delft

Kuypers V. (2008) *Groen voor Klimaat*. De Groene Stad. Alterra, Wageningen

CHAPTER 6:

Schuetze T (2008) *Climate adaptive urban design with water in Dutch polders*. (page 1). Delft University of Technology, Faculty of Architecture. Delft.

Pols L., Kronberger P., Pieterse N., Tennekes J., RPB Den Haag (2007) *Overstromingsrisico als ruimtelijke opgave*. NAi Uitgevers, Rotterdam

CHAPTER 7

Tjallingii S., Berendsen R. (2007) E*en Rijke Bron, een nieuwe rol van water in ontwerpen.* Techne Press, Amsterdam

Pols L., Kronberger P., Pieterse N., Tennekes J., RPB Den Haag (2007) *Overstromingsrisico als ruimtelijke opgave*. NAi Uitgevers, Rotterdam

CHAPTER 8

DSV Municipality of Rotterdam (2004) *Pendrecht, Cultuurhistorische analyse en beschrijving*

(1948-1958) Rotterdam

KEI Kenniscentrum Stedelijke Vernieuwing (2009) *Rotterdam, Pendrecht* (www.kei-centrum.nl) Rotterdam

KEI Kenniscentrum Stedelijke Vernieuwing (2009) *Rotterdam, Zuidwijk* (www.kei-centrum.nl) Rotterdam

CHAPTER 9

Tjallingii S., Berendsen R. (2007) *Een Rijke Bron, een nieuwe rol van water in ontwerpen*. Techne Press, Amsterdam

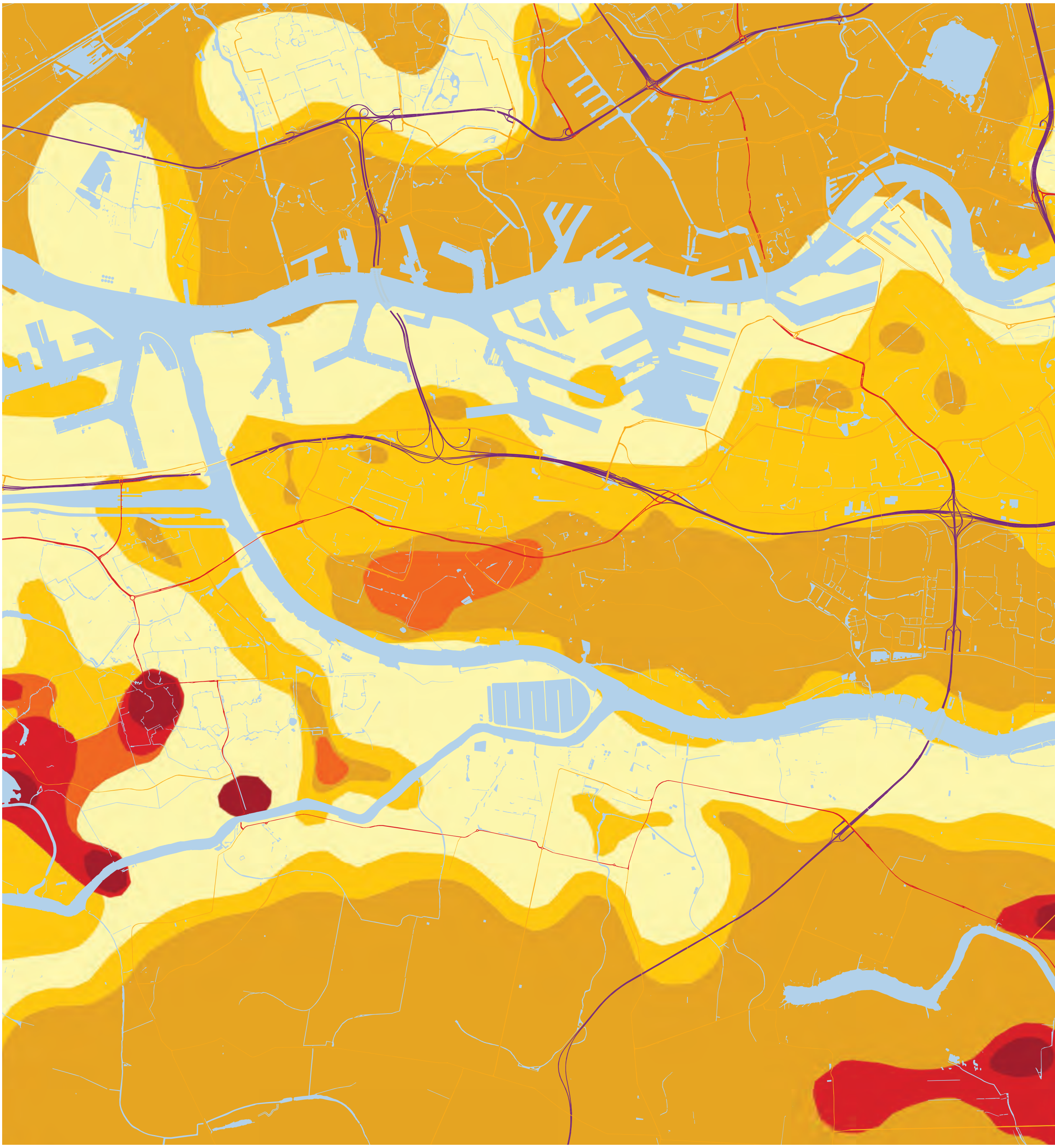
Deleuze G., Guattari F., Massumi B. (1976) *A Thousand Plateaus: Capitalism and Schizophrenia. Rhizome, introduction.* Les Editions de Minuit. Paris

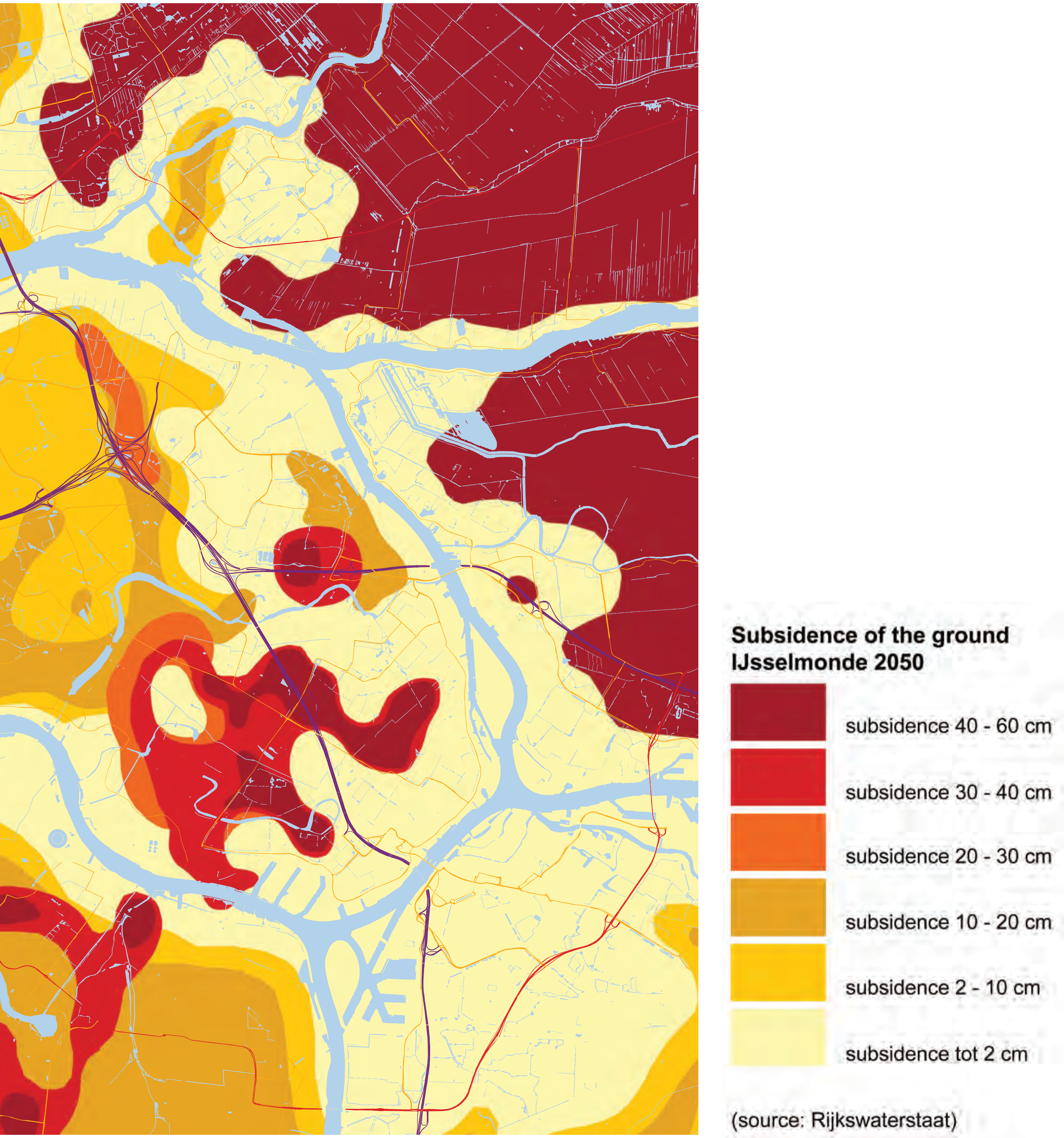
France R.L. (2002) *Wetland Design: Principles and Practices for Landscape Architects and Land Use Planners*. W. W. Norton & Company. New York

STOWA (Stichting Toegepast Onderzoek Waterbeheer) *Handboek zuiveringsmoerassen voor licht verontreinigd water*. Utrecht, 2001.

Dien F. van (Ecofyt) (2009) personal communication

APPENDICES




Subsidence of the ground
IJsselmonde 2050
subsidence 40 - 60 cm
subsidence 30 - 40 cm
subsidence 20 - 30 cm
subsidence 10 - 20 cm
subsidence 2 - 10 cm
subsidence tot 2 cm
(source: Rijkswaterstaat)

		G	G+	W	W+
Global temperature rise		+1°C	+1°C	+2°C	+2°C
Change in air circulation patterns		no	yes	no	yes
Winter [3]	average temperature	+0.9°C	+1.1°C	+1.8°C	+2.3°C
	coldest winter day per year	+1.0°C	+1.5°C	+2.1°C	+2.9°C
	average precipitation amount	+4%	+7%	+7%	+14%
	number of wet days (≥ 0.1 mm)	0%	+1%	0%	+2%
	10-day precipitation sum exceeded once in 10 years	+4%	+6%	+8%	+12%
	maximum average daily wind speed per year	0%	+2%	-1%	+4%
Summer [3]	average temperature	+0.9°C	+1.4°C	+1.7°C	+2.8°C
	warmest summer day per year	+1.0°C	+1.9°C	+2.1°C	+3.8°C
	average precipitation amount	+3%	-10%	+6%	-19%
	number of wet days (≥ 0.1 mm)	-2%	-10%	-3%	-19%
	daily precipitation sum exceeded once in 10 years	+13%	+5%	+27%	+10%
	potential evaporation	+3%	+8%	+7%	+15%
Sea level	absolute increase	15-25 cm	15-25 cm	20-35 cm	20-35 cm

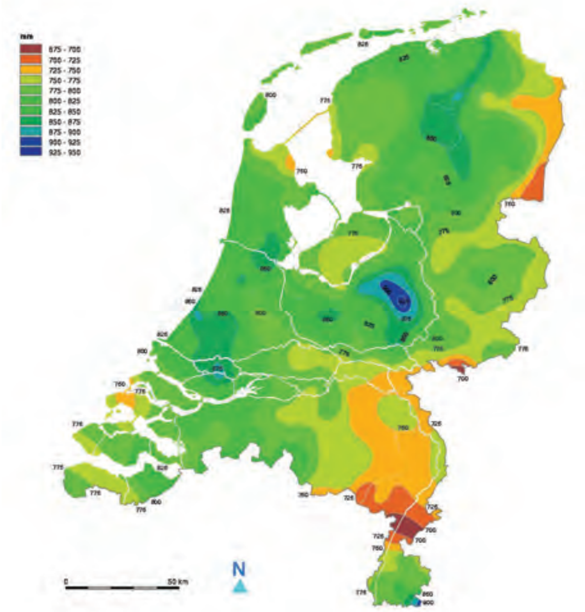
Climate change in the Netherlands around 2050, compared to the baseline year 1990, according to the four KNMI '06 scenarios. Source: KNMI '06

The average precipitation surplus in winter time and the precipitation shortage (evaporation surplus) in summertime are calculated for the region of IJsselmonde.

No exact data is available about average evaporation in summertime and average evaporation in wintertime. From evaporation data of the last twenty years can be gathered that it is a 'dry summer', when from the total evaporation in a year 80% evaporates in summer and 20% in winter. This observation leads to the following assumption for the calculations for the watermachine:

From the total, average potential evaporation per year, 20% evaporates in wintertime and 80% evaporates in summertime

1 Average precipitation



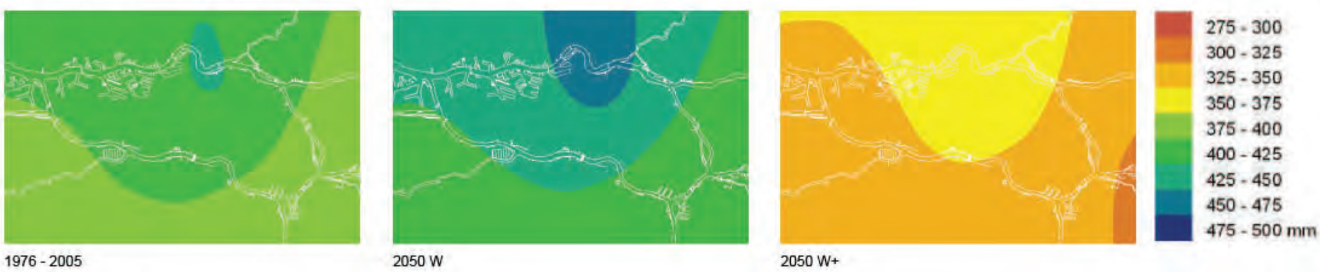
KNMI data 1971-2000

It is clear that IJsselmonde lies in an extra wet patch. The average precipitation for IJsselmonde region is 875 mm / year. For the calculations, climate changes for 2050 will be included. Furthermore, differences between summer and winter are becoming more important. Therefore the specific information for IJsselmonde in summer and winter in 2050 (below this page) will be used to calculate the precipitation:

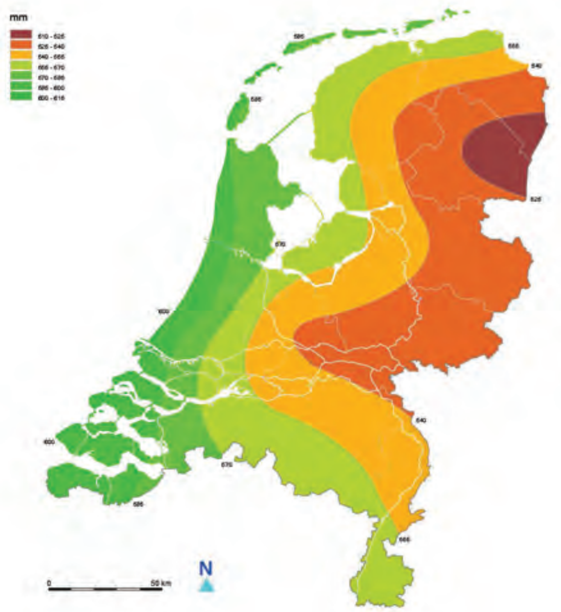
Average precipitation winter time (W and W+):
525 mm

Average precipitation summer time (W+):
350 mm

Average precipitation summer half-year (mm):



2 Average evaporation

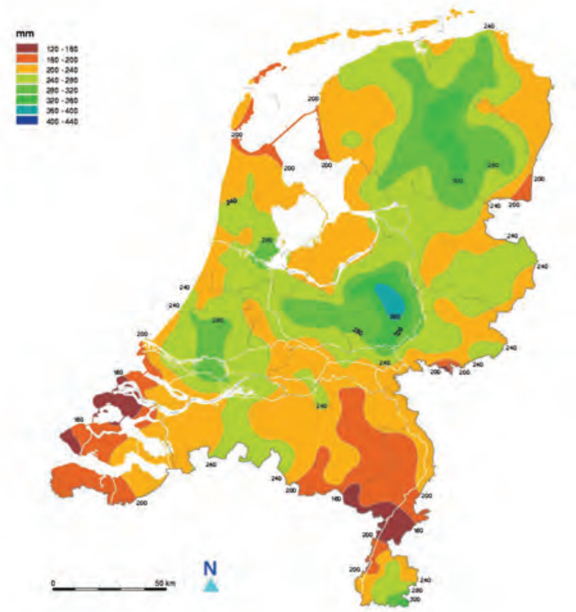


KNMI data 1971-2000

IJsselmonde shows an average evaporation of 570 mm / year. Scenarios G+ and W+ show an increase of averagely 5% for 2050 (Klimaatschetsboek Zuid Holland). That makes 570 x 1.05 = 600 mm.

Summer time:	80% x 600 =	480 mm
Winter time:	20% x 600 =	120 mm

3 Precipitation surplus



KNMI data 1971-2000

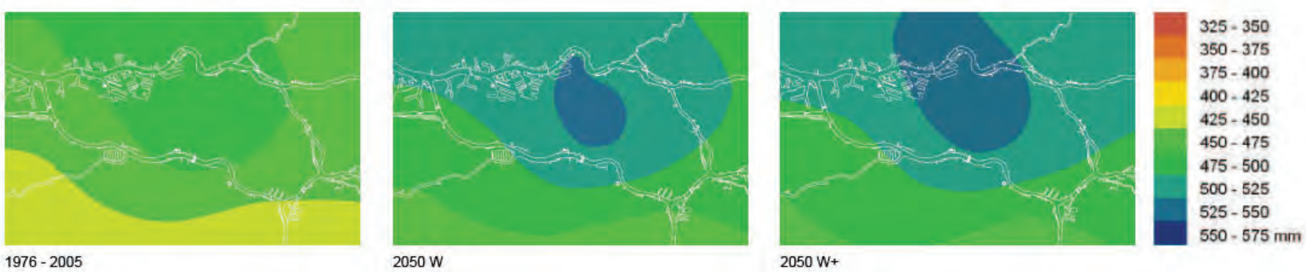
Average precipitation minus average evaporation results in the average precipitation surplus, as showed in the last map. This is:

875 – 600 = 275 mm / year

Specific for winter and summer, based on climate scenarios for 2050 (as calculated in point 1 and 2) show a different picture:

Summer 2050:	350 – 480 = -130 mm
Winter 2050:	525 – 120 = 405 mm

Average precipitation winter half-year (mm):



Data for calculations

Surface island IJsselmonde (inside the delta dike):
105 km2

Urban (built up) area:
5000 ha.

Average 4% open water of built up area:
200 ha open water

Average 55 % of surface directly running off. (roofs and pavement):
2750 ha. roofs and pavement

Determining rain shower:
As data for 'extreme rain', the biggest rain shower calculated by KNMI will be used. This extreme situation occurred in 1976, with 101.4 mm of precipitation in 24 hours.
Increased by 11% for 2050, the determining rain shower will rise to:
11% x 101.4 mm = 112 mm in 24 hours

423. 000 inhabitants
4028 inhabitants / km2

Water retention extreme rain precipitation

112 mm on 2750 ha. = 112 * 2750 (0.112 * 27500000) = 3.080.000 m3 water

When 0.5 m fluctuation is allowed, a surface for water retention is needed of:

3.080.000 / 0.5 = 6.160.000 = 616 ha.

How much buffer needed in dry summers?

In appendix 3 the precipitation surplus in 2050 is calculated:

Summer 2050: 350 – 480 = -130 mm

Winter 2050: 525 – 120 = 405 mm

For Ijsselmonde (10.000 ha.) the winter surplus and summer shortage in m3 amounts:

Summer 2050: 10.000 ha. x -130 mm =
- 13.000.000 m3 (in 6 months)

Winter2050: 10.000 ha. x 405 mm =
40.500.000 m3 (in 6 months)

Surface of water needed for water inlet during summer of 13.000.000 m3, fluctuation 0.5m:

13.000.000 m3 / 0.50 m1 =
26.000.000 m2 (2600 ha.)