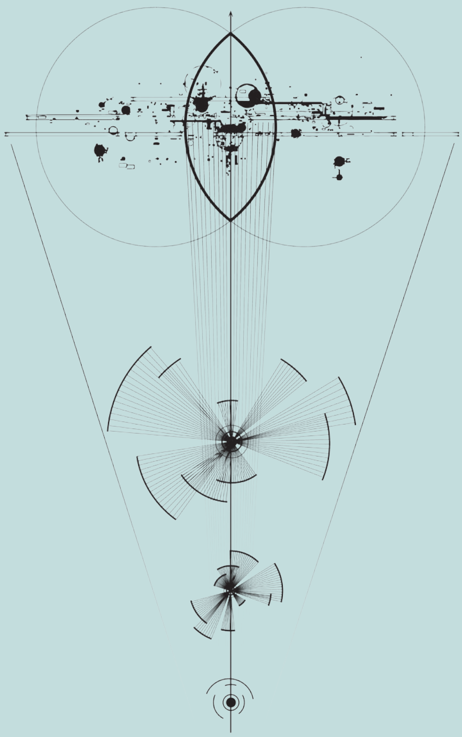
TURNING THE TIDE

INVERTING ECOSYSTEM SERVICE ASSESSMENT
AS A PLANNING AND DESIGN INSTRUMENT FOR DECISION-MAKERS
TO DEVELOP SUSTAINABLE ECO-BASED SOLUTIONS IN AN UNCERTAIN REGION



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Colophon .

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P5 Thesis Report

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Preface and Acknowledgements .

With these first words I would like to express my gratitude to my mentors from the TU Delft Taneha Kuzniecow Bacchin and Alexander Wandl and my supervisor from the Municipality of Rotterdam Mechteld Oosterholt. In this year they guided me during the development of this thesis with their time, input, words, encouragement and feedback. This made the thesis to what it is now.

The project 'Turning the Tide' is part of the Transitional Territories studio of the master Urbanism of TU Delft. The studio offers the possibility to find ways to control the pathways of nature development, preservation and regeneration through time. How can we anticipate, prepare and react to the ever-changing conditions for designing with nature in order to gain most crucial values through time? The studio explores the altered state of the North Sea territory and the possibility of a new development logic between land and sea. I am thankful for the challenging experience of being part of this studio. Thankful for the opportunities the symposiums and exhibitions brought me, for the theoretical input from external academics and practicioners and for the comments, suggestions and feedback the fellow urbanists and architects gave me during this year.

Besides that, I would like to thank Han Meyer for his time and interest to discuss the developments of my project during several conversations. His extensive knowledge about the Rotterdam Region and the dynamics of the delta brought my thesis to a next level. I'm also thankful to the program leader and partners of the project of the 'River as a Tidal Park' for their openness and time during the interviews, workshops and conversations, and to the team from the Living Lab 'Building with Sediment' for the masterclasses, presentations and excursions, which all provided me with new insights, inspiration and knowledge.

Last but not least, I would like to thank my family and friends for their support, patience, encouragement and care during this graduation year. I could not have done it without you.

Thanks to all!

Summary .

An estimated sixty percent of the earth's ecosystems have been degraded in the past fifty years. Considering that our whole society is based on ecosystem services – the benefits we obtain from nature – it is contradictory to think it is man who has applied the greatest amount of pressure and is the main actor in the environment degrading. The manipulation of the delta landscape in the Rotterdam region, to meet the economic desire of society, resulted in a degradation of ecosystem services. Each eco-based design, such as 'the River as a Tidal Park', being the case-study for my thesis, is subjected to a wide range of environmental, societal and political risks. Considering the extremely uncertain projected risks for increasing sea levels and more extreme river discharges after 2050, the river does not provide the flexibility the future demands. After the implementation of relatively short term and local scale initiatives the project is still subjected to these uncertainties. This makes the final values it can produce in the future uncertain and might conflict with long term and large scale projects. Therefore, it might result in a loss of capital for partners as the project appears to be unsustainable. Accordingly, the thesis aims for ensuring the project provides the desired ecosystem services for 2100. Costs and benefits are distributed more evenly among stakeholders through time and space without destroying capital for collaborating partners.

To bridge the gap between time and space, the thesis considers the concept of seeing and working with "Nature as a New Economy' as a starting point. This concept focuses on the development, preservation and regeneration of nature to obtain most values from it. In order to make sure the 'River as a Tidal Park' provides the values society desires in the far future, the thesis approaches two scenarios for 2100. The Rest Scenario considers moderate climate change and socio-economic decline and the Steam Scenario investigates extreme climate change and socio-economic growth. The research follows in a search for value synergies among both scenarios to find 'no regret' measures for the short term. To guide decision-makers in the process between short term investments and long term needs, an adaptive framework is developed. This framework provides guidelines to take action when specific tipping points in time are reached. The thesis approaches eco-based projects from a different perspective as it provides a method to design and plan with ecosystem services in a deeply uncertain region. It considers the demanded ecosystem services on the long-term for short term developments which makes short term projects more future-resilient and adaptable through time. The hypothesis which will be tested is to what extend the value of ecosystem services can be inverted in time to use it as a design instrument in relation to decision-making processes in order to obtain most values from it. The research question which leads this thesis is:

How can the concept of 'Nature as a New Economy' be used for the development of an adaptive design for the spatial transformation of the fluvial zone of the Nieuwe Maas considering the uncertain future?

The thesis' results show that, with the proposed adaptive design, most ecosystem services increase through time. This results in increasing interest and a model of revenue for stakeholders, which makes sure that the project can be extended until 2100. The concept of 'Nature as a New Economy' is providing decision-makers with a language to give insight in the benefits for them on the long term, is increasing the financial support for the project and will reduce the risks related to the uncertain future for society. It makes decision-makers aware of the value of nature and that it could go beyond economic growth. It can be seen as an inversion of the concept of nature: nature is no longer seen as something we have to fight against to strive for economic growth. Nature can now be seen as an economy itself which is the new value for producing economic growth.

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introduction

Context

The project 'Turning the Tide' is part of the Transitional Territories studio of the master Urbanism of TU Delft. The studio offers the possibility to find ways to control the pathways of nature development, preservation and regeneration through time. How can we anticipate, prepare and react to the every-changing conditions to design with nature in order to gain most crucial values through time? The studio explores the altered state of the North Sea territory and the possibility of a new development logic between land and sea. An inspirational trip to the coastal zones of the North Sea helped to develop a fascination for certain sites and made me understand the influences of economic growth on the natural environment. Visiting transitional territories along the North Sea coast with relicts scattered around in the landscape, made me understand the effects of human economic processes on the functioning of the landscape. However those sites are often abandoned and in altered state, they now form amazing and fascinating scenes in the coastal regions of the North Sea.

Motivation

An estimated sixty percent of the earth's ecosystems have been degraded in the past fifty years (Millenium Ecosystem Assessment, 2005, Science for Environment Policy, 2015). Taking into account the fact that our whole society is based on ecosystem services, i.e. the benefits we obtain from nature, it's quite contradictory that man-made pressures are the main causer of this environmental degradation (Science for Environment Policy, 2015). To meet the demand from the built environment, we keep on taking from the natural environment, with waste being one of the main outputs that are given in return. Trends such as population growth, urbanization and consumerism are even increasing our ecological footprint and the linear economy is causing a high pressure on the natural capital. Besides this, climate change is also depleting the ecosystems, mainly due to shifts in temperature (Center for Climate and Energy Solutions, 2017). Not only will the biodiversity decrease, also other ecosystem services (such as food, clean air and recreational possibilities) which we obtain from nature, will become scarce. What will happen when cities keep on growing, the demand keeps on increasing and at some point the landscape is depleted and cannot support the cities anymore? Preservation of nature and sustainable use of its services would prevent more vulnerable groups and future generations from being the victim of our behavior today.

The natural environment can be seen as a common good, which we can understand as a good which is beneficial for all or most members of a given community. Current generations do not feel responsible for the common good as they do not see the long term benefits of this good, for themselves and for future generations (Gilbert, 2014, Hardin, 1968). Since several decades, the concern about the quality of nature, landscape and environment became a major subject in debate. When the impacts of climate change became more clear, adaptation measures to mitigate and adapt to changing environmental circumstances are more and more addressed in urban planning and design (Meyer, 2016). However, adaptation measures to restore ecosystems and their services are still under-utilized by policymakers (Munang, et al., 2013, Bennett et al., 2015). Greater understanding of the institutional influences on ecosystem services are of a crucial importance to the conservation and regeneration of ecosystems and therefore to their services and human well-being (Bennett et al., 2015). Eco-based approaches, focusing on protecting ecosystems by managing, conserving and restoring nature, are part of larger socio-ecological systems. Eco-based solutions are focusing on providing ecosystem services for future needs, but the complex socio-ecological systems have to consider the dynamics of systems over time to make them sustainable in an uncertain world (Ostrom and Cox, 2010).

Using the concept of ecosystem services in planning and design processes is strongly related to scales; both spatial and temporal. Ecosystems and its services are not static, but operate within different spatial and temporal scales, called the spatio-temporal dynamic, which can help in planning and design with ecosystem services for uncertain futures (Hein et al., 2006, Fisher et al., 2009). The spatio-temporal dynamic of ecosystem services result in unexpected, or maybe expected, but consciously neglected, outcomes in other spaces or timeframes. Therefore, it might result in destroying capital for stakeholders as projects appear to be unsustainable. Knowing beforehand which investments affect which stakeholders through time and space can help in a better distribution of costs and benefits among stakeholders, resulting in well-considered investments.

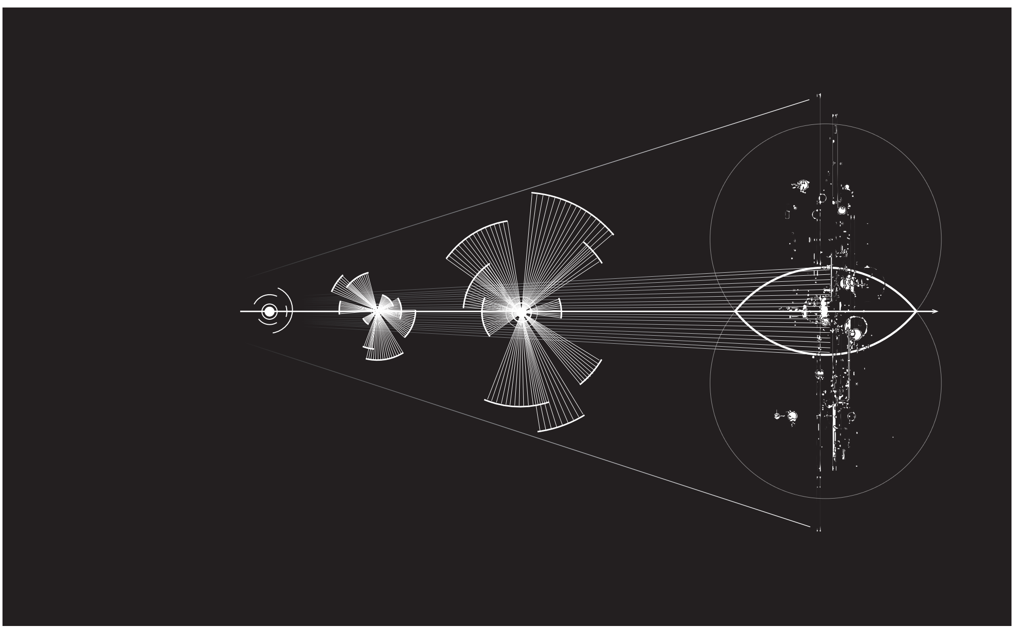
Turning the Tide

In order to bridge the gap between time and space, the starting point of this thesis is the seeing and working with nature as a new economy. Quantifying nature is a way to frame the concerns of ecology in a modern and common language. The concept gives insight in the value of investing in nature for stakeholders, resulting in increasing financial support. The common language to bridge the gap between economy and ecology can provide decision-makers with a tool to exceed their personal frame of time and space and work towards the objective of a sustainable future. The concept focuses on the development, preservation and regeneration of nature in order to obtain most values from it. This can be seen as an inversion of the concept of nature: nature is no longer seen as something we have to fight against to strive for economic growth, nature can now be seen as an economy itself which is the new value for producing economic growth.

After implementation of an eco-based design, the design is still subjected to uncertainties which affect the final outcome and corresponding ecosystem services. Designing for the 'most plausible' future could therefore result in the loss of capital when the future appears to be different. The project 'Turning the Tide' focuses on making sure that eco-based solutions can be adapted to uncertainties of the future, to change the spatial configuration of the project according to adjusted future needs. This results in the ultimate economic value of nature through all time frames.

For this to happen, a shifting logic of planning and design with ecosystem services is needed. The project 'Turning the Tide' uses a backcasting method which investigates the desired values for several plausible futures and takes the synergies back to short term implementations. The method investigates the desired ecosystem services for (in this case) two long-term scenarios, searches for value synergies among them and uses these similarities to develop 'no-regret' measures for the short-term. As these measures are desired in each plausible future, the short-term implementation is able to adapt to changing circumstances without destroying capital for involved stakeholders. To guide decision-makers in the process between short term investments and long term needs, an adaptive framework is developed. This framework provides guidelines to take action when specific tipping points in time are reached. The thesis approaches eco-based projects from a different perspective as it provides a method to design and plan with ecosystem services in relation to the uncertain future. A conceptual diagram of the method is represented in figure 1 in which the right side indicates the long-term with two scenarios. The value synergies among them are backcasted towards the left: the short-term 'no regret' measures. During the projects pathway, specific tipping points are reached which change the pathway accordingly and provide a specific range of ecosystem services on different scales.

The environment, and therefore also society, desires for increased awareness of the importance of implementing eco-based solutions on the short term. As the project provides insight in the range of values which short-term measures can provide on the long-term, it bridges the complexity of the socio-ecological systems. The carrying capacity of short-term eco-



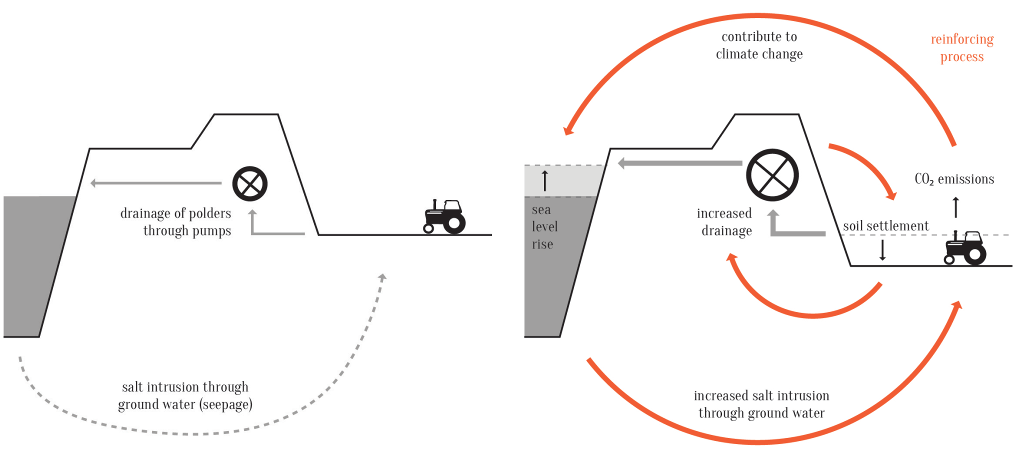
▲ Figure 1 | Conceptual diagram of the developed method for backcasting ecosystem services (source: by author) based solutions increases as the benefits for this generation become visible. In this way, the 'no-regret' measures provide values for the current generation and keeps options open for providing the values future generations needs as well. Therefore, the concept of 'Nature as a New Economy' is providing decision-makers with a language to give insight in the benefits for them on the short- and long term, is increasing the financial support for eco-based solutions, will reduce the risks related to the uncertain future for society and will therefore function as nature being the economy itself, which is the new value for producing economic growth.

Case-Study

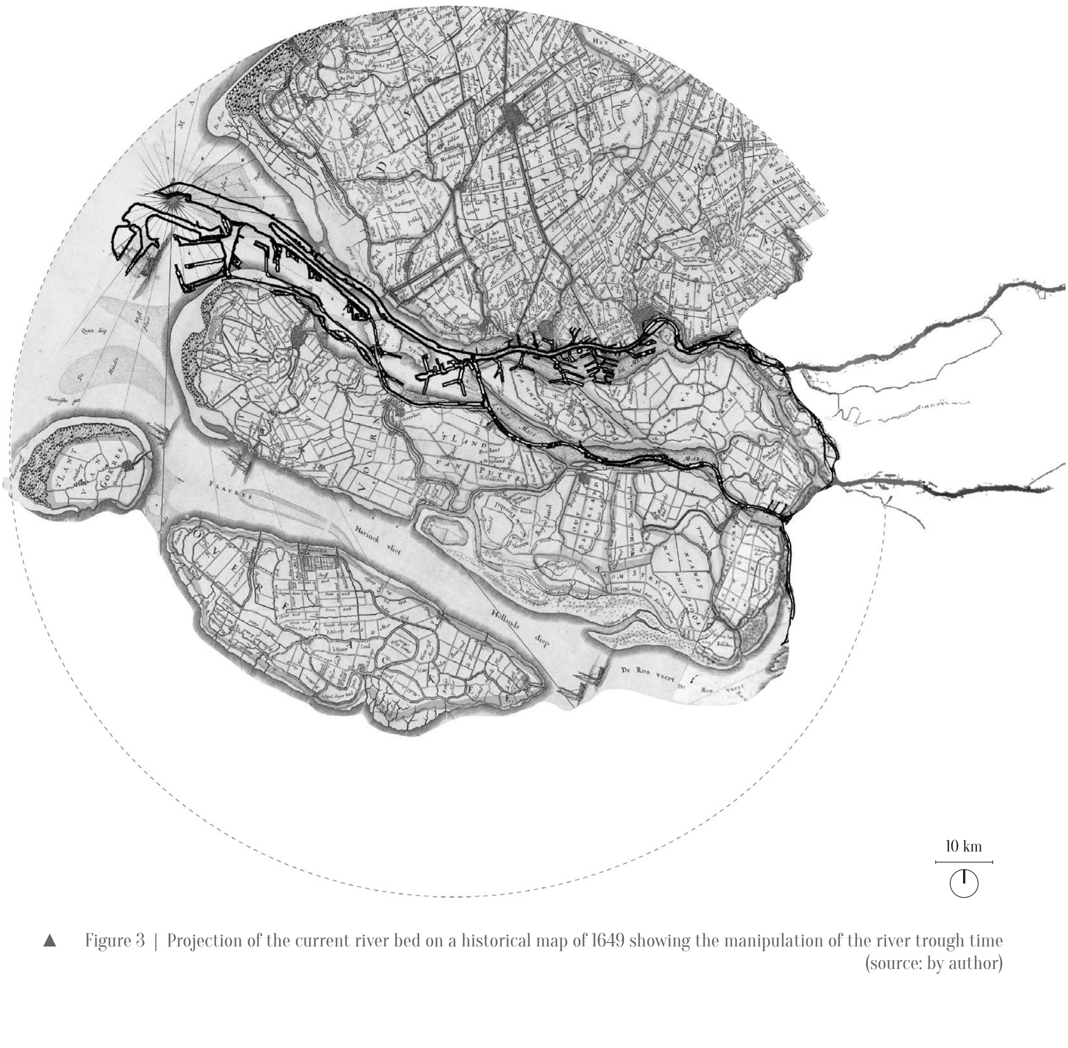
The previously described theories and methods, which will be further elaborated in part I of this thesis, are tested on a case-study: the Rotterdam Region along the North Sea coast. This delta region has been subjected to a strong manipulation of nature, which resulted from the desire for economic growth. Figure 3 shows a projection of the current river bed of the Nieuwe Waterweg and the Nieuwe Maas on the Delta Landscape of 1649 to illustrate the drastic changes. This resulted in a degradation of nature along the riverside, but also results in unattractive riversides for recreational possibilities. The water system which contributed to this extreme manipulation of the river is one consisting of hard measures. The Dutch have always protected themselves against the water by dike systems, sluices, dams and through drainage of the polders. This resulted in the fact that the polders within the dikes are located much lower than the current river water levels due to soil subsidence. The height difference between land and water now results in flood risks of several meters water depth when a primary dike collapses and also stimulates saline intrusion through ground water. This is conflicting with both agriculture and nature on land as it decreases water quality. Besides that, soil subsidence causes huge amounts of CO2 emissions due to peat oxidation, which contributes to climate change. The scenarios which are considered in this case-study (the Deltascenarios for the region of Rijnmond Drechtsteden (Deltaprogramma Rijnmond-Drechtsteden, 2011)) show warning numbers for sea level rise which, in combination with constant soil subsidence, increases the problems (see figure 2). The question is if it will be feasible to keep draining the land as it increases the problems for agriculture, reduces the access to fresh water, increases water safety problems and increases CO2 emissions.

Should we try to keep fighting against nature with possibly disastrous consequences as a result? Or should we accept that we live in a delta landscape and regenerate natural ecosystems to prevent future generations from being the victims of the behaviour we have adopted today?

One project in the Rotterdam Region that anticipates to these questions and aims to work with nature instead of fight against is the project of the 'River as a Tidal Park'. The development of this thesis went hand in hand with an internship at the Municipality of Rotterdam, which is closely involved in this project. The project aims for restoring nature in the fluvial zone of the Nieuwe Maas in order to restore the natural values and at the same time provide an attractive river for recreational purposes. It aims for producing value with tidal nature for future purposes and is therefore producing a type of



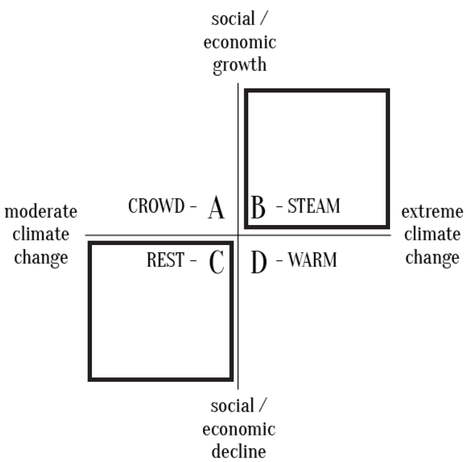
▲ Figure 2 | Reinforcing process of human actions, climate change and risks (source: by author)



▲ Figure 3 | Projection of the current river bed on a historical map of 1649 showing the manipulation of the river trough time (source: by author) economy with nature. With this project the partners aim for providing the following ecosystem services (de Urbanisten, 2018):

1. Relate city, river and harbor, by increasing recreational values and the accessibility of the water
2. Increase natural value and biodiversity
3. Create an educational environment where the tidal parks create awareness of living in the delta and can provide in playing grounds for kids to get acquainted with nature
4. Increase water safety by protection of the dikes
5. Food production by generating fishing spots and produce edible plants and animals
6. Function as a basis for urban development, because tidal parks increase land and real estate values and provide a green business environment
7. Contribute to regional circularity by reusing Rest flows.

However, as explained before, each eco-based project, such as 'the River as a Tidal Park', is subjected to a wide range of environmental, societal and political risks. Considering the extremely uncertain projected risks for increasing sea levels and more extreme river discharges after 2050, the river does not provide the flexibility the future demands. The project now mainly focuses on one future: the one towards economic growth and increasing urbanisation, while there could be more than one plausible future. In order to make sure the project provides the values society desires in the far future, the thesis approaches scenarios for 2100: the Deltascenarios for the region of Rijnmond Drechtsteden (Deltaprogramma Rijnmond-Drechtsteden, 2011). They are based on two main uncertainties, related to social-economic decline or growth and to moderate or extreme climate change. In this project two scenarios (Rest and Steam) are considered, see



▲ Figure 1.4 | Considered scenarios (source: by author)

figure 1.4. The scenarios are combined with the new published numbers of sea level rise, developed by Deltares (2018). Considering these two scenarios, two desired ecosystem services for the 'River as a Tidal Park' have to be added to the list of seven in order to meet future desires: 8) the provision of fresh water and 9) climate regulation. Therefore, in total, there are nine ecosystem services which are considered in this project.

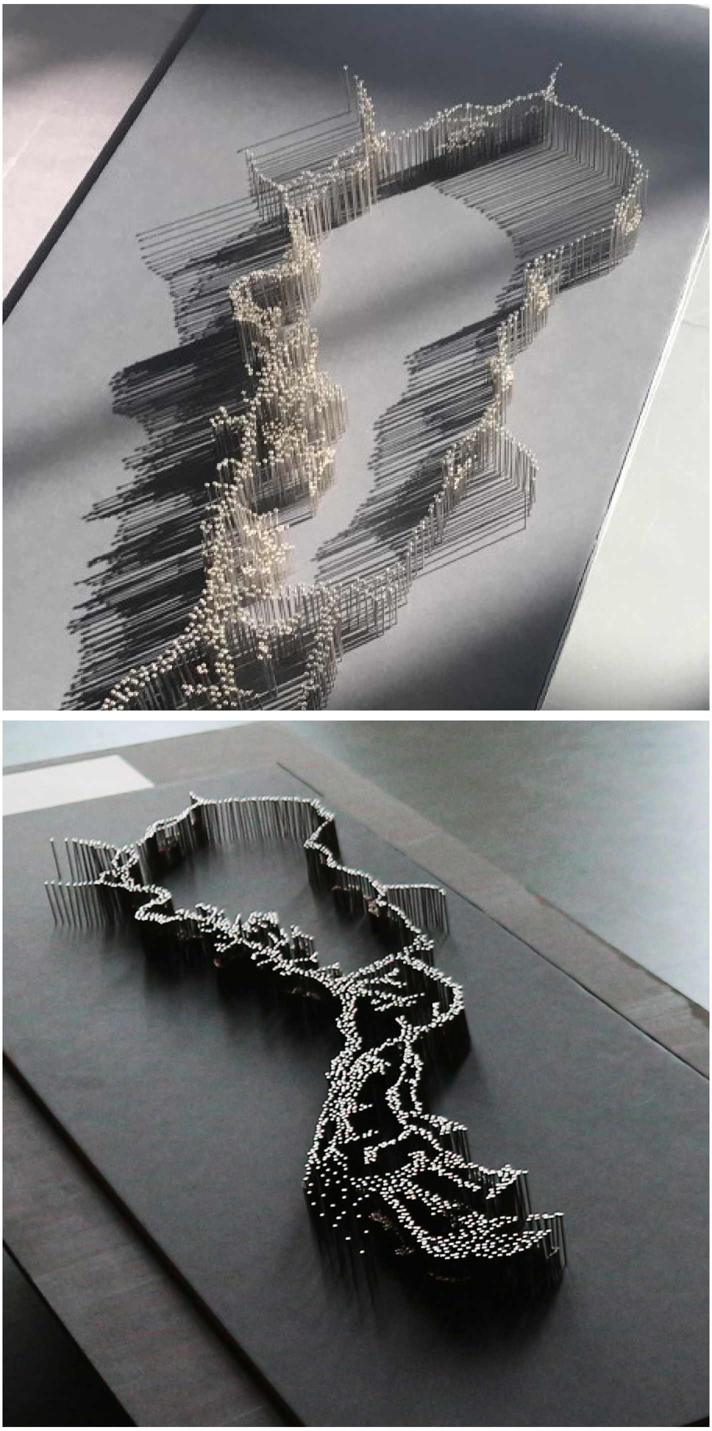
This thesis focuses on investigating the possible extension of the project of the River as a Tidal Park for the long term until 2100. This in order to ensure the desired ecosystem services for 2100 will be achieved and costs and benefits are distributed more evenly among stakeholders through time and space. Therefore, the research aim of this thesis is to ensure the project of the River as a Tidal Park provides the region with the desired ecosystem services society needs in 2100. The project will be able to adapt to future uncertainties it is facing through time, resulting from the spatio-temporal dynamic of ecosystem services, without destroying capital for the collaborating partners. The hypothesis which will be tested is to what extend the value of ecosystem services can be inverted in time to use it as a design instrument in relation to decision-making processes in order to obtain most values from it. The research question which leads this thesis is:

How can the concept of 'Nature as a New Economy' be used for the development of an adaptive design for the spatial transformation of the fluvial zone of the Nieuwe Maas considering the uncertain future?

A conceptual model showing the project from problem statement to hypothesis is represented in figure 5.

Reading Guide

This thesis consists of three parts. Part I considers the theory, research design and methods. This part elaborates on the concept of nature as a new economy and how an optimum can be reached by backcasting ecosystem services. This is the part which is not related to a specific site or project and is therefore transferable to other eco-based projects. Part II shows the testing of this method on the case-study of the Rotterdam region. It gives insight in the way in which the method can be used during a design process. Part III evaluates and reflects on the results of part I and II. The thesis ends with the conclusion, discussion, limitations and recommendations for further research.



▲ Figure 5 | Conceptual model of the case-study showing the problem, uncertainties, values and hypothesis. The model shows a representation of the river mouth constructed with steel pins. The preciseness of the pins represent the staticness of the river, the way in which it is manipulated and the lack of flexibility. The shadows the pins produce show the uncertainties the fluvial zone is subjected to as the lights of nature constantly project changing circumstances. The silver flow the pins produce represents the value the river could produce in the future when enhancing nature. The fact that the river is the most dense part of the model instead of the urban area, shows that the river could be the new value for producing economic growth. Conservation, preservation and regeneration can now be seen as an economy itself, which is the new value for producing economic growth (source: model by author, upper photograph by Taneha Bacchin, lower photograph by author)

PART I

nature as a new economy: backcasting ecosystem services

1

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theory

1.01. Nature as a Common Good

Currently, there is a huge pressure on the natural environment which depletes the natural resources humanity needs. This environmental degradation can be defined as any change or disturbance to the environment perceived to be deleterious or undesirable (Johnson et al., 1997). Causes of environmental degradation are urban disturbance, like overpopulation, industrialisation and unsustainable agricultural practices, and climate change, like soil depletion and fresh water shortages (Choudhary, 2015).

The natural environment can be seen as a common good, which we can understand as a good which is beneficial for all or most members of a given community. According to Professor of Cultural and Political Theory, Jeremy Gilbert (2014), nowadays a culture has arisen in which individualistic lifestyles predominate. A culture in which we do not want or are not stimulated to do the kind of things that require us to co-ordinate our desires and capabilities with those of others. American ecologist and philosopher Garrett Hardin (1968) claims humanity is not able to make sustainable use of collective property, because an individual will always try to maximize its own profit instead of acting for the common good.

In his article, Hardin uses an example to explain this phenomenon, describing a pasture shared by several herdsmen. It is assumed that each herdsman will try to keep as many cattle as possible to gain as much profit from the common land. To maximize their gain they ask themselves: “What is the utility to me of adding one more animal?”. This individual herdsman gains the profits from adding one animal to the pasture, while all the herdsmen share the negative effect of overgrazing. Because one of the individuals adds an animal, the others also feel like adding more animals to make sure they gain enough profit, which depletes the pasture. In the end, all the herdsmen have to deal with the negative effects of their short-term self-interest. He calls this the ‘Tragedy of the Commons’, because when each individual pursues its own best interest in a world which is limited, the final result is a society as a whole which suffers: the tragedy.

This theory can be projected to decision-making processes for nature development in which nature can be seen as a common good. Current generations do not feel responsible for the common good as they do not see the long term benefits of this good, for themselves and for future generations.

1.02. Growing Awareness of Nature's Value

Natural Capital and Ecosystem Services

The welfare of our society is based on the services we obtain from nature. The stock of natural ecosystems that provides us with valuable products and services, the ecosystem services, is called the natural capital (Natural Capital Project, 2006). Four types of capital, of which the natural capital is the most fundamental one, provide a nation's wealth: a) the manufactured capital (e.g. machines and buildings), b) the human capital (e.g. people's skills and knowledge), c) the social capital (e.g. trust, norms and institutions) and d) the natural capital (e.g. minerals and ecosystem services). The reason why the natural capital is the most fundamental one is because it provides human's basic needs, such as food, clean air and water. These benefits and services we obtain from nature are called ecosystem services. Many of them are of fundamental importance to human well-being (Costanza et al., 1997, Millenium Ecosystem Assessment, 2005, TEEB, 2010). Ecosystem Services include a) provisioning services, such as food, fiber and fresh water, b) regulating services, such as improving air quality, water purification and pollination, c) cultural services, such as cultural heritage values and recreation and d) supporting services, such as photosynthesis and nutrient cycling. Due to the degradation of ecosystem services a shift of costs from one group of people to another or defer of costs to future generations is the result (Millenium Ecosystem Assessment, 2005). Because of climate change and the ever increasing human consumption these threats are expected to become greater. Biodiversity and its associated ecosystem services can no longer be seen as inexhaustible and free goods, because they become scarce (de Groot et al., 2010).

Increasing Awareness

Since the 60s, the concern about the quality of nature, landscape and environment became a major subject in debate. The report '*The Limits to Growth*' (Meadows, et al., 1972) made the concerns about the increasing environmental pollution and the depletion of resources due to industrialisation and consumption in western societies explicit. Since this publication the awareness to care for the natural capital and ecosystem services grew. This awareness increased when the impacts of climate change became in discussion since the 1990s. The debate on the one hand was about the mitigation of climate change and on the other hand about creating conditions to adapt to changing circumstances resulting from climate change. The mitigation of climate change is subjected to complex international political discussions, which result in a long term view on, for example, decreasing CO2 emissions. Therefore, we have to consider the continuing increasing process of human's influences on it. Adaptation measures are therefore all the more important and more and more addressed in urban planning and design (Meyer, 2016).

1.03. Decision-Making, Planning and Design with Nature

However, adaptation measures to restore ecosystems and their services are still under-utilized by policymakers (Munang, et al., 2013, Bennett et al., 2015). Greater understanding of the institutional influences on ecosystem services are of a crucial importance to the conservation and regeneration of ecosystems and therefore to their services and human well-being (Bennett et al., 2015). The complex interactions between ecological systems and human engineered systems are now often addressed with an overreliance on panaceas. This results in simplified and general models in order to derive ideal types of governance (Ostrom and Cox, 2010).

Enabling society to better adapt to climate change and changing societies demands for approaches that are addressing the crucial links between climate change, biodiversity and sustainable resource management, called the eco-based approaches. Those approaches focus on protecting ecosystems and their services by managing, conserving and restoring nature. Besides the benefits for climate change mitigation and adaptation, it also provides a win for environmental protection and biodiversity conservation, sustainable socio-economic development and it provides a basis for new economic growth (Munang, et al., 2013).

Eco-based approaches are part of larger socio-ecological systems that are defined as social systems 'in which some of the interdependent relationships among humans are mediated through interactions with biophysical and non-human biological units.' (Anderies et al., 2004). Complex socio-ecological systems cannot rely on general models, especially because the systems has become more difficult and increasingly interlinked through time. They demand for an adaptive approach which is self-sustainable in disturbances over time. Eco-based solutions are focusing on providing ecosystem services for future needs, but the dynamics of systems over time have to be considered to make them sustainable in an uncertain world (Ostrom and Cox, 2010).

1.04. Uncertainty in Planning and Design with Nature

Planning and designing with uncertainties is important to come to sustainable and future-proof decisions. Insight in the future of the region is necessary, because large investments demand for a long preparation and execution period for which a period of twenty or thirty year is no exception (Deltaprogramma Rijnmond Drechtsteden, 2011).

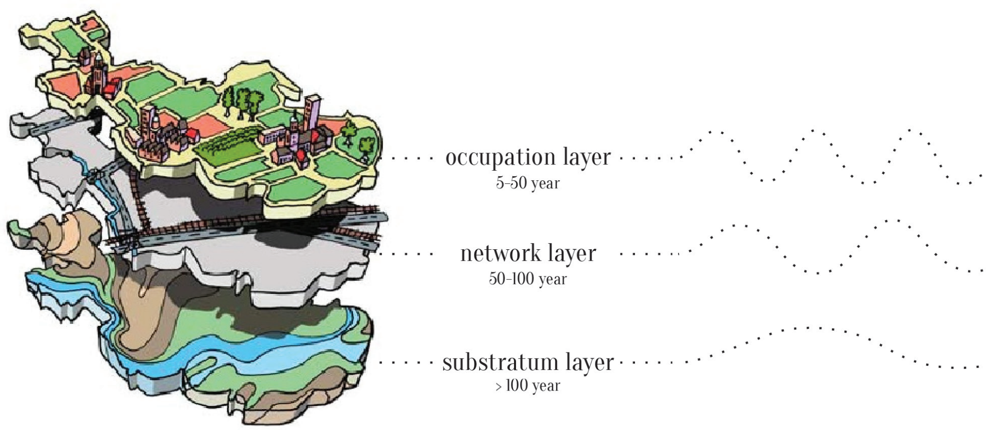
Spatio-Temporal Dynamic

Using the concept of ecosystem services in planning and design is strongly related to scales; both spatial and temporal. Ecosystems and its services are not static, but operate within different spatial and temporal scales, called the spatio-temporal dynamic, which can help in planning and design with ecosystem services for uncertain futures (Hein et al., 2006, Fisher et al., 2009).

Firstly, the time frame of decision-making and ecosystem services are not functioning in line. Human systems often operate in gaining benefits on the short-term, while the natural systems function on much longer timescales. Economic development provides short-term profits within specific sectors, but is often degrading ecosystems and its services on the long term. This environmental degradation results in long term-costs which are exceeding the short-term gains (Hancock, 2010).

Han Meyer and Steffen Nijhuis describe this temporal dynamic for delta regions in their paper *Designing for Different Dynamics: The Search for a New Practice of Planning and Design in the Dutch Delta* (2016). They describe the complex system of an urban region consisting of three subsystems in which small changes in one system can affect other systems. The urban delta consists of systems with their own dynamic and speed of change (see figure 1.1). There are three levels of dynamics related to three layers in the landscape:

- The substratum layer, related to the natural environment. This layer is characterised by slow processes of change, repetition and natural cycles. These layers are the substratum and climate.
- The network layer, related to long-term social, economic and cultural history. These are infrastructural networks for transportation, water management and energy supply.
- The occupation layer, related to short-term events and actions, of people and politics, land use and urban settlements.



▲ Figure 1.1 | Three systems with different dynamics and speeds of change (source: Provincie Overijssel, 2000, modified by author)

As the dynamics of the three systems are different, the unexpected changes can appear in different time frames. This makes planning within such complex urban regions extremely unpredictable. This is also the reason why general models do not work in such complex regions.

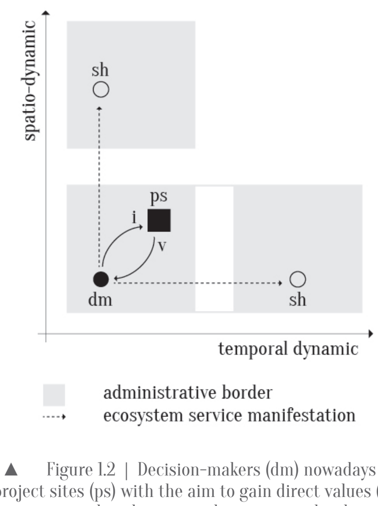
An illustration of this temporal dynamic within the case study can clarify the issue. The historical desire for economic growth through the development of industries, ports and residential expansions of the city of Rotterdam, can be seen as short-term decision-making aiming for direct economic profit. The effects of decision-making processes by then, now results in a lack of the possibility to use ecosystem services provided by the river, such as water storage, water purification and a rich biodiversity. To restore the capacity of the river to provide these services and prevent events such as flooding, costly investments have to be made. In this way the temporal dynamic of ecosystem services show how short-term decision-making processes, aiming for direct economic profit, have an effect on stakeholders within a different time frame: the future generations.

Another uncertainty of planning and design within such complex systems is related to spatial scale. Services a specific stakeholder obtains from an ecosystem can be provided by a different stakeholder. This means investing in the management or regeneration of a specific ecosystem is not always beneficial for the stakeholder providing the ecosystem and therefore its services. This side of the issue is related to the spatial scale of providing ecosystem services and obtaining the benefits and how this reveals among stakeholders (de Groot et al., 2010, Geijzendorffer and Roche, 2014 and Bennett et al., 2015).

An illustration of the spatial dynamic within the case study is the following. As the river Nieuwe Maas is in the downstream of the Rhine-Meuse Estuary, it is subjected to uncertainties in the whole estuary. Due to the flow direction of the river towards the North Sea, changes affecting the river upstream will in the end also affect the river downstream in which the Nieuwe Maas can be seen as the 'receiving end' of the estuary. For example, agricultural and industrial activities in the upstream have a direct effect on the water quality of the river. This results in the Nieuwe Maas having to deal with the most contaminated water and sediment disposals, which is not advantageous for the ecosystems and its services. In this way, the investments of stakeholders in the upstream of the river benefit them, because of their economic profit gained from industrial and agricultural activities, but have a negative effect on stakeholders downstream. This spatial dynamic of ecosystem services is resulting in an unfair distribution of costs and benefits among stakeholders.

The spatio-temporal dynamic of ecosystem services results in unexpected, or maybe expected, but consciously neglected, outcomes in other spaces or timeframes (figure 1.2). This can reveal in both positive and negative ways, but most important is that the unexpected outcomes make it hard to plan and design with it. Local scale initiatives are usually focused on an execution within short or medium-long term, about one to ten years, while large scale infrastructural projects are planned and realised within a much longer period of time. Those large scale projects are mostly related to the network layer of Meyer and Nijhuis (2016) and can consist of water safety projects, generation of ecological networks or transportation networks. There is a large chance that relatively short and local scale initiatives are disturbing the long and large scale projects, which can lead to slowing down the process of a project or to destroying capital as projects appears to be un-sustainable (Urban Region in the Delta, 2013).

Knowing beforehand which investments affect which stakeholders through time and space can help in a better distribution of costs and benefits among stakeholders, resulting in well-considered investments. In this way, an economic consideration is made in relation to the preservation of the environment.



▲ Figure 1.2 | Decision-makers (dm) nowadays invest (i) in project sites (ps) with the aim to gain direct values (v) from the investments within their own administrative borders. The spatio-temporal dynamic of ecosystem services result in unexpected effects on stakeholders (sh) in different spaces and timeframes. (source: by author)

Scenario Planning

The uncertainties in climate, technology, socio-economic and political situations demands for a need for approaches in planning and design to make long-term plans, functioning under deep uncertainty. There is a need for decisions which have satisfactory performance across a range of plausible futures. Those plans need to be flexible and adapting over time in response to how the world actually unfolds. Traditional frameworks follow the approach to come to a best option in order to accommodate to the expected future, the most probable future (Kwakkel, et al., 2016). However, due to the extreme uncertainties in long-term planning and design, the expected and most probable future is uncertain as well. According to architect and urban designer Christian Salewski (2010) any view into the future reveals major uncertainty and complexity, which predictive forecasts do not oversee. Since the 1960s, scenarios were introduced as a new method to counter this problem.

Scenarios are a combination of imagination and ratio, implying a plausible future. It combines both analysis to predict possible developments, as imagination to speculate about possible developments. Scenarios are therefore not scientific, not a view into the future, as the future will always be open and unknown. However, the combination of imagination and ratio do make them convincing. They provide a logical argumentation of a development over time starting from the present. The aim to work towards an utopia can be included in scenarios, but the strength of scenarios is that it, besides that, also includes developments which cannot be influenced, an inclusion of the undesirable or unexpected futures. In general, Salewski's book distinguishes two main scenario typologies: the anticipatory and explorative scenarios.

The anticipatory scenarios starts with a desirable hypothetical future state and work back to the present. The desirable image of the future functions as a communication tool to find support in order to construct the development process starting in the present. It is more of a convincing tool to strengthen the argumentation of why it is important to start the process leading to the desirable future (Salewski, 2010).

The explorative scenarios are mainly used as a tool to discover relations, threats and potentials which give insight into how the project could evolve in the future. In that way, those scenarios are part of the research by design method (Salewski, 2010) in which the focus lies on the production of new knowledge through the act of design. To plan for the future, especially concerning projects with complex environmental challenges as is the focus of this thesis, it is necessary to use the Research by Design approach. Roggema (2016) describes two main arguments why: 1) Planning the future can no longer only rely on the certainty of conditions as it is constantly subjected to change. There has to be a constant reflection of the effects of the planned interventions and 2) Most of the current day problems cannot be solved with one final solution, because they are too complex. These so called 'wicked problems' cannot be described with a single formulation and there is also not a clear answer to the problem. The method of Research by Design uses design to spatialize research. It investigates the qualities and problems of a location and tests its (spatial) potentials. At the same time, it enables to deal with the uncertainties of changing conditions (Roggema, 2016).

The exploration of the range of plausible futures and the threats, potentials and relations between them can result in design proposals which are adaptive to a wide range of uncertainties. The use of explorative scenarios functions as argumentation behind the design proposal (Salewski, 2010) and is in this way used in this thesis.

Adaptation Pathways Framework

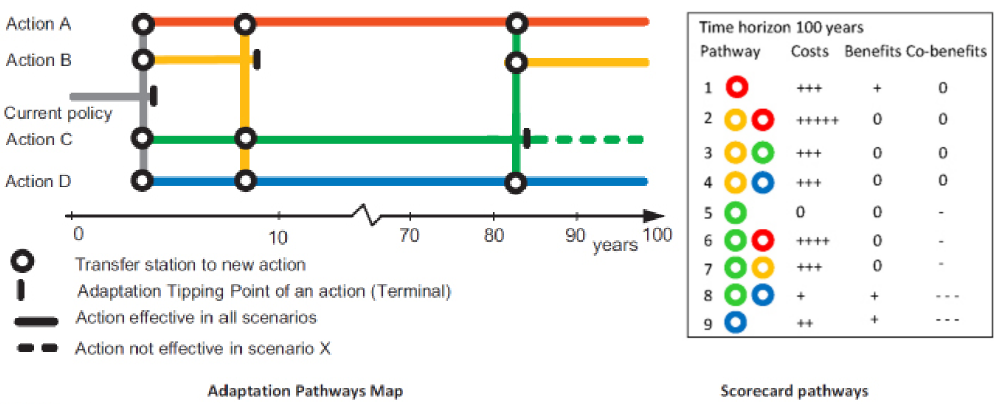
Dealing with uncertainties in planning and design demands for an approach which can adapt through time, together with the changing future. For this, the literature describes adaptation pathways which can guide policy-makers between short-term actions of a project and long term uncertainties the project is subjected to (Kwakkel et al., 2016 and Haasnoot et al., 2013). Meyer (2016) describes the characteristics of an approach like this as followed:

- Search for different development pathways, the adaptation pathways, instead of final pictures
- Connect short term decisions in spatial configuration with long term challenges
- Decrease the chance to invest too little or too much through the flexibility of adaptation pathways
- Connect investments with other political agendas to create synergies

Adaptation Pathways give insight in the order of actions over time, potential lock-ins and path dependencies. The project process takes off with a short-term implementation of a design. Together with this take off the project defines a definition of success, meaning: What are the objectives the project needs to accomplish? At this moment in time it is still unsure what the future of the project will be exactly.

From the moment of implementation, the project is subjected to uncertainties. Central are the tipping points which define the change of a pathway. At one point in the process the project reaches a tipping point, which are the points in time when a limit is reached and a new action in the project has to be taken, resulting in a change of pathway. The reaching of the tipping points and the following pathway results in a direction towards a certain spatial configuration of the project. The adaptation pathway map, see figure 3.3, presents alternative routes to get to the same desired point in the future, the definition of success. In the adaptation pathway map in figure 1.3 there are 9 possible pathways of which the relative costs and benefits are defined in the scorecard. The scorecard defines a gradient of costs and benefits for each pathway, in order to define the most favourable pathway for each stakeholder (Kwakkel et al., 2016, Haasnoot et al., 2013).

To illustrate the theory, an example of a tipping point is: the sea level reaches an increased level of 200 cm. This would result in an action which provides in more water safety, for example by the development of fore land in front of the primary dikes to reduce storm waves intensity.



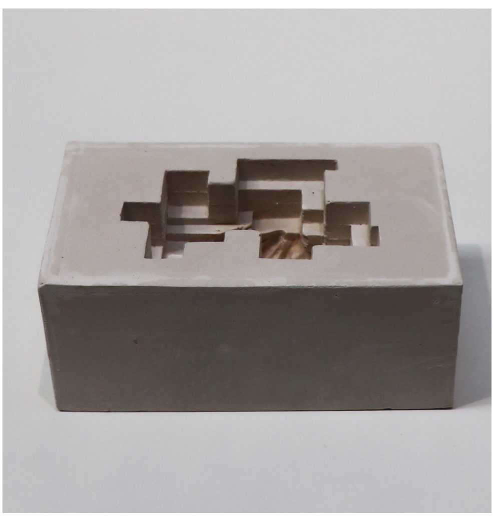
▲ Figure 1.3 | Example of an adaptation pathways map and a scorecard presenting the costs and benefits of 9 possible pathways presented in the map. (source: Kwakkel et al., 2016)

1.05. Nature as a New Economy

In order to make the effects of investments affecting ecosystems more tangible throughout different scales of time and space, seeing and working with nature as a new economy can help. It can function as a common language between stakeholders operating within specific spaces and timeframes.

The first time the term of 'Nature as a New Economy' was used is in the book written by Gretchen Daily and Katherine Ellison: *The New Economy of Nature: The Quest to make Conservation Profitable* (2002). According to them, nature has always had an economic value, namely by way of extracting something from nature which then becomes a tradable good, such as oil and timber. *The New Economy of Nature* describes a theory which turns nature itself into a source of profit. Instead of exploiting and destroying nature and natural resources, the basis of economic activities should be the conservation of nature. According to Juniper (2013), our society has lost sight of the connections between natural processes and our human well-being. The fact that what nature provides for humans is free, is the reason for our destructive overuse of it. The only way to protect nature is by giving it a value itself. Juniper calls this the concept of the bio-economy, in which we should create a synergy between the world of human economics and human needs and what the biosphere can sustain. Capturing nature in economic terms is a way to frame the concerns of ecology in a modern and common language. The concept gives insight in the value of investing in nature for stakeholders, resulting in increasing financial support. The common language to bridge the gap between economy and ecology can provide decision-makers with a tool to exceed their personal frame of time and space in order to work towards the objective of a sustainable future. The concept focuses on the development, preservation and regeneration of nature in order to obtain most values from it. This can be seen as an inversion of the concept of nature: nature is no longer seen as something we have to fight against to strive for economic growth, nature can now be seen as an economy itself which is the new value for producing economic growth. This concept is the base for my thesis and is represented in the gypsum model in figure 1.4.

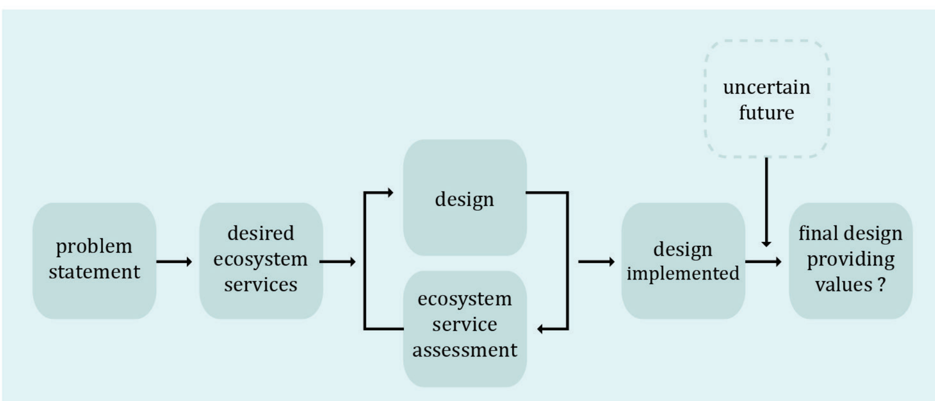
The concept of nature as a new economy is outreached through the development of several tools to assess ecosystem services. Two tools, which are commonly used in planning and design practices, are the Dutch TEEB tool (2013) and the British B£ST tool (2018). They are analysed to understand in what way ecosystem services are assessed in planning and design before. This analysis is enclosed in appendix 1.



▲ Figure 1.4 | Conceptual gypsum model representing the shifting logic of nature as a new economy. Economic development is inverted and produced by nature instead of produced by easy accessibility to economic opportunities. Society should not only take from nature, but the production of new nature produces even more economic value (source: by author).

1.06. Knowledge Gap

The concept of Nature as a New Economy is the starting point of this thesis. Linking nature to economic terms by assessing ecosystem services helps in starting up nature conservation projects which results in providing ecosystem services. The common language created by this concept provides a tool to integrate the implementation of nature projects more in urban planning and design. It gives insight in the importance of implementing nature projects nowadays to prevent future problems and meet future needs. However, if we bring the concept of nature as a new economy to a higher level, we should also care for the values these implementations bring for the future. It does not necessarily mean that the ecosystem services we provide today are still needed in the future. Besides that, short term investments in a certain type of nature might lead to friction with long term desires in different types of nature. This could result in a loss of capital. After implementation of a design, the design is still subjected to uncertainties which affect the final outcome and corresponding ecosystem services, see figure 1.5. The partners of an eco-based project (such as the River as a Tidal park) might therefore invest in the project now, while it does not provide the services they desire in the future. If we want to make sure nature is the basis for economic growth for both current and future generations, planning and design with uncertainties have to be integrated in the concept.1



▲ Figure 1.5 | Knowledge Gap: Planning and design with ecosystem services to provide a new economy of nature under deep uncertainty (source: by author)

1.07. Problem Statement

As described before, the project of 'the River as a Tidal Park' comes from the future perspective that the city will grow and get more and more dense. In this future, the river can provide a public green space for recreational and natural purposes. This focus is also reflected on the ecosystem services the project addressed until now, which mainly focuses on improving natural and recreational values. The focus is less on providing ecosystem services such as water safety, food production and closing regional cycles.

However, the theories as described before, provides us with the insight that the future cannot be predicted. Eco-based projects in complex regions demand for approaches which can be adapted over time, as the future is uncertain due to the spatio-temporal dynamic of ecosystem services. The project of 'the River as a Tidal Park' works towards one future, the one of economic growth and densification, but does not consider other plausible futures. If it appears the population in the region shrinks and sea level rises, there might be no reason to try to 'safe' the land outside the dikes as there is no space pressure, which could result in a highly dynamic delta landscape. Or, if the future projects a global food scarcity, demanding for highly efficient use of agricultural land, the tidal parks could provide new types of food production. In these plausible futures, the current implementation of the tidal parks does not provide the ecosystem services society needs most in that particular future. If one of those 'other' futures becomes reality, it might lead to a loss of capital as projects have to be redesigned.

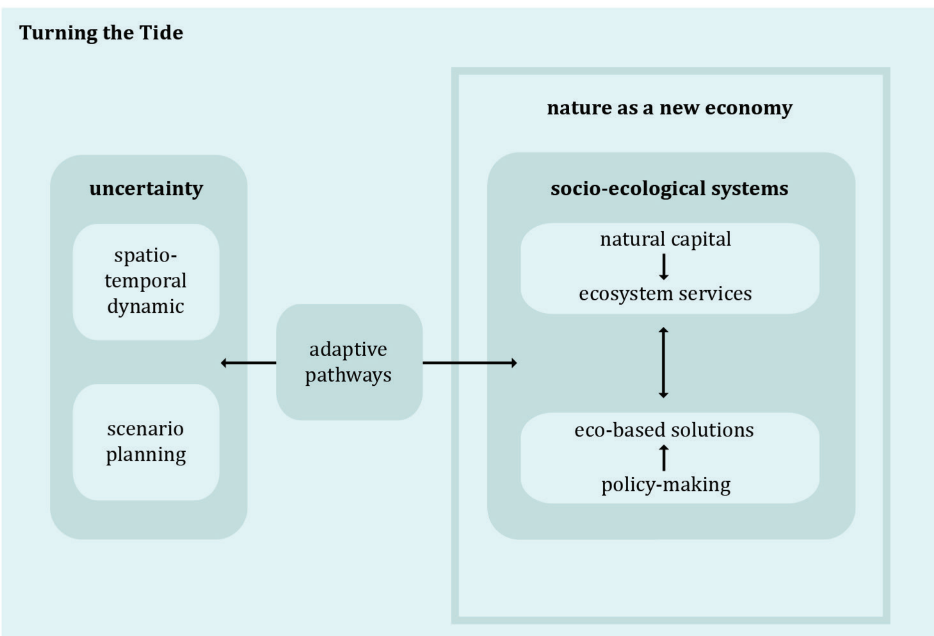
Nowadays, the partners of the project of 'the River as a Tidal Park' invest in the short term implementation of tidal parks along the Nieuwe Maas, while it might not provide the services they desire on the long term. The friction this would result in on the long-term results in a loss of capital for future partners. Therefore, the costs and benefits are not distributed equally among stakeholders functioning in different frames of time and space.

1.08. Theoretical Framework

Nature as a New Economy is focusing on providing a common language to integrate nature conservation in planning and design to provide ecosystem services for the future. The project 'Turning the Tide' is, besides this, also focusing on making sure the nature projects can be adapted to uncertainties of the future, to change the spatial configuration of the project according to adjusted future needs. This results in the ultimate economic value of nature through all time frames.

The way in which the earlier described theories are interrelated and used in the project is visualised in figure 1.6, showing the theoretical framework. The natural capital provides ecosystem services, which are beneficial for society. However, due to environmental degradation, society works towards less and less use of those services. A new tendency is rising in which policy-making aims for planning and design with eco-based solutions. Those solutions aim for managing, conserving and restoring ecosystems to maintain the use of their services in the future. However, planning and design with nature is subjected to a wide range of uncertainties which have to be taken into account. The spatio-temporal dynamic of ecosystem services results in unexpected outcomes on the long term, which can result in providing no or different ecosystem services than needed in each plausible future. Therefore it is needed to plan with scenarios, as they provide insight in the most plausible futures and related desires. The adaptive pathways are the bridge between the dynamic acting of ecosystem services on the long term and the policy making resulting in short term implementations. The adaptive pathways provide a framework in which implemented projects can be adapted to the changing desires of the future, making sure that in each plausible future we obtain the ecosystem services we desire and need. The adaptation pathways framework is not one on one used in this thesis, but functioned as base for the development of my own method for backcasting ecosystem services, which is further explained in the next chapter.

Nature as a New Economy is the overall concept encompassing those theories. If we want nature to be the basis for further economic growth, we need to make sure that nature projects provide values for the current generation, but also for future generations.



▲ Figure 1.6 | Theoretical Framework (source: by author)

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research design & methods

2.01. Research Purpose

Research Aim

This thesis focuses on investigating the possible extension of the project of the River as a Tidal Park until after 2020. This in order to ensure the desired ecosystem services for 2100 will be achieved and costs and benefits are distributed more evenly among stakeholders through time and space. Therefore, the research aim of this thesis is to ensure the project of the River as a Tidal Park provides the region with the desired ecosystem services society needs in 2100. The project will be able to adapt to future uncertainties it will face through time, resulting from the spatio-temporal dynamic of ecosystem services, without destroying capital for the collaborating partners. The hypothesis which will be tested is to what extend the value of ecosystem services can be inverted in time to use it as a design instrument in relation to decision-making processes in order to obtain most values from it.

Scientific Relevance

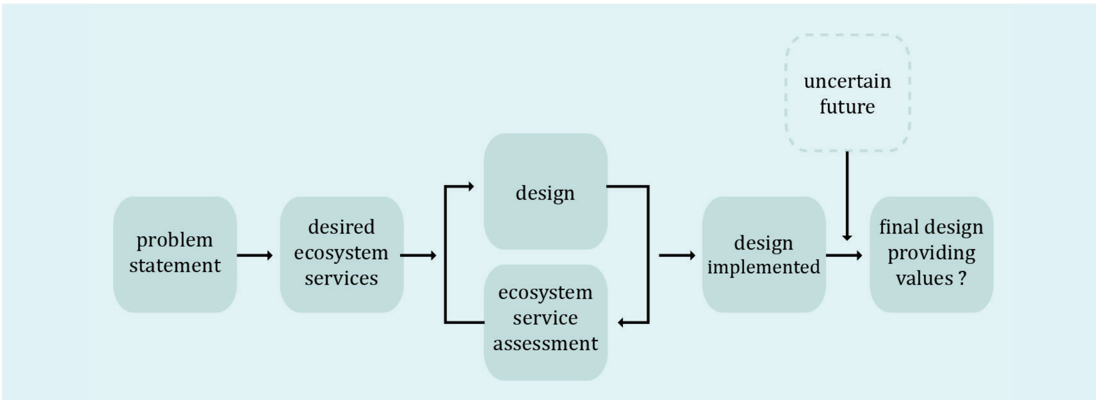
The knowledge gap is the use of the concept of 'Nature as a New Economy', i.e. the assessment of ecosystem services, in planning and design practices considering the uncertain future. The research described in this thesis will contribute to fixing this knowledge gap, as the methodology takes the desired impacts of stakeholders within specific time frames and spaces, followed from the uncertainties, as the starting point for the design proposal. This proposed methodology for addressing the problem is represented in figure 2.2 on the next page where it is compared with the traditional approach.

Societal Relevance

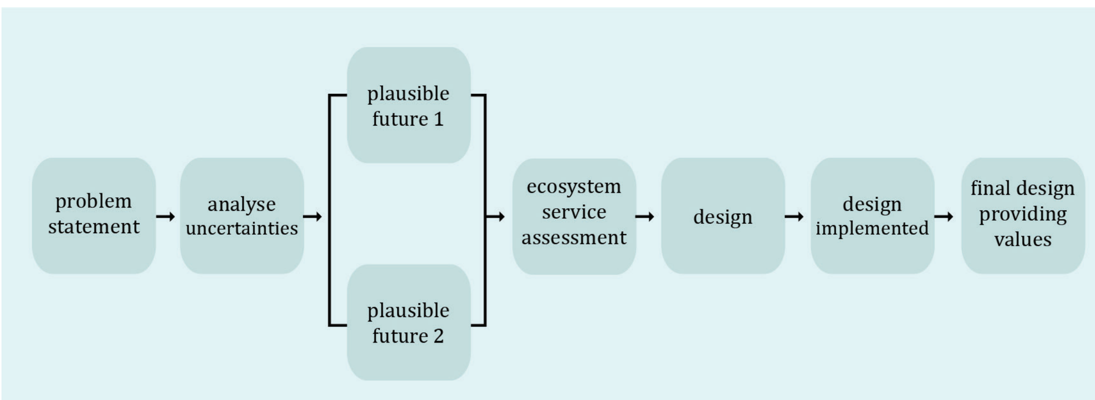
The thesis results in an overall better understanding of the values of the natural environment, because economic terms are understandable for most people in our society, and therefore results in better integration of ecosystems in and around cities. Specifically for the city of Rotterdam the thesis provides a more reliable future, which is able to deal with uncertainties. The image in figure 2.1 shows floodings of December 2018 along the Nieuwe Maas near Schiedam and Vlaardingen, illustrating how topical the problem is. Adapting to futures uncertainties can result in less of these and similar events along the Nieuwe Maas. The ecosystems of the Nieuwe Maas will provide the city with the services it needs, resulting in a liveable future city of Rotterdam.

▲ Figure 2.1 | Floodings along the Nieuwe Maas near Vlaardingen on 9 December 2018, showing the relevance of addressing the problem (Source: AD, 2018)

Traditional Approach



Proposed Approach



▲ Figure 2.2 | Shifting methodology: showing the change from the traditional approach (above) to the proposed approach (below) (source: by author)

2.02. Research Questions

Research Question

The starting point for this research is planning and design with the concept of 'Nature as a New Economy'. To relate this to the problem statement of the uncertainties the region has to deal with, due to the spatio-temporal dynamic affecting ecosystems and its services in the Nieuwe Maas, the main question for this thesis is the following:

How can the concept of 'Nature as a New Economy' be used for the development of an adaptive design for the spatial transformation of the fluvial zone of the Nieuwe Maas considering the uncertain future?

Sub Questions

The sub questions which are needed to answer the main question are the following:

1. What are the uncertainties of the dynamic context until 2100 to take into account and how are they affecting the project?
2. Which ecosystem services can tidal nature in the coastal zone of the Nieuwe Maas provide (in combination with the contextual green-blue network) and how do they contribute to plausible future problems until 2100?
3. What are the desired values to achieve with the project until 2100, according to the partners of the project of the River as a Tidal Park?
4. What are value synergies in the development of the project of the River as a Tidal Park in both scenarios for 2100 and how to translate this to a short term implementation?
5. How will the project of the River as a Tidal Park evolve until 2100 by reaching design specific tipping points and how does this result in varieties among the provided ecosystem services through time?
6. How will the interest of stakeholders change over time, according to the provided ecosystem services, and how could this result in a more even distribution of costs and benefits among them?

2.03. Research Approach

Research By Design

While some studies declare that the two phenomena of research and design differ widely, this thesis uses the methodological approach of Research by Design in which both are strongly interrelated. This approach focuses on the production of new knowledge through the act of design (Roggema, 2016).

To plan for the future, especially concerning projects with complex environmental challenges such as this one, it is necessary to use the Research by Design approach. Roggema (2016) describes two main arguments why: 1) Planning the future can no longer rely solely on the certainty of conditions as it is constantly subjected to change. There has to be a constant reflection of the effects of the planned interventions and 2) Most of the current daysproblems can not be solved with one final solution, because they are too complex. These so called 'wicked problems' cannot be described with a single formulation and there is also not a clear answer to the problem. The method of Research by Design uses design to spatialize research. It investigates the qualities and problems of a location and tests its (spatial) potentials and at the same time makes it able to deal with the uncertainties of changing conditions. Spatializing research produces new insights and knowledge which can be beneficial to the broad public.

xplorative scenarios (Salweski, 2010) are a form of research by design in which the plausible futures are used as an argumentation behind the design proposal. The explorative scenarios are used within the design process of this thesis in order to produce design solutions which are most adaptive to future uncertainties.

Mixed Approach

The problem addressed in this thesis, encompasses several complex dimensions from an environmental, economic and governance point of view. In order to investigate these complex dimensions of the project an approach with mixed methods is used. The mixed approach encompasses qualitative, quantitative, applied, fundamental and deductive research approaches.

Qualitative research is used as primary exploratorive research which gives insight in the context, relevance, problems and motivations, while the quantitative approach can help to create insight in the value of the natural capital by assessing ecosystem services. Fundamental research approaches are used to advance knowledge and enhance existing theories. This knowledge is then used in the case-study through 'applied research' to test the proposed method of inverting ecosystem services. The research takes of with a theory-driven starting point, namely 'Nature as a New Economy', which indicates towards a deductive research approach.

Focus of Scales

For this project, four scales are taken into consideration: the North Sea Estuary and Rhine-Meuse Water Sheds, the region Rijnmond-Drechtsteden, the Municipality of Rotterdam and the Waalhaven (figure 2.3).

For this thesis it is important to understand both the ecological as socio-economic systems, in order to find relations between them. The choice of scales results from this. As part of this thesis an internship at the Municipality of Rotterdam is included. The municipal borders are not directly related to natural systems, as they are administrative borders. They exceed local ecosystems and are pertinent to regional and territorial ecosystems. Therefore, the other scales are taken into account as well. Those scales are related to ecological systems and can help to understand the ecosystems and their services for society. The scale of the region Rijnmond-Drechtsteden (L) is integrated in the project as it is related to the Deltascenarios (Deltaprogramma Rijnmond-Drechtsteden, 2011) which are used in this thesis. The S scale forms the case-study on which the proposed concept is tested. All the scales together form a project in which ecological and socio-economic systems are brought together. The scale of the Waalhaven will function in order to elaborate on the spatial implementation of the different pathways.

XL
Rotterdam as the Receiving end of both the North Sea Estuary and the Rhine-Meuse Estuary

L
Region Rijnmond-Drechtsteden including a large part of the Dutch South-West Delta

M
Municipality of Rotterdam with a focus on the Nieuwe Maas River

S - Waalhaven as an important harbor basin along the Nieuwe Maas with potential to transform in the future

▲ Figure 2.3 | Focus of scales (source: by author)

Project Variables

In the thesis three variables are used, which are nine ecosystem services, two scenarios and two timeframes, see figure 2.4.

The nine ecosystem services resulted from the existing objectives of the project of the River as a Tidal Park (which are seven) and the ecosystem services which are added according to the regional problem analysis (which are two).

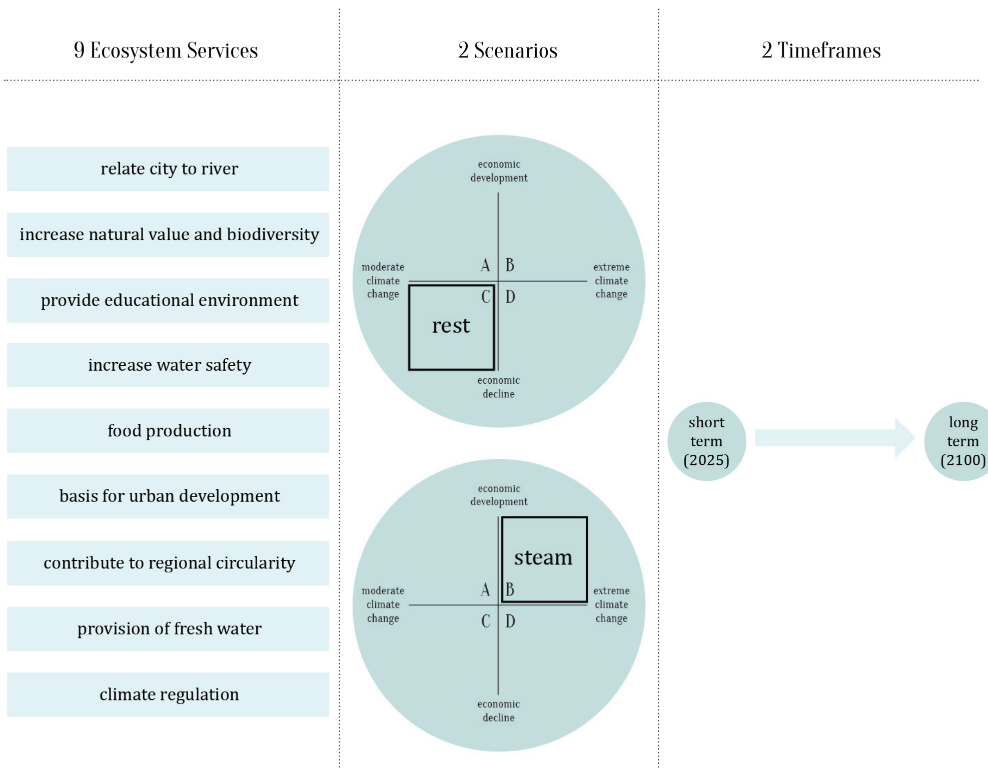
The two scenarios provide input for the two plausible futures. The scenarios which are used in this thesis are a combination of the Deltascenario's (Deltaprogramma Rijnmond-Drechtsteden, 2011, Wolters et al., 2018) and the new estimations for sea level rise (Deltares, 2018). As described before, due to a limitation in time, the scenarios for Crowd and Warm are not taken into account.

The two timeframes and the pathway between them are used to develop a sustainable and adaptive strategy and design, functioning on the short term, but also on the long term, without destroyment of capital.

Within the thesis, those three variables are strongly interrelated. The project constantly seeks towards a maximisation of the provision of the ecosystem services through different scales of time and in different ecological and socio-economic scenarios.

The methodology starts with defining strategies for 2100 for each of the nine ecosystem services through the maximisation method. These nine services are combined with each scenario in 2100, resulting in two strategies (one for Rest and one for Steam). The phasing, which makes the project adaptive, is the interaction between the two timeframes, finally resulting in a short term design providing value synergies for both plausible futures.

The exact use of the variables will become more clear in the coming sections of this chapter.



▲ Figure 2.4 | Three variables: ecosystem services, scenarios and time frames (source: by author)

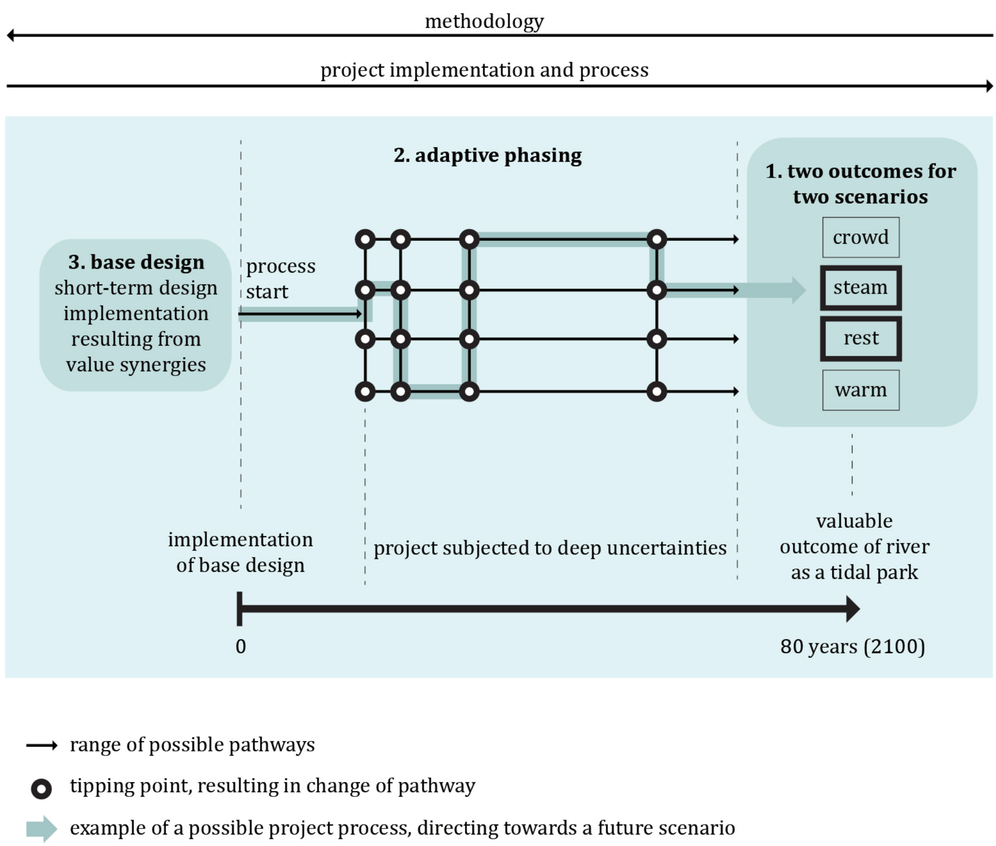
Project Framework

In general the way in which the thesis is approached is represented in the diagram in figure 2.5. The methodology for this thesis works from right to left, while the implementation of the project through time works from left to right.

The methodology starts with looking into the uncertainties until 2100 where the project of the River as a Tidal Park is subjected to. By defining which ecosystem services are most important in each scenario, two different strategies arise, providing the desired benefits. This is done for two scales, namely the region and the Waalhaven, so in total four strategies. After this, the value synergies (the services which are important in both scenarios and therefore important 'no matter what') are defined, which will be taken back to the short term base design, providing 'no regret' measures.

Between the strategies for 2100 and the design for 2025 there will be a phasing framework, which shows how the project would adapt through time according to the reaching of design specific tipping points.

After implementation of the short-term design, the project is subjected to uncertainties which direct towards different project pathways and finally to one of the final states of the scenarios.



▲ Figure 2.5 | Project framework (source: by author)

2.04. Methods

The project consists of four major phases, which are 1) the system analysis, 2a) the uncertainty analysis, 2b) the system diagnosis and 2c) the system design. Central within those four phases is the system evaluation and assessment (0a and 0b), which function is to evaluate, assess and reflect on the four phases throughout the whole process from analysis to design. Within each phase, the relation to the evaluation framework is explained in text and is visualised in the methodological framework in figure 2.6. For each phase the major steps will be explained, showing why it is needed to take these steps and the addressed methods are explained resulting in envisioned outcomes. Besides these main methods, the following contributing methods are used: literature review, mapping, field trip, interviews, ecosystem service assessment and maximisation method.

1. System Analysis

The process starts with the system analysis, in which the main steps to be taken are the vision analysis and the project analysis.

1.1 Vision analysis
The aim of this step is to gain insight in the vision and objectives of the project of the River as a Tidal park. First, the background problem will be analysed, to get understanding which problem the project addresses. An historical analysis can show how the river banks are manipulated over time and how this affected the natural and recreational values of the river. The result is to gain a clear understanding of how the historic development of the region affected the natural and recreational values of the Nieuwe Maas. This problem statement is the starting point for the original project of the river as a tidal park. Second, it's important to gain understanding in the vision perspective of the project. What is the project aiming for? This analysis shows the objectives of the project, for which future the project is designing and what the definition of success is. The objectives which are defined in this step are the ecosystem services which the project expects to produce. Third, the stakeholders are analysed. This analysis shows the contributing partners of the project and what their objectives within the project are. This analysis is important to understand the main objectives of the project and why it's important to achieve those objectives.

Methods
This analysis will be done by doing a literature review of the analysis, vision and design documents of the river as a tidal park, which are De Rivier als Getijdenpark Groeidocument 2.0 and 3.0 (de Urbanisten, 2016 and 2018) and the Landschappelijk Raamwerk (de Urbanisten and Strootman Landschapsarchitecten, 2016). Also, a field trip will help to understand the problem of the manipulated river and how this affected the recreational and natural values of the river. Besides that an important method is to have conversations with the project managers (de Greef, 2018 and de Groot, 2018). Those three methods provide insight in the addressed problem, the vision of the project and related objectives and the interest of the stakeholders. The general interest of the partners of the project can be understood by interviewing de Greef (2018) and de Groot (2018), but for a more detailed understanding the other partners have to be interviewed, such as the Port of Rotterdam, the World Wildlife Fund, Rijkswaterstaat and the Municipality of Rotterdam. These interviews will focus on understanding the interest of each stakeholder to be a partner in the project. Understanding their objectives can help in finding value synergies, but also conflicts, among stakeholders. The assessment method is used to 'quantify' the interest of the stakeholders for the nine main ecosystem services. This is done through organising a workshop where the stakeholders could assess the ecosystem services on their importance, followed by a discussion to explain the assessment. Each stakeholder assesses each of the nine ecosystem services with an assessment from 1 (very low interest) to 5 (very high interest). This workshop provides evidence of the stakeholders' interest. Throughout the development of the project, the subservices of the main services become clear through literature reviews. After that, these subservices are assessed with 1 to 5 as well, by making a consideration according to the interviews and my own interpretation. In this way, the interest of the stakeholders is determined by a combination of evidence and consideration.

1.2 Project analysis
The aim of this step is to gain insight in the project development until now, by looking into the characteristics and ecosystem services of the

implemented and planned parks. For this step, first an analysis of the characteristics of the existing and planned parks will be done. This analysis focuses on understanding the location of the parks in relation to the river, the size, the spatial characteristics of the original river bank, the level of nature and culture of the park, which design principles are used, the natural conditions for tidal nature, the relation to urban density and the main initiators of the projects. These characteristics are then used to define the ecosystem services we obtain from each park by using the assessment method. This method provides a score to the provided services of the project until now to analyse which services are addressed most and least. The assessment of the project contains value 0, meaning that the park does not contribute to providing the service, value +, meaning the park does contribute to providing the service, and value ++, meaning the park does contribute to providing the service to a great extent. This score is then assessed with the corresponding value of 0, 1 or 2, which results in the ecosystem service assessment. When more then one ecosystem service is included in an objective, the average of those two results in the objective assessment. This information shows to what extent each objective is addressed in the project until now. In the evaluation framework this information is used to reflect on the definition of success, as defined in the vision analysis.

Methods

The analysis of the characteristics of the park can be done by doing a literature review of the analysis, vision and design documents of the river as a tidal park and by researching and assessing each park specifically. Besides that, a field trip can help to gain insight in the characteristics of each park and what services they provide. The gradient to what extend the parks provide each service are strongly related to the characteristics and is therefore a logical following of the previous analysis.

System Analysis Relation to Evaluation Framework

The evaluation of this phase is to see to what extend the project as how it is developed now is achieving the intended objectives and definition of success. This is done by comparing the intended objectives with the ecosystem services the existing and planned parks provide. Are there objectives which are not (yet fully) addressed? Is there a clear focus on specific objectives? This evaluation moment is important to adjust the definition of success for the project of the River as a Tidal Park from 2020 until 2100. Together with the information gained in the uncertainty analysis the definition of success for the future of the project can be defined.

2a. Uncertainty Analysis

The main steps to be taken in the uncertainty analysis are the scenario analysis and the development of the uncertainty framework.

2.1a Scenario Analysis

For the thesis the Deltascenarios (Deltaprogramma Rijnmond-Drechtsteden, 2011 and Wolters et al., 2018) in combination with the updated numbers for sea level rise from last year (Deltares, 2018) are the starting point. Due to time limitations the thesis focuses on the two most extreme scenarios, which are Rest and Steam. The analysis therefore creates understanding of two plausible futures of the delta region until the year 2100. It is used to understand the uncertainties the project of the River as a Tidal Park has to deal with and the desired benefits which are most crucial to cope with the risks.

Methods

Within this phase a literature review will be done to understand the Deltascenarios and the related risks for 2100. The mapping method is used to spatialize the problems the future brings.

2.2a Definition of TIpping Points and Project Pathways

The tipping points define the point in time when a limit is reached and the project pathway has to change accordingly. The thesis considers tipping points and actions which are affecting the amount of available space for tidal parks and the type of nature of the tidal park. This results in the uncertainty framework, which can be used to bridge the gap between short term actions and long term uncertainties. The framework starts with a short-term design (developed later in the system design phase) which have to be implemented and then the pathway starts running. At the moment in time we reach a tipping point (still uncertain when this will happen), the pathway will be changed and we need a new action to react on the tipping point, resulting in a different phase of the design. On the long term (2100) one of the plausible futures will be reality, but until then it is unsure which one it will be. It depends on the uncertainties through time and the reaching of the tipping points, because they direct towards specific scenarios.

Methods

The tipping points will come from a logical following of the scenarios and the two plausible futures of the project, as defined in the previous steps. Therefore these tipping points are mainly based on a literature review of the Deltascenarios, and the increased numbers for sea level rise, combined with my intuition of how this affects the project specifically.

Uncertainty Analysis Relation to Evaluation Framework
The uncertainty framework will be used in the evaluation framework (in combination with input from the system diagnosis and system design) to propose a change in distribution of investments in the project among stakeholders.

2b. System Diagnosis

The aim of the system diagnosis is to define the provided ecosystem services for each of the design phases, starting from the final state of both scenarios and to search for value synergies between them. As the uncertainty analysis, system diagnosis and system design happen at the same time, there is a constant reflection between them. With the new gained knowledge of this phase, the uncertainty framework can be adjusted. The output of the system design is also needed for the defining of the provided ecosystem services. The system diagnosis encompasses two steps: the ecosystem service analysis and the value synergy analysis.

2.1b Ecosystem Service Analysis
In the uncertainty analysis the importance of the objectives for each scenario is defined. In this system diagnosis the range of ecosystem services can be defined, following from the existing objectives of the project and the increasing risks according to the uncertainty analysis. This will result in an overview of a range of ecosystem services which can be obtained from tidal parks. This can show the importance of the project of the River as a Tidal Park for the existing partners, but can also gain interest with new collaborative partners, resulting in new finance models. The nine ecosystem services which form the base of the thesis are investigated in space by maximising each of them for the region and for the Waalhaven using the maximisation method. For this, each of the nine ecosystem services is maximised to investigate the optimal values. This is done for both the region and the Waalhaven. After the development of the nine strategies, which are enclosed in the appendix, a consideration is made which of the services are most important in each scenario, using the assessment method. This provides insight in the most relevant ecosystem services in each scenario. With this, a gradient can be defined to define the least and most important ecosystem services for Rest and Steam. With this different gradient for both scenarios the nine strategies merge into two different strategies, providing the optimal values within that specific scenario. This provides insight in the optimal outcomes of each of the services. Furthermore, in this step, the key performance indicators can be defined, according to the range of ecosystem services. This will be used to define for each of the design phases to what extend the phase contributes to each of the ecosystem services.

Methods
For this step it is important to obtain knowledge about all the possible ecosystem services we can obtain from tidal parks. Firstly ecosystem services in general are reviewed, using the publications of the Millenium Ecosystem Assessment (2005) and the European Commission (2013 and 2015). Besides that, more specific literature about ecosystem services of tidal nature is reviewed, like the book Valuing Ecosystem Services, the Case of Multi-Functional Wetlands (Turner et al., 2008). After that, the mapping method is used to explore the optimal benefits each of the ecosystem services can provide. Besides this, knowledge about assessing ecosystem services have to be gained. For this, a literature review of the TEEB tool (2010) and the B£st Tool (2016) and an existing assessment of ecosystem services from the Haringvliet area (Böhnke-Henrichs and de Groot, 2010) is used. This provides insight in the ways in which ecosystem services are assessed before and which key performance indicators are used to assess the different ecosystem services. This information can be used to link the ecosystem services to key performance indicators in this project, which is then used in the evaluation framework.

2.2b Define value synergies
Comparing the ecosystem services within each scenario can result in the finding of synergies. These synergies would be ecosystem services which we need to obtain in each plausible future and are therefore important no matter what – the 'no regret measures'. The synergies are the start for the short-term base design, which will be explained in the next phase.

Methods
This step demands for an assessment of the ecosystem services within each scenario, using the assessment method. Comparing the assessments within the scenarios results in a validation of the most important ecosystem services, which are the ones used in the base design.

System diagnosis relation to evaluation framework
Use the range of ecosystem services and key performance indicators to define for each design phase how effectively each service is addressed.

Show the relative values the different stakeholders obtain from the ecosystem services by comparing this information to the interest of the stakeholders. While planning and designing a tidal park in the future this information can be used to distribute investments among stakeholders more evenly throughout the process.

2c. System Design

The system design consists of three steps: the strategy building, the short-term design and the phasing.

2.1c Strategy building
This step focuses on the translation of the nine ecosystem service strategies (following from the maximisation method) within the two scenarios towards strategies for 2100.

Methods
The importance of the ecosystem services in both scenarios is used to make considerations. This results in two regional strategies and two strategies for the Waalhaven, outreached by using the mapping method.

2.2c The short-term design
The short-term design considers the Waalhaven scale and follows from value synergies in the strategies for 2100. Within this phase it is important to consider the current characteristics and constraints of the site, so that the design can function together with existing land-use functions of the harbor.

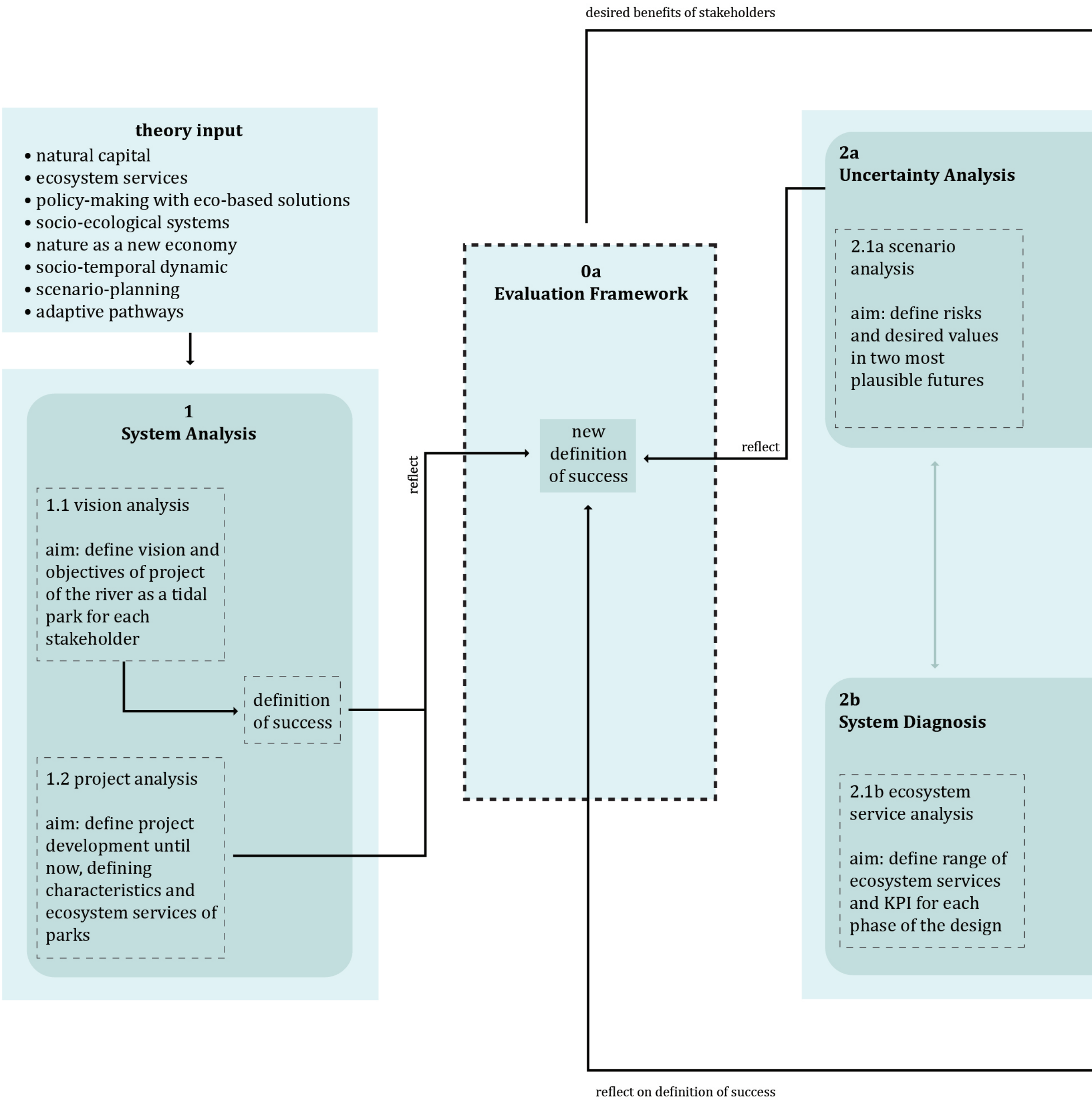
Methods
To develop a spatial configuration for the Waalhaven a site analysis is needed through mapping, showing the existing characteristics and constraints of the site. The design will be underpinned with a technical elaboration by the use of, for example, sections.

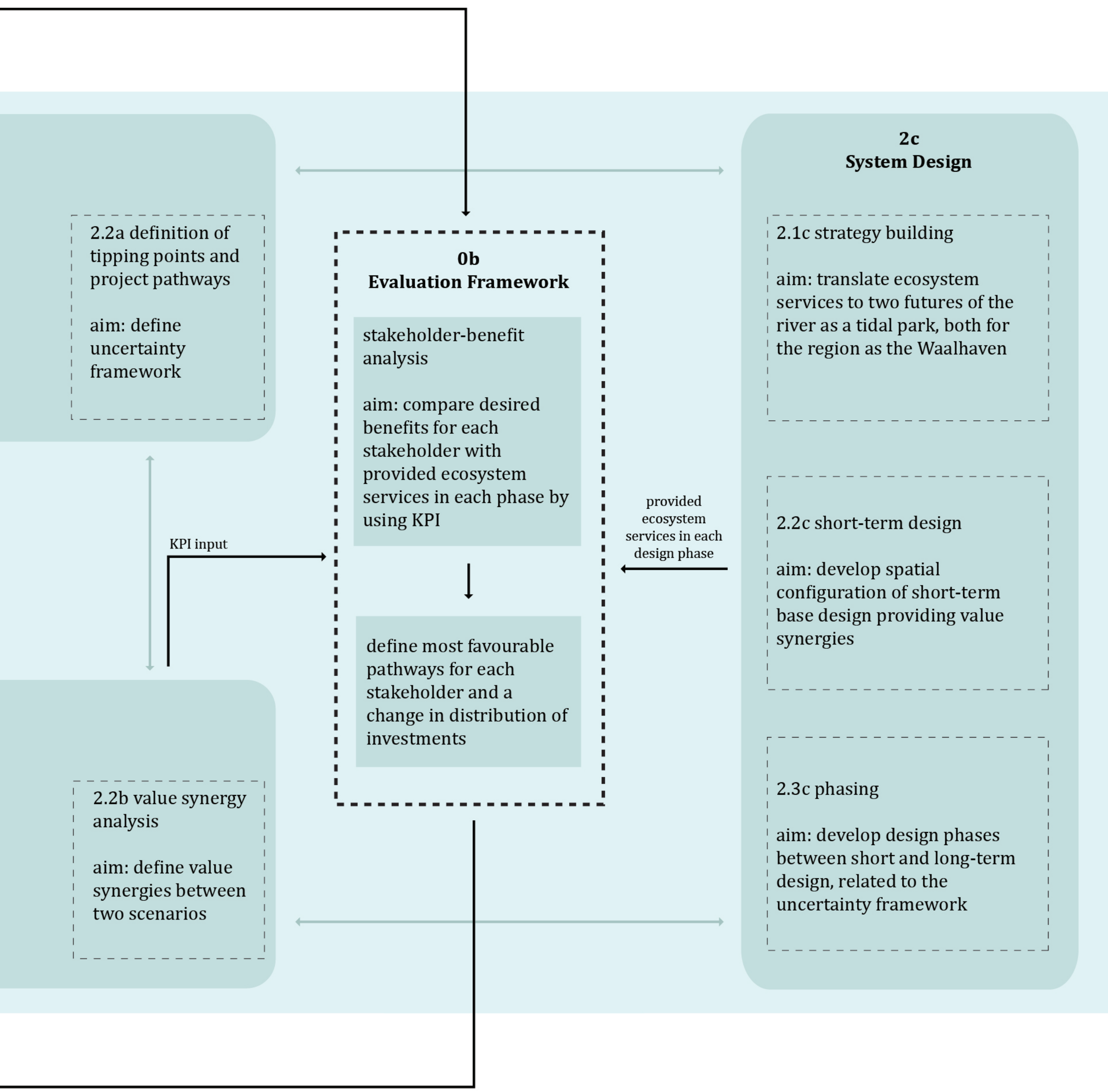
2.3c Phasing
Following from the investigated constraints, the reaching of the tipping points and the desired ecosystem services through time, several design phases can be developed. These phases (focusing on providing an optimal outreach of ecosystem services through time) are used in the system diagnosis to define the exact provision of ecosystem services according to the key performance indicators.

Methods
The different design phases are outreached through mapping. They follow from the earlier described tipping points, the desired ecosystem services through time and the current land-use constraints.

System design relation to evaluation framework
The phases, including the short-term design and long-term strategy, are used in the evaluation framework to do a stakeholder-benefit analysis. By comparing the provided ecosystem services for each phase with the interests of the stakeholders, the thesis can provide insight in the change of their interest through time. This information can be used to define the most favourable pathway for each stakeholder and could result in a change in distribution of investments among them. In the system diagnosis the provided ecosystem services per phase are defined. This shows whether the service provides higher values in specific phases, compared to others. From this, the prefered pathways can be defined for each service. For each stakeholder, the services for which the interest is the highest (assessed with score '5'), are compared to define the most prefered pathway for them. The final conclusion can be drawn by comparing the prefered pathways of the stakeholders among each other. This could result in a prefered pathway benefitting most ecosystem services and a proposal to distribute costs and benefits differently among the stakeholders.

research question
How can the concept of 'Nature as a New Economy' be used for the development of an adaptive design for the spatial transformation of the coastal zone of the Nieuwe Maas under deep uncertainty?





▲ Figure 2.6 | Methodological Framework (source: by author)

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PART II

method testing: the case of 'the River as a Tidal Park' in Rotterdam

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3

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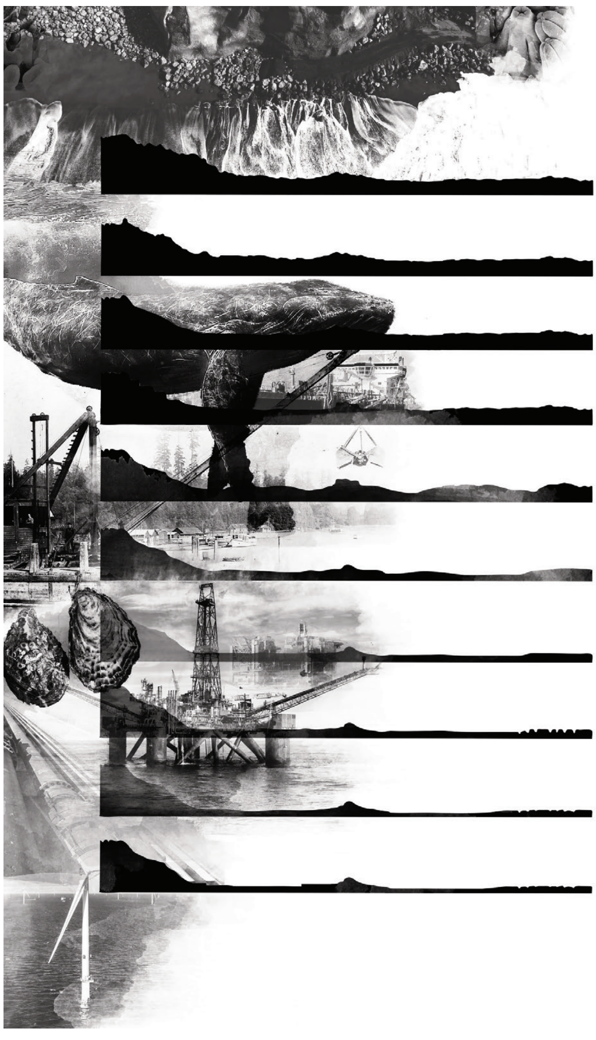
context of the case-study

3.01. Territorial Problem Context

The ecosystems within the territory of the North Sea have been subjected to changes due to climate change and human interventions. Over the past millennia, the North Sea's seascape has been constantly altered. The historical shifts in its patterns, profile and ecosystems are an expression of the tide of natural and anthropogenic, extractivist processes that have stimulated these alterations. We can therefore understand that the base condition of any landscape or seascape is that of constant flux through time, because the external stresses themselves are constantly evolving. Each landscape has to deal with the 'unstoppable tides of change'.

Reaching Limits

In recent decades, extractivist processes can be seen as being the most ecologically critical stress on the North Sea territory. Since one and a half century, but mainly since the 1970s, extractivism has evolved extremely in order to stimulate economic growth. Anthropogenic processes like overfishing, oil and gas extraction, shipping and energy production, but also natural processes like sea level rise and erosion are altering the seascapes and coastal zones (PBL, 2018), see figure 3.1.



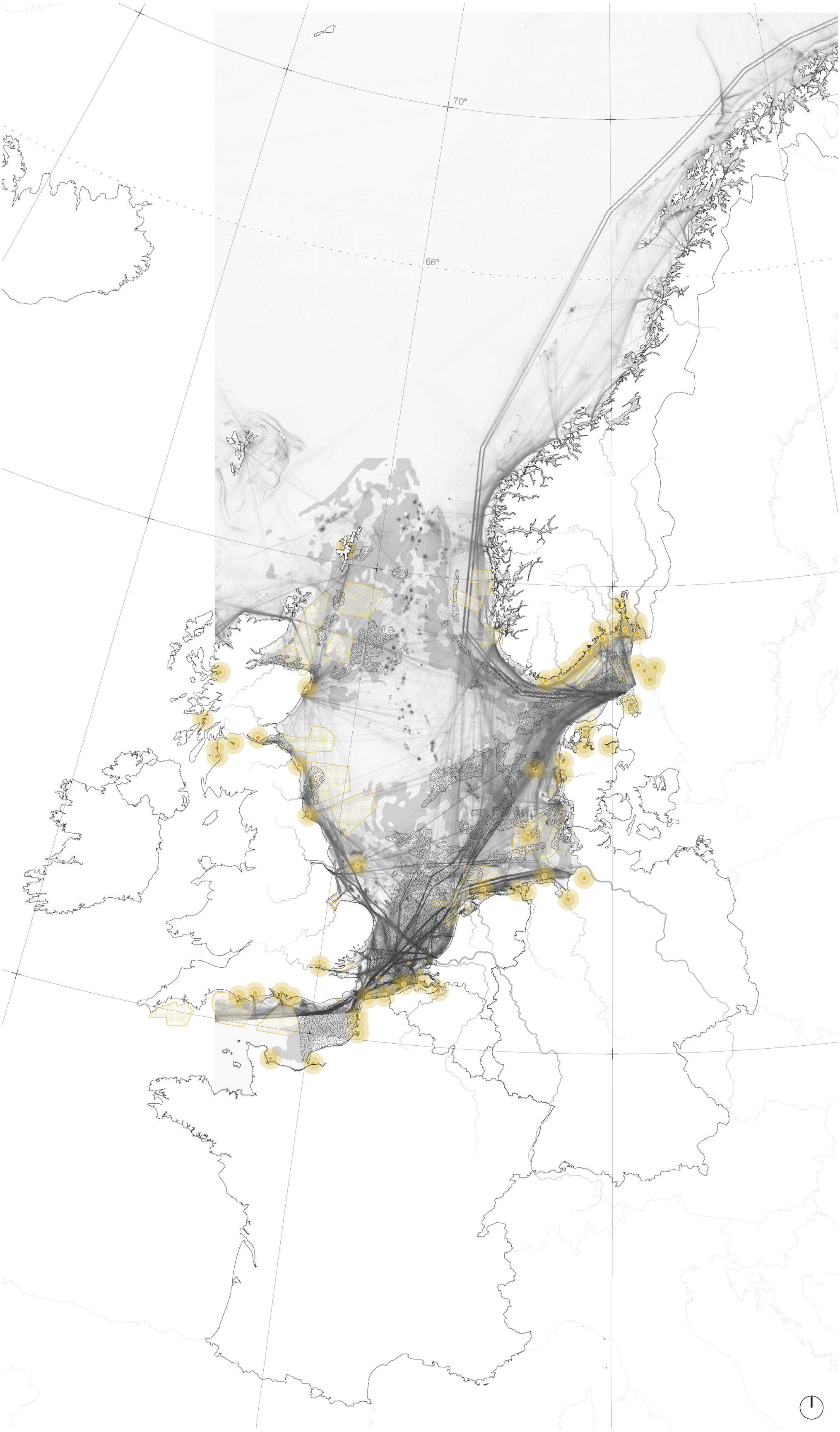
▲ Figure 3.1 | Extractivism of the North Sea Territory (source: collective work Transitional Territories Studio)

Several factors can negatively influence the ecosystems within the North Sea. Firstly, overfishing poses as a significant problem as it is dramatically depleting specific fish species populations. Invasive fishing and dredging techniques that harm the sea bed, such as trawling and sand extraction respectively, have a destructive impact on seafloor habitats. It is noted that 74 percent of the accessible areas of the North Sea have consistent anthropogenic pressures and physical disturbances on the seabed, which severely affect the ability for marine habitats to recover.
Secondly, hypoxia areas, which are classified as zones that lack oxygen, can cause an imbalance of nitrogen and phosphate levels, often resulting in algae blooms. This can also lead to further eutrophication and reduction of marine life.
Third, military exercise areas are polluting the environment as well as altering and disturbing habitats.
Finally, shipping routes can heavily degrade the environment with oil spills, chemicals, waste and biocides. Shipping routes also cause a variety of noise pollution issues, introduce invasive species from other areas and can cause wave disturbance (PBL, 2018, Ospar Assessment Portal, 2018).

The map in figure 3.2 shows a concentration of reached limits for ecosystems along the Dutch coastline. This is mainly due to the location of the Rotterdam harbor, demanding for intensively shipping traffic, as this is the only open connection of the Netherlands between sea and hinterland. This open connection is crucial for the functioning of the harbor, but also makes the city of Rotterdam more vulnerable due to rising sea levels and changing river discharges.

legend

shipping route density
dredging
overfishing
military exercise area
hypoxia areas



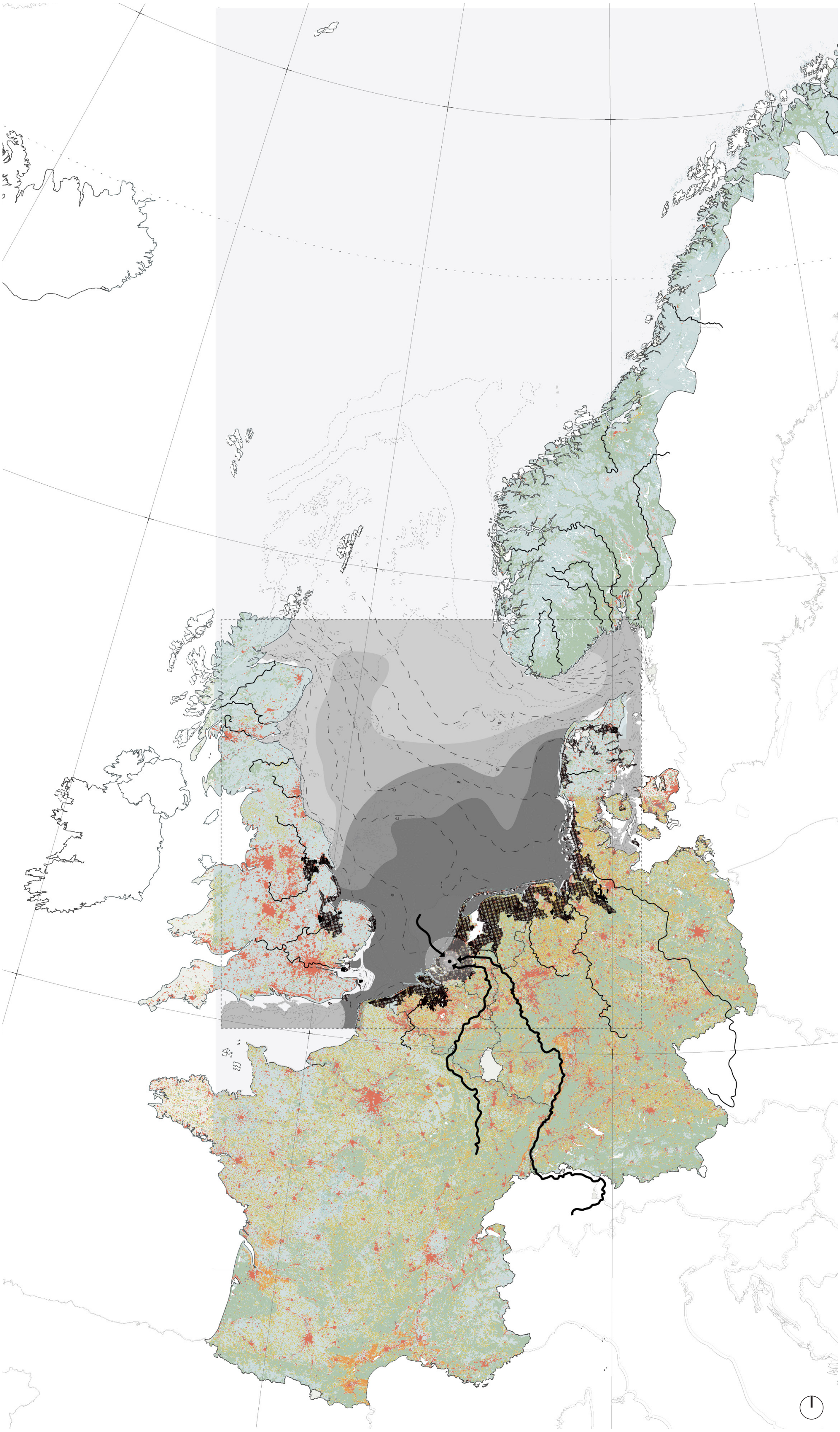
▲ Figure 3.2 | Human disturbance affecting seascapes (source: collective work Transitional Territories Studio)

The river near Rotterdam is subjected to as well changes in the seascapes (e.g. sea level rise and changing salinity levels) as to changes affecting the rivers in the hinterland (e.g. pollution by urban, industrial and agricultural land use and changing river discharges) (OSM Landuse Landcover, n.d.). These vulnerabilities of being the receiving end of both the marine and the river estuaries are caused by both climate change and human interventions and is represented in figure 3.3.

All these uncertain processes through time are affecting the sea-, river and coastal landscapes and therefore also the services we can obtain from them. The degree of the human's right to take what is 'needed' from the natural sphere for developmental purposes is being fundamentally called into question. As our understanding of ecosystems as complex systems – that are heavily interdependent – develops, so does the realisation of the uncertainty of the ecological future. We are now a society at risk and are entering a realm of uncertainty, which may benefit from a more adaptive civilisation. The only certainty we are facing is that sea-, river- and landscapes are subjected to continuous change due to economic development and the changing climate.

legend

- forest
- fields
- pastures
- permanent crops
- urban area
- flood risks
- low-high sea level rise



▲ Figure 3.3 | Rotterdam as the receiving end (source: collective work Transitional Territories Studio)

3.02. Regional Problem Context

Manipulation of the Delta Landscape

The city of Rotterdam is, due to its location in the receiving end of both the North Sea Estuary and the Rhine-Meuse Estuary, extremely vulnerable for uncertainties, related to changes in ecosystems. However, this location is also the reason for the economic growth of the city, resulting in Rotterdam being the second largest city of the Netherlands with the largest port of Europe (Port of Rotterdam, 2018).

The Rotterdam Region with the river Nieuwe Maas is transformed and manipulated that much due to natural and human actions that it now hardly contains nature types. This section describes both the natural and human processes which transformed the natural delta landscape into a manipulated river. Figure 3.4 shows a projection of the current river bed of the Nieuwe Waterweg and the Nieuwe Maas on the Delta Landscape of 1649 to illustrate the drastic changes.

Centuries ago the Merwede was a natural river, subjected to the dynamics of both the North Sea as the Rhine-Meuse Estuary (Palmboom, 1990). It was a tidal landscape with a braided river structure and a dynamic gradient from sweet to salt, providing a wide variety of habitats for flora and fauna. Since the construction of the Nieuwe Waterweg in the second part of the 19th century (to make Rotterdam accessible for large sea ships), the character of the river changed extremely. This was the start of a long process of manipulating the delta. The river is now largely canalised and the natural slope is transformed into hard quays, functioning for industrial activities, ports, residential areas and embankments (Stikvoort et al., 2002).

In the 19th and 20th centuries the Dutch thought it would be possible to control the urbanization process of the delta landscape completely. The landscape became subjected to the needs of human society, through land making, urbanisation and flood defense (the Zuiderzee Works and the Delta Works). These flood defense works contributed in a spectacular economic growth of the whole country (Meyer and Nijhuis, 2016).

The historical development resulted in the situation that nowadays, about 70 percent of the river bank of the Nieuwe Maas and Nieuwe Waterweg consists of hard, paved and steep quays (European Commission, n.d.). This caused a degradation of nature along the riverside, but also produced unattractive riversides for recreational possibilities. The images in figure 3.5 to 3.10 show the spaces the fluvial zone knows today as a result of the manipulation of the delta landscape.

▲ Figure 3.4 | Projection of the current river bed on a historical map of 1649 showing the manipulation of the river trough time (source: by author)

▲ Figure 3.5 | Urban development along the river banks putting high pressure on the river bed of the Nieuwe Maas. Hard water management measures provide more space for urban development, but also increases the risks (source: by author)

▲ Figure 3.6 | Urban Development along old harbor basin at Katendrecht (source: by author)

▲ Figure 3.7 | At the Europoort harbor area, the primary dike divides the area within and outside the dikes as a huge barrier (source: Google Streetview)

▲ Figure 3.8 | Hard quay with extremely low natural and recreational values (source: by author)

▲ Figure 3.9 | Low recreational and natural values along the river Bank Maasboulevard (source: Google Streetview)

▲ Figure 3.10 | No recreational and natural connections between city park and the river (source: Google Streetview)

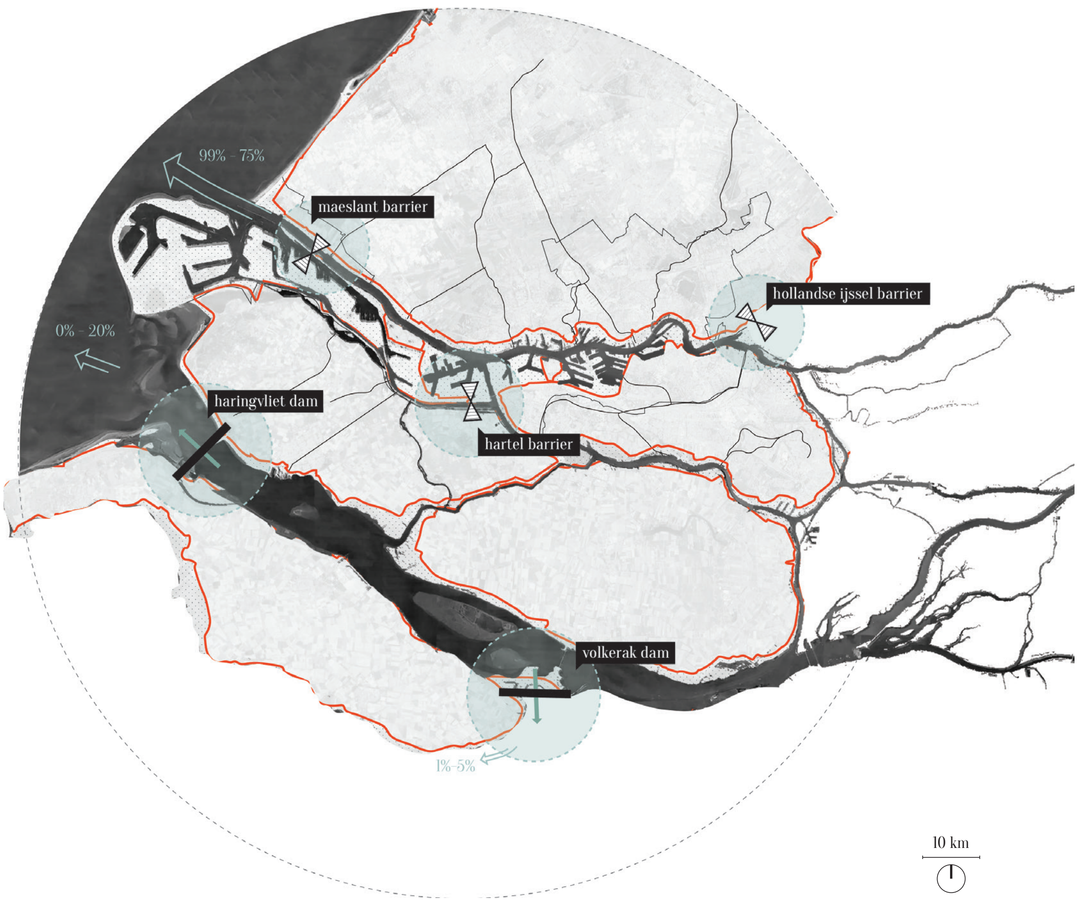
Water Management System

The water management system of the region, which contributed to this extreme manipulation of the river, is the one represented in the map in figure 3.11.

The river combination of the Nieuwe Waterweg, the Scheur and the Nieuwe Maas is the only open connection with sea in the Netherlands. After the construction of the Delta Works all the other sea arms were closed off. Due to this intervention the major part of the river discharge flows through the Nieuwe Waterweg towards the sea. This is important for the current water system as it pushes back the salt which intrudes through the open connection and causes problems for drink water and agriculture in the region (Meyer, 2016). The high river discharge in the river is also important for the shipping which is crucial for the harbor of Rotterdam.

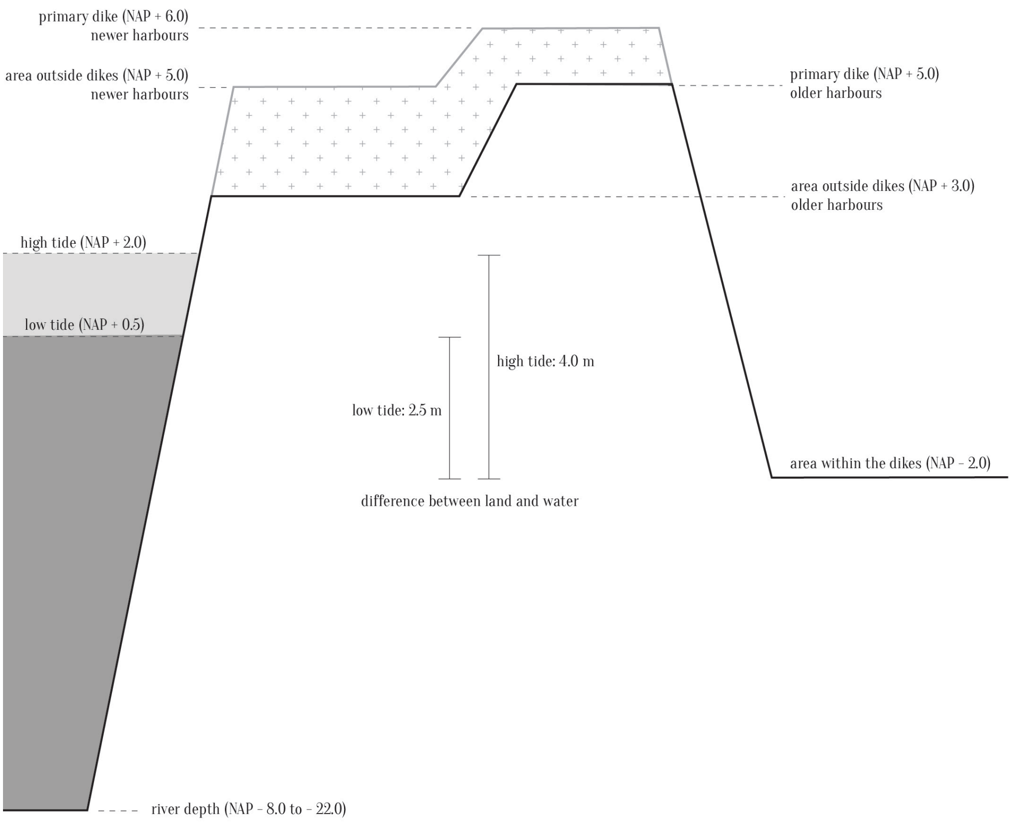
The open connection between sea and hinterland is crucial for ecological (migration of species) and economic (harbor activities) purposes. It, of course, also increases the risks as the area outside the primary dikes is subjected to increasing sea water levels and salinity intrusion. Also, this existing water system demands for a good maintenance of the primary dikes along the river, as they are subjected to the external influences of changing sea levels, storms waves, tides, etc.

Besides the dikes and dams there are a few barriers to protect the region from flooding of which the Maeslant Barrier is the most important one for Rotterdam. This barrier is designed to only close ones a year, with a maximum of three times a year. This is an important given, as closing of the barrier has huge consequences for the shipping. The Maeslant barrier only closes during extreme storms and has a failure chance of 1/100 times closing (Deltares, 2018).



▲ Figure 3.11 | Current water management system of the region (source: by author)

The section in figure 3.12 shows there is already a large height difference between the water levels in the river and the hinterland. During high tide this is already 4 meters and during extreme storms or waves this is even more. The height difference between land and water will increase due to soil subsidence and sea level rise. The oldest harbor basins, which are located most close to the city center, are located much lower than the newer harbor basins and are therefore more vulnerable for flooding.



▲ Figure 3.12 | Height difference between land and water (source: by author)

The Dutch have always protected themselves against the water by dike systems, sluices, dams and through drainage of the polders. This resulted in the fact that the polders lowered constantly, which increases the risks when a dike collapses. The map in figure 3.13 shows the water depth when a primary dike collapses and the flood risks outside the dikes.

Agriculture is very much under pressure due to the low location of the fields in the landscape. Human's constant process of draining the land, resulted in subsidence of land. Therefore, the polders are located much lower than the surface water which makes the necessity to pump more intensively crucial to keep the land dry for agriculture. In our current agricultural land-use, the drainage is still an important aspect, which makes that the soil keeps subsiding (figure 3.14). The difference between land and water also increases the salt intrusion through ground water (seepage).

The expected sea level rise and the agricultural land-use which constantly intensifies is a reinforcing process. The increasing height difference between land and water demands for increasing drainage. This increases soil subsidence, resulting in oxidation of the peat landscape causing extreme CO2 emissions. As this contributes to climate change it would also contribute to more extreme sea level rise and temperature change.

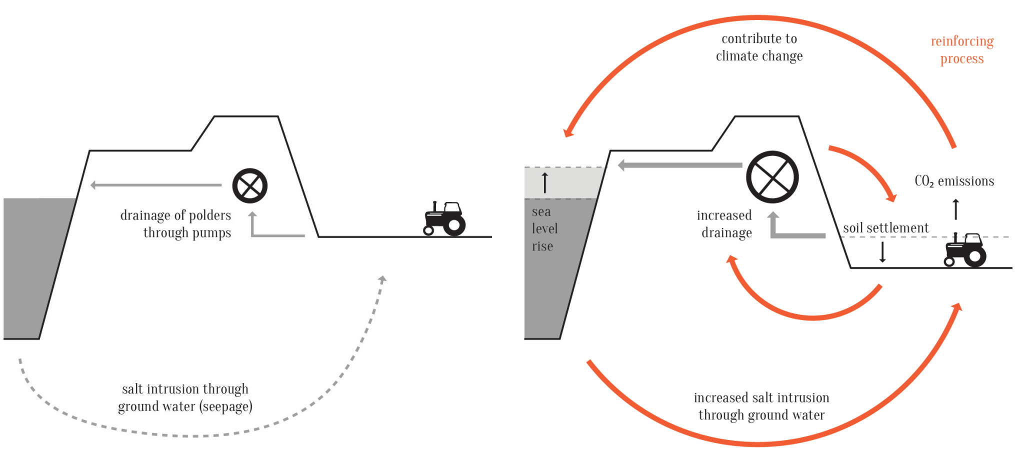
The question is if it will be feasible to keep draining the land as it increases the problems for food production, increases water safety problems, decrease the accessibility to fresh water and increases CO2 emissions (figure 3.15).

legend

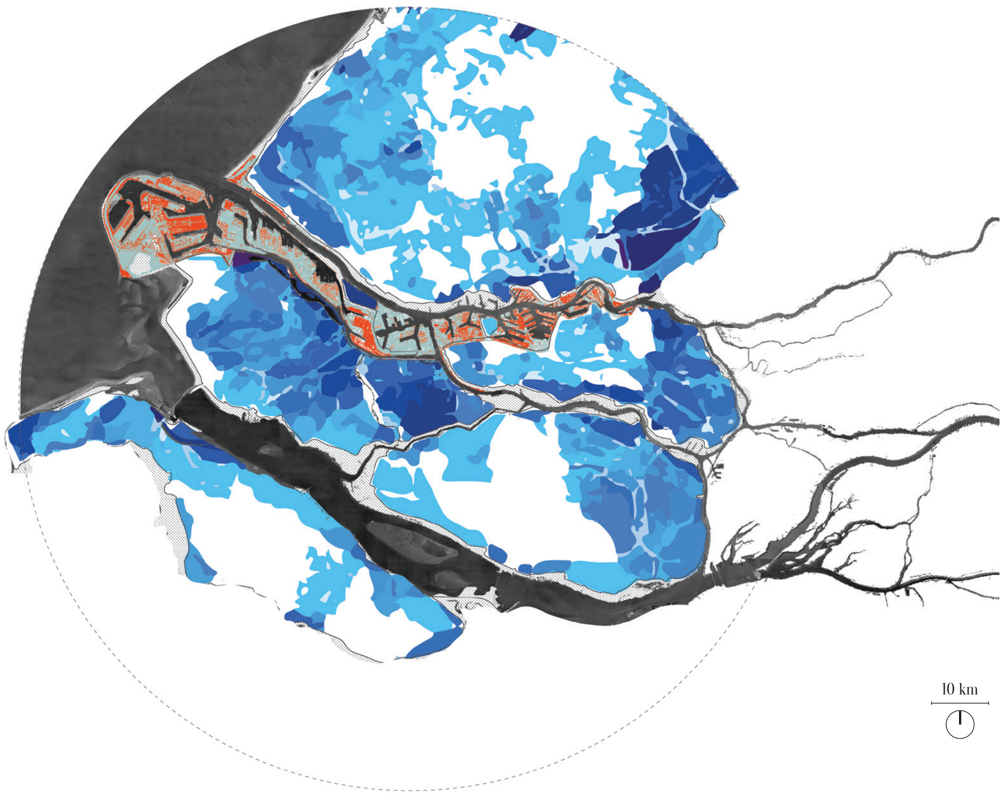
- > 6.0 m water depth if primary dike collapses
- 4.0 - 6.0 m water depth if primary dike collapses
- 2.0 - 4.0 m water depth if primary dike collapses
- 1.0 - 2.0 m water depth if primary dike collapses
- 0.5 - 1.0 m water depth if primary dike collapses
- < 0.5 m water depth if primary dike collapses
- flood risk areas
- 'safe' areas for flooding
- primary dikes
- built environment
- water

legend

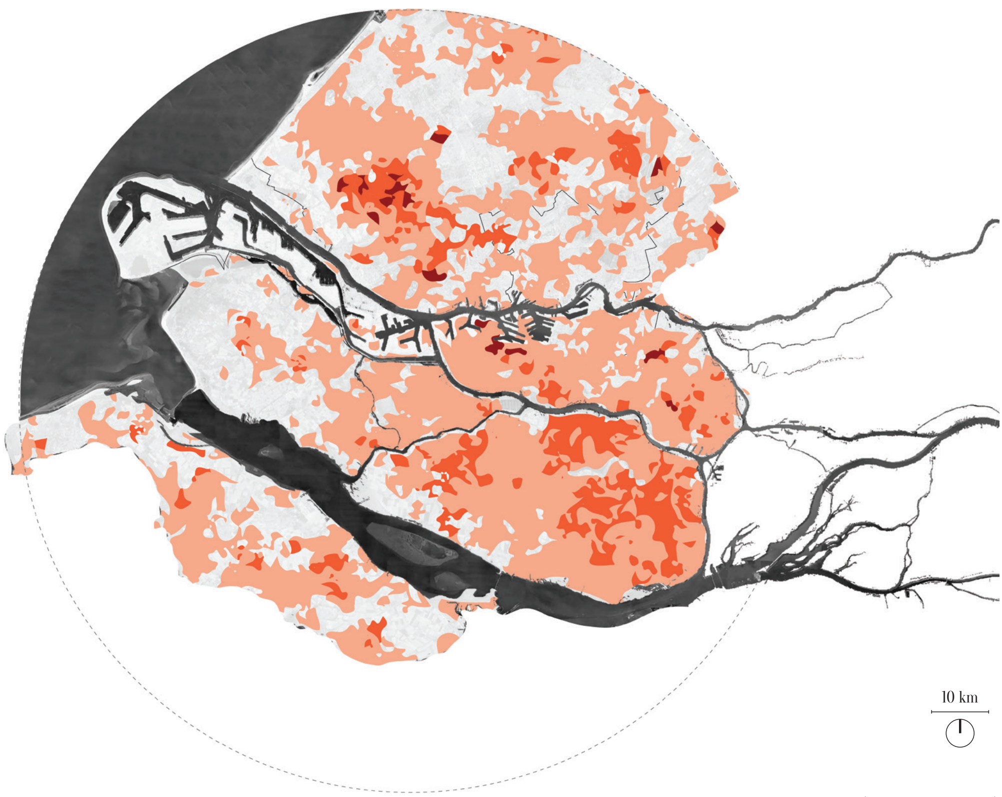
- little soil settlement - < 2 mm
- significant soil settlement since may 2015 - 2 to (
- significant soil settlement since october 2016 - 2
- extreme soil settlement - > 6 mm



▲ Figure 3.15 | Reinforcing process of human actions, climate change and risks (source: by author)



▲ Figure 3.13 | Flood risks within and outside the dikes (source: by author)



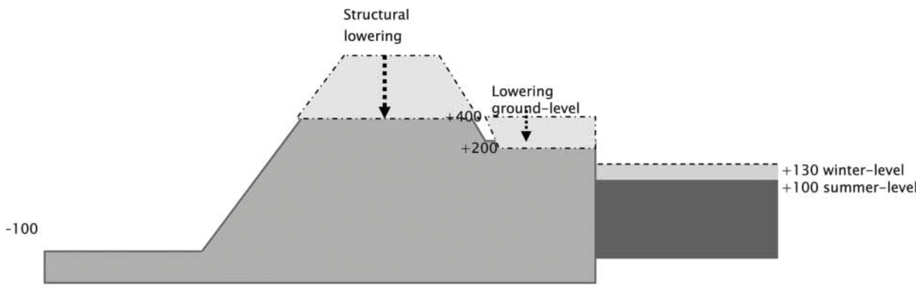
▲ Figure 3.14 | Soil subsidence (source: by author)

Keep fighting against nature?

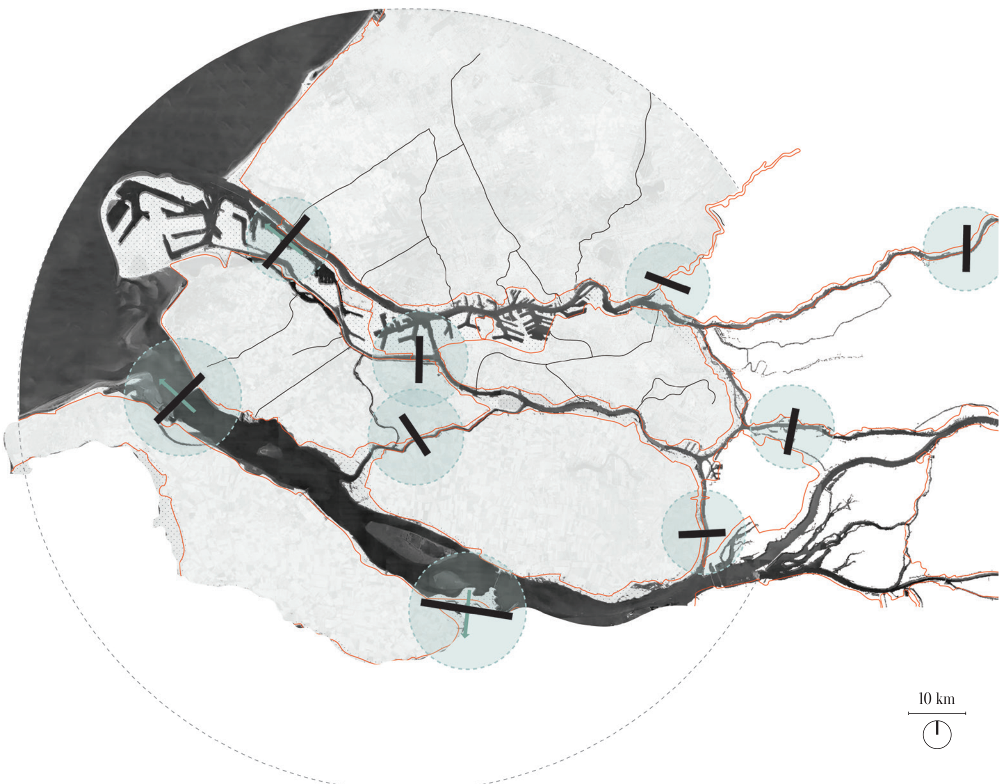
The Delta Platform, which does research and develops strategies to improve water safety in the Netherlands, defined options how to deal with the future sea level rise. Besides the current open / closable system there are two more options (Ministerie van Infrastructuur en Milieu en het Ministerie van Economische Zaken, Landbouw en Innovatie, 2013).

Option for Future Water System: Closed Rivermouth
One option to deal with the expected sea level rise is to close off the river mouth with sluices and dams (figure 3.16 and 3.17). This would result in the possibility to lower the dikes and increase connectivity between the areas within and outside the dikes, but conflicts with shipping and ecology.

Option for Future Water System:
Open Rivermouth with Heightened Dikes
The other option is to create an open rivermouth with increased and enforced dikes along all waterways (figure 3.18 and 3.19). This alternative is very expensive and also increases the drainage process as the difference between land and surface water levels becomes bigger. It does provide favourable conditions for ecology in the tidal rivers and for shipping.



▲ Figure 3.16 | Option of closed river mouth (source: Anne Loes Nillesen, 2019)

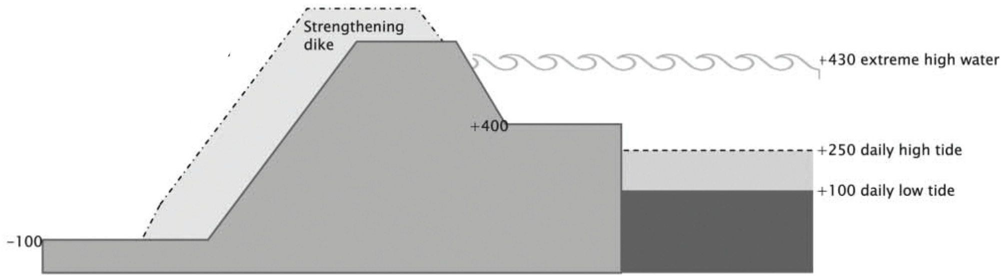


▲ Figure 3.17 | Option of closed river mouth (source: by author)

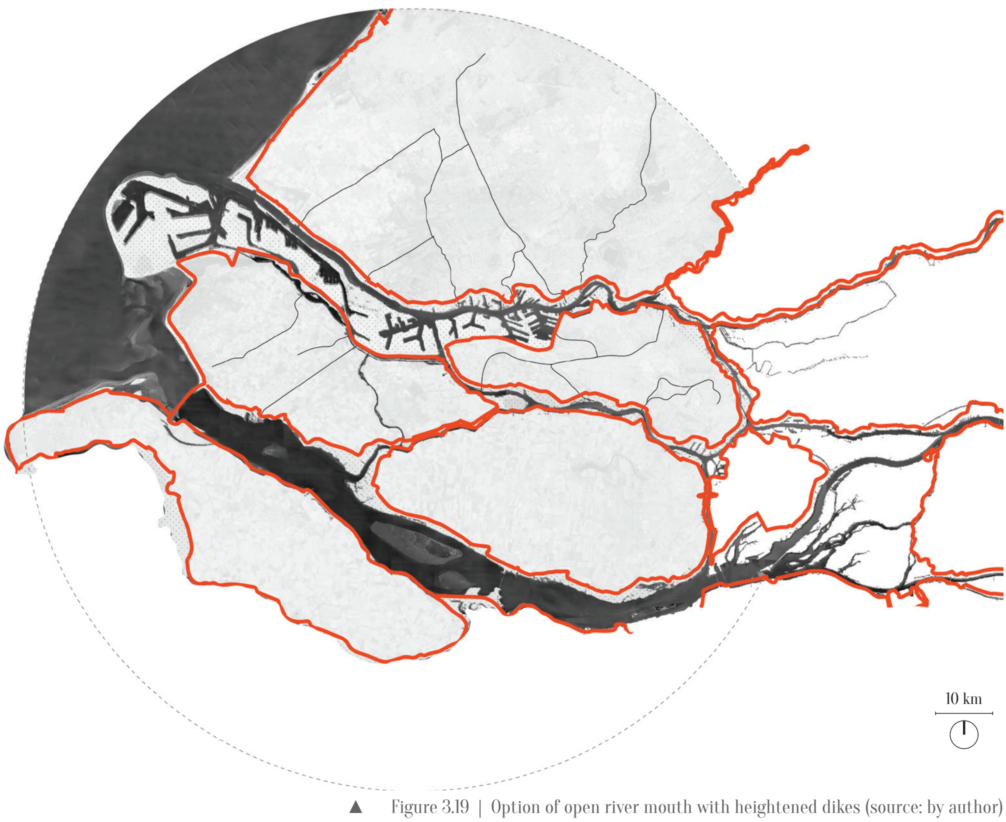
Hard versus Soft Measures
The previously described options are both hard measures, which finally increases the risks as described before. Should we try to keep fighting against nature with possibly disastrous consequences as a result? Or should we accept that we live in a delta landscape and regenerate natural ecosystems to prevent future generations from being the victims of the behaviour we have adopted today.

However we used to think, the previously described processes are pushing us forward: we now start to see we need nature, its ecosystems and its services to survive.

Therefore, this thesis investigates on reducing risks by using soft instead of hard measures. One existing project focusing on adapting to future circumstances by providing ecosystem services with soft measures is the project of the 'River as a Tidal Park' in the Rotterdam Region. Therefore, this is the case-study to test the previously described method.



▲ Figure 3.18 | Option of open river mouth with heightened dikes (source: Anne Loes Nillesen, 2019)

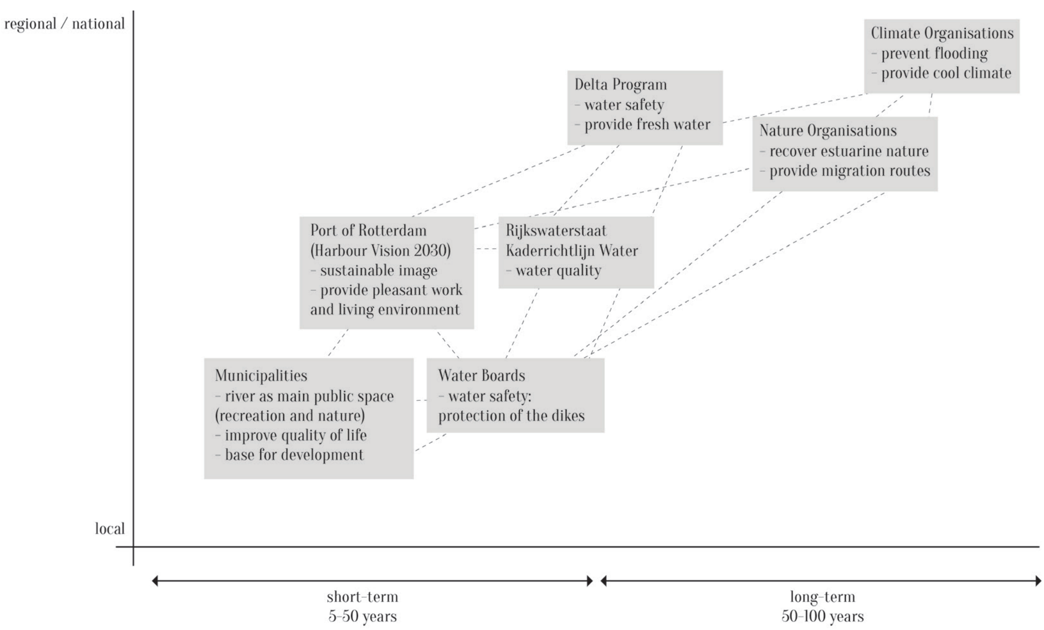


▲ Figure 3.19 | Option of open river mouth with heightened dikes (source: by author)

3.03. Using Soft Measures to Reduce Risks: the Case-Study of the 'River as a Tidal Park'

The project of the 'River as a Tidal Park' in the Rotterdam Region aims for restoring nature and green areas along the riverside of the Nieuwe Maas in order to recover natural values and at the same time provide an attractive river for recreational purposes. Therefore, it can be seen as an example of seeing and working with nature as a new economy. The Future Perspective Urban Nieuwe Maas - Toekomstperspectief Binnenstedelijke Nieuwe Maas in Dutch - (Gemeente Rotterdam, 2018) describes Rotterdam is growing in all aspects and will get more and more dense. They aim for providing 50.000 new dwellings in 2040. The Future Perspective sees the Nieuwe Maas as the chance to provide a unique public space in the center of the city, which is the area where most people live and where least public green is available. The river can become the identity of the region, providing natural and recreational values and, therefore, creates light, air and space in the dense city. This aim followed in the Program River Banks - Programma Rivieroevers in Dutch - (Gemeente Rotterdam, 2016) of which the River as a Tidal Park is part. As the river is the only open connection between sea and hinterland in the Netherlands it has a lot of potentials, for as well economy as ecology. The project aims for the development of tidal parks along the Nieuwe Maas and Nieuwe Waterweg in order to re-establish the delta characteristics with the rhythm of tides and together with that the corresponding recreational and natural values. The tidal parks can provide, due to the tidal influence and gradients in salt and fresh water, an unique ecological environment in the Netherlands (Port of Rotterdam and World Wildlife Fund, 2013). At the same time, the function of the river as a transportation route between sea and hinterland have to be maintained to not conflict with the harbor's activities, tourism and migrating species (Port of Rotterdam and World Wildlife Fund, 2013). The project started in 2013 with a coalition between the Port of Rotterdam and the World Wildlife Fund for which both is the open connection extremely important (Port of Rotterdam and World Wildlife Fund, 2013, de Greef, 2018).

As part of the National Deltaprogram it is crucial to think about the effects of sea level rise and increased river discharge in the Rhine-Meuse Mouth. Before the start of the project of the river as a tidal park, the Deltaprogram discussed one of the possibilities to cut off the open connection by sluices and dams to provide water safety for the hinterland (de Greef, 2018). The Deltaprogram, the WWF and the PoR saw the possibility to work with nature to meet collaborative goals, e.g. water safety, nature and recreational values and at the same time



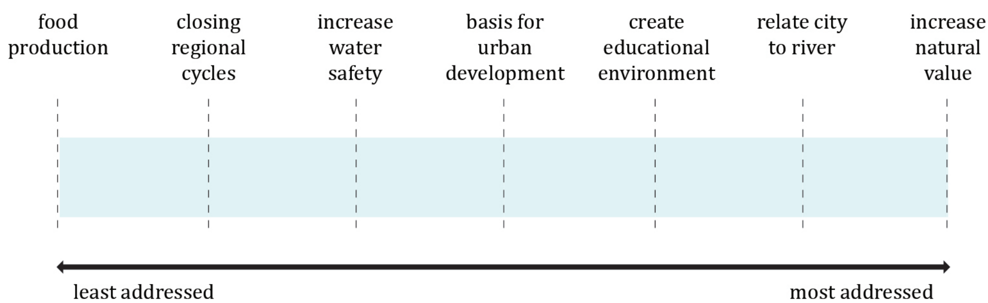
▲ Figure 3.20 | Interest of groups of stakeholders in the project of the River as a Tidal Park (source: by author)

maintain the transportation route for shipping. They defined two main goals (Linkit Consult, 2017):
- Increasing the natural and recreational value of the river banks
- Provide a future-proof spatial configuration of the delta in relation to climate change

Very fast, this resulted in a partnership with the Department of Waterways and Public Works (Rijkswaterstaat in Dutch) and the Municipality of Rotterdam. The interest of Rijkswaterstaat is the increasing water quality due to the development of ecological river banks (de Greef, 2018, de Groot, 2018, Rijkswaterstaat, 2018). In the highly urbanized area of Rotterdam and their expectation to become even more dense, the Municipality saw their chance to develop the river into the main, green public space for Rotterdam. The fact that the river is very central in the city, providing space and air and can function in being the identity of the city, resulted in the collaboration of the Municipality of Rotterdam (de Greef, 2018). In 2015 ten partners signed a partnership in which they collectively decided on what the River as a Tidal Park aims for to meet everyone's interest. Nowadays, this partnership consists of twenty partners in total, among whom municipalities, the Port of Rotterdam, Rijkswaterstaat, nature organizations, climate organizations, water boards and the Deltaprogram. The general interest of the groups of stakeholders is represented in figure 3.20. With the project the partners aim for providing the following ecosystem services (de Urbanisten, 2018):

1. Relate the City to the River, by increasing recreational values and the accessibility of the water
2. Increase natural value and biodiversity
3. Create an educational environment where the tidal parks create awareness of living in the delta and can provide in playing grounds for kids to get acquainted with nature
4. Increase water safety by protection of the dikes
5. Food production by generating fishing spots and produce edible plants and animals
6. Function as a basis for urban development, because the tidal parks increase the land and real estate value of the environment and because costs are saved due to decreased maintenance of the hard quays.
7. Contribute to regional circularity by reusing Rest flows and the tidal parks can function as a lab or testcase to provide in knowledge production.

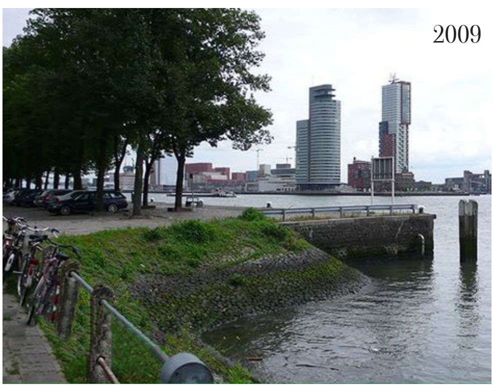
In order to get better understanding of how the seven ecosystem services reveal itself within the project until now, the constructed and planned projects are analyzed. In total there are seven constructed parks and nine planned parks. The images in figure 3.22 on the next page represent an impression of some of those parks and how they changed the spatial quality. The projects are analyzed on the following aspects: the size of the park, the degree of nature and culture, the used design principles, the natural conditions of the saline levels in the water, the accessibility and the main initiators. The analysis resulted in an evaluation on the earlier described objectives of the partnership. This assessment shows whether the tidal park contributes in achieving the seven goals / ecosystem services. The conclusion of this analysis is represented in the assessment bar in figure 3.21, showing to what extent the objectives are achieved until now. The analysis of the characteristics and related values shows the main focus of the current project lies on increasing the relation between the city and the river by improving the recreational values and increasing the natural values. The values which are least addressed are increasing water safety, food production and closing regional cycles. The full analysis of the characteristics of the constructed and planned parks and the assessment of the provided ecosystem services is enclosed in appendix 2.



▲ Figure 3.21 | Focus of provided ecosystem services by current generation of tidal parks (source: by author)

▲ Maashaven transformation to tidal park
(source: Dieuwertje Komen (left), Municipality of Rotterdam and de Urbanisten (right))

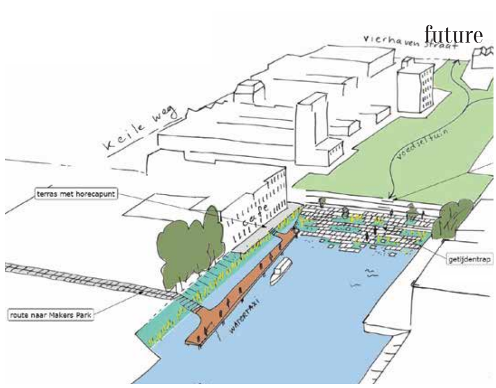
▲ Maasboulevard transformation to tidal park
(source: Google Streetview (left), Municipality of Rotterdam (right))



▲ Van Ommeren Haventje transformation to tidal park
(source: Municipality of Rotterdam (left), Okra Landschapsarchitecten (right))

▲ Maassluis transformation to tidal park
(source: Plein 06 (left and right))

▲ Groene Poort transformation to tidal park
(source: Municipality of Rotterdam (left), ARK Natuurontwikkeling (right))



▲ Keilehaven transformation to tidal park
(source: Google Maps (left), Municipality of Rotterdam (right))

▲ Figure 3.22 | Impression of the transformation of several planned and constructed tidal parks

An extensive problem analysis of the region is done to define the main problems for now and for the future. For each of the main ecosystem services the problem analysis provides insight of the risks and opportunities related to this service. This analysis is enclosed in appendix 3 of this report. Besides the seven earlier mentioned ecosystem services which are necessary to provide in the future, this thesis considers two more: the provision of fresh water and climate regulation.

8. Provision of Fresh Water
Salinization is a huge problem in the region, due to the open connection with sea. This problem will only increase in the future, because of the expected rising sea levels and periods of extremely low river discharge. Tidal parks can contribute to the reduction of this saline intrusion as it provides a gradient between water and land. Salt water is denser than fresh water and therefore transports on the bottom of the river. A gradual river bed pushes back the saline intrusion.

9. Climate Regulation
Climate change results in increasing temperature by 1 to 4 degrees. This, mainly in relation to urbanization, results in the heat stress effect, which makes that cities are several degrees warmer than the rural area. Besides that, our current lifestyle produces huge amounts of CO_2 and air pollution. These three problems can be addressed with tidal parks by providing coolness, sequestrate CO_2 in the salt marshes and improve air quality.

Considered Ecosystem Services

In the current objectives of the program it stands out that the interests of the Port of Rotterdam are not included in the descriptions. As the Port is an important partner within the program, their interest has to be better integrated to maintain their interest over time. This is done by changing the first objective into the search for an equilibrium between the city, the harbor and the river. The nine main ecosystem services which are considered are divided in several subservices. In these subservices, the interest of the harbor is also better integrated. The subservices are defined by doing literature reviews about the possibility of tidal nature to provide ecosystem services (Turner et al., 2008, TEEB, 2010, Ciria, 2016, Böhnke-Henrichs and de Groot, 2010). This literature is also used to define which landscape type is able to provide the service. The total overview of considered ecosystem services is represented in figure 3.23.

Ecosystem Services

1. Relate City, River and Harbor
   - 1.1. Attractive landscape for visitors (day-trips / recreation)
   - 1.2. Recreation: water sports
   - 1.3. Recreation: fishing
   - 1.4. Tourism: holidays
   - 1.5. Accessibility of water / coastal zone and increasing visibility towards harbor

2. Increase Natural Value and Biodiversity
   - 2.1. Water Purification
   - 2.2. Refugia for migratory and resident species
   - 2.3. Transition zone between land and water providing migration routes

3. Provide Educational Environment
   - 3.1. Awareness of living and working in a delta
   - 3.2. Awareness of coastal dynamics by visitors
   - 3.3. Characteristic landscape: improving identity of Rotterdam as Delta region
   - 3.4. Characteristic landscape: improving cultural identity of Rotterdam as Harbor City

4. Increase Water Safety
   - 4.1. Reduce water depth to reduce currents and waves
   - 4.2. Protection of the existing dikes by creating foreland, resulting in less maintenance costs

5. Food Production
   - 5.1. Fish Production
   - 5.2. Shellfish production
   - 5.3 Crop production

6. Basis for Urban Development
   - 6.1. Increasing Land and Real Estate Values
   - 6.2. Provide green business settlement climate

7. Contribute to Regional Circularity
   - 7.1. Reuse of coarse residual material
   - 7.2. Reuse of sediment flows

8. Provision of Fresh Water
   - 8.1. Reduce saline intrusion by surface water
   - 8.2. Reduce saline intrusion by ground water

9. Climate Regulation
   - 9.1. Temperature Regulation
   - 9.2. Air quality regulation
   - 9.3. Carbon sequestration

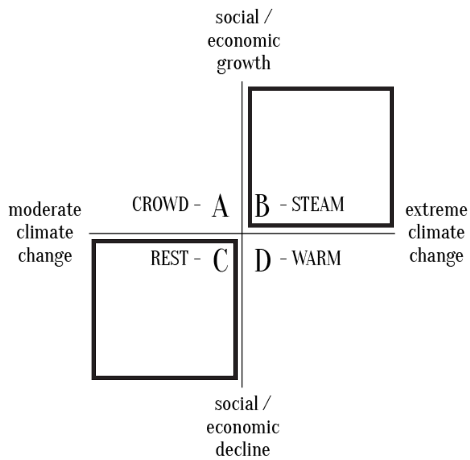
Surface Providing the Ecosystem Service
The whole project site after development (limited to 500 m distance from accessible area for people as this is the zone which is still perceptible for people (Gehl, 2017)).
All water surface
Hard quays, piers and paths next to water
Area provided for holiday houses / overnight stays
Coastal zone, piers, quays, paths which are accessible for people
Intertidal areas (both mud flats and salt marshes)
All tidal nature and un-dredged water
Gradual and green river banks connecting water and land
Residential and office / harbor area located in or directly next to an intertidal area
Coastal zone, piers, quays, paths which are accessible for people and located next to tidal nature or culture
All area with delta characteristics (tidal water, tidal nature)
All area where harbor activities or relicts of the harbor are visible, taking into account that this would be visible from 500 m distance from accessible area as this is the zone which is still perceptible for people (Gehl, 2017).
Deep water where dredging activities are stopped and un-deepening is happening.
Primary dikes which are protected by heavy waves and tides due to the development of tidal nature in front of the dike.
As fish is disturbed by dredging and shipping activities, the water area which is un-dredged and where natural processes start to take place can provide this service.
Hard structures in an intertidal zone, functioning as habitat for the shellfish
Land which is not permanently flooded and available for production of food crops
All built parcels (real estate values) and parcels of land (land values) located next to tidal nature
All office or harbor area located next to tidal nature
All hard straight and hard gradual quays which are removed of which the coarse residual material can be reused. This service can only be provided once, when the quay is removed.
Sediment can be captured in areas where no dredging takes place and which is subjected to tidal influence, so in these areas the sediment can be reused for the development of tidal parks.
A gradient in the bottom of the basin pushes back the salt, which is provided by un-dredged water where sediment can settle and in tidal nature
The brackish seepage comes up in low located areas with a low ground water table, so increasing the ground water table in these areas reduces the saline intrusion by ground water.
All unpaved area
All upgoing vegetation, such as alluvial willow foRest and reed and rush
All tidal (both mud flats and salt marshes) and fresh nature

▲ Figure 3.23 | Overview of considered ecosystem services (source: by author)

3.04. Scenarios and Related Uncertainties

As explained before, each project (especially eco-based solutions in dynamic delta regions) is subjected to a wide range of uncertainties. In order to understand the uncertainties which could affect the project of the River as a Tidal Park since the moment of implementation, the Deltascenarios for the region of Rijnmond Drechtsteden (Deltaprogramma Rijnmond-Drechtsteden, 2011) are analyzed. The objective of these scenarios is to provide insight in the plausible futures for the long term, until 2100.

The Deltascenarios are based on two main uncertainties, related to social-economic decline or growth and to moderate or extreme climate change. In this project two scenarios (Rest and Steam) are considered, see figure 3.24. The scenarios are combined with the new published numbers of sea level rise, developed by Deltares (2018). The numbers which are used throughout the project are described in figure 3.25.



▲ Figure 3.24 | Considered scenarios (source: by author)

	Reference Year	Rest		Steam	
	2000	**2050**	**2100**	**2050**	**2100**
Sea level rise (cm)	0	24	108	29	195
Uitgiftepeil (ground level height for new buildings) behind barrier (m + NAP)	3,00	3,24	4,08	3,29	4,95
Uitgiftepeil (ground level height for new buildings) in front of barrier (m + NAP)	4,50	4,74	5,58	4,79	6,45
Average Rhine River Discharge February	2900	3100	3200	3400	4000
Average Rhine River Discharge September	1800	2000	2100	1300	900
Extremely High Rhine River Discharge	12000	13000	14000	14000	15000
Extremely Low Rhine River Discharge	630	650	670	520	420
Temperature Rise	0	+1	+2	+2	+4

▲ Figure 3.25 | Numbers used for calculations throughout the project (Data for sea level rise (Deltares, 2018). Other data (Wolters, et al., 2018)) (source: by author)

In order to make distinctions for defining strategies for both scenarios, the consideration has to be made which service is more important in both scenarios. The diagram in figure 3.26 shows the assessment of the nine ecosystem services for both scenarios. The following pages describe the argumentation behind this assessment.

Please note that this consideration is not my own interpretation of what should be most important within each scenario, but what the Deltascenarios presume society considers as most important in 2100. It is important to get into the imagination of future generations, as the people might think different within those two scenarios than I do now.

Basically, the main difference is that the Steam Scenario focuses more on increasing land values and provide a green business settlement climate for urban development, finding ways to cool down the inhabitants and give them space for recreation, so mainly focused on the people. The Rest Scenario focuses more on nature, being aware of living in the delta and food production. A general description of both scenarios and the explanation of how the assessment in figure 3.26 is determined is described on the following pages.

consideration of importance	rest	steam
+++++	increase water safety	
++++	provision of fresh water	
+++	increase natural value and biodiversity food production contribute to regional circularity	basis for urban development climate regulation relate city to river
++	relate city to river provide educational environment	provide educational environment contribute to regional circularity
+	climate regulation basis for urban development	food production increase natural value and biodiversity

▲ Figure 3.26 | Assessment of nine ecosystem services for both scenarios (source: by author)

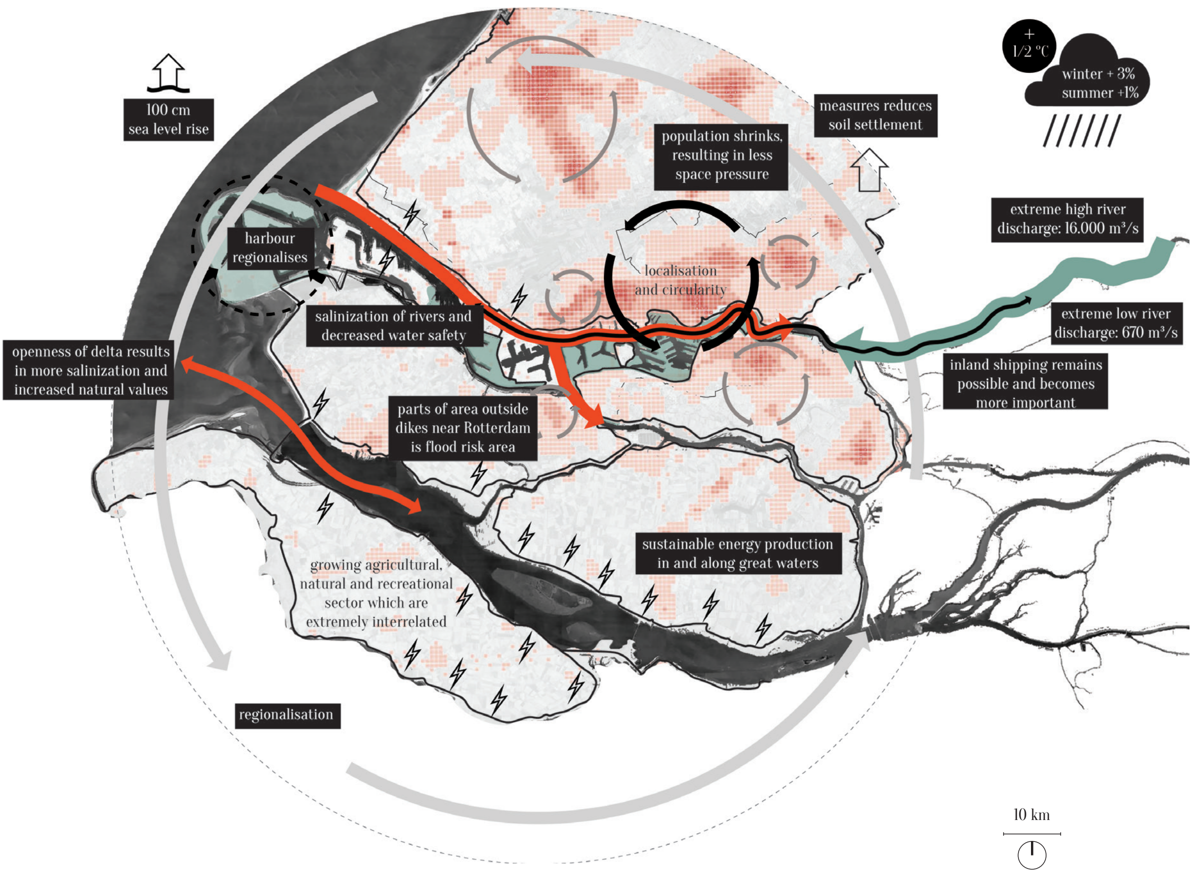
Rest Scenario

The driving actors of the Rest Scenario are represented in figure 3.27 and the corresponding change of land use in figure 3.28. The Rest Scenario considers a socio-economic decline and a moderate climate change. Sustainability and self-sufficiency are extremely important which resulted fast in a bio-based economy. The energy transition makes that the effects of climate change are relatively limited. The region does not attract many immigrants and due to the ageing inhabitants, the population in general decreased. Under the people who remained, an awareness culture has arisen. In general, the whole region is more focused on localization and regionalization. Awareness in all aspects resulted in a fast energy transition for which green energy took over the function of oil and gas. Decreasing pressure on space for urbanisation results in space for self-sufficiency in energy and food. The region even produces more food than they need, which can be exported to other countries. Living, working and recreating all happens locally around centers, so inhabitants do not have to travel far and can use the bicycle. Also the cradle to cradle movement makes that less transport is needed to distribute goods.

+++++ / Increase Water Safety
The Rest Scenario considers a sea level rise of 108 cm which, according to Deltares (2018), results in an exceeding of existing barriers and dike systems. The frequency of closing of the Maeslant barrier will increase with a factor 30, which means it has to close 3 times a year. Besides that, the Maeslantkering is designed to deal with water levels of 5.00 m + NAP, which will be exceeded once every 10 years, meaning the region will not be protected when this happens. In this case, there is especially a high vulnerability for areas outside the dikes and a high pressure on the primary dikes, increasing the risks within the dikes. With 100 cm sea level rise, major areas in the area outside the dikes are risk areas for flooding and especially now the Maeslant barrier has an increased chance of failure, the flood risks are large. The largest risks appear when the threatening events happen at the same, meaning high sea levels in combination with high river discharges, which will happen more often. Due to closing of the barriers to keep the sea water out, the river water is cumulating in the rivers behind the barrier, resulting in extreme risks for the Rotterdam region (Deltares, 2018). These arguments for the necessity to increase water safety show that even in the Rest Scenario, the emergency is high. As providing a safe future living environment is a first necessity of life, this service is assessed with +++++.

++++ / Provision of Fresh Water
The river water discharge is organized in a way that 75-90% of the Rhine discharge is directed through the Nieuwe Maas and Nieuwe Waterweg in order to push back the salt. When sea levels rise and during periods of low river discharge, the salt water intrudes through the rivers, causing problems for sweet water intake points in Bernisse and Gouda. With 100 cm sea level rise the mouth of the Hollandsche Ijssel will salify long-lasting yearly, which means the fresh water inlet point near Gouda will need an alternative. The inlet point near Bernisse needs adjusting measures to maintain in function in this scenario (Deltares, 2018). Besides that, increasing sea levels leads to increasing ground water pressure, resulting in increased salt or brackish seepage, threatening agriculture and nature. In the Rest Scenario, regional agriculture will be important for economy, which asks for an increasing demand for fresh water. Also, biodiversity and nature development is high on the political agenda, which demands for a high water quality and low salt levels in the ground and surface water. However, the demand for drinking water will decrease slightly – due to a decreasing population – the agriculture and nature demands for a high quality of ground and surface water (Deltaprogramma Rijnmond-Drechtsteden, 2011). Therefore, the demand for measures decreasing saline intrusion through surface water (rivers) and ground water is high and assessed with ++++.

+++ / Food Production / Increasing Natural Value and Biodiversity / Contribute to Regional Circularity
Food Production – The Rest Scenario focuses on a regionalization which results in the region producing food for own use. The population is very sustainable and aware of the effects of their lifestyle on the environment. Therefore it is against the global functioning food chain which demands for lots of energy and emissions due to the transportation of food. This results in a demand for new types of agriculture and local farming close to urban settlements (Deltaprogramma Rijnmond-Drechtsteden, 2011). The coastal zone of the Nieuwe Maas can provide new types of agriculture (due to varying salt and wetness levels) which increases the diversity in the inhabitants' diet. The fact that the sustainable and circular lifestyle demands for regional and local food production makes that this ecosystem service is quite important in this scenario.
Increasing Natural Value and Biodiversity – Due to the relatively slow climate change, species are able to adapt and migrate respectively to the changing climate. (Deltaprogramma Rijnmond-Drechtsteden, 2011). The low economic growth in the Rest Scenario results in the fact that the government does not

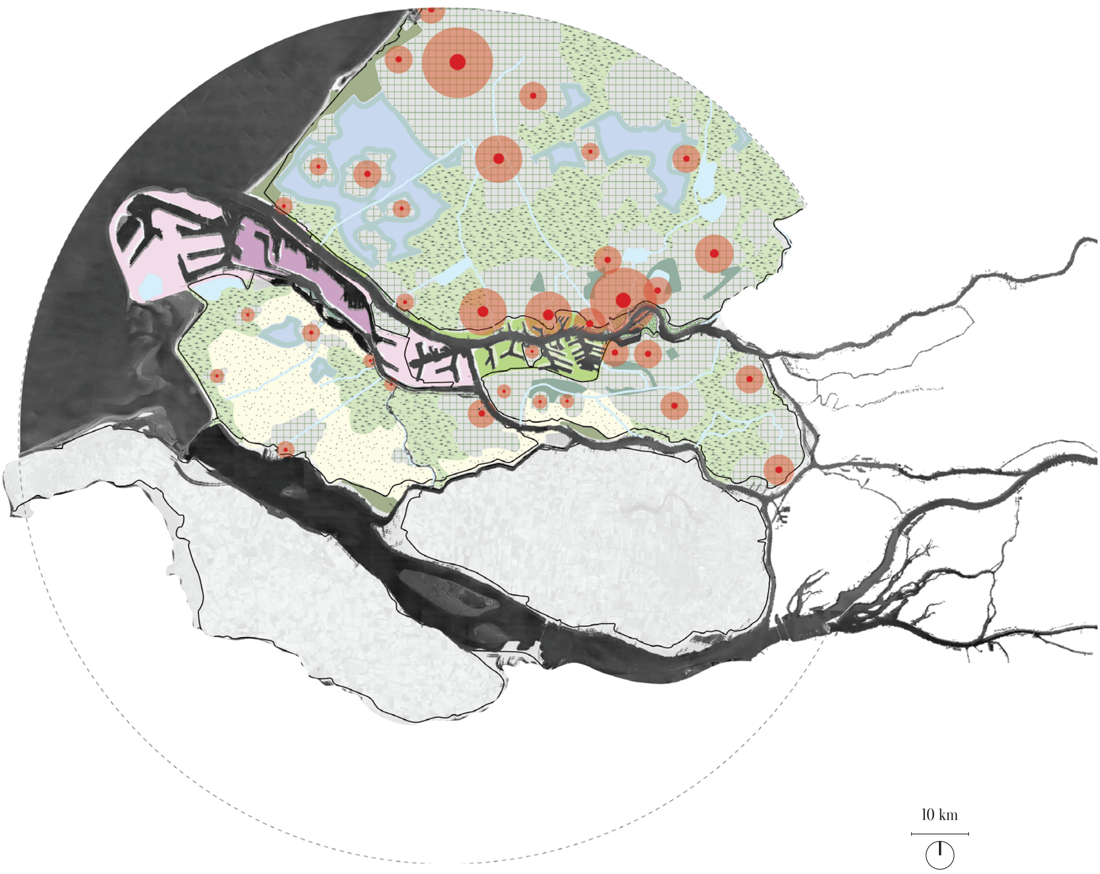


▲ Figure 3.27 | Driving actors Rest Scenario

have the capacity to invest in nature development and maintain them. The 'lack of maintenance' or 'laissez-faire' increases nature values as the type of nature follows the characteristics of the landscape, creating opportunities for native species to settle. Urban and industrial / harbor areas which become abandoned does not have the necessity to be redeveloped as there is no space pressure, resulting in nature taking over. Besides this, inhabitants realize the value of nature for other purposes and then mainly for improving agriculture in a sustainable way. Green-Blue networks are combined with the agricultural landscape to make use of its ecosystem services for circular farming, for example by making use of natural disease and pest control and pollination (Wolters et al., 2018). The inhabitants are proud of their region, where water and green is respected and part of the city. Foreigners call the region the Dutch Riviera, as the amount of water and green creates a very favorable climate. This identity attracts tourists and high educated people and therefore there is a lot of attention to keep it intact and create conditions for improvement (Deltaprogramma Rijnmond-Drechtsteden, 2011).
Contribute to Regional Circularity - In the Rest Scenario, the population experienced a true behavioral change in which they started living in a very 'aware' way. The region regionalizes and inhabitants try to develop closed cycles in terms of food, energy, waste and water. The focus is on self-sufficiency (local food and energy production to not be part of the large-scale and consuming industries) and circularity (produce as least waste as possible in terms of goods and food and try to re-use products) (Deltaprogramma Rijnmond-Drechtsteden, 2011). As tidal parks can contribute to the production of energy and food and can reuse materials like sediment, this concept can be of great use in the provision of this ecosystem service and therefore is it assessed with +++.

++ / Provide Educational Environment / Relate city, river and harbor
Provide Educational Environment - The region and its cultural identity is the reason behind the fact that the remaining inhabitants didn't leave the region. They are proud of the delta. This also becomes an important factor for the economy as the historical centers are important touristic attractions. The Delta attracts tourists from the Netherlands and central and south Europe as the climate is very favorable (Deltaprogramma Rijnmond-Drechtsteden, 2011). As this identity of the region is important for the inhabitants itself and for their economy, it's important to preserve this. However, it is not part of the first necessities of life and therefore it is assessed with ++.
Relate city, river and harbor - In the Rest Scenario, urban and rural area is intertwined, which, in combination with green-blue structures in the urban area, contributes to a very green living environment with a lot of public space. The urban area is not very crowded and warm which makes the desire for a cool, public space along the river less of importance than for example in the Steam Scenario (Deltaprogramma Rijnmond-Drechtsteden, 2011). As the river, especially in combination with future nature development along the river banks, does reflect the identity of the Delta the relation between the city and the river is still of importance, but not crucial. Therefore, this ecosystem service is assessed with ++.

+ / Climate Regulation / Basis for Urban Development
Climate Regulation - The temperature rises with 1°C by 2050 and 2°C by 2100, which could result in a heat stress effect in cities. However, due to the shrinkage of the population and the density in cities and the interrelatedness of green and blue in urban areas, the heat stress effect will be minimal. Besides that, due to the increasing 'aware' and 'sustainable' way of living and producing, the industries and mobility are clean and waste production is limited, resulting in a good air quality (Deltaprogramma Rijnmond-Drechtsteden, 2011). This together makes the ecosystem service of tidal parks to provide a cool climate and improve the air quality of a quite low importance for the Rest Scenario and therefore assessed with +.
Basis for Urban Development - From 2030 the shrinkage of the population starts slowly, and especially in Rotterdam due to the loss of economic value of the harbor, the population starts to shrink faster from 2050 (Wolters et al., 2018). The inhabitants live and densify in existing urban centers as this quality can provide them with a local way of living, focused on circularity. As the locations for possible tidal parks are often not located close by the urban centers, this ecosystem service is not of great importance for the Rest Scenario. When there are possibilities to develop tidal parks in close proximity to the urban centers, it can function as a basis for urban development and increase land values. The tidal parks provide an unique type of public space which is different from the usual green-blue structures in the cities. Besides that, this ecosystem service focuses on the provision of a settlement climate for businesses. As the economic value declines in this scenario, the demand for providing a favorable and green business climate by developing tidal parks is not of great importance. Those two factors result in the assessment of this ecosystem service with +.



legend

- Primary dike
- Sustainable greenhouse district
- Inland water ways
- Harbour remains in function in combination with sustainable energy production and nature development on empty zones
- Add sand to harbour to reduce flood risks and keep harbour in function combined with energy production and nature development on empty zones. As the Nieuwe Maas is still being dredged, the dredged material can be reused to keep costs low.
- Existing urban centers transform into self-sustaining, dense living centers where inhabitants live in small communities and are aware of their ecological footprint.
- The lack of space pressure results in shrinkage of the suburbs. They slowly transform from living environment to small scale (urban) agriculture and allotment gardens to support the center.
- Population of existing suburbs shrinks and the urban area gets less dense. Areas which become abandoned are used for allotment gardens, urban farming or nature development, creating a transition zone between city and landscape.
- People recognize the drainage of the peat polders is not future proof and a shift of mind happens where the polders can be given back to nature, in combination with energy production, agriculture and recreation
- The crop fields in the southern part are less vulnerable for flooding and soil settlement so are maintained to keep producing food for the region. Due to salinization through ground water the focus lies on salty food types.
- High flood risks and no financial capacity to transform the buildings into more adaptive ones, so try to save this area with the other measures and otherwise they will be given back to nature.
- Due to the regionalisation the connections with the hinterland (Europe) become more important. Also the river discharge allows ships to still use the Nieuwe Maas as shipping route. Together with that, in terms of water safety and salinisation, the demand for allowing sedimentation in the Nieuwe Maas is lower than in steam, which all together results in the continuing of the dredging of the River.
- The flood risks in the Eem- and Waalhaven increase and there is no financial capacity to safe those harbour basins as they are also less productive than the harbours more seawards. The focus of the harbour will shift to the more modern harbours, so those older harbours can be transformed.

▲ Figure 3.28 | Land Use Rest Scenario

Steam Scenario

The driving actors of the Steam Scenario are represented in figure 3.29 and the corresponding change of land use in figure 3.30. The scenario considers a strong economic and population growth and an extreme climate change. The population of the Netherlands grows until 24 million in 2100, which means a doubling in population in the region. The Randstad has become extremely urban, resulting in cities growing together and the region of Amsterdam, the Hague, Rotterdam and Antwerp functioning as one urban area. The harbor is highly efficient and is a major player in the world. In general, the lack of space demands for multifunctional use of space. Extreme sea level rise results in increasing salinity levels in the river and more flood risks which increases risks for agricultural losses. More and more diseases and plagues hit the crops due to increasing temperatures. In general, the lack of space results in the fact that most agricultural production moves towards less dense area, followed by a high demand for food in the region. Due to the high concentration and density in the region it is a true challenge to transport from A to B. Two important ways of transport in the dense city is transport through air and on water, which becomes heavily efficient. The smog and heat in the city makes people flee to space and coolness in the weekends, for which the riverside and coastline become extremely important.

+++++ / Increase Water Safety

The Steam Scenario considers a sea level rise of 195 cm, which of course increases the risks compared to the Rest Scenario. The Maeslant barrier will not function properly as it has to be closed almost permanently. The exceeding of the design level of 5.00 m + NAP of the Maeslant barrier will happen more than once every 10 year. The sea level rise creates flood risks in the entire area outside the dikes and due to the function loss of the Maeslant barrier these areas are seriously threatened (Deltares, 2018). Both the average river discharge as the extremely high river discharge will increase intensively, which results in more frequently events where the water is cumulated behind the barriers. As the emergence to increase water safety is already underpinned in the Rest Scenario, the importance of increasing water safety is even more important in this scenario and therefore also assessed with +++++.

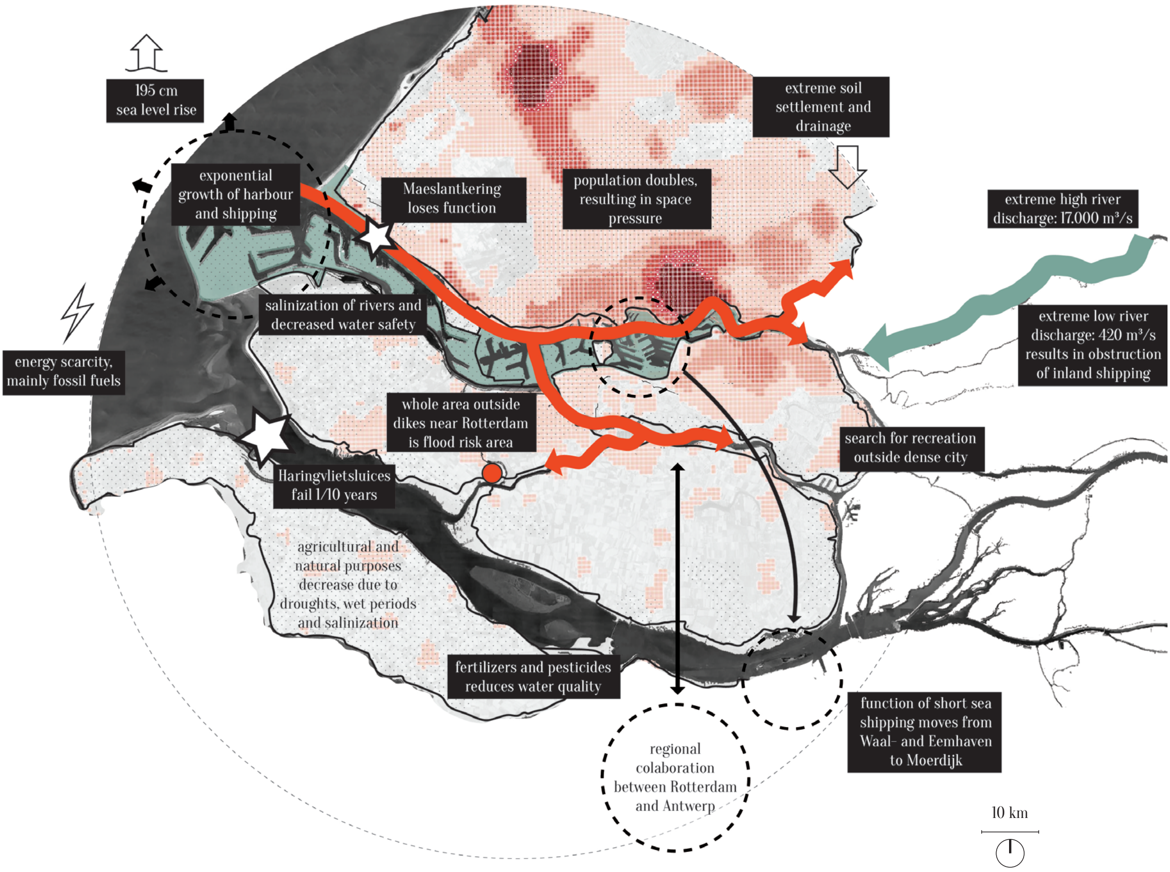
++++ / Provision of Fresh Water

With 195 cm sea level rise, an average river discharge and high tide, the river mouth near the Hollandsche Ijssel is silt, which makes it impossible to extract water from the inlet point near Gouda. During low river discharge, this river mouth is silt during the whole tidal cycle, which demands for a permanent alternative for the fresh water supply for the West of the Netherlands. The inlet point near Bernisse won't be useful frequently as the concentration of salt will be too high during high tide in combination with river discharges of 2200 m³/s. For this inlet point large scale alternative measures are needed (Deltares, 2018). The agricultural sector will be faced with a decreased areal of land as it becomes too salt or too wet in certain areas and as increasing urbanization causes a pressure on rural land. This results in more intensive types of agriculture on the areas where agriculture is still possible. The increasing temperatures makes the seasons of cultivation longer and the speed of growth of crops shorter, which makes double productions possible within one season. This all together results in a growing demand for fresh water for agriculture. Due to the increasing population and growing economy, the demand for drinking water and industrial water also increasing, putting high pressure on fresh water supply (Deltaprogramma Rijnmond-Drechtsteden, 2011). The increasing salinization through surface water and ground water in combination with the increasing demand makes this ecosystem service extremely important in the Steam Scenario and therefore assessed with ++++.

+++ / Climate Regulation / Relate city, river and harbor / Basis for Urban Development

Climate Regulation - In the Steam Scenario the temperature rises with 2°C by 2050 and 4°C by 2100. Besides that, the urbanization and densification in existing urban areas results in an extreme heat stress effect. Also, due to the slow energy transition, the growing industries, the consuming life-style and increasing soil subsidence, the CO2 emissions are high (Deltaprogramma Rijnmond-Drechtsteden, 2011). This, together with smog in the urban areas, makes that this ecosystem service is extremely important in this scenario. The fact that tidal parks can provide a cool climate for inhabitants, is able to improve the air quality and can contribute in CO2 storage makes that this ecosystem service is assessed with +++.

Basis for Urban Development - There is a huge challenge to densify existing urban areas and together provide a favorable living climate with sufficient proximity to green and public space. Analysis of the future trends for urbanization shows that the river banks will be a primary location for future urban development. The river and its banks, in combination with high quality recreational (tidal) parks can contribute to the creation of new work and living environments along the riverside, functioning as an identical public space in the

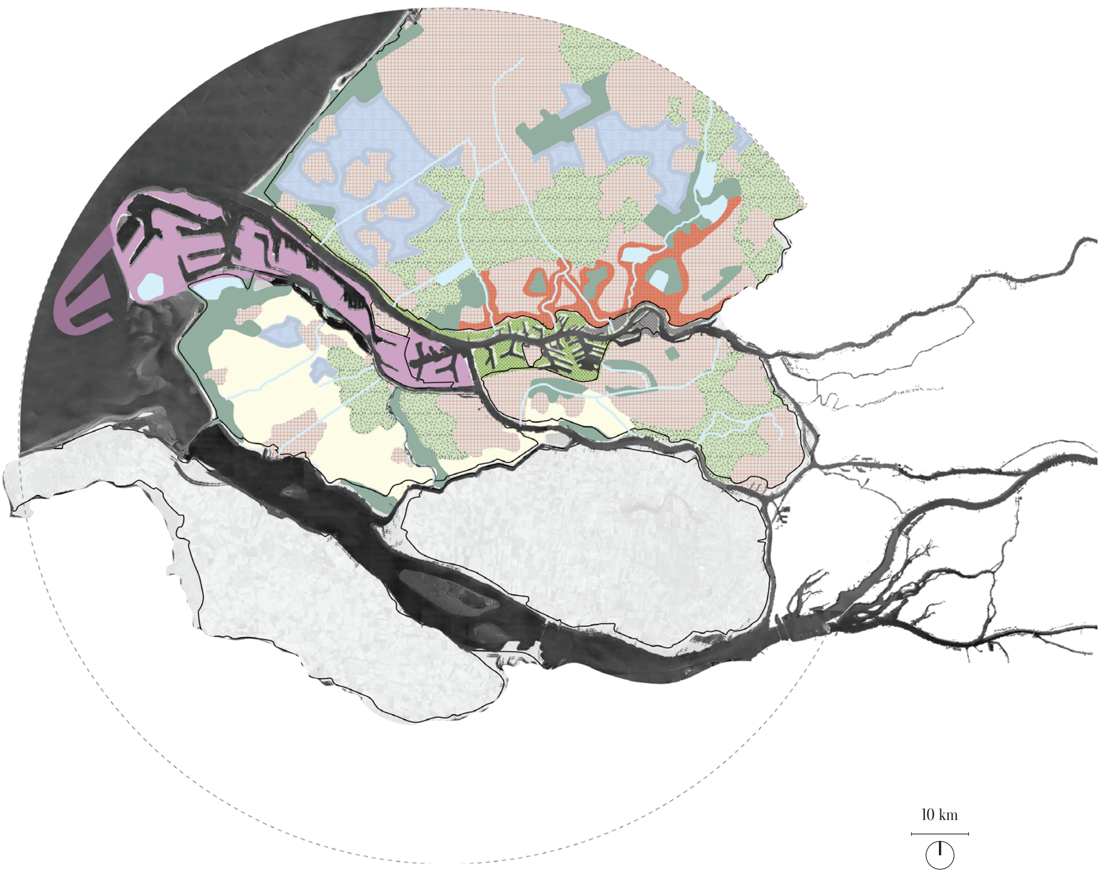


▲ Figure 3.29 | Driving actors Steam Scenario

densifying city (Gemeente Rotterdam, 2018). Besides that, due to the economic growth of the region, the development of a good quality of life by improving living environments can contribute to a favorable climate for businesses to move into the region, stimulating further economic growth. As tidal parks can contribute to this, as well as improving the quality of life in the densifying city, results in the high assessment of this service with +++.
Relate city, river and harbor – The demand for new building locations in the existing city puts high pressure on existing public space and the development of new public space has to be considered in comparison with new buildings (Deltaprogramma Rijnmond-Drechtsteden, 2011). In this scenario, the river can provide an unique public space in the city, providing space, air and light. This is important in terms of climate regulation and recreation, but also in terms of mobility as transportation on land takes a lot of time and transportation by boat can improve mobility. As the river is the largest 'open space' in the city, it creates huge opportunities for improving the accessibility and recreational facilities along the river banks and develop the river in the public space of Rotterdam.

++ / Provide Educational Environment / Contribute to Regional Circularity
Provide Educational Environment – As the sea levels are rising rapidly in the Steam Scenario (Deltares, 2018) it is important to educate people about the risks to prevent them from water nuisance and effects of flooding. Tidal parks can provide a transition zone from land to water, making the tides and storm waves more visible and therefore the people more aware of the fluctuation of the water. The global harbor is, more than the Delta, the cultural identity of the region (Deltaprogramma Rijnmond-Drechsteden, 2011). Tidal parks can strengthen the experience of this identity by improving the relation between the city, the water and the harbor. Tidal parks in old harbor areas can make use of harbor relicts, the integration of local tidal parks in existing harbor area can strengthen the connection of people to the harbor and tidal parks in general improve the accessibility to the river and create visibility and sight lines to harbor areas.
Contribute to Regional Circularity – The increasing economy creates opportunities for large scale circularity, for example by reusing heat, produced at harbor sites, in the greenhouse complex (Deltaprogramma Rijnmond-Drechtsteden, 2011). However, the way in which tidal parks could contribute to circularity is not related to the demands of the Steam Scenario, also because the scale of contribution does not align with the constantly increasing demands of society. Energy, which could be produced in tidal parks, is still mainly produced by fossil fuels and the energy transition starts slowly. New types of energy production, such as algae and seaweed are not profitable enough. Where possible, people do try to reuse sediment, as the harbor demands for more and more dredging and the development of tidal nature demands for the reuse of this material.

+ / Increasing Natural Value and Biodiversity / Food Production
Increasing Natural Value and Biodiversity – Nature will pay the bill for the economic and population growth. The high space pressure and the demand for urban development results in the transformation of nature areas into economically more valuable types of land use. In general, the nature which will be left is mainly used for recreational purposes and the value of nature and a high biodiversity is strongly undeRestimated (Deltaprogramma Rijnmond-Drechtsteden, 2011). The aim of this thesis is to provide insight in the value of tidal nature for future societies. In this scenario this is quite contradictory, as this value seems hardly appreciated by society, which is why it is assessed with +. However, the fact that nature is able to provide more values than increasing biodiversity, such as increasing surrounding land values, creating opportunities for densification, climate regulation, water safety, etc., makes that also in this scenario nature in the end will be developed.
Food Production – In the region, agriculture will be faced with extreme salinization, extreme wet periods due to peak precipitation and periods of drought. The higher temperatures and humidity result in more chances for diseases and plagues. This, together with extreme soil subsidence of maximum 144 cm and the extreme space pressure due to urbanization makes that agriculture on land is overall moved to less urbanized and higher located regions in the Netherlands. As the region's population and amount of mouths to feed is growing extremely, the demand for food is high. This is met due to intensification of the horticulture in green house complexes and increasing import through the global harbor. There are some small scale initiatives for innovative types of agriculture, such as the production of salt resistant crops, but as this would never meet the increasing demand this is not profitable. Because of these regions, food production in tidal parks is not valuable enough within this scenario and is therefore assessed with +.



legend

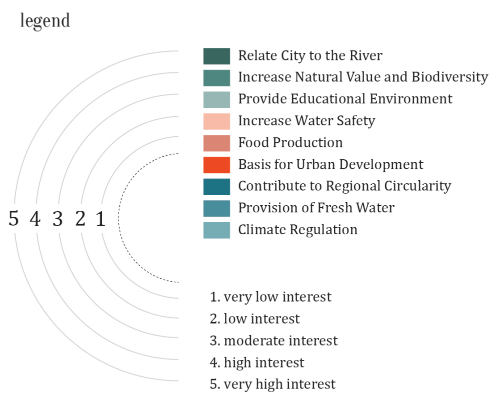
- Primary dike
- Intensive greenhouse district
- Inland water ways
- Harbour becomes of great global importance and measures are taken to protect the functioning harbour against flooding.
- The harbour is extending seawards to make space for the new generation of container ships.
- Existing cities densify in between the city's borders to provide a living environment for all new inhabitants.
- Main densification of existing cities happens along the existing fresh water and green spaces. However, the city still becomes too warm and crowded and people seek to escape the city.
- The soil settlement in comparison with the rising sea levels is too extreme and cattle-breeding is causing too many (climate) risks, so people decide to turn the area in another economically profitable function: urban expansion. There will be a combination of nature and housing, mainly alongside the fresh water ways, because it's most favourable in the extreme climate.
- Existing crop fields become more and more intensive. There has been a transformation to more salty and drought resilient crops to keep the region profitable in terms of agriculture.
- Existing recreational green is maintained to provide green recreational space for the crowded and dense city
- The flood risks in the areas outside the dikes are high, but there is financial capacity to transform the buildings and quays into adaptive living environments which can deal with the tides and still have the cultural identity they build up.
- In extreme seasons the river has a low river discharge, together with the increasing salinity and water safety problems it is necessary to stop dredging the Nieuwe Maas and naturally undeepen the river in order to protect the city of Rotterdam and the region.
- The Eem- and Waalhaven become too small and old to function in the growing economy and corresponding size of ships. Therefore, transformation of those harbour basins becomes possible and creates opportunities for the further urbanization and densification of the region.

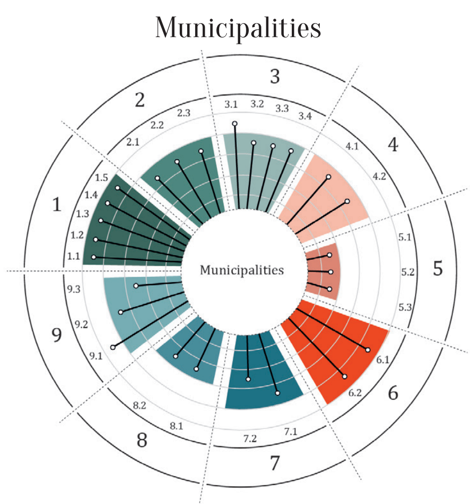
▲ Figure 3.30 | Land Use Steam Scenario

3.05. Partnership and Interests

Basically, the objectives of the project and the partnership are set until 2020 (de Urbanisten, 2016). The expiration of the agreement creates opportunities for the partnership to redefine the goals and reorganize the partnership. The success of implemented parks, the strenghtening of existing goals and new insights in approaching problems, such as climate change, can work as an objective for new stakeholders to join. However, this expiration can also result in the loss of partners if they feel the program is not benefitting them sufficiently. Therefore, this is the time to reflect on existing goals, sharpen them and broaden the program in order to extend the partnership. Thanks to the internship at the Municipality, the network with the different partners was good. This gave the opportunity to organise workshops, interviews and conversations. This section describes for each partner the general ambition, the interest in the project, the possible conflicts or difficulties and the importance of each ecosystem service. The assessment of the main ecosystem services (represented with the colours) is gathered through a workshop which I organised and related discussion and interviews with the partners. The assessment of the subservices (represented with the black bars) is not one on one discussed with the stakeholders, but is partly coming from the interviews and partly a logical consideration of their interest. The assessment of the subservices is in the 'result chapter' related to the actual provided subservices per phase.

This assessment of ecosystem services is a short term assessment, showing which services are important for the partners now. For the partners which have long term goals (for example the Delta Program and Climate Organizations) the desired ecosystem services will not change through time as their goals are already focusing on the long term. For the stakeholders which have short term goals (for example Municipalities), the goals and desired ecosystem services will change. This change will be defined by the different scenarios. For example, in the Rest Scenario food production becomes more important due to localisation of the food system and awareness of the ecological footprint. In the Steam Scenario, the focus of Municipalties might more lean towards the function as basis for Urban Development as cities are densifying and the demand for green public space is high.



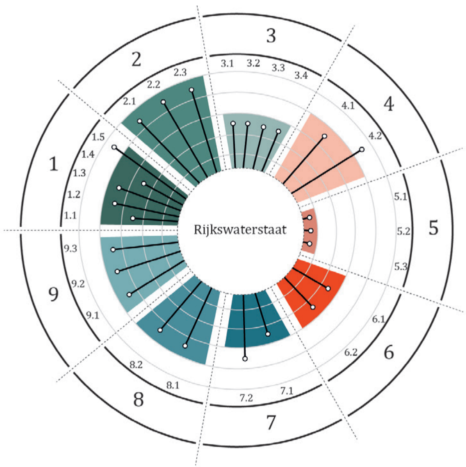


Ambition
The general ambition of the involved municipalities is to provide a good quality of life for inhabitants. In this thesis, the Municipality of Rotterdam is taken as a case-study.

Interest in the River as a Tidal Park
The ambition is to provide a new, public, green space in the center of the (densifying) city. Tidal parks can contribute in creating a more attractive, lively and natural river for inhabitants.

Possible Conflicts or Difficulties
The development of tidal parks along the quays can result in a 'loss' of land. It is important that the parks are accessible and improve the quality of life and therefore provide opportunities for further urban development.

Rijkswaterstaat

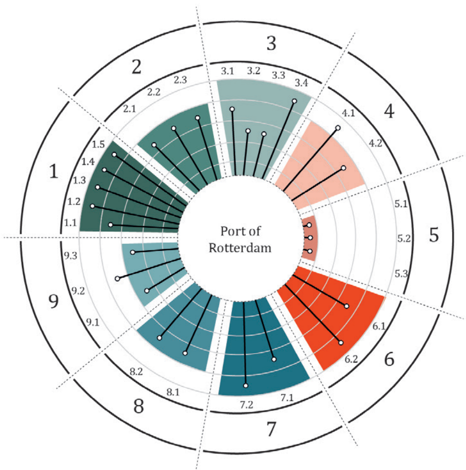


Ambition
The general ambition of Rijkswaterstaat is to protect the country from flooding, provide a green environment with sufficient clean water where people can transport fast from A to B. The guideline behind this is the KRW (Kaderrichtlijn Water) which focuses on the maintenance and development of an ecological water quality creating habitats for plants and animals.

Interest in the River as a Tidal Park
Tidal nature creates a transition zone between land and water, creating opportunities for animals and plants to find a habitat and migrate between land and water. It also improves the water quality and functions as a fore land for the dikes, increasing water safety.

Possible Conflicts or Difficulties
Rijkswaterstaat has the objective to maintain the water ways in function for shipping by dredging the river bed. This measure has effects on the development of tidal parks as it changes currents and water speeds. With the development of tidal parks the shipping routes and water depth has to be considered.

Port of Rotterdam

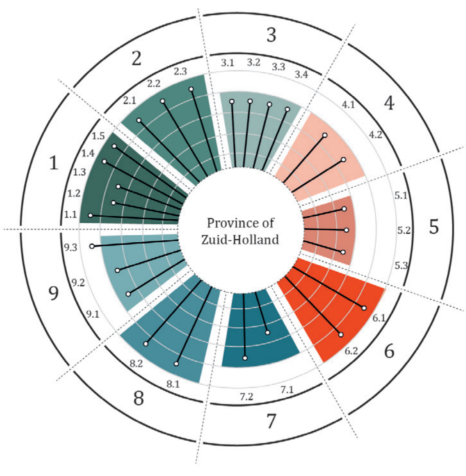


Ambition
The Port of Rotterdam aims for becoming the most efficiënt, safe and sustainable harbor in the world, to strenghten the international competitiveness and to improve the quality of life in and around the harbor

Interest in the River as a Tidal Park
The relation between people and water, which the tidal parks provide, result in increasing visibility and awareness of the functioning of the harbor, improving the harbor identity and acceptation within the Rotterdam region. It also improves the quality of life and business climate, resulting in the attracting of companies to the Rotterdam harbor and therefore stimulating the economy. Also, sediment which is dredged from the harbors can be reused locally in the tidal parks, resulting in less costs in the transportation and processing. Besides that, with the project they also focus on a more sustainable reputation to compensate for taking land from the sea, like what happened in the Maasvlakte.

Possible Conflicts or Difficulties
The transformation of quays into tidal parks result in the fact that ships cannot moor. Besides that, the water ways have to be dredged in order to not conflict with the shipping and accessibility of the harbor, which effect the tidal parks as the currents and water speeds change. As the Rotterdam region's economical wellfare depends on the harbor, it is important to not disturb the harbors functioning. The transformation of quays into tidal parks have to go hand in hand with harbor activities and strenghten each other.

Province of Zuid-Holland

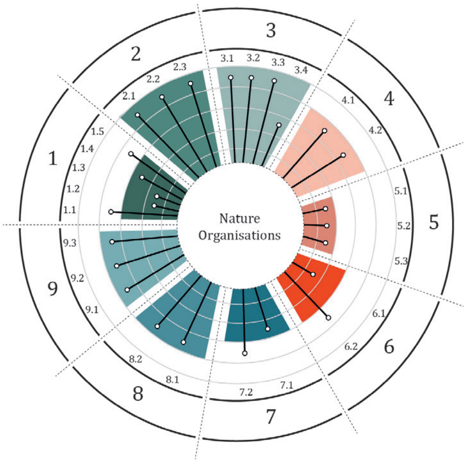


Ambition
The ambition of the Province of Zuid-Holland is to develop a healthy living environment and an attractive settlement climate for both businesses and residents.

Interest in the River as a Tidal Park
The Province aims for developing more green which starts within the city and stretches out to large scale nature areas. The River as a Tidal Park is able to provide a continuous green blue structure which connects the city to the landscape. This supports a healthy lifestyle, which is important for the Province.

Possible Conflicts or Difficulties
The Province focuses on connecting people with Blue-Green Networks in which nature and recreation are central. This could work contradictory as a high recreational pressure on nature areas might disturb flora and fauna.

Nature Organisations

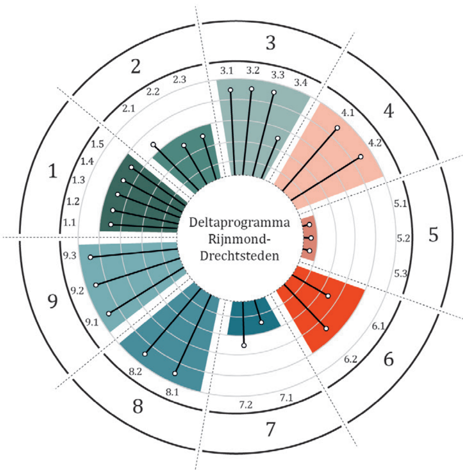


Ambition
Strive towards a world where man lives in harmony with nature, creating a robust, coherent network of nature with connections to urban areas. Focus on the protection and regeneration of biodiversity and habitats, tackle the main threats for vulnerable nature areas (such as climate change, drought, defoRestation) and create awareness of the importance of nature among society.

Interest in the River as a Tidal Park
As the river now hardly contains nature types, the natural value and biodiversity is low. Tidal parks can create a transition zone between land and water, providing habitats for animals and plants and opportunities for migration between land and water. It also increases the water quality, resulting in more life in the water.

Possible Conflicts or Difficulties
In general, the development of tidal parks instead of hard quays is always beneficial for nature organizations, as it improves the natural value and biodiversity. However, due to the high demand for recreational opportunities in the growing city, the park could become too cultural where recreationalists disturb the habitats. The project should focus on a balance between the amount of nature and amount of culture.

Deltaprogramma Rijnmond-Drechtsteden

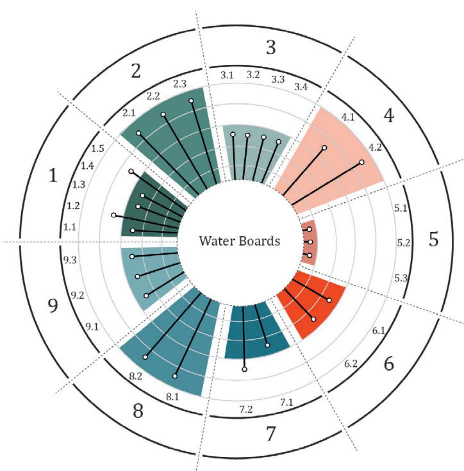


Ambition
Create a robust and adaptive delta which is able to ensure water safety, provide fresh water and will be able to deal with the extremes resulting from the changing climate.

Interest in the River as a Tidal Park
The Dutch have always fought against the water with hard measures. The project of the river as a tidal park provides a large scale test case whether nature and soft measures can contribute to increasing water safety and reduce saline intrusion. It contributes for example by creating a fore land for the dikes, reduce currents and water speed and the gradual parks push back the saline intrusion. This would create opportunities to become more adaptive and resilient as nature transforms gradually with the changing climate.

Possible Conflicts or Difficulties
It is not proven yet that nature can provide water safety and reduce saline intrusion on a large scale, which could mean that in the end hard measures have to protect the Netherlands anyhow. However, the development of nature is a 'no regret' measure, which provides values on the short term (such as natural and recreational values) and might provide values in terms of climate adaptation on the long term.

Water Boards

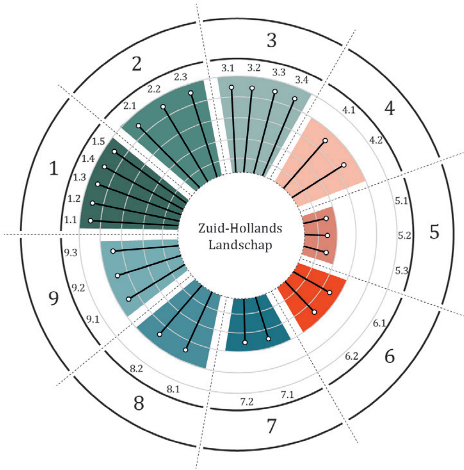


Ambition
Provide the concerned water management area with sufficient fresh water and increase water safety by managing the water system (dikes, quays, river beds, etc).

Interest in the River as a Tidal Park
Tidal nature creates a transition zone between land and water, improving the water quality as the plants are able to purify the water. The gradual banks also reduce saline intrusion, which improves the water quality. It can also function as a fore land for the dikes, increasing water safety.

Possible Conflicts or Difficulties
The development of tidal parks, in relation to objectives of other stakeholders, often goes together with recreation. This might result in disturbance of wildlife which are therefore less able to increase the water quality. Recreational activities in more 'cultural' types of tidal parks can also result in pollution of the water and river banks. The consideration between cultural and natural parts of the park have to be made carefully.

Zuid-Hollands Landschap

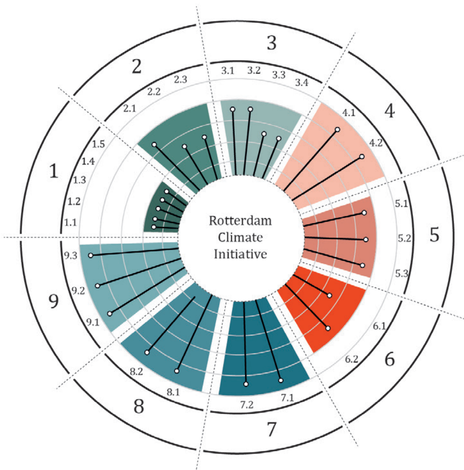


Ambition
Increase the amount of protected nature and cultural heritage areas. The nature maintenance and development increases biodiversity and natural habitats. It also focuses on the experience of nature, as accessibility and recreation is an important objective. By connecting people and nature awareness can be created resulting in more cherishing of nature.

Interest in the River as a Tidal Park
Tidal parks can increase natural values and biodiversity in an area which now hardly contains nature types, the river. It is an unique type of nature, as the salinity levels in the water and the tidal influence result in varied types of nature, different from nature within the dikes. Besides that, the cultural identity of the region can be strenghtened, focusing on experiencing of the harbor and delta identity.

Possible Conflicts or Difficulties
This organisation focuses on improving natural and cultural values at the same time, which could work contradictory. The consideration have to be made how to improve them both without disturbing the natural habitats with the amount of recreation.

Rotterdam Climate Initiative

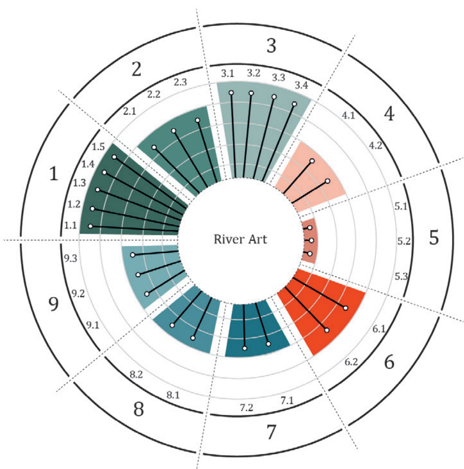


Ambition
Prepare the region for the risks it is facing due to climate change by focusing on climate mitigation and adaptation in terms of flood risks, heat stress, $CO2$ emissions, circularity, energy production, etc.

Interest in the River as a Tidal Park
The project of the river as a tidal park can contribute to several objectives related to climate mitigation and adaptation. Mitigation can focus on circularity as this reduces the amount of CO2 emissions and pollution in the environment, for example by local food production which shortens the linear food chain. Adaptation can focus on reducing flood risks, provide a cool climate for inhabitants and reduce saline intrusion.

Possible Conflicts or Difficulties
The main debate about this initiative is to what extend such a project can really contribute to climate mitigation. The objective of the initiative is to decrease CO2 emissions with 20 megatons in 2025, while China already produces 20 megatons of CO2 in one day. The challenge is to not try to focus on solving a global problem like climate change, but use the opportunity that tidal parks are able to store CO2 as an optional 'extra'.

River Art



Ambition
Increase the connection between industry, cultural heritage, water, nature and urbanization by the development of 25 art pieces along the river.

Interest in the River as a Tidal Park
As tidal parks connect people and water this can increase visibility and accessibility of art projects in or close by the tidal parks. The chain of art projects can create an art route which connects the tidal parks along the river bank as one and therefore strenghten the accessibility.

Possible Conflicts or Difficulties
For the experience of the river art the accessibility of the tidal parks is important. When the parks become too natural with a lack of recreational opportunities it creates some kind of boundary between the land and the art project. The tidal parks therefore should focus on the accessibility and visibility of the projects.

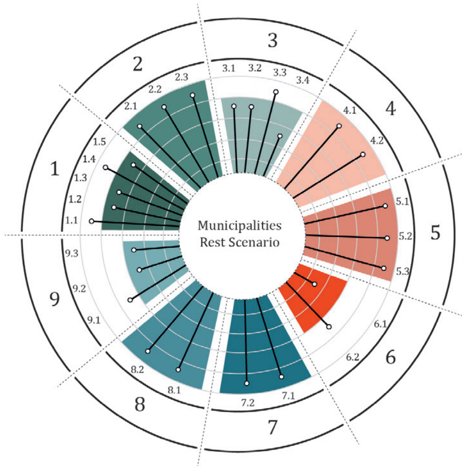
Change of Interest over time

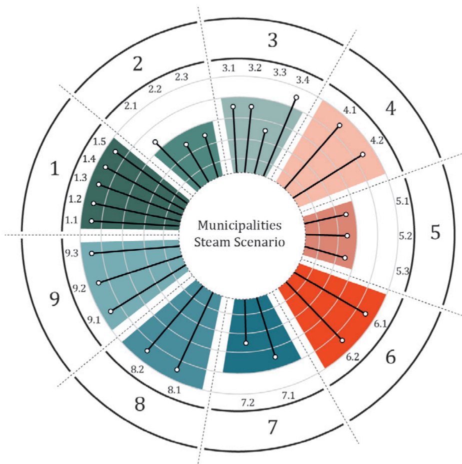
The interest of stakeholders as just described is determined according to their current interests. However, through time, we can distinguish three types of stakeholders:

1) The stakeholders with objectives which are not expected to change over time as they tackle long term problems or focuse on one specific objective. These stakeholders are Rijkswaterstaat, Nature Organizations, Zuid-Hollands Landschap, the Deltaprogram, Waterboards, Climate Initiative and River Art.
2) The municipalities, which are stakeholders with a broad range of objectives mainly considering the short term. They will adjust their objectives and desired ecosystem services through time in relation to the importance of the services in the scenarios.
3) The Port of Rotterdam, which aims for obtaining most benefits of tidal parks on the short term with having least conflicts with the current harbor activities. When the harbor transforms to other land-use types, the focus would change to services which aim for connecting and reminding people of the former harbor activities. In general, the benefits which the port can obtain will decrease over time in harbor basins which are transformed to other land-use types, but relatively the services provide high values for the Port as it is an area which is not owned by the Port anymore.

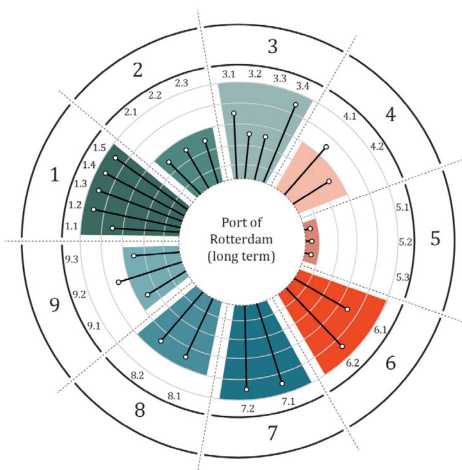
The objectives and desired ecosystem services of the Municipalities and Port of Rotterdam will change over time. This is made visible in figure 3.31. For the Port of Rotterdam the long-term assessment takes into account the harbor basins which are in transformation and losing harbor activities. The desired ecosystem services of the other stakeholders are expected not to change and will therefore remain similar in both scenarios.

Municipalities





Port of Rotterdam



▲ Figure 3.31 | Change of objectives over time (source: by author)

4

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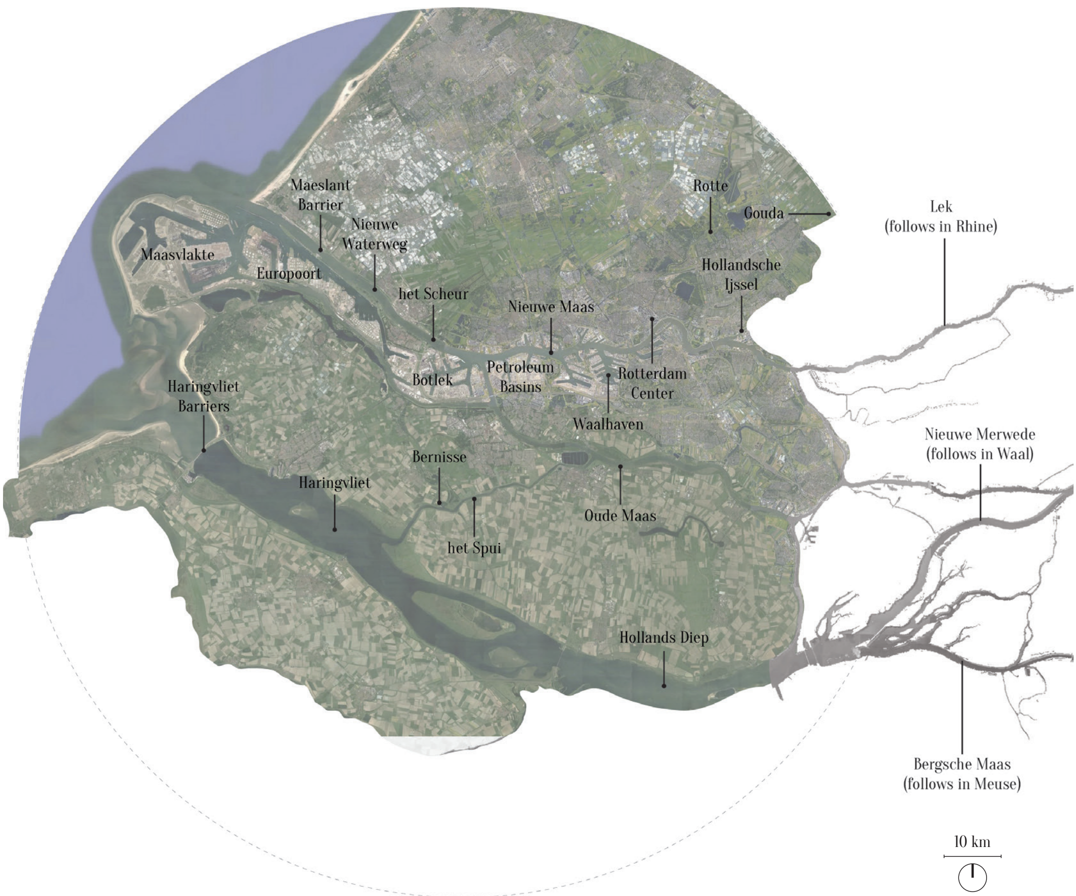
long-term strategies for maximising ecosystem services

4.01. Regional Opportunities

In order to derive to regional strategies, this section introduces the region and its opportunities for future development. The map in figure 4.1 describes the topographical terms which are used throughout this chapter.



▲ Figure 4.1 | Designation of topographical terms within the Rotterdam Region (source: by author)

Dynamics of the Delta

Originally the entire region was a delta and was subjected to changes in sea water levels, river discharge, tides and salinity. Nowadays, due to dike systems, only the area outside the dikes is subjected to these dynamics (figure 4.2). The area within the dikes contains of a fresh water system which flows towards the brackish river. With these inland rivers the polders are drained.

legend

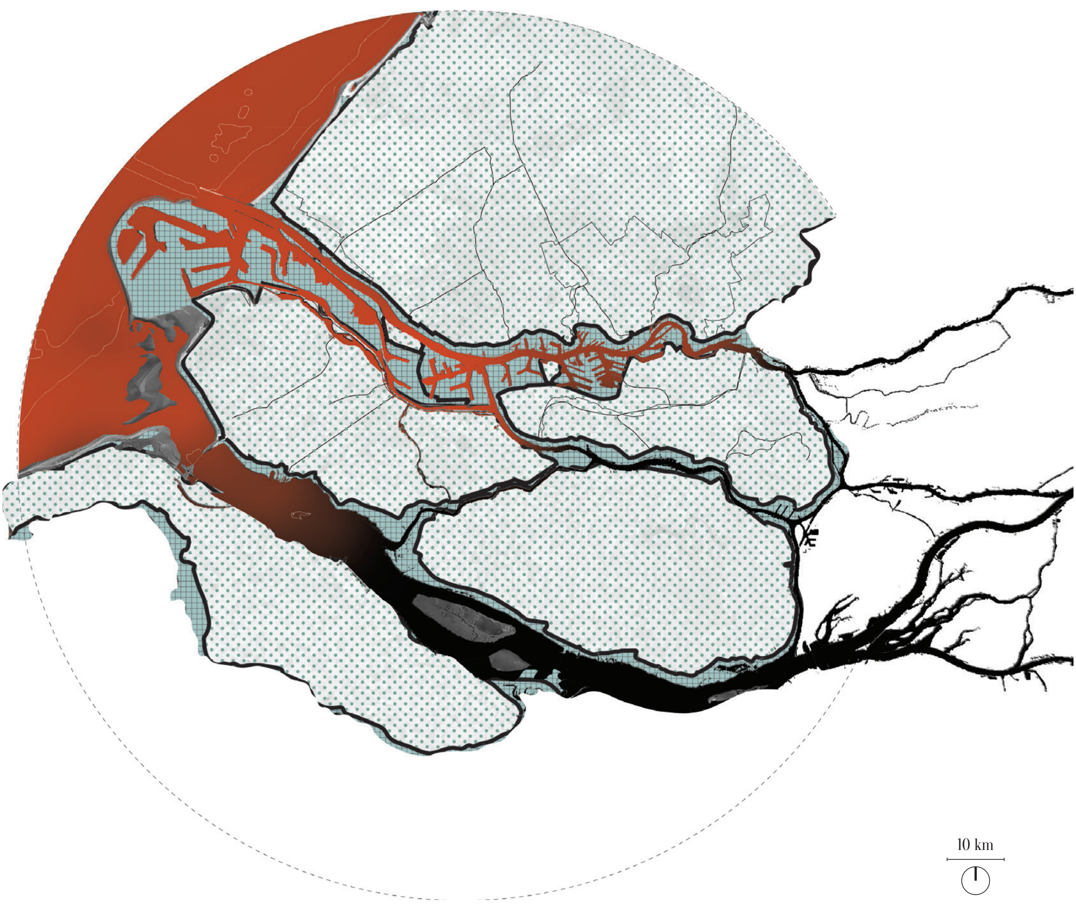
salt water

fresh water

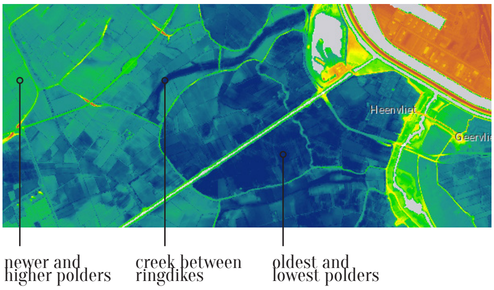
exposed to dynamics of the delta

not exposed to dynamics of the delta

primary dikes



▲ Figure 4.2 | Dynamics of the Delta (source: by author)



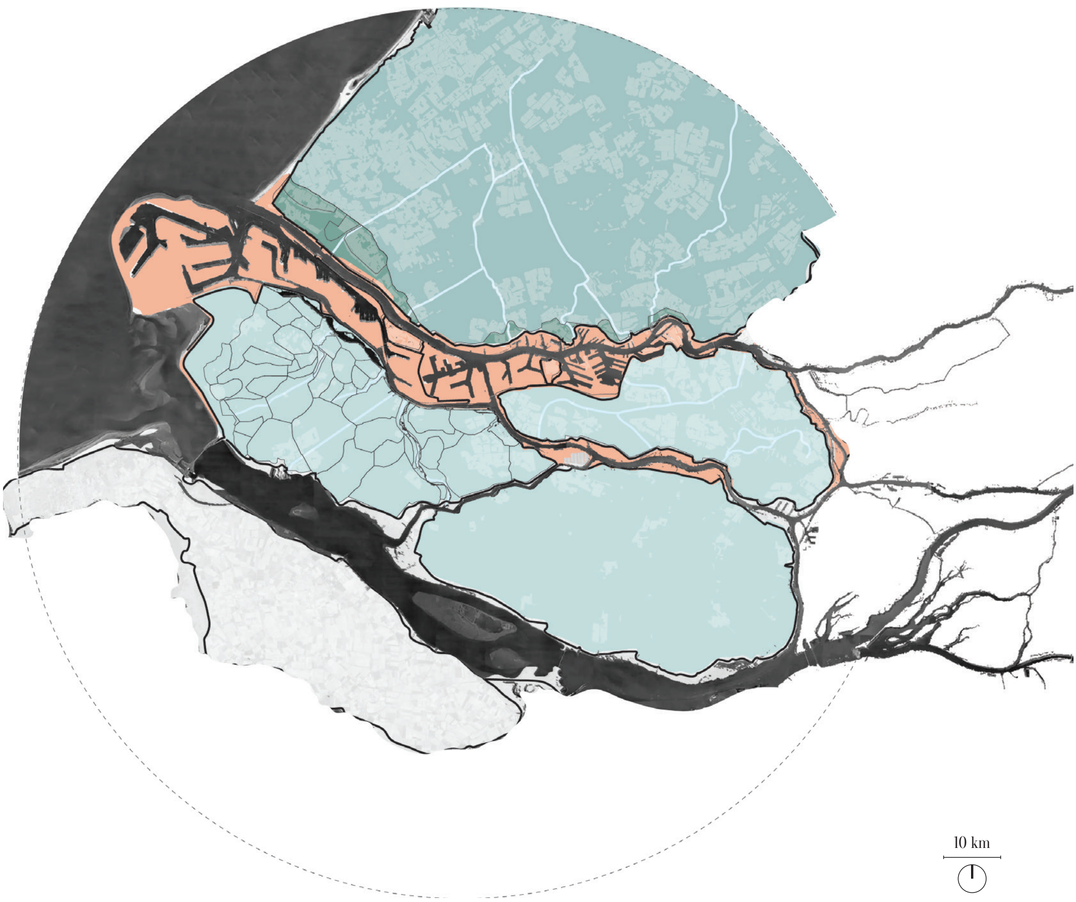
▲ Figure 4.4 | Height difference between low located old polders (blue) and high located newer polders (green) (source: by author)

legend

- clay soils
- peat soils
- sandy soils
- newer polders between historical dikes and primary dikes
- inland, fresh water ways
- historical ring dikes
- water

Landscape Characteristics

The land in this region consists of three main soil types, shown in the map in figure 4.3. These are: 1) clay soils, which can be found south of the river, 2) peat soils, which can be found north of the river and 3) sandy soils in the area outside the dikes, which are constructed by humankind in order to make the area less vulnerable for flooding and make it functional for harbor activities. Other characteristics which are visible in the landscape are the rivers in the peat landscape which are located perpendicular to the river. In this landscape you can also find some old dikes parallel to the primary dikes, which used to be the original primary dikes. In the clay landscape you can find some old creeks in between an accumulation of historical ringdikes. The ringdikes show the constant process of poldering the historical delta. Due to constant soil subsidence through time, now the oldest polders are located the lowest in the landscape. These historical structures are clearly visible in the heightmap in figure 4.4.



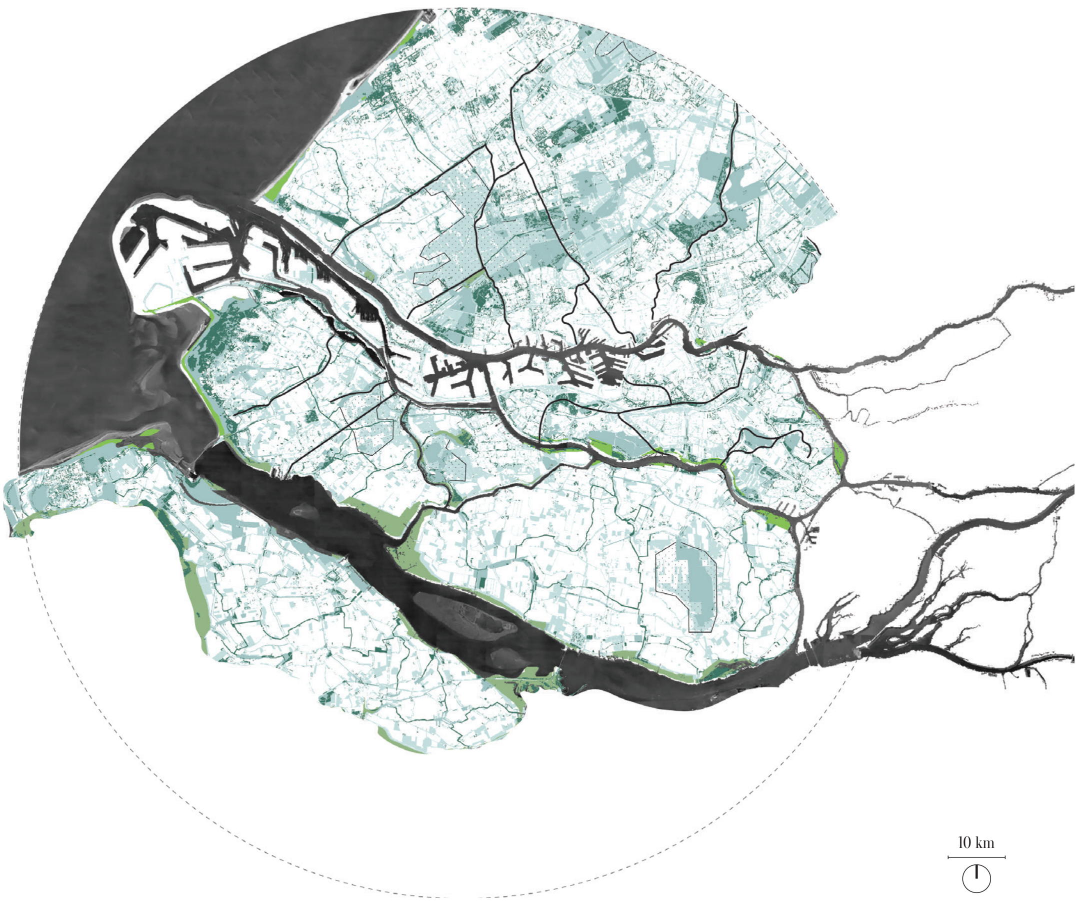
▲ Figure 4.3 | Landscape identity and characteristics (source: by author)

Green-Blue Network

The green-blue network is important to provide ecosystem services for a wider context. The structures are attractive for people, but also provide migration routes for animals. The connection between the inland rivers and tidal river can provide possibilities to distribute the water between areas inside and outside the dikes and can create connections between fresh and tidal nature. The green-blue network is represented in figure 4.5.

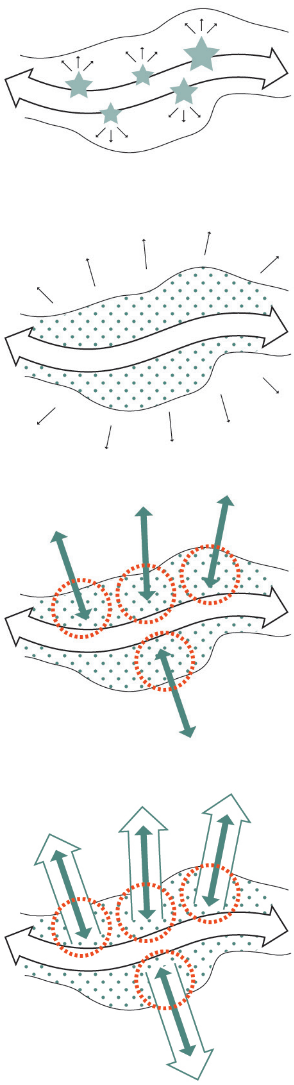
legend

- grassland
- woodland bird zones
- ecological corridors
- existing nature and recreational zones
- wet nature
- tidal nature
- forest
- water



▲ Figure 4.5 | Green-Blue Network (source: by author)

For the regional strategy different elements are considered to provide ecosystem services for the local environment, but also to provide the services for the wider context. Figure 4.6 shows those different elements. These four elements are not a linear process through time, but it happens integral and at the same time.



Local tidal parks providing ecosystem services for direct surroundings.

Connecting tidal parks to provide ecosystem services for a wider environment.

Use inland connections (green, blue and recreational) to make the parks and ecosystem services accessible to a broader audience (people, animals, plants).

Use inland connections (green, blue and recreational) to provide ecosystem services land inwards and make the whole region able to profit.

▲ Figure 4.6 | Tidal nature providing highest values (source: by author)

Opportunities for Giving Land Back to Nature

The regional strategy uses the opportunities for giving land back to nature. The map in figure 4.7 shows which land has the highest opportunities to be the first to be given back to nature. The darker the area, the higher the opportunity.

Inside the dikes these zones are defined by using the layer approach (figure 4.8) which combines maps with ground water tables, water depth when a primary dike collapses and landscape heights. When the ground water table is high, the area is already more wet from itself, which makes it more easy and logic to develop wet nature here. Areas with the largest water depth when a primary dike collapses show the areas with the highest risks for flooding. They have therefore a high opportunity to give land back to nature. Water in the landscape will flow most easily to areas which are low located, so these areas also form an opportunity to give back to nature.

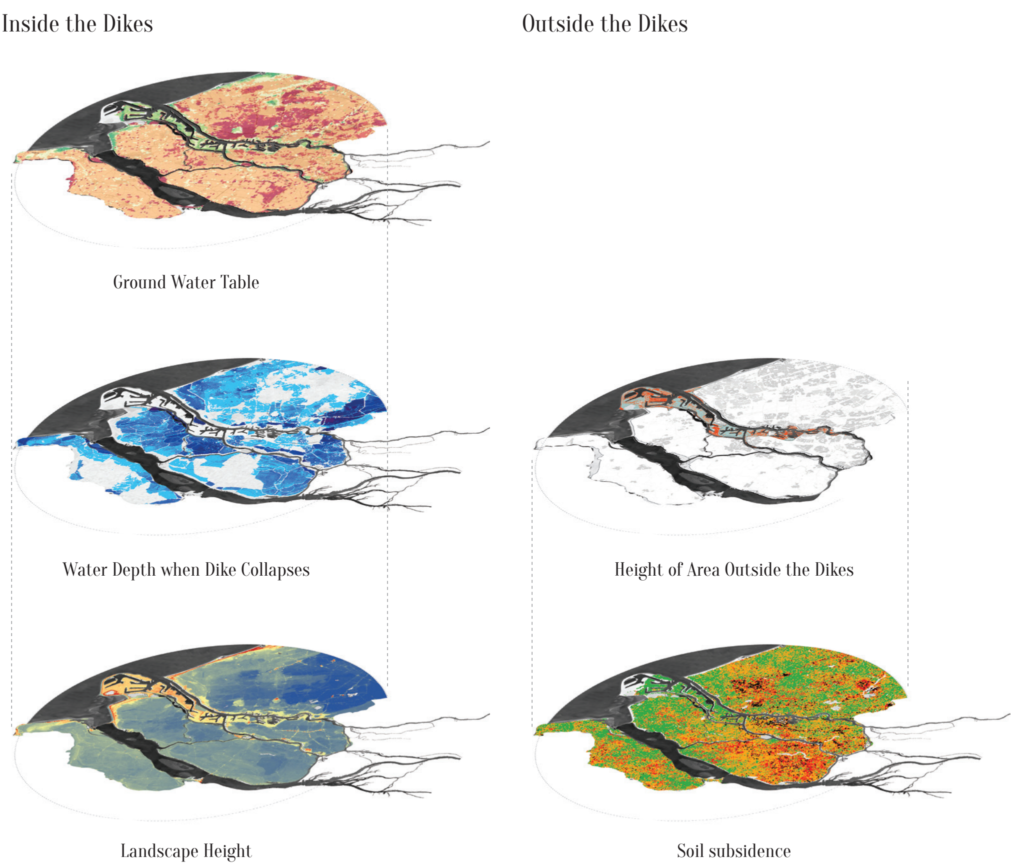
In the area outside the dikes, landscape height and soil subsidence are considered to define opportunities for giving land back to nature. Areas which are located lowest are directly vulnerable for flooding as they are not protected by dikes. In areas where there is also a high soil subsidence this process will be enforcened and therefore the flood risks increase. This goes together with opportunities for giving it back to nature the first.

legend

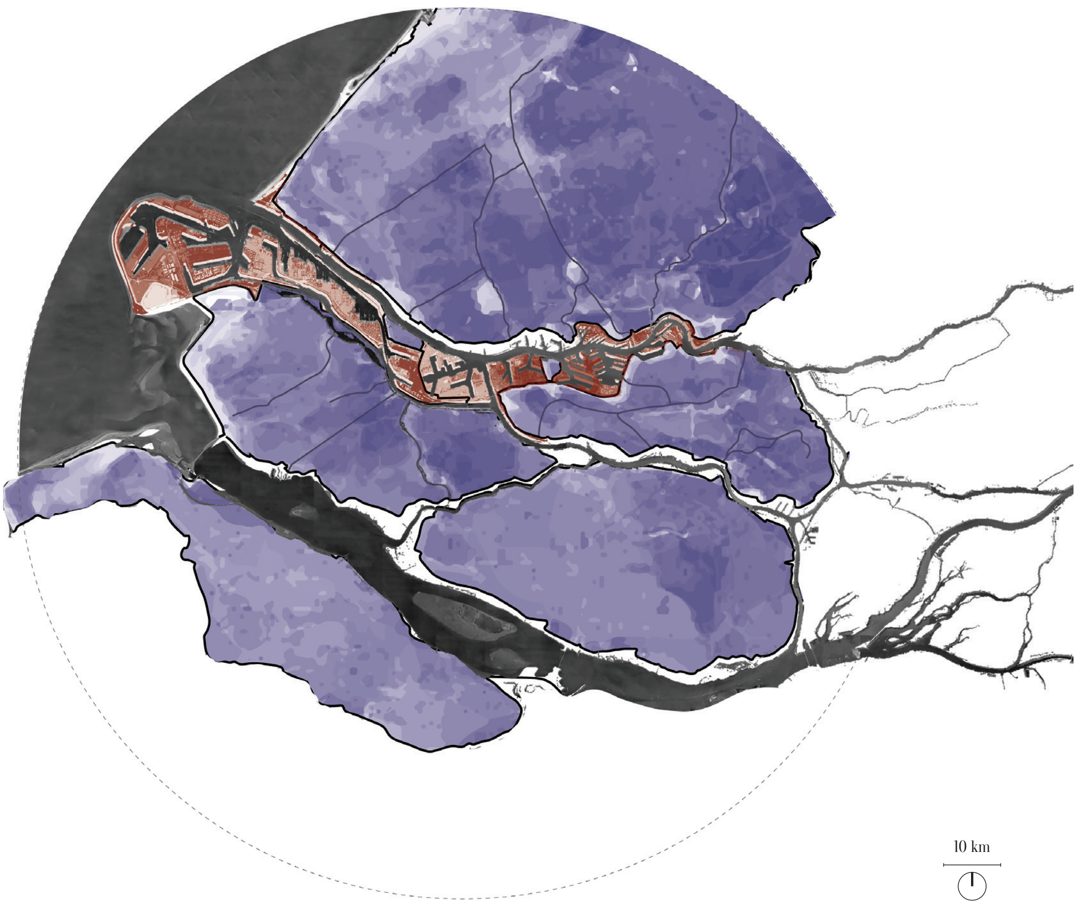
area outside the dikes
high opportunities
moderate opportunities

area within the dikes
high opportunities
moderate opportunities

primary dikes
water



▲ Figure 4.8 | Layer approach to define opportunities for giving land back to nature (source: by author)



▲ Figure 4.7 | Opportunities for giving land back to nature (source: by author)

Assumptions for the Strategy

Followed from the previously described analysis, a few assumptions are made. The ones which are considered in each strategy and are important to frame the project are the following (figure 4.9):

1. The current water management system with the open / closable river mouth will be maintained. This starting point is taken as the other options for providing water safety for the future are hard measures and does not stimulate my view on the region.

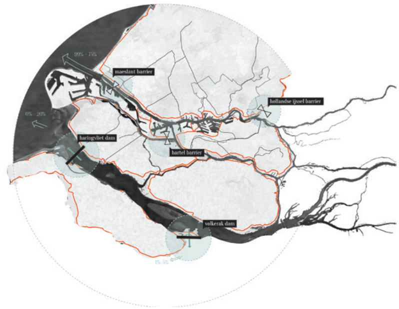
2. The main green-blue network remains similar and these connections can be used for the strategy until 2100.

3. The opportunities for giving land back to nature, following from the height of land, ground water table and water depth during a flood, remains similar. It is possible that the characteristics of land change, but the assumption is made that if this happens the balance remains the same, so that the same zones have the largest opportunity.

4. The primary dikes remain in the same location. The reason for changing the location of the dike would come from educational or nature perspectives and does not outweigh the risks it would bring for water safety and salinity intrusion. Therefore, in the Steam Scenario people do not see the benefit a change of location would bring as they do not consider nature and awareness of living in the delta important. In the Rest Scenario, the value of nature, biodiversity and awareness of living in the delta is considered important. However, in this scenario there is no financial capacity to restructure the primary dikes. Therefore in both scenarios it would result in a similar location for the primary dikes.

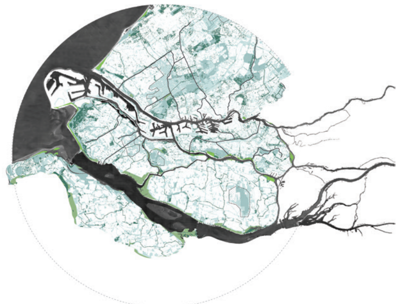
5. The Botlek East, Eem- and Waalhaven lose their harbor functions after 2050 in both scenarios. In the Steam Scenario, the ships become too large for the Nieuwe Maas as this river is quite undeep. Deepening this river is not an option as this would increase the already extreme water safety and salinity problems. Also, due to the global position of the harbor in this scenario, the harbor moves more seawards to make room for the increasing amount of ships. The small and old harbors (Botlek East, Eem- and Waalhaven) become outdated and too small. Due to the huge water safety problems in this area the costs to improve these harbors and make them adaptive for the sea level rise does not make the maintenance of these harbors profitable. In the Rest Scenario the harbor regionalises and a shrinkage is the result. In this scenario, the 100 cm sea level rise already results in flooding of the Botlek East, Eem- and Waalhaven. Due to a lack of financial capacity the harbors will not be improved and the harbor activities continue in the less vulnerable harbor areas. Therefore, the assumption is made that in both scenarios these harbor areas can be transformed.

6. The grassland and meadows lose their current agricultural function due to extreme CO_2 emissions and soil subsidence. In the Steam Scenario the risks which result from the increasing difference between land and water become that large that more innovative and intensive agriculture on the less vulnerable ground will take over. In the Rest Scenario, the risks due to increasing land and water differences are less extreme, but there is also less space pressure. Therefore, the land of the grassland and meadows is not necessarily needed for intensive agriculture and can be transformed to a more sustainable landuse type.



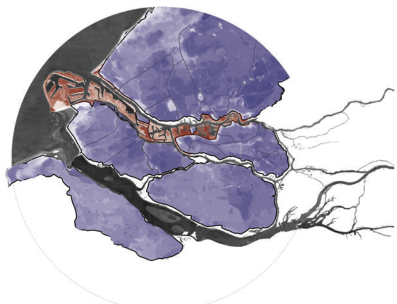
Assumptions

- The current water system with the open / closable rivermouth will be maintained -



Assumptions

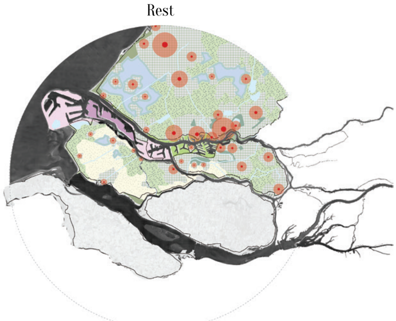
- Main Green-Blue Network remains similar -



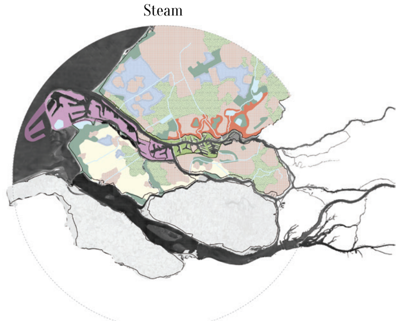
Assumptions

- Height of land, ground water table and water depths during floods give opportunities for giving land back to nature -

Rest



Steam



Assumptions

- Primary dikes remain in the same location -

- Botlek East, Eemhaven and Waalhaven lose their harbor function after 2050 -

- Grassland / meadows lose current agricultural function due to CO2 emissions and soil subsidence -

▲ Figure 4.9 | Assumptions for regional strategies (source: by author)

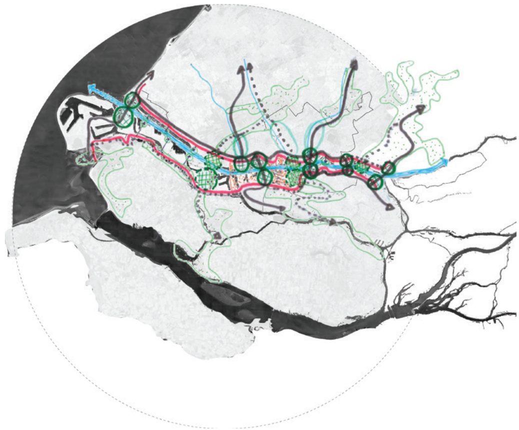
4.02. Maximising Regional Ecosystem Services

In order to make sure the final strategies for each scenario consider the services society desires in 2100 a maximisation method is applied for each of the nine ecosystem services, see figure 4.10. For each of the strategies the previous described assumptions are taken into account. With that information, each strategy represents the maximal outcome of how nature would be able to provide that specific service. The full explanation for each strategy and larger maps are enclosed in appendix 4.

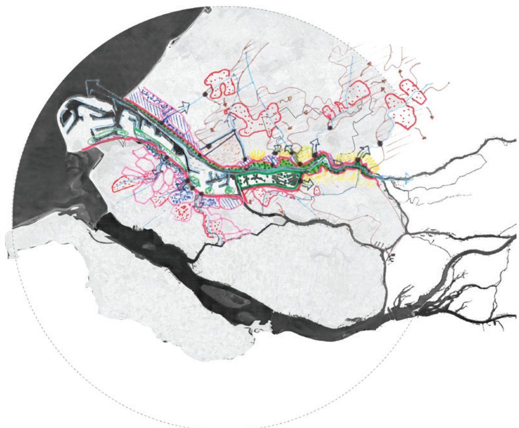
Relate city, river and harbor
Tidal parks can function as attractive city parks to create a connection between the city and the river. The transition zone between land and water can be used for recreational activities, like walking, fishing, playing, sports, etc. At the same time, it can also create access to the water which makes recreational facilities on the water better accessible. The regional recreational network is crucial to make sure the tidal parks provide most recreational values. Without connecting it in the contextual network the parks are less accessible and therefore provide less values for the wider context. The existing structures will be used to define the focus points for tidal parks within the area outside the dikes.

Increase Natural Value and Biodiversity
Tidal parks can provide a transition zone between land and water which provides different types of habitats for species (due to different water depth, different vegetation). The parks can function as stepping stones for migration routes along the river or can function as a transition zone to migrate between water and land.

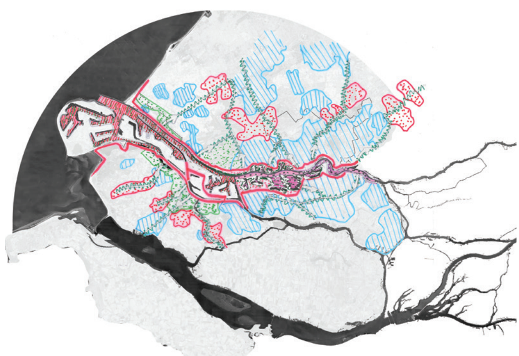
In order to function as a migration route along the river the river bank outside the dikes will be transformed into natural banks as far as possible. In the Botlek and Waal Eemhaven, this will be elaborated to the full extent. In the other parts of the harbor small locations for stepping stones will be investigated. The river structures landinwards function as points where tidal parks can provide the entrance between water and land. This connects fresh and tidal water nature to provide a wide combination of habitats in the region.



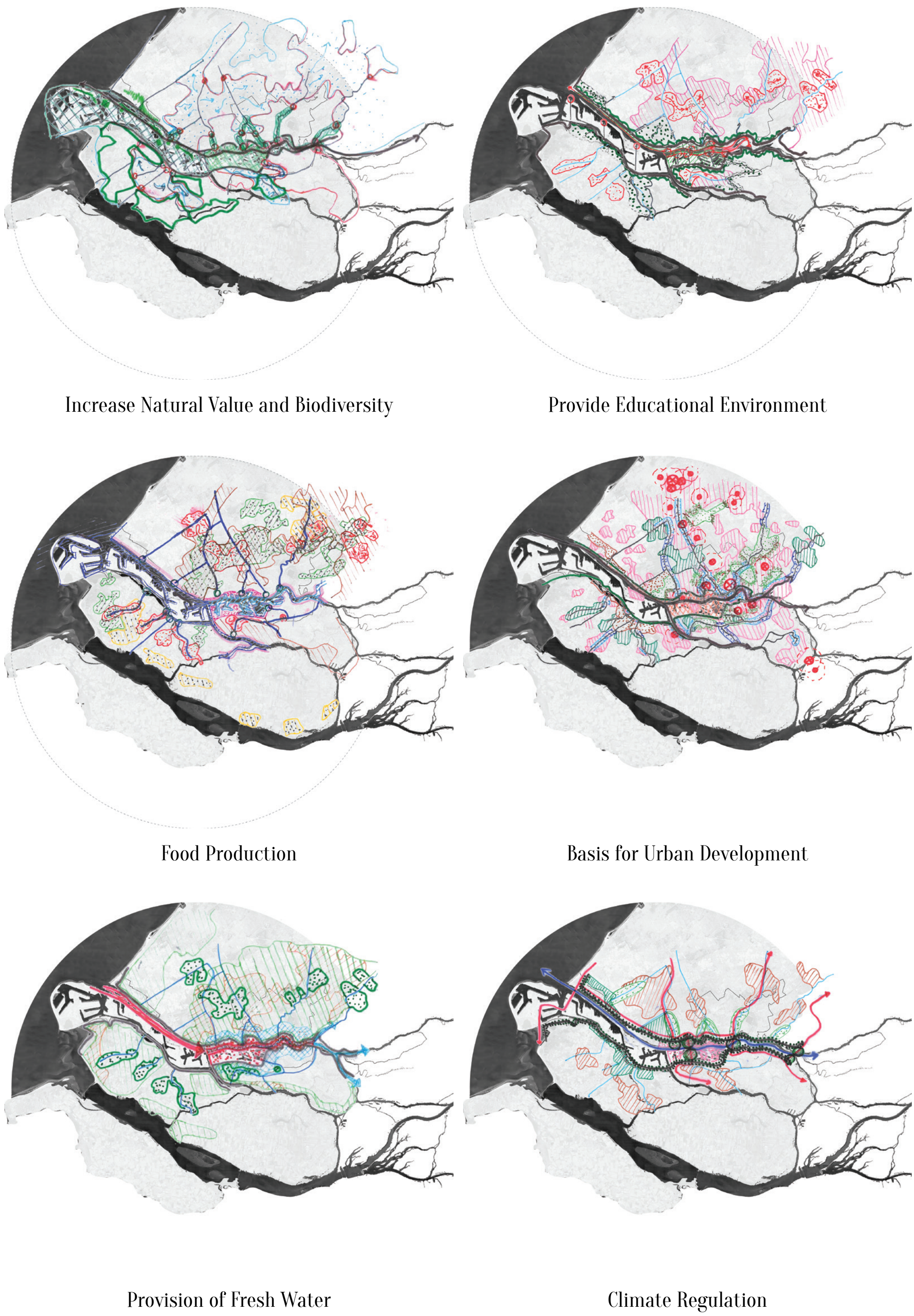
Relate city, river and harbor



Increase Water Safety



Contributing to Regional Circularity



▲ Figure 4.10 | Regional strategies for nine ecosystem services (source: by author)

Provide Educational Environment

Tidal parks can provide a transition zone between land and water which can connect people more to the tides and dynamics of the delta. Nowadays, the often hard quays and non accessible river banks do not allow people to experience the fact that they are living in the delta. Creating more destinations along the river attracts people to the river and the tides. Providing tidal parks in between the primary dikes (which are often well used recreational routes) and the river connects people directly to the delta.

Tidal nature is originally the type of nature which could be found in the historical delta. By developing tidal parks along the river bank, people become more aware of living in the delta as they are subjected to the tides. The base for this strategy to increase awareness of living in the delta is two sided:

1. Lead people to the river / tides / delta.
Create destinations along the river bank, provide routes along and to the river bank, develop the primary dike as a destination which enables people to experience the delta from the dike. Besides that, due to the height difference between outside and inside dikes the difference between the delta landscape and the hinterland can be experienced well.
2. Lead the river / tides / delta to the people.
Let the tides in in the area outside the dikes to connect the primary dike (where the people are) directly to the tidal landscape. Besides that, the historical landscape with old dikes is used to let the tides come into the land. In certain areas, this brings the tides further land inwards and can therefore also create awareness there. This also improves the cultural identity of the region as it gives old dikes again the function of a dike. Provide water detention zones along the inland rivers to let the fresh tides in during peak rainfall or high river discharge which increases awareness of the fact that people live in the receiving end of an estuary.

Increase Water Safety

Tidal parks can contribute in creating more water safety by slowing down the water speed and reduce the intensity of waves and tides. This reduces flooding and protects the existing dikes from eroding. The regional strategy for increasing water safety provided by tidal parks is four sided:

1. Create a fore land in front of the primary dikes. This slows down the tides and waves and therefore protects the dikes which makes them more safe.
2. Slow down the water in general by reducing river water depth in order to reduce storm waves entering the quays/land and create floodings.
3. Create intertidal wetlands behind the primary dikes to stimulate sediment disposal and create more stable and wide (climate) dikes
4. Create water detention zones along the inland rivers to temporary store the water during peak rain fall or during high river discharge, which can be reused in periods of drought

In order to function as a migration route along the river the river bank outside the dikes will be transformed into natural banks as far as possible. In the Botlek and Waal Eemhaven, this will be elaborated to the full extent. In the other parts of the harbor small locations for stepping stones will be investigated. The river structures landinwards function as points where tidal parks can provide the entrance between water and land. This connects fresh and tidal water nature to provide a wide combination of habitats in the region.

Food Production

First of all, tidal parks and wetlands can reduce soil subsidence and therefore salt intrusion through ground water by stimulating sediment disposal. They can also provide space for the production of new types of food, like fish, meat, shellfish and plant production. As tidal parks in the Nieuwe Maas are close to urban development this can provide local food which can be directly consumed by inhabitants. It can be maintained by farmers and sold in local shops or maintained by inhabitants itself and used directly. For this strategy, the river depth and salt levels of the river are very important as they define the types of food that can be produced.

The zones that are affected by salinity intrusion through ground water and are noy vulnerable for flooding, have to transfer their production to salt resilient crops. In the areas which are vulnerable for flooding and have to be given back to nature, this will be combined with food production.

Basis for Urban Development

The river and its banks are attractive areas for urban development. Tidal parks along the river bank can provide green, public space in existing cities and can therefore improve its land values. Development of tidal parks in or close to the city can also go together with new urban development as it can provide an unique living environment where people can live in adaptive and flood proof housing within the tidal landscape. The regional strategy at first focuses on improving land values by improving existing green and blue structures. It also takes the opportunity to combine other services provided by wetlands and tidal parks with new urban development. For example, intertidal zones behind the primary dikes which create robust climate dikes to improve water safety can go together with new urban development.

Contribute to Regional Circularity
The strategy for contributing to regional circularity focuses mainly on the sediment cycle. The natural sediment influx in the rivers and harbor basins will be used. In areas like the Nieuwe Waterweg, where the sediment is not demanded, the dredging activities continue, but the dredged material can be reused in the construction of tidal parks. Within some older harbor basins that have to be transformed, the sediment influx can take place in a natural way, without dredging. Besides the use of the natural sediment disposals, the strategy focuses on reusing coarse residual material of old quays and demolished buildings in urban environment. This material can be used for the development of dams or other artificial structures within new tidal parks.

Provision of Fresh Water
Due to the higher density of salt water compared to fresh water, the salt water transports on the bottom of the river. This given can be used to reduce saline intrusion by surface water by creating a river bottom which gradually undeepens. To reduce saline intrusion by ground water, the seepage areas can be given back to nature, providing wet lands within the dikes. The higher ground water table in these areas would create pressure to brackish/salt seepage to come up, reducing saline problems land inwards. Besides that, retention zones along the inland waters can store fresh water during peak precipitation or high river discharge, providing fresh water for agriculture and nature in times of drought.

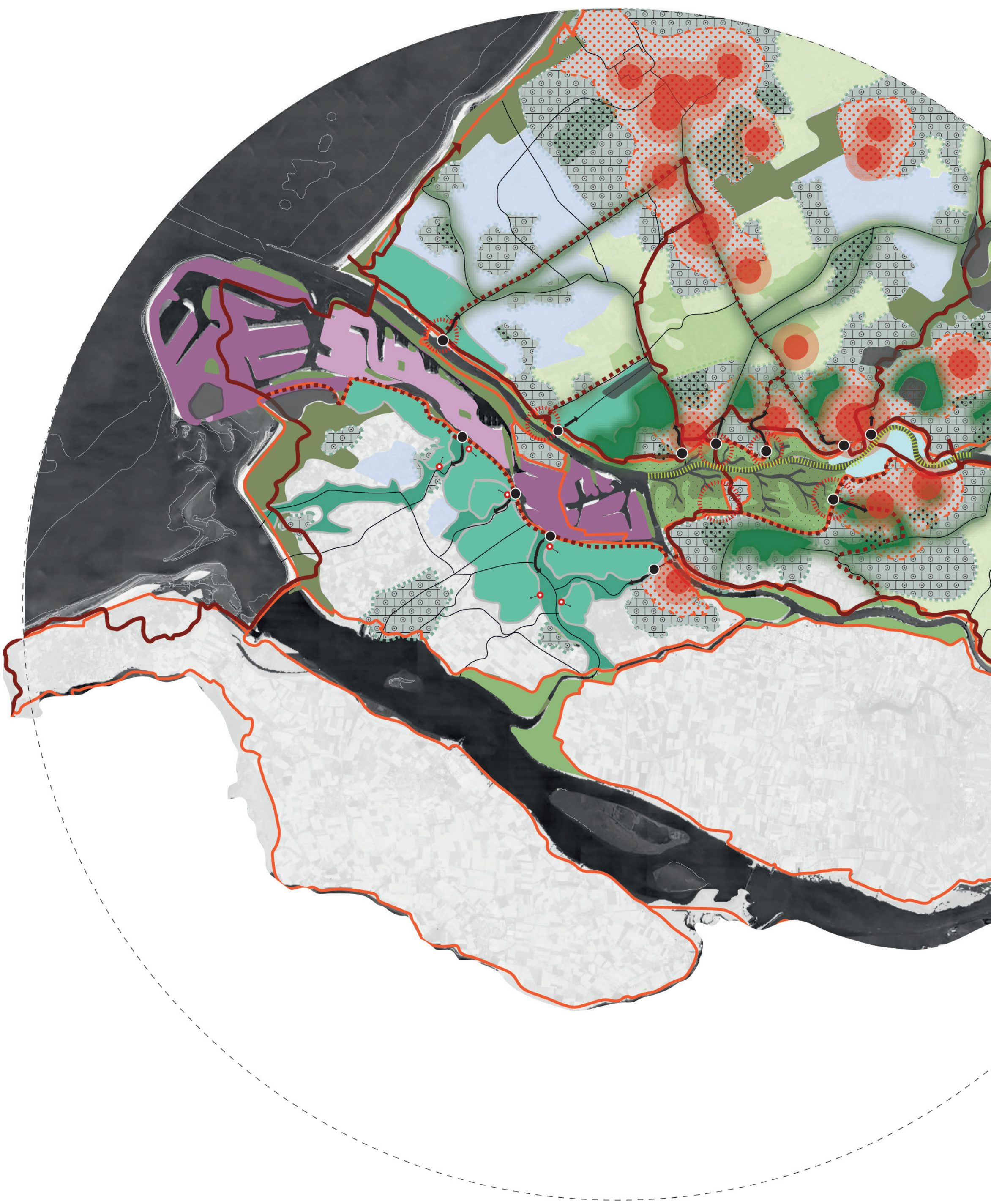
Climate Regulation
As described before, the main problems related to this ecosystem service are the heat stress effect, CO2 emissions and bad air quality. This strategy tackles these problems by:

1. Providing green structures, mainly upgoing, (alluvial willow foRest and reed and rush) to capture NOx, SO2, CO2 and fine dust.
2. Increasing the ground water table in oxidating peat areas to reduce CO2 emissions. The development of wet nature, both fresh wetlands as salt marshes, also contributes to the sequestration of CO2, which reduces the amount of CO2 in the air.
3. Reducing the heat stress effect by the development of green and blue structures in the existing urban areas, providing coolness for inhabitants. If green and blue structures can be provided outside the urban areas the focus lies on the connection of people to these areas by connecting them to recreational routes.

Regional Strategies

After defining the regional strategies for each ecosystem service separately, the assessment of the nine ecosystem services, as explained before, is used. With this assessment the consideration can be made on which ecosystem service is predominant in both regional strategies. It defines which of the design rules of the nine strategies for each ecosystem are most important and therefore prioritized. The outcome of this process (a regional strategy for each scenario) is represented in figure 4.11 and 4.12 on the following pages.

Rest Regional Long-Term Strategy



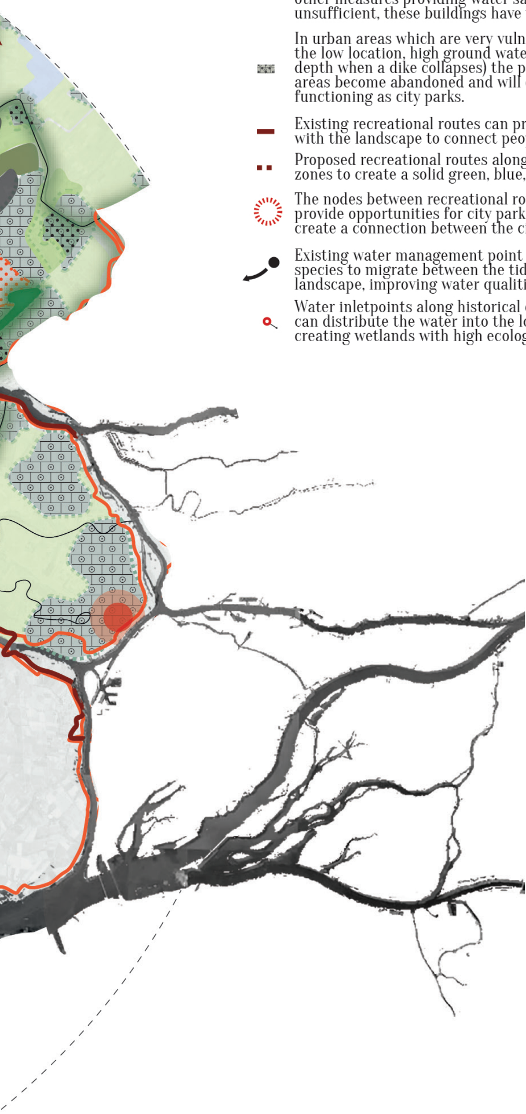
legend

general

- Primary dike
- Greenhouse district
- Inland water ways
- Harbour which doesn't have flood risks can remain in function.
- Sand will be added to the harbour to reduce flood risks and maintain the function of the harbour.
- Existing urban centers are first places where densification takes place and people live in small, sustainable and circular communites.
- Areas around existing urban centers will densify and function as a community with the centers.
- Population of existing suburbs shrinks and the urban area gets less dense. Areas which become abandoned are used for allotment gardens, urban farming or nature development, creating a transition zone between city and landscape.
- High flood risks in th area outside the dikes results in vulnerable buildings in this area. There is no financial capacity to adjust the existing buildings, so those buildings rely on the other measures providing water safety. If this appears to be unsufficient, these buildings have to be given up.
- In urban areas which are very vulnerable for flooding (due to the low location, high ground water table and high water depth when a dike collapses) the population will shrink. The areas become abandoned and will develop in wet nature, functioning as city parks.
- Existing recreational routes can provide a good connection with the landscape to connect people to nature.
- Proposed recreational routes along waterways and nature zones to create a solid green, blue, recreational network.
- The nodes between recreational routes and the delta landscape provide opportunities for city park development in order to create a connection between the city and the landscape.
- Existing water management point allow fresh water and species to migrate between the tidal and fresh water landscape, improving water qualities and migration routes.
- Water inletpoints along historical creeks and ring dikes can distribute the water into the low located polders, creating wetlands with high ecological values.

nature development

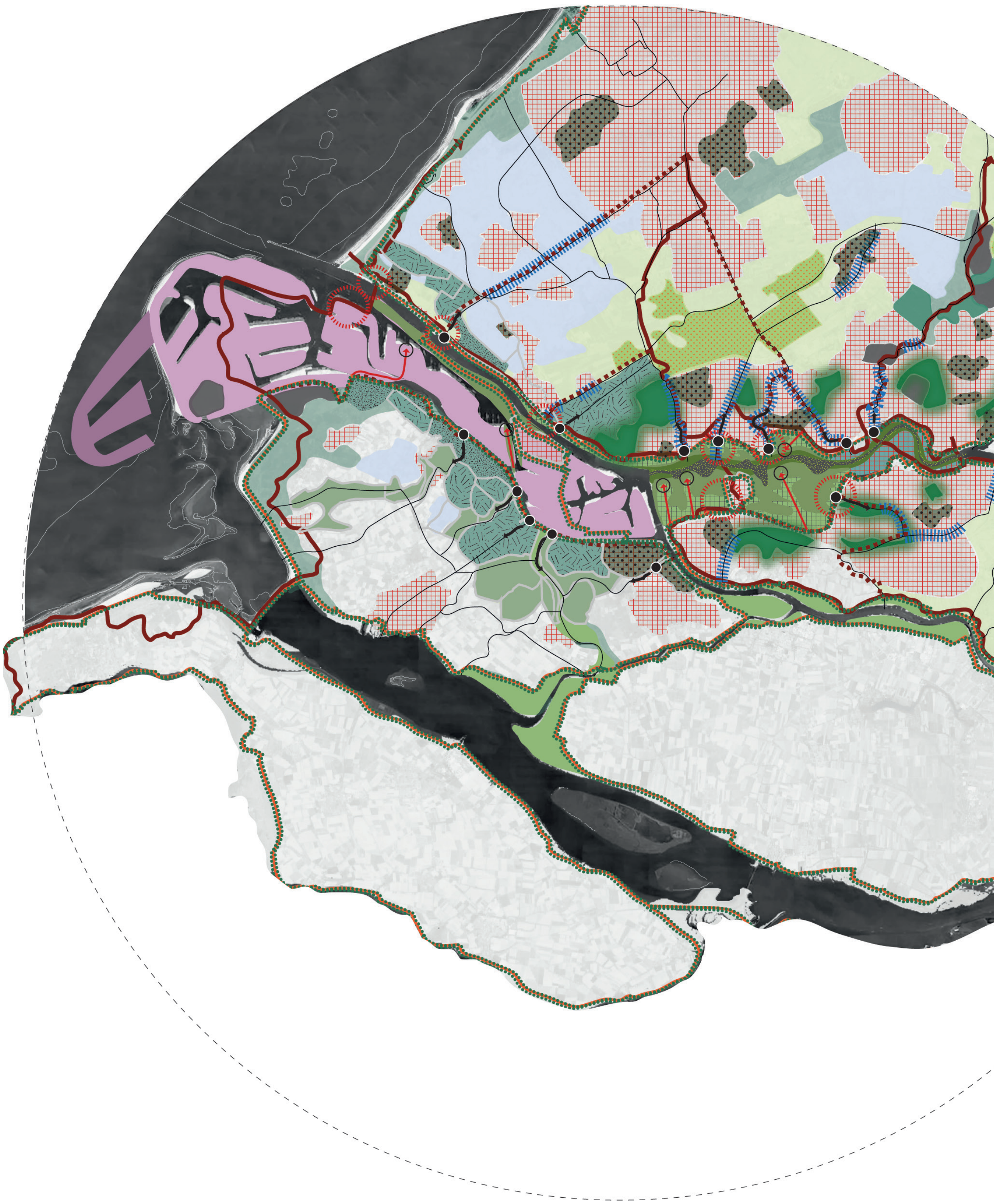
- the harbour area will be combined with nature development on empty zones to provide ecological stepping stones for species
- Due to extreme CO2 emissions of the oxiding peat landscape the draining will be stopped, reducing soil settlement. Fresh water from the inland rivers can be connected to these wetlands to improve ecological values and connect the ecological main structure
- The dark parts of the grassland are due to its low location, high ground water table and high water depth during a flood most feasible to give back to nature and will therefore be given back first. During peak rainfall or high river discharge those zones can be used as retention zones
- Existing nature zones are maintained and connected to new nature zones within the larger context to improve ecological migration routes
- Use land along old creeks in between historical ring dikes to bring back the tides in a controlled way by using the main water management points. This creates a landscape as how the delta must have been in the past
- Due to extreme CO2 emissions of the oxiding peat landscape in between the ring dikes, especially in the oldest polders, the draining will be stopped and the areas develop into wetlands. The inletpoints along the creeks allow to let water in, creating height differences and varied nature types. When a primary dike collapses these zones will be flooded, but due to the low economic value of these areas it is allowed and people profit from it due to the sediment disposal which naturall heightens the land. The zones can be combined with food production (more close to the settlements) and energy production (more land inwards).
- Existing city parks are maintained for local recreational purposes. Due to the increased water quality in the land behind the dikes, the ecological values will improve and the parks become part of the larger ecological network.
- Tidal nature along regional waterways connect the Nieuwe Maas in the large scale ecological network of the whole delta.
- The maintenance of the banks of existing water ways is stopped, resulting in more ecological green banks to improve ecological migration routes
- The river Nieuwe Maas will still be dredged for inland shippin as this becomes more important in the Rest scenario and the river discharge still allows ships to pass. The maximum depth will vary between 6-10 meters which is several meters less deep than it is now, resulting in a more gradual transition between water and land.
- Large scale natural delta park, combined with tourism and recreation. The different heights in the park define the type of holiday houses, giving an unique experience of the Dutch Riviera to tourists. At the same time, the park functions as natural recreation area for inhabitants of the region, with possibilities for extensive recreation (e.g. hiking, cycling, bird watching, fishing, mud walks, etc.)

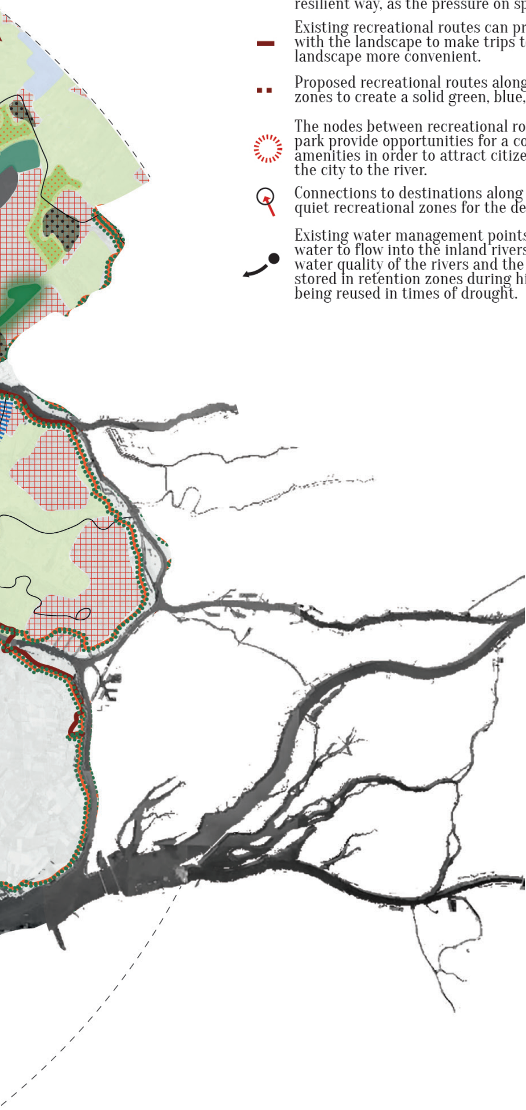


10 km

▲ Figure 4.11 | Regional Strategy for Rest Scenario (source: by author)

Steam Regional Long-Term Strategy





legend

general

- Primary dike
- Greenhouse district
- Inland water ways
- Harbour becomes of great global importance and measures, like adding layers of sand, are taken to protect the functioning harbour against flooding
- Due to the increasing size of container ships the oldest and smallest harbours become outdated. Newer and large scaled harbour areas are developed seawards.
- As the population in this region will double in size in the Steam scenario, the existing urban area will densify extremely, resulting in dense, warm and crowded cities.
- High flood risks in th area outside the dikes results in vulnerable buildings in this area. Due to the space pressure and economic value of this area the existing buildings will be transformed into flood resilient buildings.
- When urban areas which are very vulnerable for flooding (due to the low location, high ground water table and high water depth when a dike collapses) become too vulnerable, the neighbourhoods will be demolished and rebuild in a flood resilient way, as the pressure on space is high.
- Existing recreational routes can provide a good connection with the landscape to make trips to the cool and quiet landscape more convenient.
- Proposed recreational routes along waterways and nature zones to create a solid green, blue, recreational network.
- The nodes between recreational routes and the large scale city park provide opportunities for a concentration of city-related amenities in order to attract citizens to the city park and relate the city to the river.
- Connections to destinations along river to provide cool and quiet recreational zones for the dense and warm city.
- Existing water management points are used to allow fresh water to flow into the inland rivers. This improves the water quality of the rivers and the water can be temporary stored in retention zones during high river discharge, being reused in times of drought.

nature development

- Due to extreme height differences between water and land, increased by sea level rise and soil settlement, the flood risks and the saline intrusion through ground water become too extreme. The draining will be stopped and wetlands will develop on the lowest parts. The focus of providing the region with food shift towards the green houses and import through the harbour. In the dryest parts extensive types of agricultural can still happen. In the areas with extreme salt intrusion the focus can lie on more salty types of crops. In combination with subsidies and adding functions to the farms like bed and breakfast, camping at the farm, farmers golf, etc. the farms can remain profitable.
- The dark parts of the grassland are due to its low location, high ground water table and high water depth during a flood most feasible to give back to nature and will therefore be given back first. During peak rainfall or high river discharge those zones can be used as retention zones. The wetlands will be combined with another type of land use with a high economic value, namely urban expansions where people can live in very cool, water-rich, rural locations.
- Existing nature and recreational zones become vulnerable for flooding and are changed to recreational wet nature parks. The darkest parts are developed first as they are most vulnerable.
- Use land along old creeks and polders in between historical ring dikes more land inwards to develop retention zones to store fresh water temporary during peak precipitation or high river discharge. This water can be reused in times of drought by the surrounding agriculture. The zones are combined with water resilient buildings, like floating houses or houses on poles.
- Due to extreme height differences between water and land, increased by sea level rise and soil settlement, the flood risks and the saline intrusion through ground water become too extreme. As these zones in between historical dikes are located directly behind the primary dikes they can function as a intertidal climate buffer to protect the land behind. The water, let in by the water management points, can stimulate sediment disposal to heighten the soil and grow gradually with the rising sea levels. These zones can be combined with:
  - Aquaculture, where new types of food which are more salt and wet resilient can be produced.
  - Reed and rush, to catch NOx, CO2, SO2 and fine dust coming from the harbour activities and shipping and therefore improve the air quality for the urban expensions behind.
- Upgrade the existing city parks and lakes in urban areas with natural and recreational values to increase land values for urban surroundings and provide possibilities for further densification. The parks can be combined with rain water storage to reduce urban water nuisance.
- Tidal nature zones with park characteristics along regional waterways to connect the Nieuwe Maas in the large scale recreational network of the whole delta.
- Upgrade urban river fronts with natural and recreational values to increase surrounding land values. This can be combined with lower located quays and banks to provide more space in times of peak rainfall and therefore reduce urban water nuisance.
- Primary dikes will be combined with tree structures to reduce noise pollution coming from shipping and the harbour and catches NOx, CO2, SO2 and fine dust to improve the air quality for the land within the dikes.
- The dredging in the river Nieuwe Maas will be stopped and sedimentation disposal will be stimulated, undeepening the river naturally. This decision is made as the periods of extremely low river discharge increase, resulting in more saline intrusion, sea level rise increases flood risks and the ships become too large for the river. An undeep river can reduce currents and tides and therefore increase water safety and reduce saline intrusion.
- Large scale central city park with a gradient from deep wet nature (current river bed), available for recreational water sports, swimming, floating farms, etc., undeep wet nature, flooding daily by tides, with possibilities for recreational developments, like wooden pathways, fishing spots and flood resilient buildings for the creation of a working/living environment, and dryer nature which only floods in extreme situations, providing opportunities for urban expansions in combination with offices. This all together creates a lively city park for several target groups.

10 km

▲ Figure 4.12 | Regional Strategy for Steam Scenario (source: by author)

4.03. Introduction to the Local Site: Waalhaven

The regional strategy will only be developed on the long-term as it desires a long preparation period. The process until this to happen desires for local implementations on the short-term which together result in long-term local developments. Therefore, the first step towards the implementation of the long-term regional strategy is to look into the long-term desires on the local scale. What are the desired ecosystem services in both scenarios on a local scale? What are the value synergies among them? And how can we implement these value synergies on the short term, considering the existing spatial configuration on the local scale?

The local site which is suitable to answer these questions is the Waalhaven, see figure 4.13 and 4.14. This harbor basin is interesting to investigate as the current land use provides opportunities for small scale short-term projects and also for larger scale long-term projects, encompassing the whole basin. This harbor basin is chosen as, after the other Stadshavens, such as the Oude Haven, Rijnhaven, Maashaven en Keilehaven, this would be the first basin to transform. The investigation of this basin is interesting as it is directly located next to the city, namely the neighbourhood Old Charlois. The harbor basin is also located next to a major element of the Green-Blue Network, the Zuiderpark. The water and green structure is nowadays not directly connected to the Waalhaven, but it creates potentialities for future improvement.

▲ Figure 4.13 | Location of Waalhaven in region (source: by author)

To discover the long-term desires for the Waalhaven, the scenarios and regional strategy are translated to the local scale. It is important to distinguish the conditions affecting the site on the long-term and the conditions which affect the phasing towards this long-term implementation. This differentiation can be understood with the theory of the spatio-temporal dynamic as explained in part I of this thesis.

Conditions which are more related to the natural environment, to the substratum and climate, are characterised by a slow process of change. As these conditions are not expected to change soon, they are taken as a starting point for the long-term strategy. These are the dynamics of the river, the projected sea level rise and the final state of tidal nature, encompassing mud flats, salt marshes and river banks. Conditions which are related to the network and occupation layer of Meyer and Nijhuis (2016), such as current land-use and infrastructure are conditions which are changing according to changing circumstances, such as short-term events and actions of people and politics. In this way, these conditions are different than for example the dynamics of the river as they are more easily able to change according to changing desires through time.

The Waalhaven is world's largest dug harbor basin and has a total surface of 310 ha. The start for this project happened in 1907, after which it grew in several phases to what it is now. The harbor started with heavy industries, but slowly this made place for the port-related offices, the logistic sector, the transhipment of goods and light industry (Port of Rotterdam, 2018b).

The Waalhaven is neighbouring to the Eemhaven on the west-side, in between which the workers village Heijplaat is located. On the east-side the residential part of the city of Rotterdam starts. Here, Old-Charlois is located, which used to be a village on its own which grew together with Rotterdam later. The neighbourhood Wielewaal is a garden village which was build after the war and meant for temporary (about twenty years) use to meet the huge housing demand. However, the one-level houses are there now already for more than 70 years and are strongly outdated.

▲ Figure 4.14 | Designation of specific sites within the Waalhaven (source: by author)

History

The development of the Waalhaven through time is represented in figure 4.15.

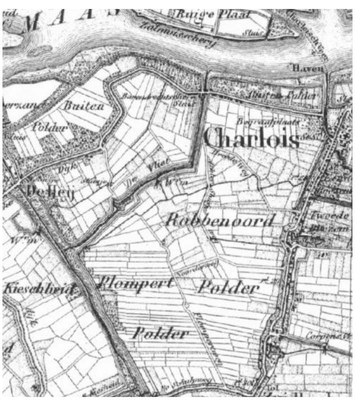
Early History
In the 19th century, the Waalhaven didn't exist yet. The landscape was yet reclaimed from the Delta and formed a polderlandscape on clay ground. The village Charlois origins from the 15th century and was build at the time the land was reclaimed from the delta by constructing dikes. The Zuidhoek, which is now a north-south directed street next to the Waalhaven, functioned as a dike, surrounding the polder landscape. Along this dike there was a building line, which is still present nowadays. This street is, as it used to be a dike, located higher in the landscape (Rotterdam Woont, n.d.). The polderlandscape was drained naturally until the second part of the 19th century. End of the 19th century, the decision was made to transform the polderlandscape into a harbor basin.

Pre-War Period
As the maps of 1915, 1930 and 1950 show the dikes are constantly transformed and moved in order to create land outside the dikes, available for harbor activities. The harbor started on the Sluisjesdijk along the Nieuwe Maas, which used to be a peninsula in the Nieuwe Maas. The function of the Sluisjesdijk was mainly for the storage of petroleum, which polluted the soil and is still present in the soil nowadays (Ontwikkelingsmaatschappij Stadshavens, 2005). As the Rotterdam Harbor started growing rapidly, the demand for more and larger harbor basins to moor sea container ships increased. The petroleum activities moved out of the Waalhaven and the Waalhaven started focusing on bulk and transhipment of containers. The dredged material which came from the basin was mainly used for the heightening of the land of Waalhaven-Zuid, which was later transformed into an airport. The airport was used during World War II, but was later bombed and never rebuild.

1850

1915

1930



Post-War Period
After the Second World War, the recovery of the harbor happened quickly. It created opportunities in the whole Rotterdam Harbor to Restructure the basins and quays, which resulted in a better spatial layout. Also new harbor basins were constructed, such as the Petroleumharbors, the Botlek, Europoort and Maasvlakte. These newer and larger harbor basins which were located closer to the North Sea attracted large industries which the Waalhaven couldn't meet. From this moment, the Waalhaven started focusing on smaller industries and port-related offices. Since the Beneluxtunnel was constructed in 1967, the largest sea container ships couldn't reach the harbors westwards, which is also the Waalhaven. Thanks to a modernisation of the Waalhaven in the second part of the 20th century the harbor was able to maintain its share in the harbor complex (Stadsontwikkeling Rotterdam, 2016 and van Merode, 2013).

▲ Figure 4.15 | Historical development of the Waalhaven through time (source: Topotijdreis, modified by author)

4.04. Waalhaven's Long Term Envisioned State

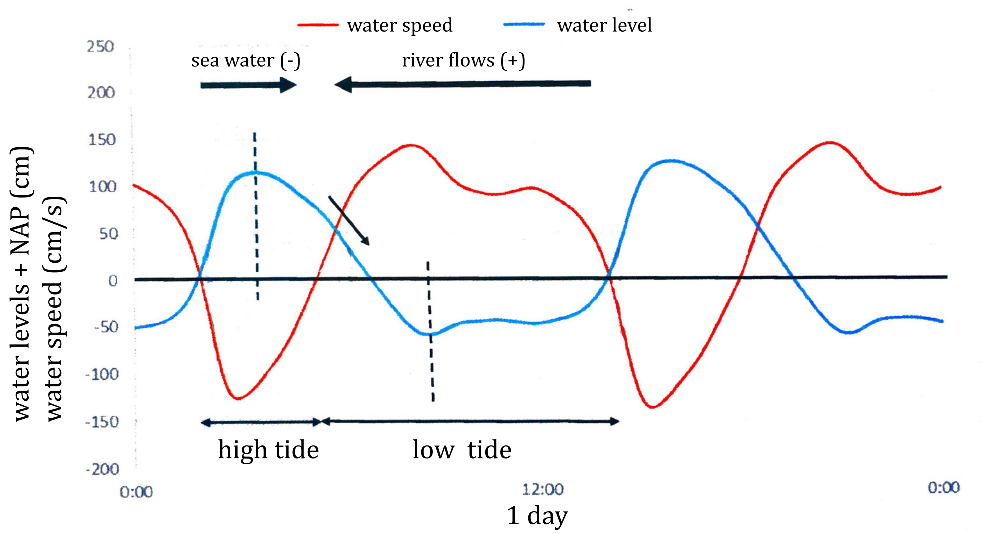
River Dynamics and Sea Level Rise

The dynamics of the river are conditions which will always consist when the open connection between the Nieuwe Waterweg and Nieuwe Maas with the North Sea remain. These dynamics create conditions with which both short- and long-term eco-based projects have to deal. The hydrodynamics which are considered in this thesis are the tidal influence, sea level rise, the natural erosion and sedimentation patterns and the salinity levels.

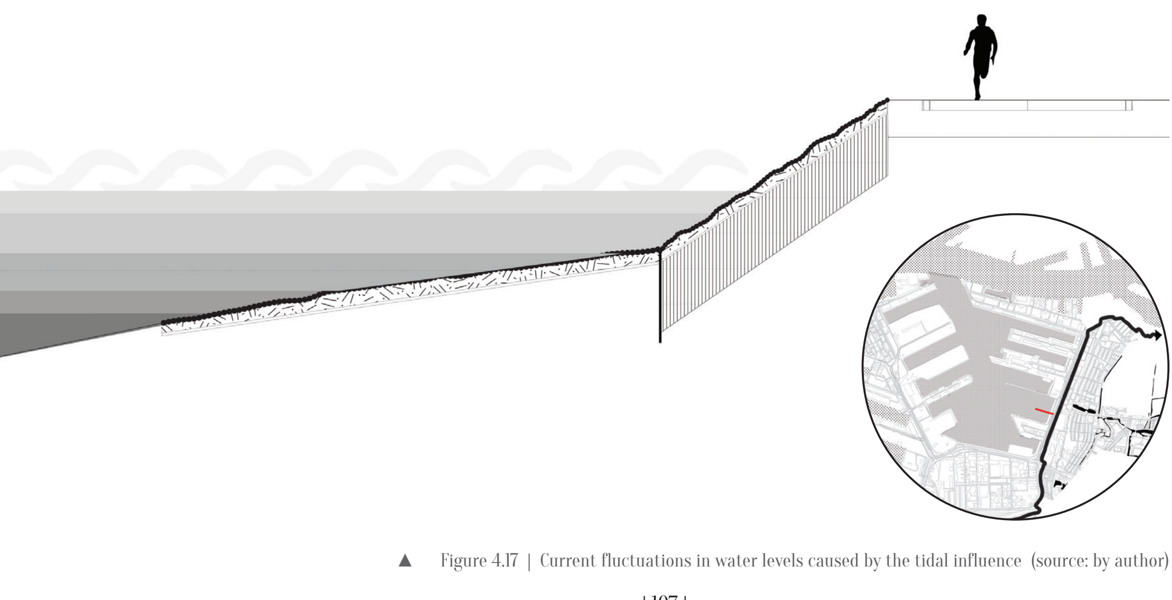
Tidal Influence
As the Nieuwe Waterweg and Nieuwe Maas is the only open connection with the North Sea (in the Netherlands) it is subjected to tides. This tidal influence, caused by the position of the sun relative to the moon, causes (in this region) an average water level difference of 1.65 m between high and low tide. These hydrodynamics of the river are of course important for the design of tidal parks as the (temporary) flooding of land demands for a flexible design.

In figure 4.16 a daily tidal cycle in the Rotterdam Region is represented. The average daily water level in the Nieuwe Maas is +0.35 m NAP. During high tide, the water is for 4 hours and 20 minutes higher than this average. During low tide the water is for about 8 hours and 5 minutes lower than this average. A total tidal cycle takes 12 hours and 25 minutes. During high tide, the water level is about +1.20 m NAP and during low tide it is about -0.50 m NAP. Once every 15 days there is a more extreme tide, the spring- and dead tide, caused by a specific location of the sun in relation to the moon. The spring tide, which is extremely high, causes a water level of +1.70 m NAP. The dead tide, which is extremely low, causes a water level of -1.00 m NAP.

The quays in the Waalhaven are designed to remain dry during this daily and fortnightly fluctuation of the water. Most quays are also designed for extra high water levels, which occur during storms. This thesis considers storm waves of about 80 cm higher than the average spring tide, which happens with a frequence of 1:10. The representation of the different water levels in relation to the current quay, caused by the tidal influence are represented in figure 4.17.



▲ Figure 4.16 | Average daily tidal cycle in the Nieuwe Maas (source: Zaat, 2019)



▲ Figure 4.17 | Current fluctuations in water levels caused by the tidal influence (source: by author)

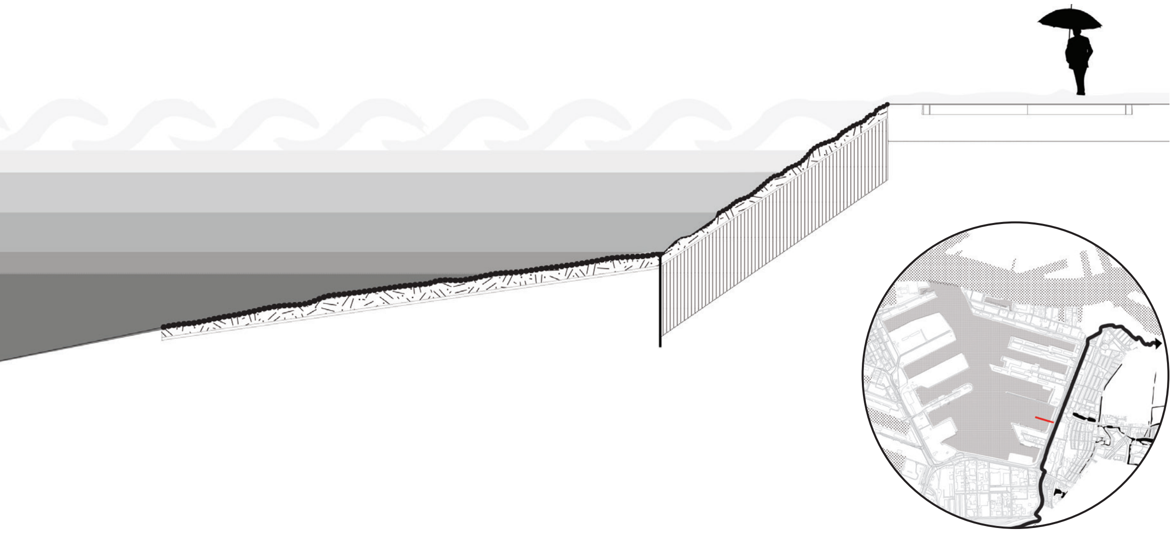
Sea Level Rise in Rest Scenario

Due to the increasing sea water levels in both scenarios, the risks for flooding increase. The Rest Scenario takes into account a sea level rise of 100 cm, resulting in several parts of the piers of the Waalhaven being subjected to the spring tide (see figure 4.18 and 4.19). This means these piers would not be usable as they are subjected to the water every two weeks. Besides that, the major part of the land is subjected to flood risks related to storm waves, which means that with a frequence of 1:10 years the piers are subjected to storms. This causes economic consequences when the land-use types will not adapt to this.

legend

- flood risks related to spring tide
- flood risks related to storm waves
- no substantial flood risks
- permanent water

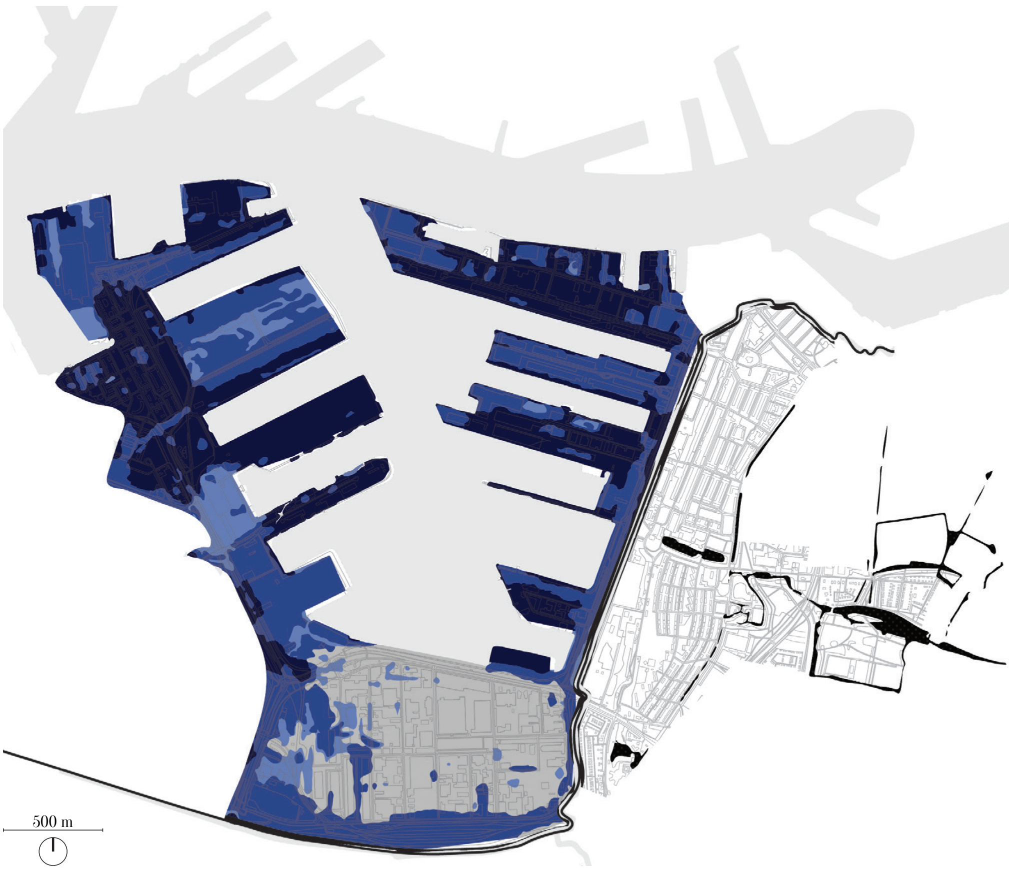
▲ Figure 4.18 | Flood risks in Rest Scenario (source: by author)



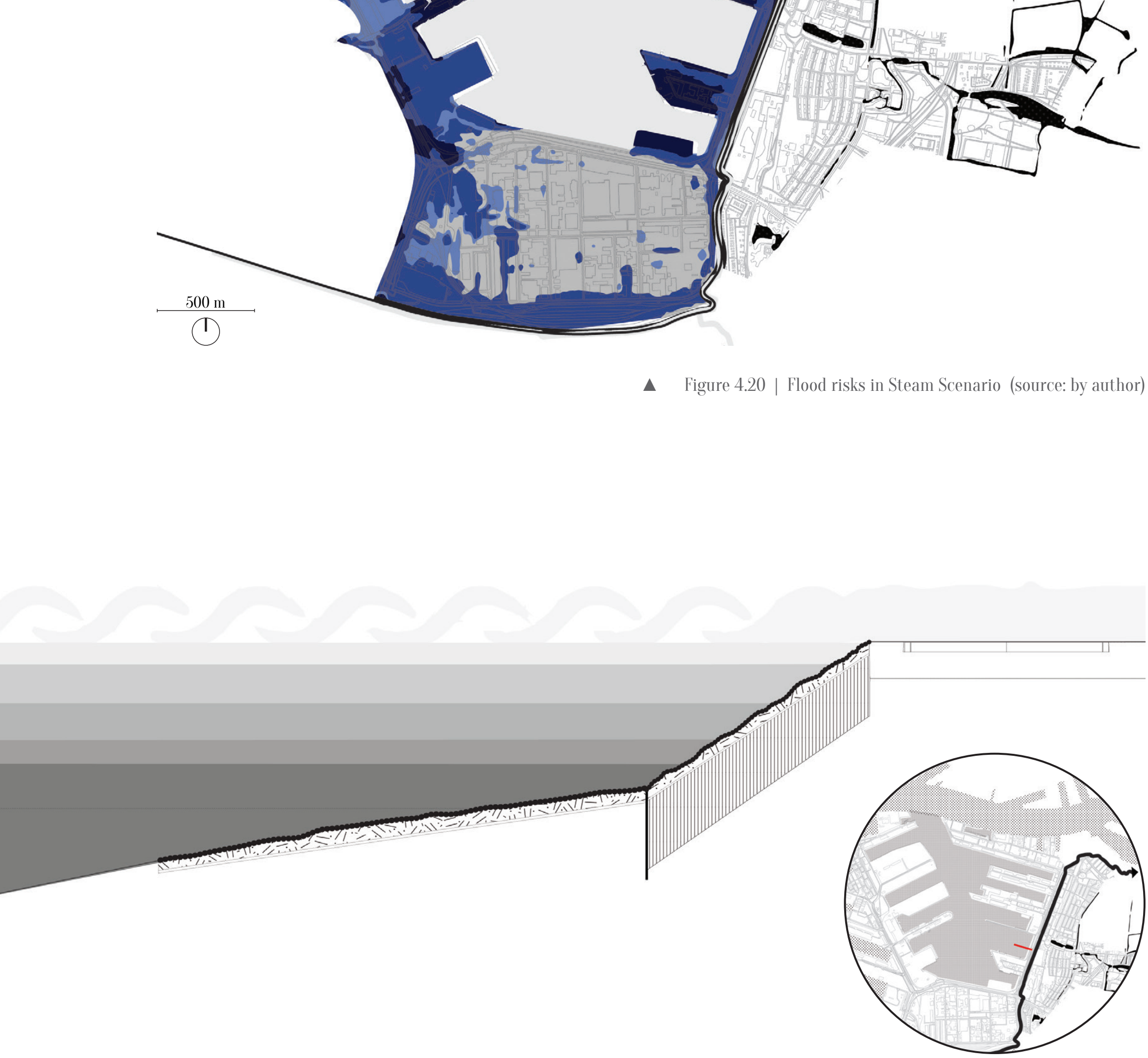
▲ Figure 4.19 | Section of flood risks in Rest Scenario (source: by author)

Sea Level Rise in Steam Scenario
The Steam Scenario takes into account a sea level rise of 100 cm, resulting in several parts of the piers of the Waalhaven being subjected to the high tide (see figure 4.20 and 4.21). This means these piers are flooded daily and therefore not usable. Major parts of the Waalhaven are subjected to spring tide, meaning they are not usable as wellthey are subjected to the water every two weeks. Besides that, the major part of the land is subjected to flood risks related to storm waves, which means that with a frequence of 1:10 years the piers are subjected to storms. This causes economic consequences when the land-use types will not adapt to this.

legend
- flood risks related to high tide
- flood risks related to spring tide
- flood risks related to storm waves
- no substantial flood risks
- permanent water



▲ Figure 4.20 | Flood risks in Steam Scenario (source: by author)



▲ Figure 4.21 | Section of flood risks in Steam Scenario (source: by author)

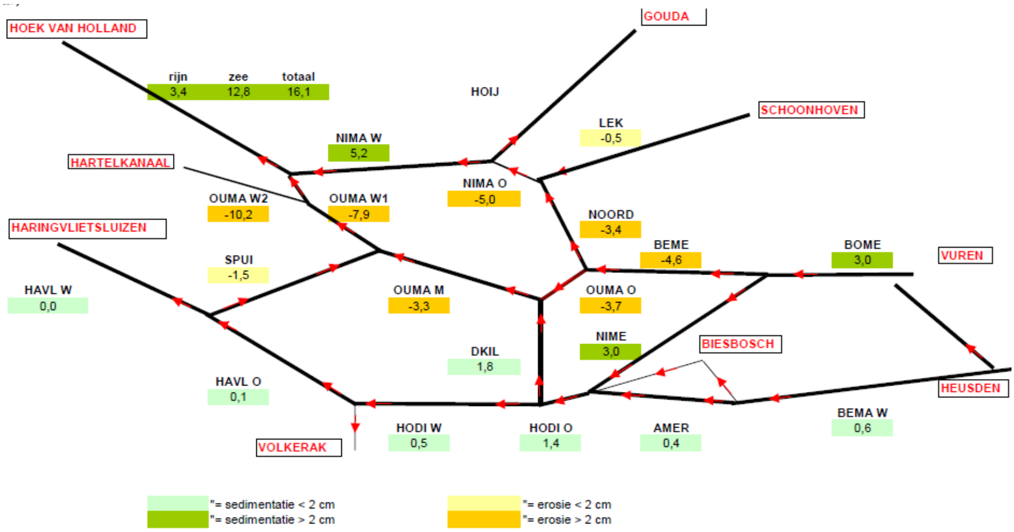
Natural Erosion and Sedimentation Processes

The fact that the river Nieuwe Maas is located in the receiving end of both the North Sea and Rhine-Meuse Estuary results in dynamics in the morphology. In a natural tidal river we would find mud flats, salt marshes, creeks, etc. The constant manipulation of the river, such as the dredging and narrowing by hard quays, results in the loss of these characteristic nature types. However we are fighting against these dynamics, they are still present and by using building with nature measures we could use them to benefit ourselves in a natural way.

The river is a system which is searching for a balance, constantly taking and disposing sand and silt through erosion and sedimentation. The abstract map in figure 4.22 shows the natural transportation of sand and silt. It shows how much sediment is disposed or eroded in each of the water ways in the South-West Delta in cm/year. In the Nieuwe Maas, the annual sedimentation disposal is very high, namely 5,2 cm/year (Rijkswaterstaat, 2005).

The existing sediment disposal in the Waalhaven is represented in the map in figure 4.23. It shows that most basins in the south part of the Waalhaven are subjected to sedimentation. There are also already several parts which are very undeep, which can be used for future transformation to a gradual bank. Besides that, the design has to take into account the quays which are subjected to erosion and to sedimentation, see figure 4.24. If you would remove a quay which is subjected to erosion, the land will slowly be taken away by the water, which results in a loss of land. When you remove a quay in sedimentation area, the water currents will first create erosion where the land is disposed in the water, creating a gradient between water and land. Due to the tidal influence, this gradient will slowly grow by sedimentation processes, which results in a growth of land along quays subjected to sedimentation.

▲ Figure 4.23 | Natural sediment disposal in the harbor basin (source: by author)



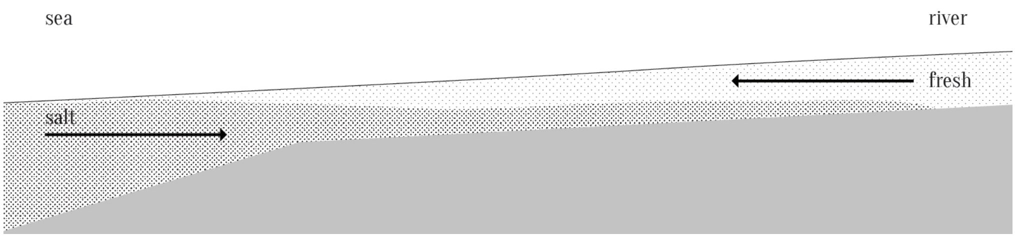
▲ Figure 4.22 | Annual sediment and erosion rates in the rivers of the South-West Delta (source: Rijkswaterstaat, 2005)

▲ Figure 4.24 | Quays subjected to sedimentation and erosion (source: by author)

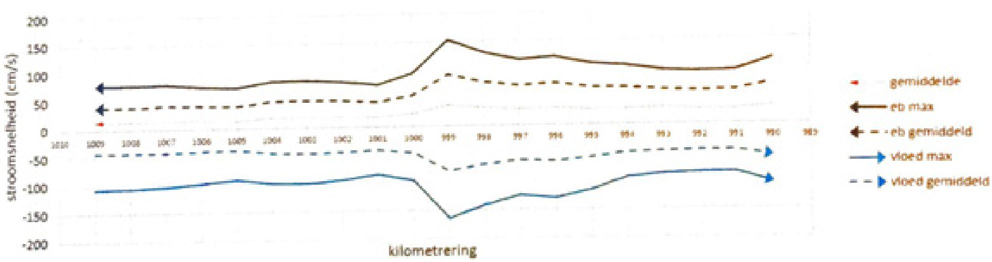
Several dynamics in the Rhine-Meuse estuary have an effect on sedimentation processes.

a) The rivers profile: in the inner bend there is naturally more sediment disposal than in the outer bend (de Urbanisten en Strootman Landschapsarchitecten, 2016).
b) Salt water has a higher density and is therefore heavier than fresh water, which creates layers in the water (figure 4.25). The salt water is located on the bottom of the river and basins and the fresh water flows on top of that. The concentration of sediment is highest where salt and fresh water meet which is nowadays somewhere between Maassluis and the Beneluxtunnel, see figure 4.27. In this area the salt water intrudes through the bottom of the harbor basins during high tide, leaving sediments behind when the water speeds reduce. When the water flows back during low tide the sediment is captured in the harbor basin (Zaat, 2019). As shown before, this saline intrusion will shift in both scenarios (Rest and Steam). With 100 cm sea level rise in both scenarios (open and closed haringvliet) the meeting between salt and fresh water is somewhere between the Eemhaven and the van Brienenoordbrug. In the Steam Scenario near 2100 this will shift even more eastwards, so in this scenario the advantage of this process has to happen around 2070-2080 when sea level has risen with 100 cm.
c) A low water speed results in more time for sediment to settle. The average water speed in rivers is about 1 m/s, but due to the amount of harbors in the Nieuwe Maas the speed reduces to about 0,5 m/s, resulting in the amount of sedimentation in the whole river as described before. Also the shift in water flow direction due to the high and low tides results in changing water speeds along the whole Nieuwe Maas. The image in figure 4.26 shows there are changes in water speeds along the length of the river. The low water speeds are related to a broad river profile, mostly at the entrance of a harbor basin. In these areas the sediment has more time to settle (Zaat, 2019).
d) The tidal influence: The land which is flooded (extra) during high tide is subjected to sediment silting up. During the average high tide the sediment does not have a lot of time to settle (4 hours and 20 minutes with a maximum water level of 0.85 m above the average of + 0.35 m NAP). However, during spring tide (happening every 14 ¾ days, so 24,75 times a year) the extra flooded land grows with 20 mm a year (Exaltus and Kortekaas, 2008).

An analysis of these hydrodynamics near the Waalhaven show there is a high chance that the sediment settlement in the Waalhaven is even higher than the average of 5,2 cm sedimentation / year. This is because the Waalhaven:
- is located in the inner bend of the river (a), resulting in sediment disposal
- the shift in saline intrusion in both scenarios results in the meeting of fresh and salt water



▲ Figure 4.25 | Higher density of salt water increases the saline intrusion (source: by author)



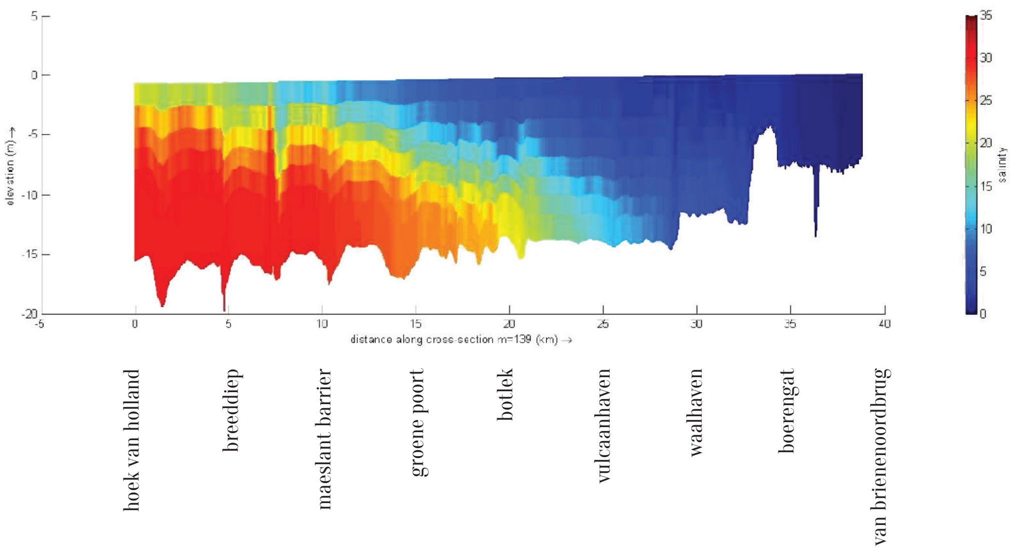
▲ Figure 4.26 | Variety in water speeds throughout the length of the Nieuwe Maas (source: Zaat, 2019)

somewhere around the Waalhaven (b), resulting in more sediment movements on the bottom towards the harbor basin
- As the image in figure 4.26 shows, the water speed near mileage 1005 (which is at the entrance of the Waalhaven) is low compared to water speeds elsewhere in the Nieuwe Maas. This is because the entrance to this large harbor basin demands for a wide river profile, creating a lee in river water speeds. This lee creates opportunities for sediment to settle and flow into the harbor basin of the Waalhaven.

This all together results in the use of the following numbers for sediment disposal in the different parts of the harbor basin with developing tidal nature.
- Part of the basin where there is always water (with low and high tide) takes into account the number of the Nieuwe Maas (5,2 cm sedimentation / year). There is no data available for the exact sediment disposal in the harbor basins compared to the average of the river, but due to the explained hydrodynamics which increase sediment disposal in the Waalhaven (a,b,c) it is assumed that the average sediment disposal will be 10% higher than the Nieuwe Maas, resulting in 5,72 cm a year.
- The salt marshes (which are not developed yet) will only flood during spring tide (once every 14 ¾ days) and grows with 2 cm a year (Exaltus and Kortekaas, 2008).
- The mudflat is also subjected to spring tide and will grow at least 2 cm a year. As it is also subjected to high tides for a total of 4 hours and 20 minutes of the total tidal cycle, of which about 2 hours the water speed is equal or lower than 0,5 m/s (average of river Nieuwe Maas). It has therefore 16% (2 hours of total cycle of 12 hours and 25 minutes) of the time for the same sediment to settle = 0,92 cm/ year. This comes to a total for the mudflats of 2,92 cm a year of sediment disposal.

The average numbers of natural sediment disposal per year would result in a very long process before the river bank would become gradual. Therefore, extra measures should be taken in order to fasten the natural process of sediment disposal.

Extra sediment disposal due to measures:
- Closing of a harbor basin through a klepduiker (culvert with gate) with which the water is imported during high tide and holded during low tide. This provides more time for the sediment to settle as the water speeds are minimal (Mosselman, 2019).
- Vegetation in the water and on salt marshes and other structures in the water which create a lee environment in the water increases the amount of sedimentation which is settling (van Veelen et al., 2018 and de Urbanisten en Strootman Landschapsarchitecten, 2016).



▲ Figure 4.27 | Visualisation of salt intrusion on the bottom of the river, due to the higher density of salt water (source: Lambèr Hulsen, 2019)

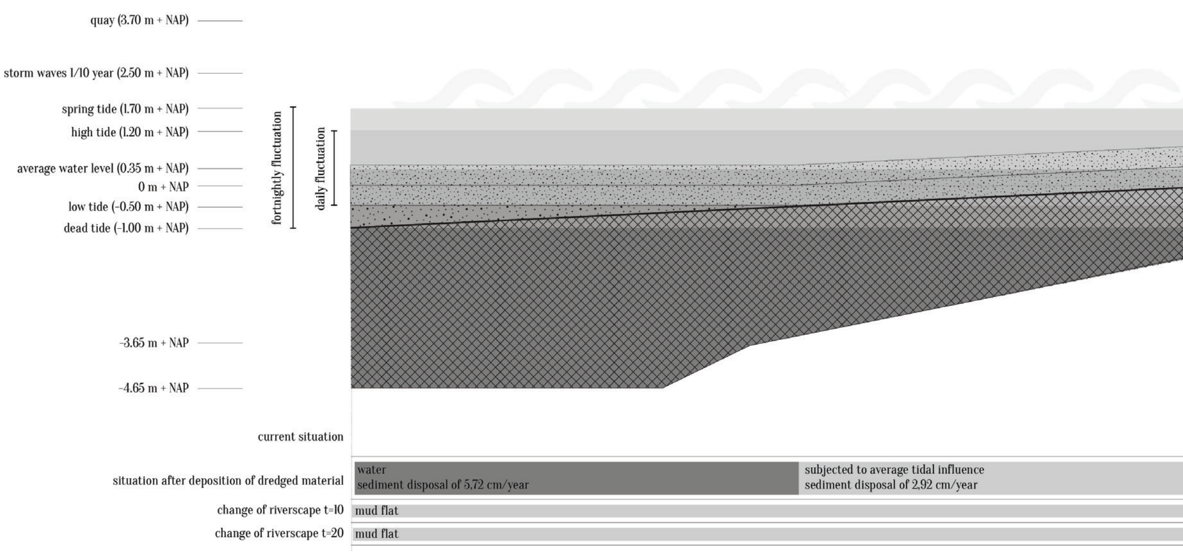
By making use of dredged material from the harbors which are still in function, the harbor can be drastically undeepened. By planting vegetation on this material or provide other structures in the water, the sediment can settle fast, resulting in a gradual bank between water and land (figure 4.29), providing a varied habitat for species and therefore increase biodiversity and nature values. It has to be noted that this section shows a linear process of sedimentation as it takes average numbers of sediment disposal per year. The reality would be that the sediment disposal shows exponential growth, which results in faster growth through time.

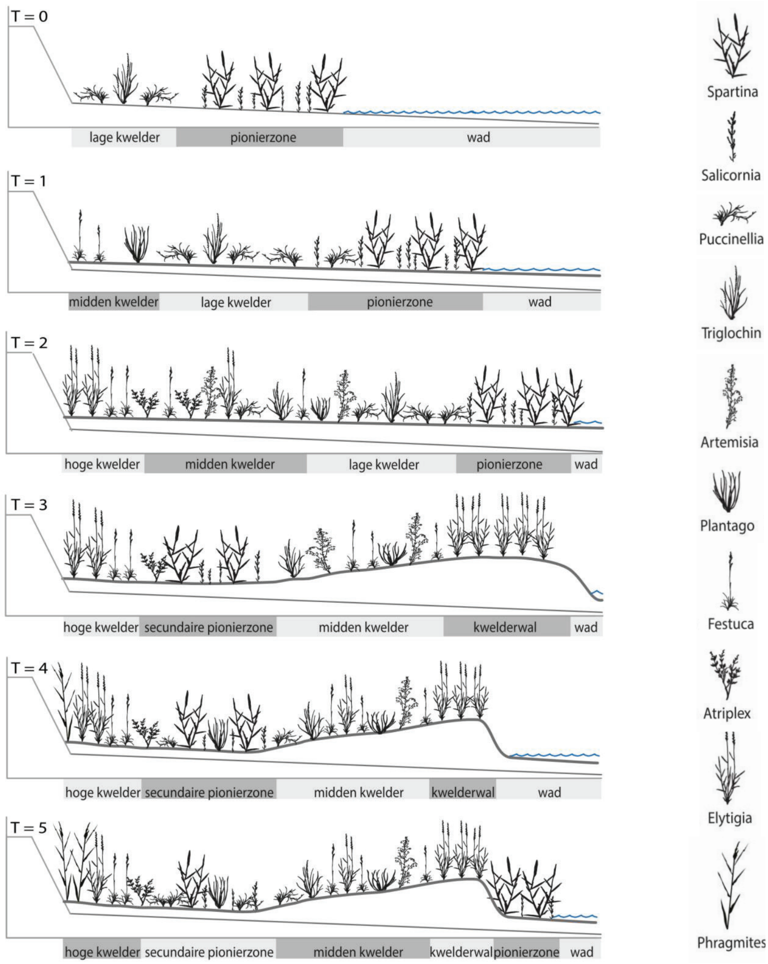
Final Ecological State of Tidal Nature

A natural tidal river knows several landscape types which vary in flora and fauna types (Kater et al., 2012 and VBNE, 2014), which are:

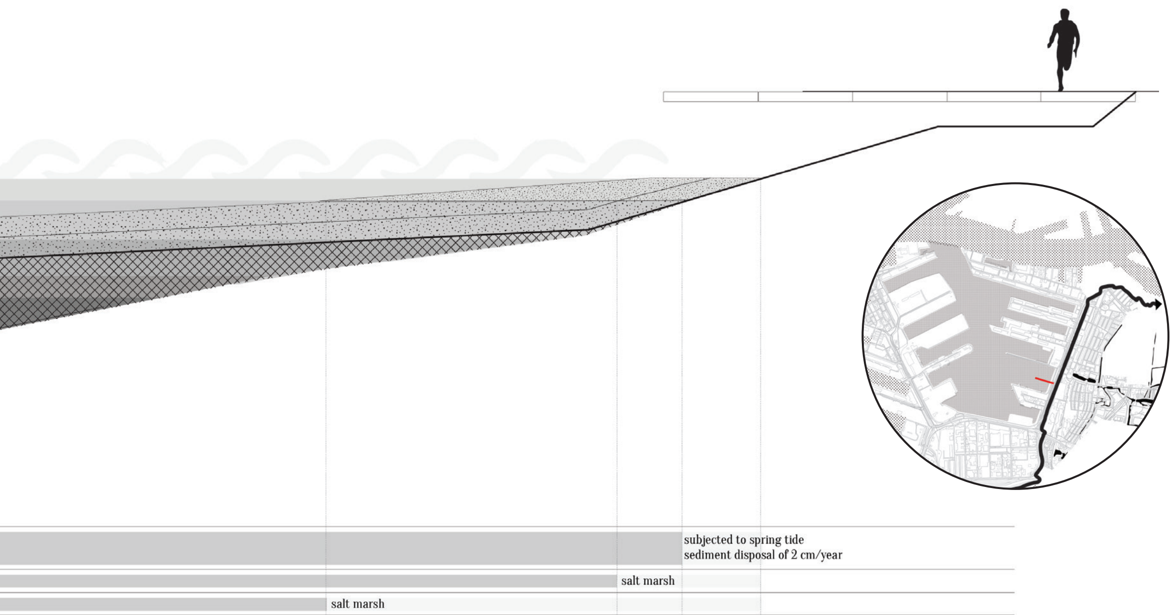
- permanent water
- mud flat (wad), which are not vegetated as they are subjected to highly morphological and hydrological dynamics
- pioneer vegetation zone, which is dry for at least 12 hours a day
- low salt marsh (lage kwelder)
- middle salt marsh (midden kwelder)
- high salt marsh (hoge kwelder)
- permanent dry banks

The development of tidal nature in a natural way consists of several phases before the final state is reached (figure 4.28). The moment in time the sediment has settled sufficiently, resulting in the first land types being dry for as least 12 hours a day, vegetation starts to grow (t=0). The growing densities of vegetation in the pioneerzone and low salt marsh results in more sediment disposal which makes the salt marsh extend (t=1 and t=2). As the lower parts of the salt marsh are inundated for a longer period of the tidal cycle, the sediment will settle faster here, creating a mound next to the mud flat (t=3). From this moment in time, the creeks are playing an important role in the development of the salt marsh. During calm periods the water is transported further land inwards via the creeks, disposing sediment on the higher parts of th salt marsh. When the tides are higher, or during storms, the water flows over the mound where it calms down behind. This is the moment in time when the most sediment is disposed, as there is very little movement in the water. It is possible that at one point in time, when the mound becomes higher and steeper, it erodes (t=4). This makes the mound move land inwards, creating possibilities for new sediment to settle on the mudflat side. From this moment in time, a secundary, younger salt marsh starts its existence in front of the older salt marsh (t=5) (VBNE, 2014).





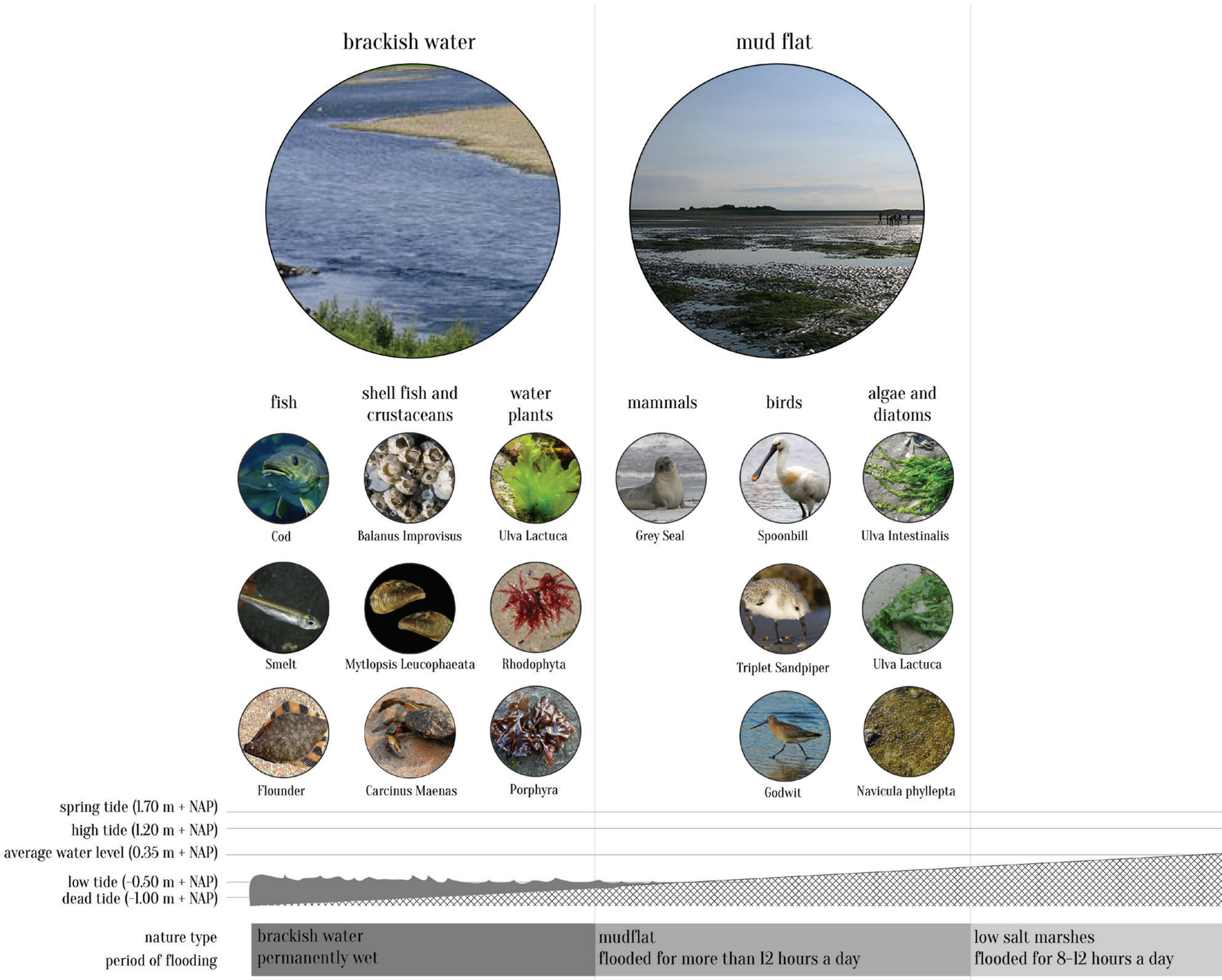
▲ Figure 4.28 | Several phases in the development towards tidal nature (source: VBNE, 2014)

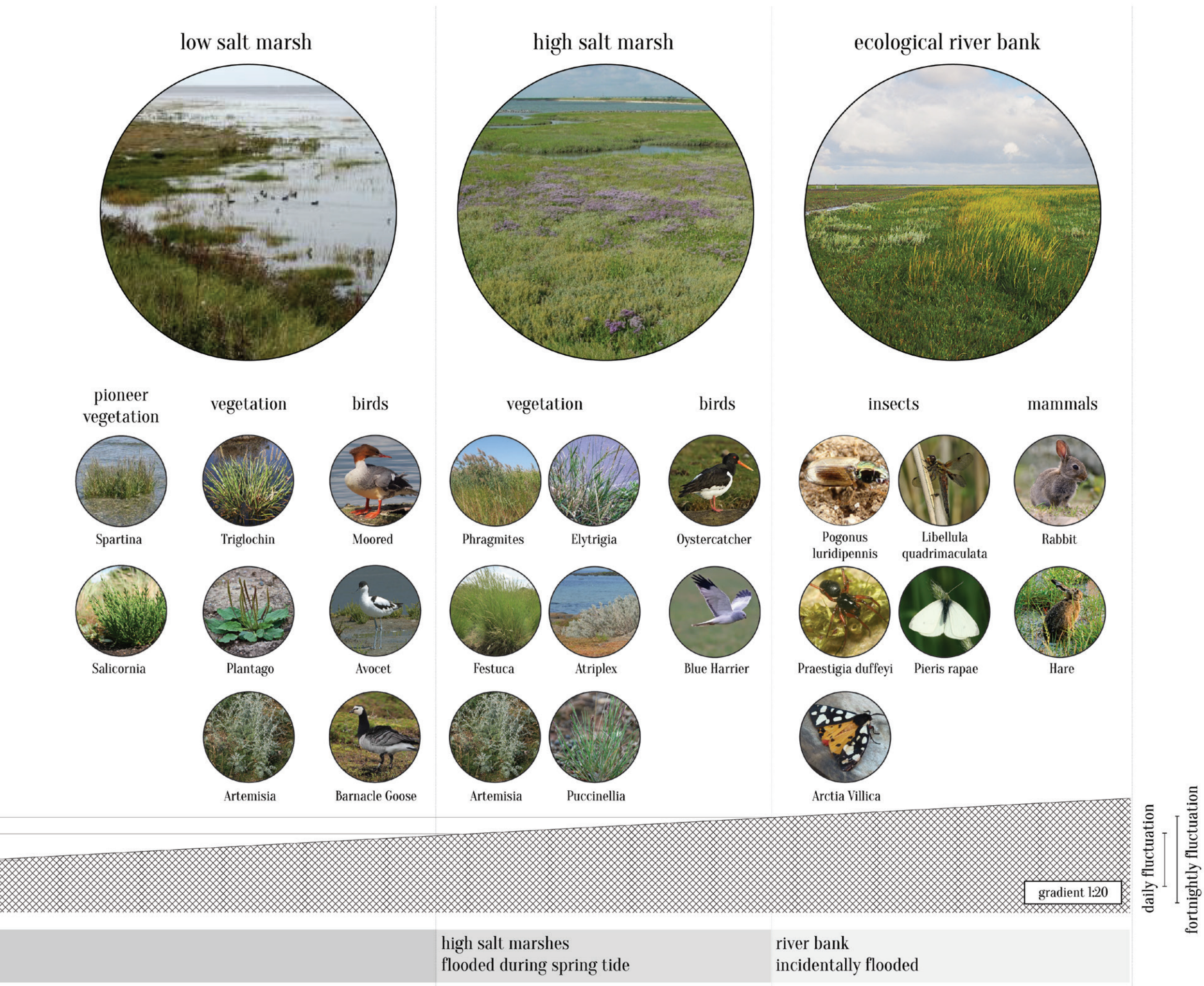


▲ Figure 4.29 | (linear projection of) natural sediment disposal after undeepening of the basin by making use of dredged material and extra measures to fastens the process (source: by author)

As the image in figure 4.30 shows, the vegetation of each landscape type differs. This creates habitas for different types of species. The different types of vegetation are related to the species which we could expect in each landscape type.

As the project takes into account the long term development of tidal nature, the changing climates have to be taken into account. Nature is able to adapt naturally to changing circumstances (as it happens gradually and not abrupt). This means that the rising temperatures would slowly make the types of vegetation change over time. The rising sea levels not only have an effect on the subjection of the different landscape types to water, but also increases the salinity levels. The vegetation would adapt to the changing salinity levels similar to the adaptation to changing temperatures. The increasing water levels would result in a shift of the landscape types land inwards. If the bank profile remains the same over time, this would result in a loss of surface of the higher parts as more and more land is taken by the water. If more space is provided land inwards, the landscape types would shift land inwards.



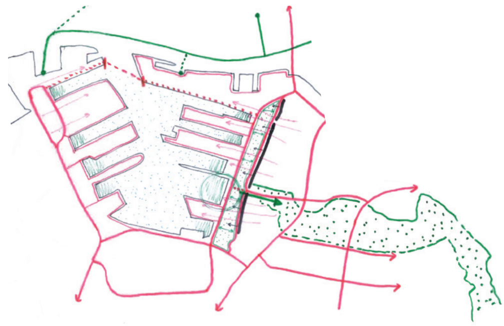


▲ Figure 4.30 | Expected flora and fauna on the different landscape types (source: by author)

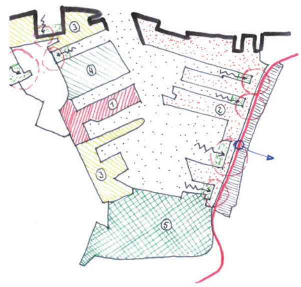
Maximising Local Ecosystem Services

In order to make sure the final strategies for each scenario take into account the services society desires in 2100 a maximisation method is applied for each of the nine ecosystem services, see figure 4.31. Each strategy represents the maximal outcome of how nature would be able to provide that specific service in the Waalhaven. The full explanation for each strategy and larger maps are enclosed in appendix 5.

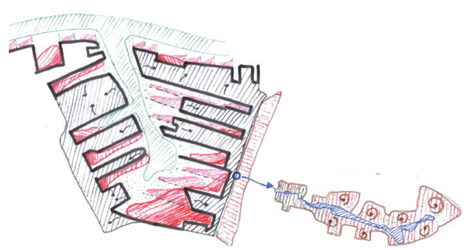
After defining the strategies for each ecosystem service separately, the assessment of the nine ecosystem services, as explained before, is used. With this assessment the consideration can be made which ecosystem service is predominant in both strategies. It defines which design rules of the nine strategies for each ecosystem are most important and therefore has to be implemented above others. The outcome of this process (a strategy for each scenario) is represented on the next pages.



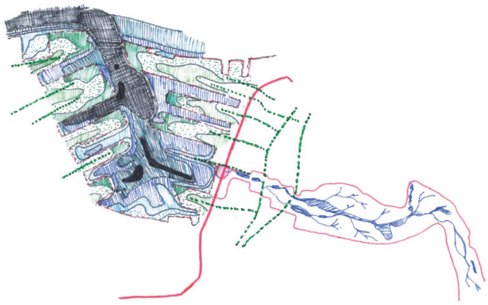
Relate city, river and harbor



Increase Water Safety

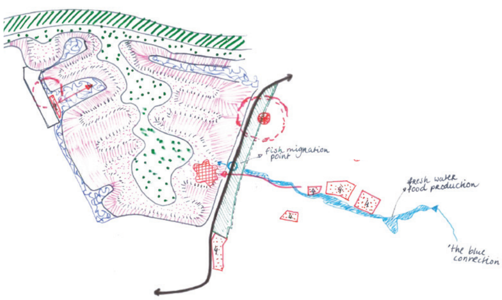


Contributing to Regional Circularity

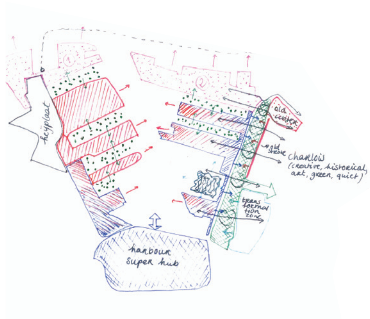


Increase Natural Value and Biodiversity

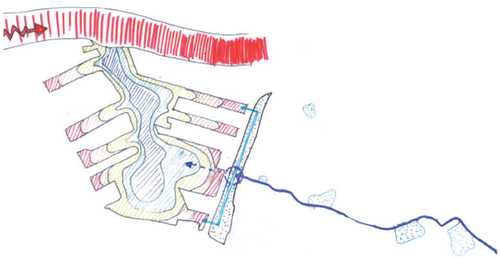
Provide Educational Environment



Food Production



Basis for Urban Development



Provision of Fresh Water

Climate Regulation

▲ Figure 4.31 | Strategies for nine ecosystem services (source: by author)

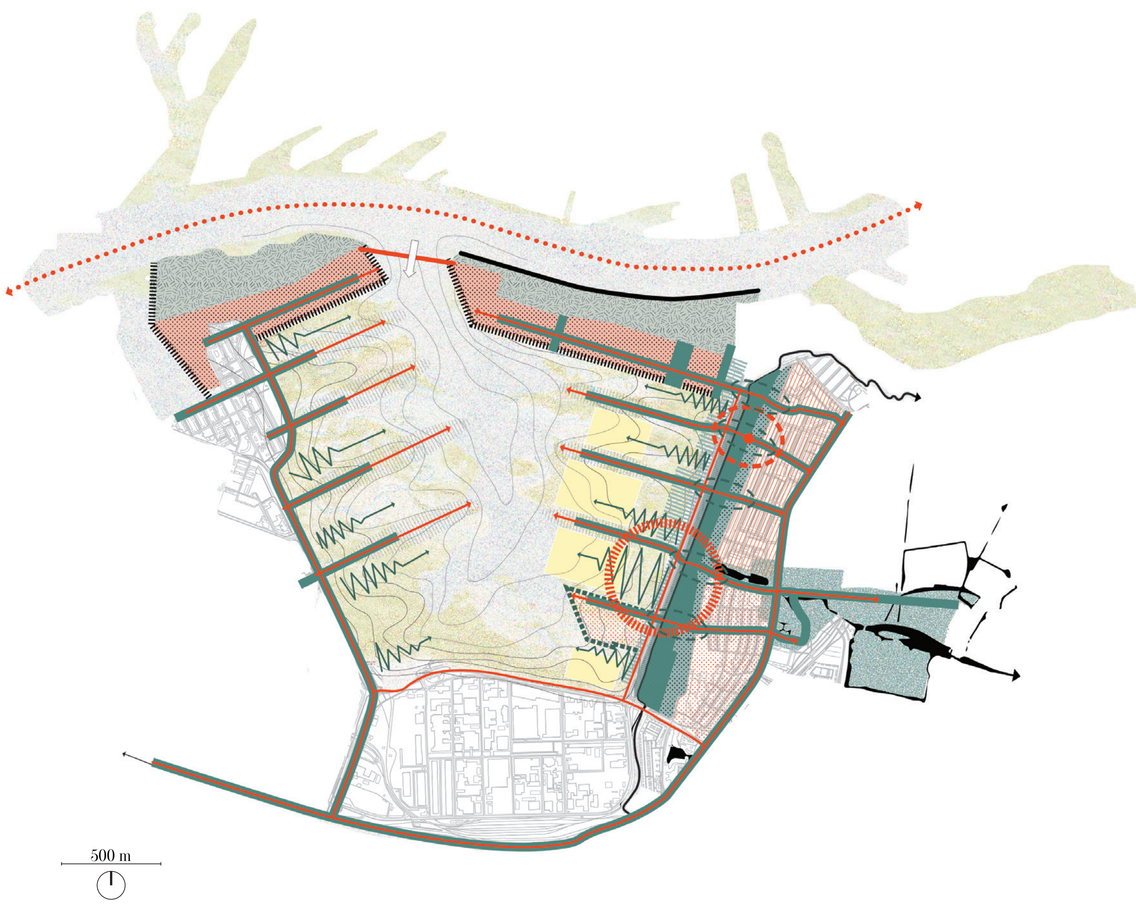
Rest Local Long-Term Strategy

The envisioned spatial conditions for the Rest Scenario for 2100 are represented in figure 4.33. Due to the constant decreasing economy and population, the space pressure is extremely low in the Waalhaven as there is enough space for working and living environments in the existing urban centers. The area becomes more and more abandoned and taken over by nature. The Rest Scenario considers that the Nieuwe Maas will still be used for inland shipping. This makes that the Waalhaven and river banks are desired to provide ultimate ecological values to function as an ecological stepping stone for migrating species. Therefore, the Rest Scenario considers a 'laissez-faire' strategy in which nature takes over the Waalhaven. The piers will slowly change according to erosion and sedimentation processes, which means that in some parts the land will grow and in some parts the land will erode. As there is no pressure on space, this is allowed and this increases the ecological values of the tidal landscape extremely. In order to increase sediment disposal, a culvert with gate is constructed at the entrance of the Waalhaven. This creates the conditions to leave water in the basin during low tide which increases the process of silting of the basin and ecological objectives are achieved earlier in time. The two piers most close to the Nieuwe Maas are prevented from erosion by the construction of cultural tidal parks. This is important to funnel the water into the basin and do not give the rising sea levels more space. Both piers are polluted due to historical land-use. Tidal nature will provide conditions to purify the soil, combined with extensive recreation and re-use of sea containers for innovative start-ups, see figure 4.32. The northern part of the RDM pier is subjected to sedimentation so there the tidal nature will grow itself. The northern part of the Sluisjeskade is subjected to erosion, so a length dam in the river is needed to reduce eroding and stimulate sediment disposal. On the long term, the basin will be used as a large scale recreational landscape with optimal ecological values. Along the former piers holiday houses are developed to make tourists experience the ultimate Dutch Delta Landscape. Locals are using the basin for extensive recreation, such as hiking and bird spotting. In the weekends they visit the tidal food production fields where they cultivate their own food in order to live self-sufficient. A more detailed explanation of this strategy can be found in appendix 6.

▲ Figure 4.32 | Purifying tidal landscape with extensive recreation behind the length dam along the Nieuwe Maas (source: by author)

legend

- extend existing routes from city towards harbour
- extend existing green structures to connect in the large scale ecological network
- connect to existing Zuiderpark
- wetland park, connected to Zuiderpark and part of climate dike
- heightened office park combined with urban farming as part of climate dike
- current primary dike, upgraded to climate dike
- city dike park with gradual slope towards primary dike
- intersections between east west routes and climate dike parks provide varied experience
- tidal city park with intensive types of recreation
- development of tidal parks
- quays which have to be maintained and transformed into cultural tidal parks as they are located in erosion area
- dam in length of river to reduce erosion and stimulate sediment disposal
- landfill area which will be combined with offices
- transparent office development along main road
- spatial develoment of piers is related to urban tissue of Wielewaal
- holiday / tourism houses along wooden paths in tidal landscape, providing unique holiday experience
- local food production where inhabitants can grow their own food. Different types of food production in water and on land, related to the salt gradient, the ground water level and the subjection to the tides.
- culvert with gate (klepduiker), providing conditions to leave the water in the basin during low tide which increases sediment disposal.
- purifying tidal park with reuse of sea containers, providing a clean soil to improve ecological values and the occupation of the sea containers by creative and catering industry and starters improves liveliness
- Nieuwe Maas is still in use for inland shipping
- use existing urban farming project in the city to create a foodhub in the intertidal park, creating opportunities for inhabitants to sell their locally produced food or buy it from their neighbours

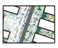


▲ Figure 4.33 | Envisioned long-term future in the Rest Scenario (source: by author)

legend

The dredging activities are quit and the Waalhaven no longer knows any harbor related activities. As the sediment disposal is showing exponential growth, the basin gets more and more silted. Therefore, the gradient between land and water is very long with an unsteep slope, providing optimal ecological values. The area consists of nature types like permanent water, temporary water bodies, mud flats, salt marshes, wetlands and permanently dry zones. The different types of flora and fauna which origined during the whole proces are extending and adapting itself gradually with the changing climate. The vegetation for example will transform into more salt resilient ones which are able to deal with higher temperatures.

Due to the constant subjection to rising sea levels, the tidal influence and storm waves, the natural landscape shows a dynamic movement over time. This results in a landscape with ultimate delta dynamics and characteristics.

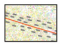


A broad climate dike on the location of the current primary dike is protecting the low located city from the rising sea levels. The existing road remains on the same location as there is no financial support to construct it underground. The road will only flood during extreme storms, but the inhabitants accept these risks and temporary disuse of the road. The climate dike consists of four different identities which creates an interesting experience when crossing the dike in east-west direction. From east to west the visitor crosses:
- A wetland park which is connected to the water structures of the Zuiderpark. This water is of high quality and improves the ecological values of this low located zone. It also functions as a climate buffer in times of peak precipitation and regulates the temperature.
- An office park with opportunities for urban farming. New offices are built alongside this dike as this provides unique and safe working environments closeby the urban center.
- The primary dike itself which is now part of the broader climate dike, providing a recreational north-south route and view points towards the Waalhaven.
- The gradual sloped city park which is able to deal with the rising sea levels. It mainly consists of grass and diagonal paths. From here, visitors can experience the tidal nature in the Waalhaven while walking or recreating in the grass.

On the Sluisjeskade new office buildings are built as this provides a unique and safe working environment closeby the urban centers and therefore easily accessible by bike or foot. People prefer to have working space closeby , but like to keep the centers itself mainly residential and to foresee in self-sufficiency.

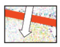
The southern part of the Sluisjeskade knows characteristic types of harbor constructions and architecture which are maintained in the current lanscape (such as cranes and historical harbor warehouses). Together with new and more dense types of offices (innovative companies, knowledge institutes, maritime services and starters) this zone can form a great business district where the history of the harbor is still visible and included. The southern quay of the Sluisjeskade is subjected to erosion and as this pier is important to maintain for funnelling the water (to increase water safety in the whole harbor basin) the quay will remain hard. This will be done in several layers of broad stairs on which the old cranes are situated. Some of the stairs will be flooded during high tide and as the stairs go together with vegetation it will still be ecologically valuable (reference: tidal park Keilehaven).

As the inhabitants of the region are very sustainable, aware of their ecological footprint and therefore circular, the focus on local food production is high. The Waalhaven and its tidal nature creates an opportunity to produce different kind of crops than the area within the dikes, for example the production of sea weed, salt potatoes and quinoa. As these kind of crops can provide regional food which extends the variety of the inhabitants' diet, the food production is still happening in the areas within the former piers.

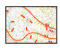


Other parts of Europe, such as Spain and France are becoming more and more warm due to climate change and the favorable Dutch climate, especially in this water-rich area, is popular for tourists. The area is known as the Dutch Riviera and tourists are eager to book an accomodation in this unique delta landscape. The Waalhaven is the ultimate location to accomodate with this demand as there is enough space and the delta characteristics are optimal. The accomodations are located along the former pier, which is now a higher located path in the landscape. The different levels of nature and ground water level demand for different types of holiday houses to fully experience the landscape. For example, some are built on poles, some are only accesible by boat and some are floating. The tourism sector becomes of huge importance for the economic growth of the region.

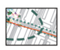
The whole landscape is combined with recreational pathways in order to provide full accessibility of the landscape. In this way, the extensive recreational types connect to the large scale recreational networ.



A culvert with gate (klepduiker) creates the possibility to let water in during high tide and close of during low tide. This makes that the water remains in the harbor basin, creating more time for the sediment to settle in order to improve ecological values faster. These type of culverts are designed to not disturb migration of species and would therefore not conflict with the ecological values which are desired.

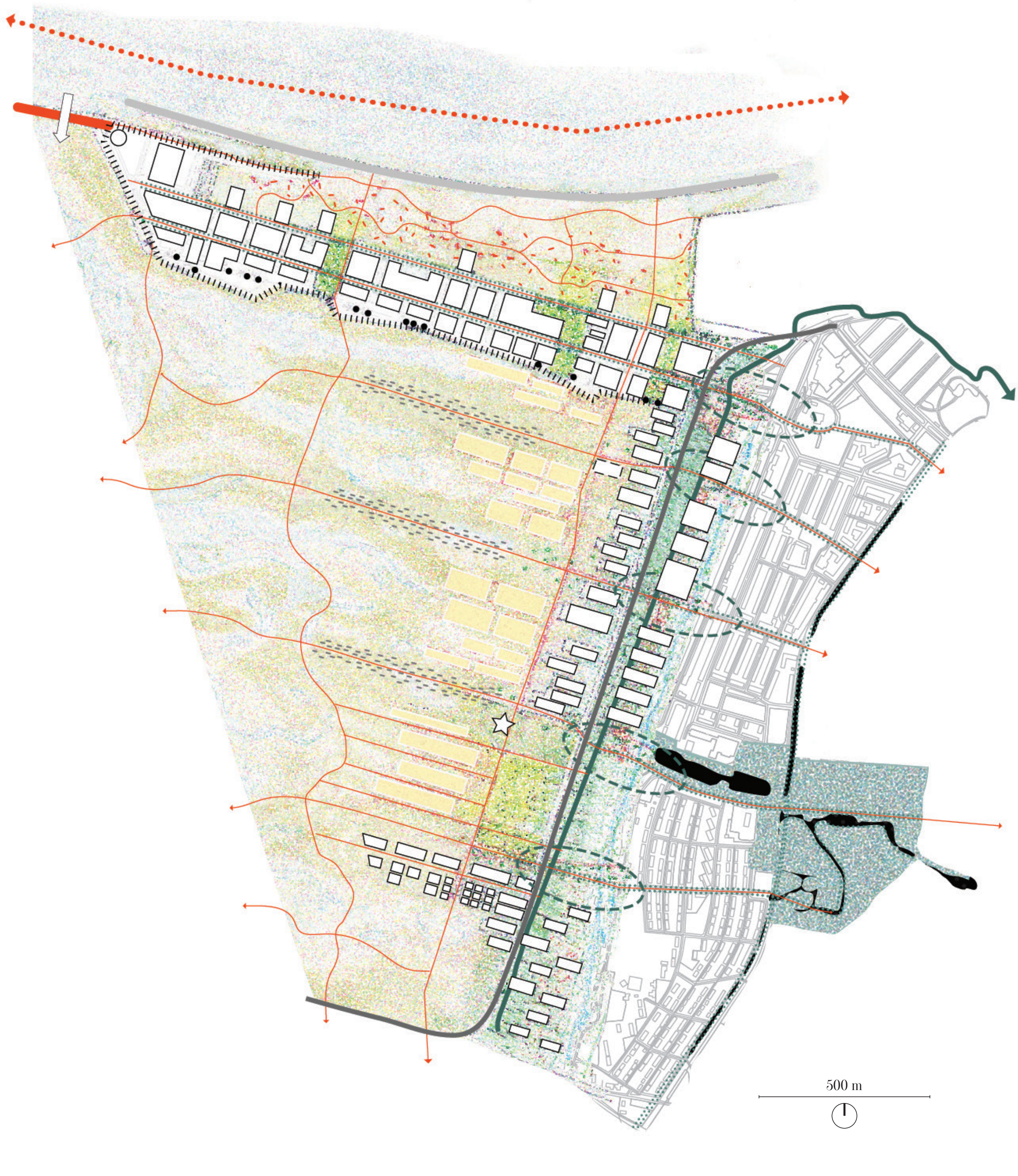


An ecological zone in the Northern part of the Sluisjeskade, along the Nieuwe Maas, functions as a migration route for species. The Nieuwe Maas is still in use for inland shipping which makes the ecological values of the river itself not extremely high. This ecological zone is of great importance for migrating species as it functions as a stepping stone between marine and terrestrial habitats. The length dam in the Nieuwe Maas provides opportunities for sediment to settle behind. As this landscape is continuously growing together with the rising sea levels, the land becomes higher and the delta dynamics become more and more visible. There is no need to cultivate this land as there is no space pressure. Also, this area can be used in a temporal way by reusing sea containers, providing possibilities for start-ups, tiny houses, creative industries, etc. which improves the liveliness.



The most important routes coming from the urban area are extended towards the Waalhaven to improve the connectivity and accessibility. The existing green structures are extended as well, to both guide visitors and function as ecological corridors between tidal and fresh nature. In the zone where the routes cross the climate dike, amenities are located to attract people from both the harbor and the city. In this way, the climate dike will function as the connecting zone between city and Waalhaven instead of functioning as a border.

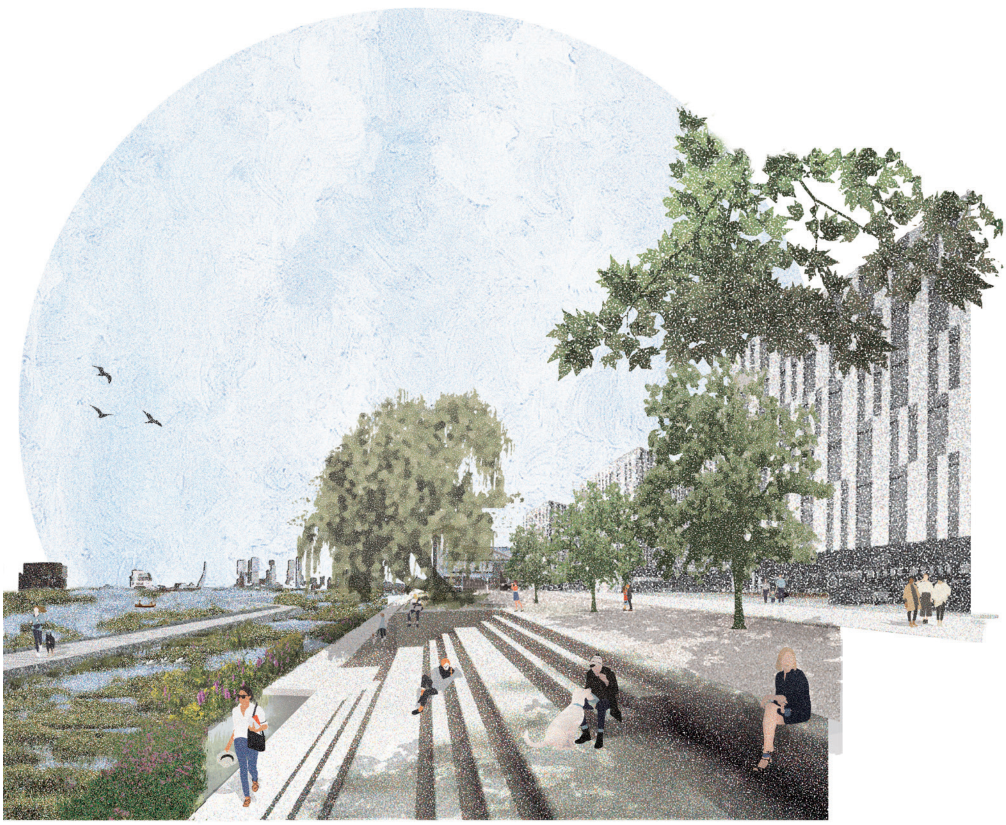
A bar and restaurant in an urban tidal park which is connected to the Zuiderpark attracts recreationalists on a large scale. Nowadays, the Zuiderpark attracts a lot of regional recreationalists, but the dike and marshalling yard forms a boundary to extend this recreation towards the Waalhaven. Now this connection is made, the Zuiderpark, climate dike and urban tidal park with bar and restaurant will function as one recreational area. This attracts more and more recreationalists to visit the whole Waalhaven.



▲ Figure 4.34 | Final state Rest Scenario (source: by author)

Steam Local Long-Term Strategy

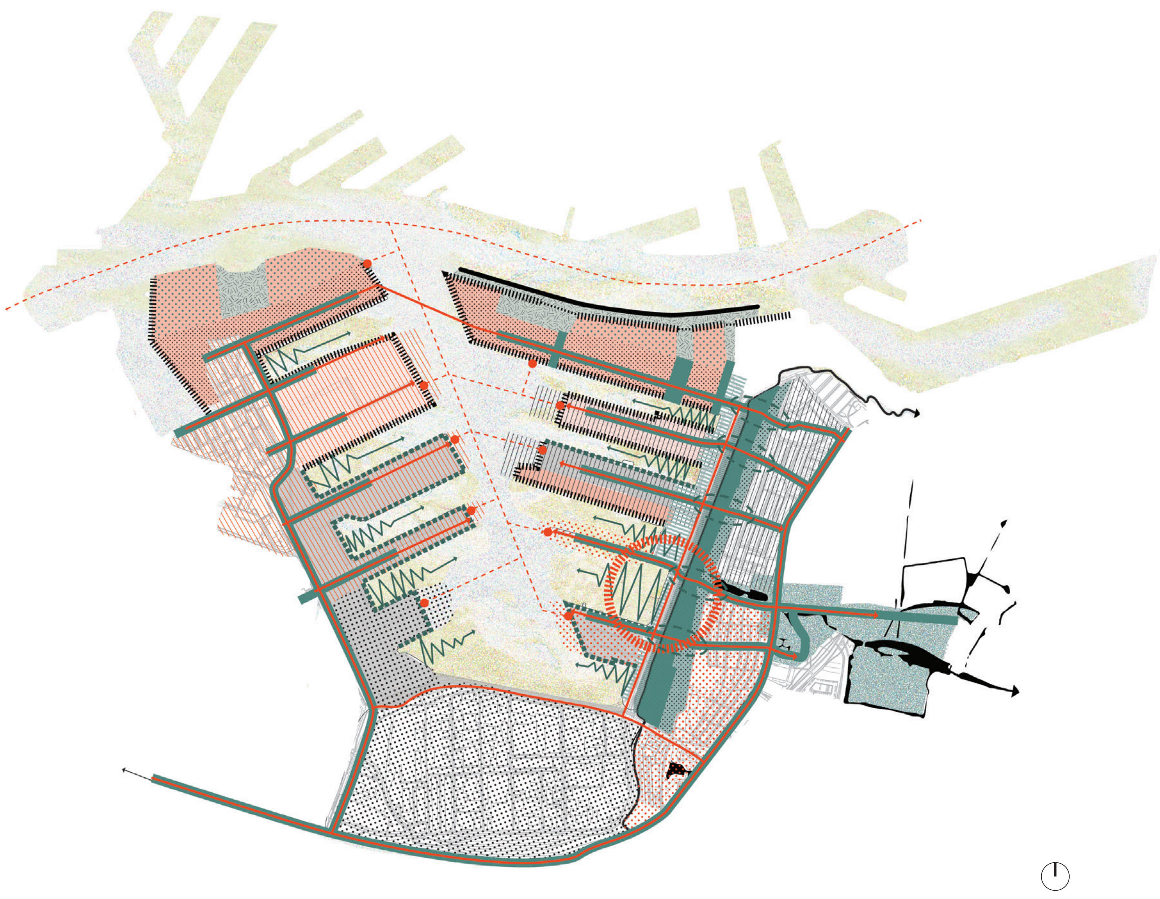
The envisioned spatial conditions for the Steam Scenario for 2100 are represented in figure 4.36. Due to the constantly growing economy and population, the space pressure is extremely high and the demand for housing and working environments keeps increasing. The dredging in the Nieuwe Maas is stopped as the risks for flooding and salinization become too high and undeepening the river can reduce these problems. The Nieuwe Maas turned into a large scale recreational tidal park, meeting the desires for more green, public space in the constantly densifying city. In order to maintain the existing piers in the Waalhaven, the quays which are subjected to erosion are developed into cultural tidal parks. The piers which are subjected to sedimentation are removed and tidal nature can develop here and make the land grow naturally due to sediment disposal. In some parts of the Waalhaven, such as the Sluisjeskade, the land grew together with the rising sea levels, making it available for further urban development, see figure 4.35. This land is now occupied by a highly intensive office district. In between the piers, urban tidal parks developed to meet the demand for green, public space for the new neighborhood. The large scale connection with the Zuiderpark and the small scale connections with the urban fabric of Charlois, Wielewaal and Heijplaat intertwine the Waalhaven in the surrounding urban fabric. In general, the risks for flooding and saline intrusion are reduced due to the undeepening of the river and basin. The broad climate dike, which extends from the primary dike towards the tidal nature, foresees in extreme safety during heavy storms. At the same time, it provides a connecting landscape between the city and the Waalhaven. As the whole region is constantly densifying, transport over water is popular. By keeping the heads of the piers accessible for boats it is made possible that inhabitants are able to commute between their living and working environment. This all together makes that the Waalhaven provides an unique new living and working environment for the city of Rotterdam. The location is close by the existing city, easily accessible, contains of high ecological and recreational values and meets the growing demand for residential and office place. A more detailed explanation of this strategy can be found in appendix 6.



▲ Figure 4.35 | Cultural tidal park in combination with purifying tidal nature behind the length dam. The long process of sediment disposal resulted in opportunities for urban occupation of the land (source: by author)

legend

- extend existing routes from city towards harbour
- extend existing green structures to connect in the large scale ecological network
- connect to existing Zuiderpark
- wetland park, connected to Zuiderpark and part of climate dike
- heightened office park combined with urban farming as part of climate dike
- current primary dike, upgraded to climate dike
- city dike park with gradual slope towards primary dike
- intersections between east west routes and climate dike parks provide varied experience
- tidal city park with intensive types of recreation
- development of tidal parks
- quays which have to be maintained and transformed into cultural tidal parks as they are located in erosion area
- tidal parks which can be closed off during high risks with a gradual slope towards a more 'dry' green public park
- dam in length of river to reduce erosion and stimulate sediment disposal
- landfill area which will be combined with offices
- land which is purified by tidal nature and grew due to sediment disposal and is now occupied for offices
- transparent office development along main road
- spatial develoment of residential buildings on piers, related to urban tissue of Wielewaal
- spatial develoment of residential and office buildings on piers, related to urban tissue of old Charlois
- spatial develoment of office buildings on piers, related to urban tissue of Waalhaven Zuid
- spatial develoment of residential buildings on piers, related to urban tissue of Heijplaat
- accessibility of head of piers by recreational and daily transport on water
- recreational pedestrian and cycling bridge, connecting the Waalhaven in the large scale recreational network
- quays which are subjected to sediment disposal and can be removed and turned into tidal parks without the risks of losing land
- areas which are flooded on the short term (10-20 cm sea level rise), become land fill sites (constructed with soil coming from dredging activites within the functioning parts of the harbour) and are occupied for residential use
- areas which are flooded during spring tide and extreme storms create an unique living environment with higher constructed buildings and infrastructure and water squares which are flooded during high tide
- areas which are low located in a sediment disposal area and grew gradually over time, which finally provides a safe, higher located site available for urban development



▲ Figure 4.36 | Envisioned long-term future in the Steam Scenario (source: by author)

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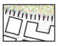
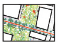
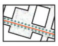


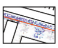
The current height of the Sluisjesdijk will flood when the sea level rise with 195 cm. The Northern part has, due to a slow process of silting of sediment, grown together with the rising sea levels. When the land became high enough some parts became occupied by office buildings to meet the growing demand. for workspace. The Sluisjesdijk now forms a business card towards the Nieuwe Maas with a highly functional, modern and safe business district.



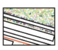
The parts in the Sluisjesdijk which used to be the three small harbor basins are now functioning as green, public space within the business district. The parks are of high value for the business district as it provides green, public space, is able to regulate peak precipitation, regulates the temperature and creates visible and spatial connections to the delta landscape.



A green promenade on the location of the former river dike connects the urbanised Sluisjesdijk within the larger scale recreational and ecological network. The green structures are extended from the existing green structures in the city, which improves accessibility and ecological values. Transporting on this promenade provides the visitor with an attractive change of experience as it crosses several parks which provide a visual connection to the delta landscape and is interspersed with more urban squares and parks. On the head of the Sluisjeskade, the promenade continues in a pedestrian and cycle bridge which extends the route towards the RDM terrain, improving accessibility of both piers.



During spring tide and storm waves, pier 1 will be flooded, so therefore the buildings and roads are constructed 1.50 m higher than the pier ground level. During spring tide, an unique living environment will arise where the whole pier is flooded, leaving water in the provided water squares in the middle of the pier. These squares are filled with water during spring tide which increases awareness among inhabitants and can function as a safe playground for children to get acquinted with nature. Besides that, the water which remains in the squares for a while will regulate the temperature on the pier. It also increases land and real estate values as the water squares can be designed as high quality public space. As the roads and buildings are build higher, the people are still able to access their houses and continue life.



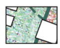
Pier 2 will be fully flooded with 195 cm sea level rise. The northern part of pier 2 is subjected to sedimentation while the southern part is subjected to erosion. Therefore the southern has been heightened with landfill and the northern part grew naturally for several decades. This now provides the opportunity to occupy it for residential land-use. The dwellings and public space will have a village type of identity to relate it to the more rural identity of the urban area within the dikes. These dwellings can partly meet the growing demand for new residentíal space.

In order to provide opportunities to transport on water and to escape the slow transformation on land due to the crowded and dense urban areas, the head of the piers are accessible by boat. This is managed by partly dredging the boat routes. A major part of the inhabitants of this scenario have their own boat so this provides opportunities to live in the Waalhaven, but work in the center of Rotterdam or Dordrecht. The head of the piers are accomodated with recreational harbors where people can store their boat.

The tidal landscape in between the piers is cultivated for recreational purposes and provide green, but cultural tidal parks. The more close to the climate dike, the higher the level of culture and the more towards the delta landscape the higher the level of nature. These parks provide recreational opportunities for inhabitants and working people and increase the land values of surrounding piers.

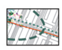
The tidal landscape more towards the head of the piers and the middle of the harbor basin has natural delta characteristics with high ecological values. This zone, in relation to the permanent water bodies and the dryer nature types more to the east, provide migration routes for species between the water, tidal nature, climate dike, fresh wetland nature and are finally able to migrate through the Zuiderpark to the larger context of the delta.

The southern part of the Sluisjeskade knows characteristic types of harbor constructions and architecture which are maintained in the current lanscape (such as cranes and historical harbor warehouses). Together with new and more dense types of offices (innovative companies, knowledge institutes, maritime services and starters) this zone can form a great business district where the history of the harbor is still visible and included. The southern quay of the Sluisjeskade is subjected to erosion and as this pier is important to maintain for funnelling the water (to increase water safety in the whole harbor basin) the quay will remain hard. This will be done in several layers of broad stairs on which the old cranes are situated. Some of the stairs will be flooded during high tide and as the stairs go together with vegetation it will still be ecologically valuable (reference: tidal park Keilehaven).



A broad climate dike on the location of the current primary dike is protecting the low located city from the rising sea levels. The existing road is constructed underground, because the sea level rise makes it too vulnerable for flooding. The climate dike consists of four different identities which creates an interesting experience when crossing the dike in east-west direction. From east to west the visitor crosses:

- A wetland park which is connected to the water structures of the Zuiderpark. This water is of high quality and improves the ecological values of this low located zone. It also functions as a climate buffer in times of peak precipitation and regulates the temperature.
- An office park with opportunities for urban farming. New offices are built alongside this dike as this provides unique and safe working environments closeby the urban center.
- The primary dike itself which is now part of the broader climate dike, providing a recreational north-south route and view points towards the Waalhaven.
- The gradual sloped city park which is able to deal with the rising sea levels. It mainly consists of grass and diagonal paths. From here, visitors can experience the tidal nature in the Waalhaven while walking or recreating in the grass.

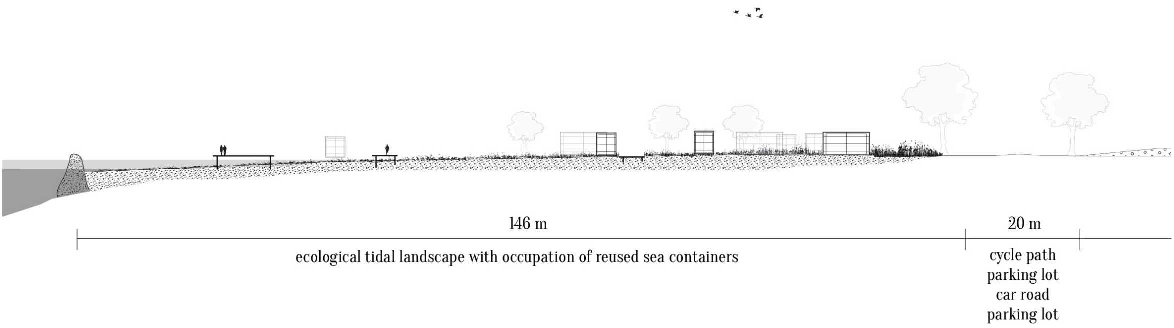


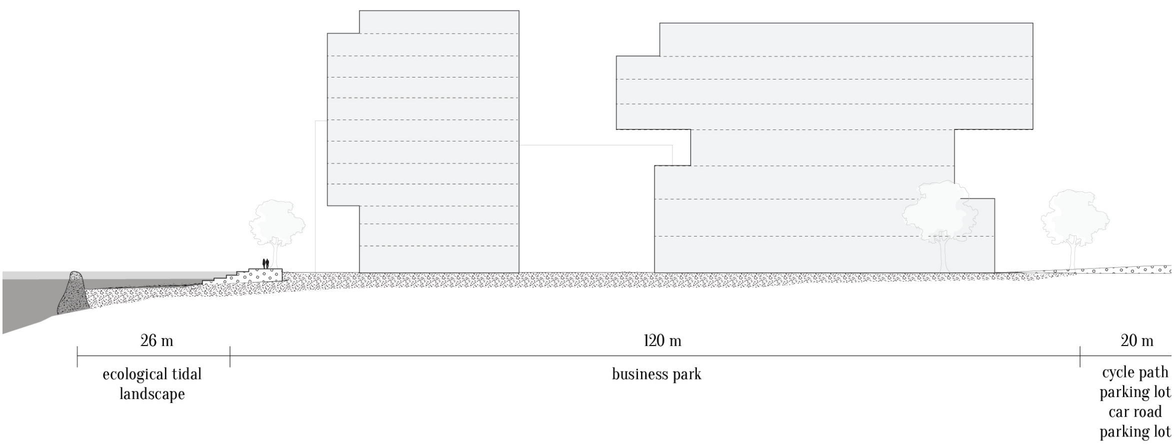
The most important routes coming from the urban area are extended towards the Waalhaven to improve the connectivity and accessibility. The existing green structures are extended as well, to both guide visitors and function as ecological corridors between tidal and fresh nature. In the zone where the routes cross the climate dike, amenities are located to attract people from both the harbor and the city. In this way, the climate dike will function as the connecting zone between city and Waalhaven instead of functioning as a border.

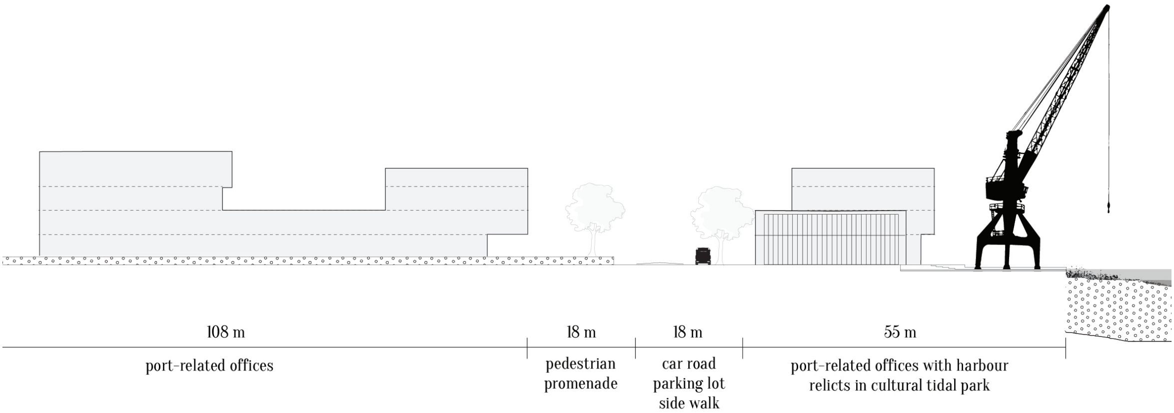
A bar and restaurant in an urban tidal park which is connected to the Zuiderpark attracts recreationalists on a large scale. Nowadays, the Zuiderpark attracts a lot of regional recreationalists, but the dike and marshalling yard forms a boundary to extend this recreation towards the Waalhaven. Now this connection is made, the Zuiderpark, climate dike and urban tidal park with bar and restaurant will function as one recreational area. This attracts more and more recreationalists to visit the whole Waalhaven.

▲ Figure 4.37 | Final state Steam Scenario (source: by author)

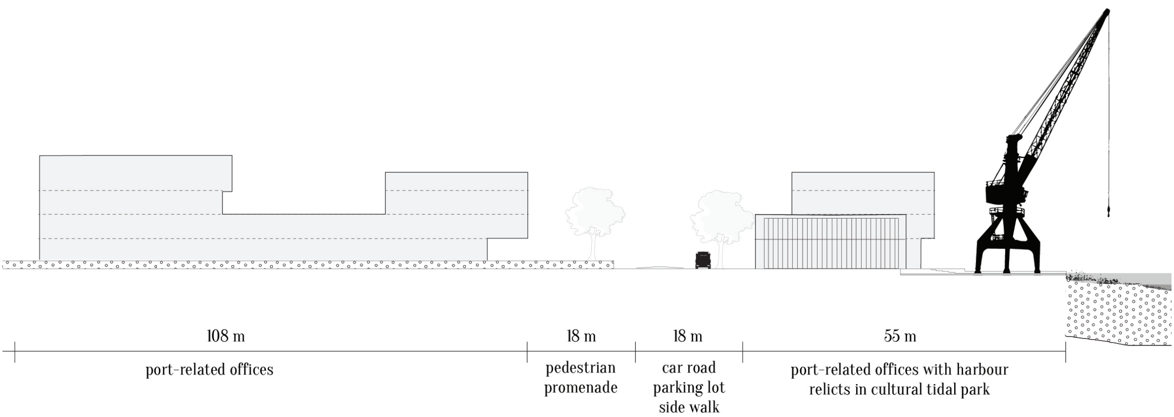
Sluisjeskade Rest and Steam Scenario







▲ Figure 4.38 | Section Sluisjesdijk final state Rest Scenario (source: by author)



▲ Figure 4.39 | Section Sluisjesdijk final state Steam Scenario (source: by author)

5

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backcasting ecosystem services in the search for ‘no regret’ measures

5.01. Local Conditions to Consider for Phasing

Conditions which are related to the occupation layer of Meyer and Nijhuis (2016), such as current land-use are conditions which are changing according to changing circumstances, such as short-term events and actions of people and politics. Conditions related to the network layer would change on the mid-long term. In this way, these conditions are different than for example the dynamics of the river as they are more easily able to change according to changing desires through time. Therefore, these conditions are considered for the backcasting, resulting in the phasing of the project.

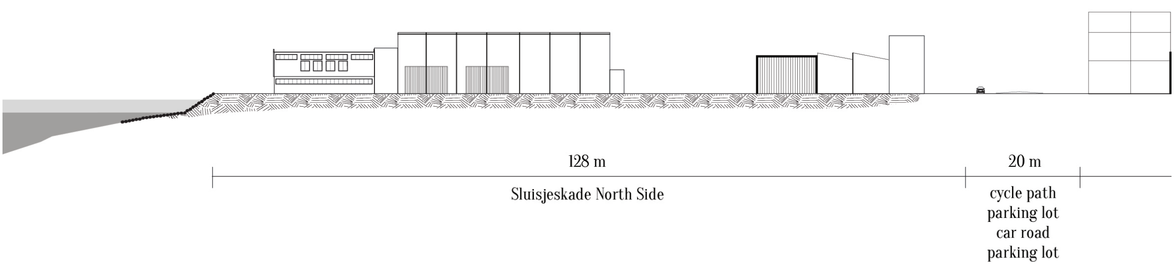
Land Use - Short Term

Nowadays, the Waalhaven is still in use by the harbor, which demands for a strategy which transforms the basin in such a way that the existing harbor activities are not obstructed. Together with that, the gradual transformation of the basin should provide values for the harbor to make sure the Port of Rotterdam is willing to collaborate and invest. The current land-use of the Waalhaven and surroundings is shown in figure 5.1.

▲ Figure 5.1 | Existing land-use of the Waalhaven and surroundings (source: by author)

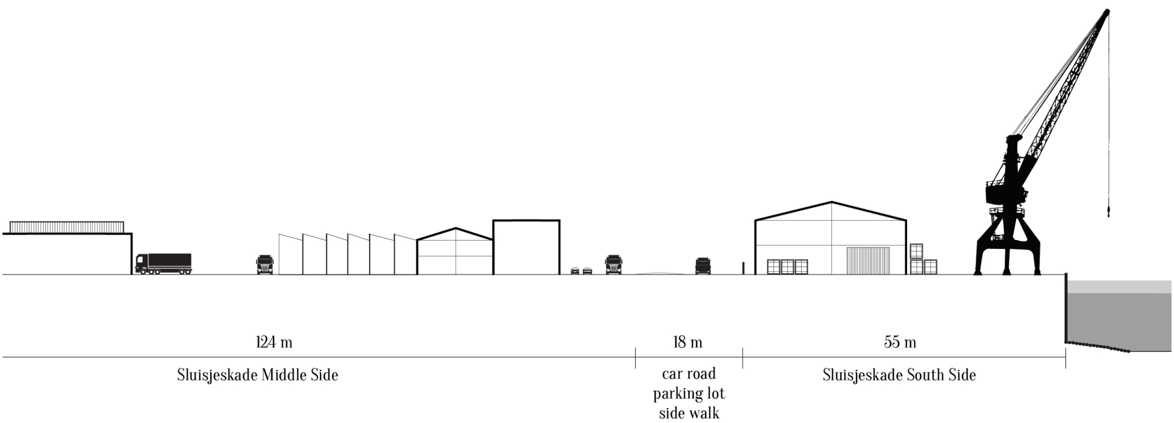
A section of the Sluisjeskade, showing the spatial layout of a pier with existing harbor activities, is represented in figure 5.2. The Sluisjeskade can be divided in three strokes: north, middle and south. In between the northern and middle stroke there is the Sluisjesdijk, which used to be the historical river dike. The northern part used to know some heavy industries, like petroleum storage, which polluted the soil (Ontwikkelingsmaatschappij Stadshavens, 2005). The southern part (middle and south stroke) was area within the dikes and consisted of polders with historical building lines along the dike. Those historical buildings are transformed into industrial buildings around the 30's of the 20th century (see figure 5.3). Later also the northern stroke transformed into more modern types of industries. Nowadays, in the southern stroke there is still a visible harbor activity with cranes, the middle part is strongly outdated, messy and of low quality (see figure 5.4) and the northern part is more modern and functional, but has high potentials to develop into a modern business district due to its location along the river.

In the area between the harbor and the city (neighbourhoods Oud-Charlois and Wielewaal) there are three areas of which the existing land use has to transform to implement the strategy (see figure 5.1). The Spuizone (3) is a linear, industrial zone which is nowadays still functioning with businesses like graphic design, printshops and storage, but will slowly become available for transformation as it creates a huge boundary between city and harbor (Programma NPRZ, 2013). Between the Spuizone and the NAM-terrain there is a closed of area with a day-care and soccer club, which is not integrated in the surroudings. These types of land-use provide opportunities for integration within the larger context of the Zuiderpark. The NAM-terrain (5) is not yet available for transformation, but will follow soon, indicated between 2025 and 2030 (dS+V, Port of Rotterdam and DCMR, 2010).



▲ Figure 5.3 | Southern part of Sluisjeskade (source: by author)

▲ Figure 5.4 | Middle part of Sluisjeskade (source: by author)



▲ Figure 5.2 | Section of existing situation Sluisjeskade (source: by author)

The main function of the Waalhaven nowadays is a container and transhipment terminal, in combination with more and more offices (see figure 5.5). The land use types related to the transhipment of cargo and goods, the container and the bulk terminals are strongly independent on their location along the water. This is also why most quays in this harbor are hard and straight or hard with a gradient, see figure 5.6, 5.7 and 5.8.

Both facts are constraining for the development of tidal nature in the Waalhaven. First of all, as long as the transhipment of cargo and goods and the container and bulk terminals are in function and dependent on their relation between land and water, the ships have to be able to moor. This desires for the maintenance of existing quays and water depth. The second constraint is that the existing quays are not providing ecological values and the transition to a gradual river bank is costly and takes time.

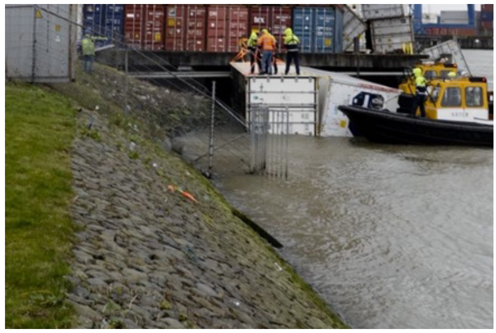
legend
- transhipment of cargo and goods (transfer water and land)
- containers (transfer water and land)
- bulk terminals (transfer water and land)
- other industries / offices
- shipping and mooring

▲ Figure 5.5 | Specific land-use types within the harbor (source: by author)

legend

- mooring places
- hard and straight quay
- hard and gradual quay
- semi-hard and gradual quay

▲ Figure 5.6 | Hard and straight quay (source: Gebr. de Koning)

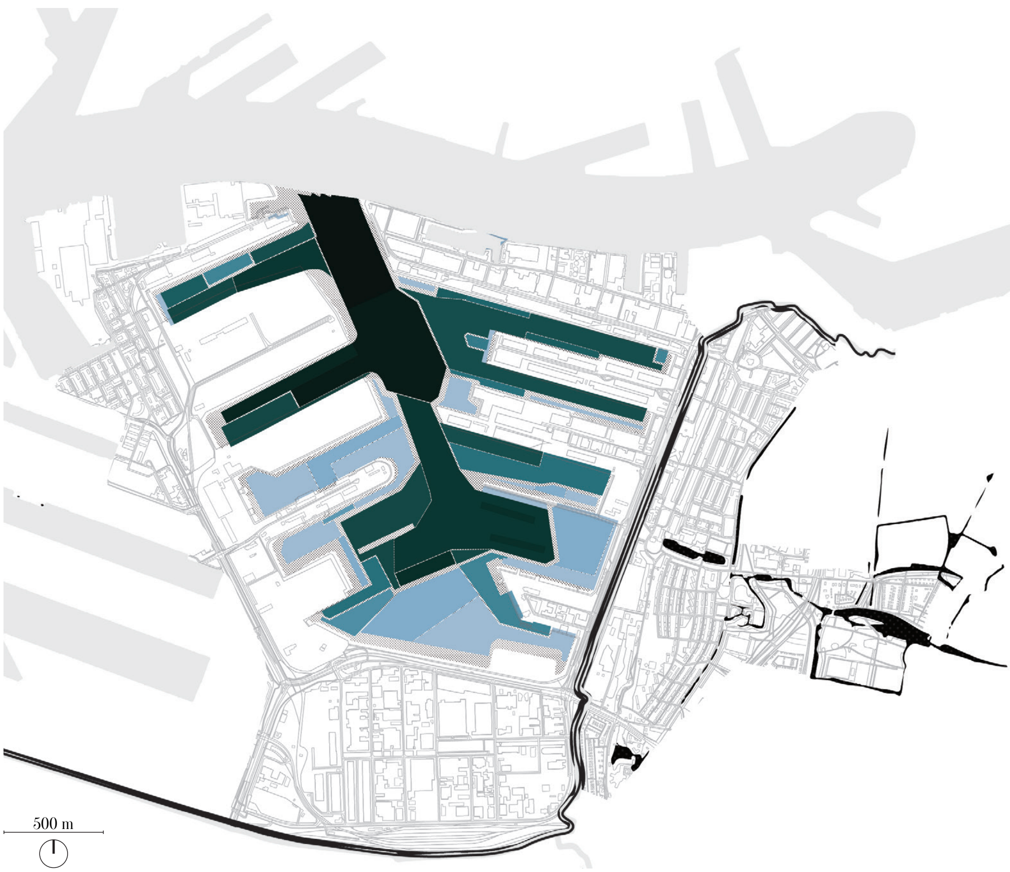


▲ Figure 5.7 | Hard and gradual quay (source: Zeevaart)

▲ Figure 5.8 | Quay constructions and mooring places (source: by author)

In order to make sure the entering ships are able to arrive in the Waalhaven there is a desired water depth, see figure 5.9. As long as the land-use functions, as described before, still desire the relation between land and water this water depth has to be maintained. The areas which are less deep already and does not function as mooring place for ships are a first location to turn into tidal parks as the development towards a gradual river bank demands for less measures. This for example considers the zone in Waalhaven-Zuid, between pier 3 and 4, between pier 6 and 7 and between pier 7 and 8.

legend
-2.65 m + NAP
-3.65 m + NAP
-4.65 m + NAP
-5.65 m + NAP
-6.50 m + NAP
-6.65 m + NAP
-7.65 m + NAP
-8.65 m + NAP
-9.50 m + NAP
-9.65 m + NAP
-10.65 m + NAP
-11.65 m + NAP
-12.00 m + NAP
-12.65 m + NAP
-13.15 m + NAP
-14.15 m + NAP
-14.25 m + NAP
-14.50 m + NAP



▲ Figure 5.9 | Current water depth, desired for harbor activities, shipping and mooring (source: by author)

As explained before, the Waalhaven is subjected to flood risks, especially when taking into account the increasing sea levels. The risks for flooding related to the existing heights are represented in figure 5.10. However, this height cannot directly be projected to the economic loss it delivers. Some of the land use types are more vulnerable for flooding than others, resulting in higher economic loss. Therefore, the Port of Rotterdam defined the order in which the piers become too vulnerable for flooding, considering the land use types in relation to existing heights. The higher the number, the earlier the economic loss is outreaching the measures to take against sea level rise (Royal Haskoning DHV, 2018). For this thesis, this information is used to define which pier can be transformed before the other.

legend

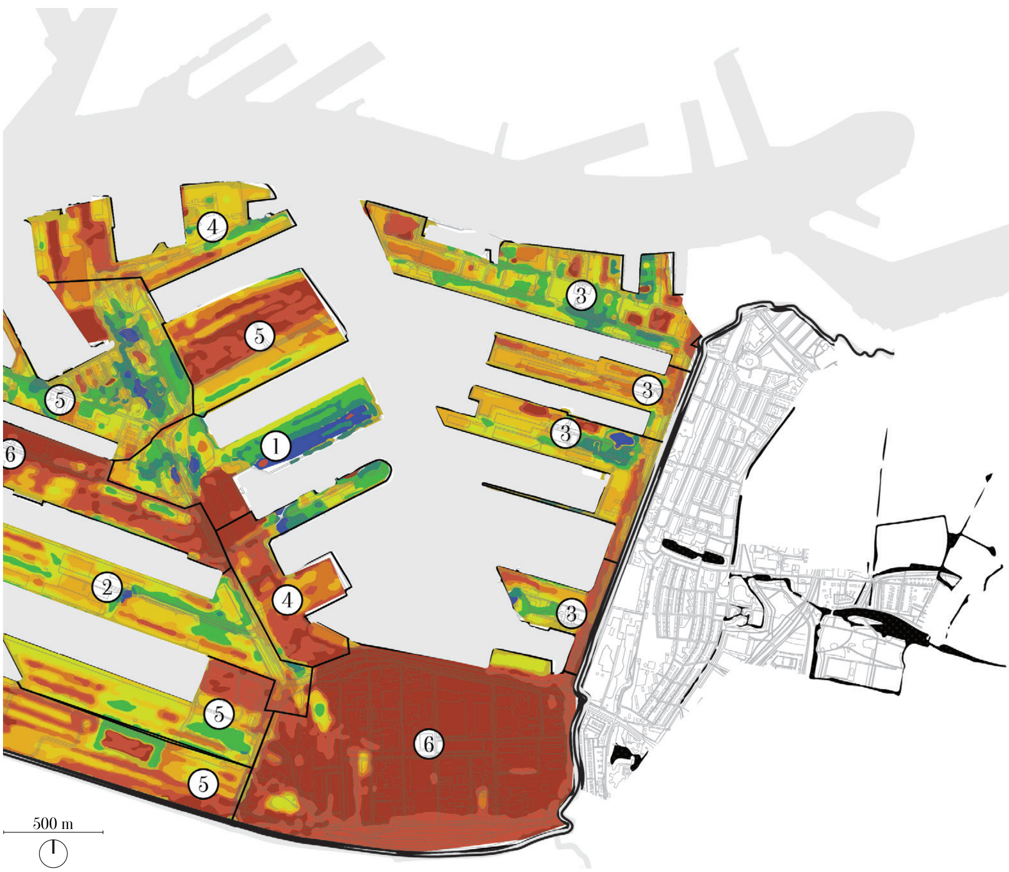
flood risks

- < +2.9 m NAP - flood risk with 0 cm sea level rise
- +2.9 m NAP - flood risk with 0 cm sea level rise
- +3.00 m NAP - flood risk with 0 cm sea level rise
- +3.10 m NAP - flood risk with 10 cm sea level rise
- +3.20 m NAP - flood risk with 20 cm sea level rise
- +3.30 m NAP - flood risk with 30 cm sea level rise
- +3.40 m NAP - flood risk with 40 cm sea level rise
- +3.50 m NAP - flood risk with 50 cm sea level rise
- +3.60 m NAP - flood risk with 60 cm sea level rise
- > +3.60 m NAP - flood risk with >60 cm sea level rise

economic consequences of flooding related to land use

1. economic loss with 0 cm sea level rise
2. high economic loss with 35 cm sea level rise
3. economic loss with 35 cm sea level rise
4. high economic loss with 85 cm sea level rise
5. economic loss with 85 cm sea level rise
6. not at risk with 85 cm sea level rise

- water



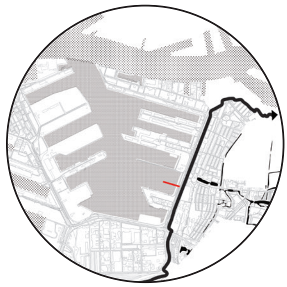
▲ Figure 5.10 | Flood risks and its related economic consequences for the Port of Rotterdam (source: by author)

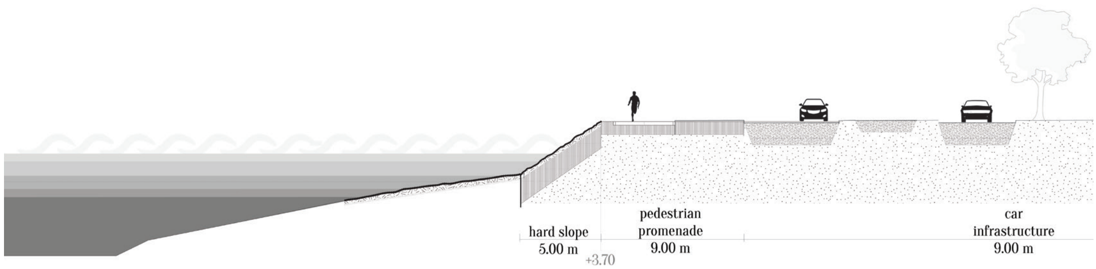
Infrastructure - Mid-Long Term

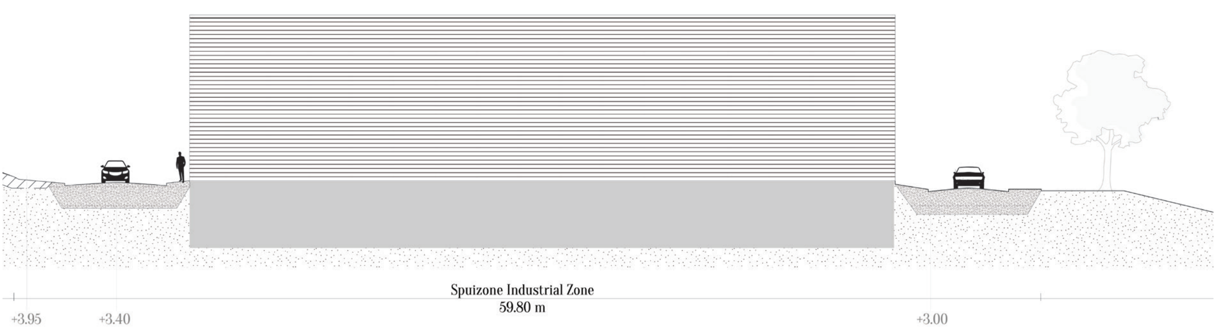
The full section of the area between the harbor and the city (Waalhaven Oost) is represented in figure 5.11, starting at the water and quay and ends at the historical building line, the Zuidhoek. Please note that the two sections together form one wide profile. The dike shown on the right side of the upper section continues on the left side of the lower section.

The section shows the infrastructural line and marshalling yard is located at +3.70 m NAP, which means it is risk area for flooding by 70 cm sea level rise. The dike is located at +5.60 m NAP and is 12 m wide. The water level which is normative for this part of Rotterdam is +3.50 m NAP. The average dike height is defined by adding +1.00 m on top of this normative in order to deal with storms and related water levels (Hoogheemraadschap van Schieland en de Krimpenerwaard, 2016). This means the dike height is sufficient until a sea level rise of 1.10 m is reached. However, the dike height is not always leading for the water safety as a narrow dike can collapse relatively easily, which could have enormous water depths within the dikes as a result. The rising sea levels could therefore also be tackled by broadening the dikes in order to make sure that a collapse is hardly possible.

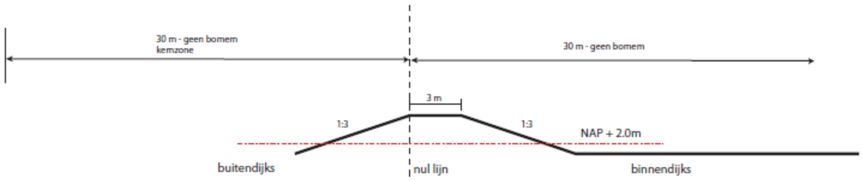
The industrial zone (Spuizone) is now located too close to te primary dike, considering the protection zone (see figure 5.12 and 5.13). The need for dike enforcements would therefore mean that the buildings have to be demolished. The Spui, which is the lower located area between the industrial zone and the historical building line will flood first during heavy storms or a dike collapse. The historical building line is the historical primary dike and is therefore located higher in the landscape (+2.50 m NAP). This fact could be used to create an intertidal area in the low located Spui. However, it would not prevent the urban area from flooding when the primary dike collapses as the height is not sufficient.



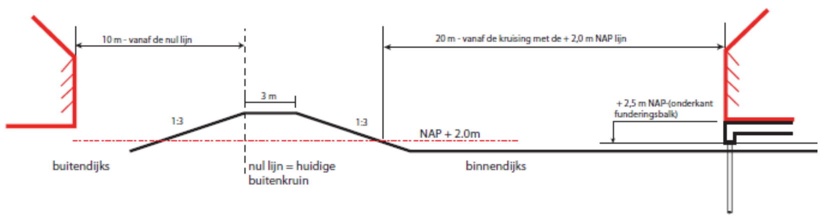




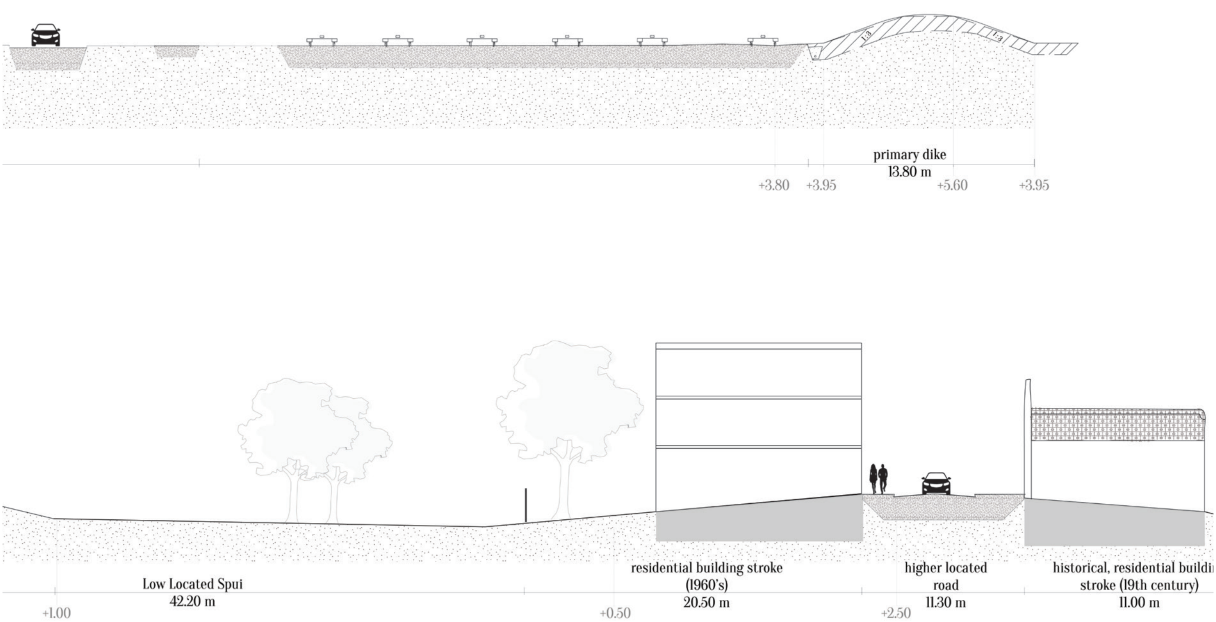
The primary dike is a central line between the harbor and the city and therefore also an important line in the strategy. A constraint relating to the dike is that there is a protection zone on both sides to ensure the safety and strength of the dike. For new buildings and trees this zone is limiting the freedom in new developments. The rules for new buildings and trees in the protection zone of the primary dike is represented in the sections in figure 5.12 and 5.13 (Hoogheemraadschap van Schieland en de Krimpenerwaard, 2016).



▲ Figure 5.12 | Protection zone primary dike: minimal distance for planting trees (source: Hoogheemraadschap van Schieland en de Krimpenerwaard)



▲ Figure 5.13 | Protection zone primary dike: minimal distance for buildings (source: Hoogheemraadschap van Schieland en de Krimpenerwaard)

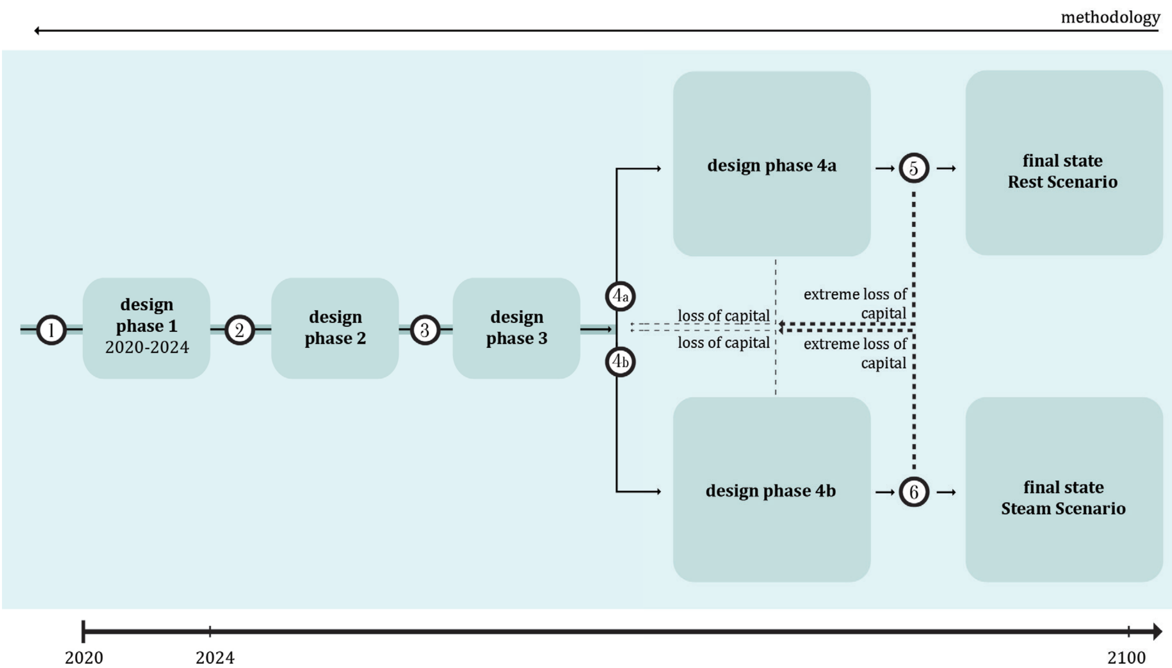


▲ Figure 5.11 | Section of existing situation Waalhaven Oost (source: by author)

5.02. Backcasting Ecosystem Services

Uncertainty Framework

In order to provide a framework for decision-makers to adapt the design through time according to the reaching of tipping points, the uncertainty framework in figure 5.14 is developed. The tipping points define the point in time when a limit is reached and specific measures have to be taken to react to the tipping point, resulting in a different phase of the design. These measures and design phases are further described later in this section.On the long term (2100) one of the plausible futures will be reality, but until then it is unsure which one it will be. It depends on the uncertainties through time and the reaching of the tipping points, because they direct towards specific scenarios. The numbers in the diagram, representing the tipping points, are described in the legend.



▲ Figure 5.14 | Uncertainty Framework (source: by author)

legend

1
- Economic growth continues for more than 5 years, resulting in a demand for the development of (port-related) working space.
- Awareness of rapidly increasing sea level rise and the related risks for the harbour basin and surrounding urban areas, due to the publication of Deltares (2018).
- The development of the first east-west connection (a pedestrian bridge) between the Zuiderpark and pier 3 as a first step to connect the Waalhaven in the recreational context.
- The northern part of pier 4 loses its harbor function.

2
- Economic growth continues for more than 10 years
- Population growth for more than 10 years, resulting in a demand for expansion areas for the constantly densifying city.
- The lose of harbor activities on Pier 4, the middle part of the Sluisjesdijk and some parts of the northern part of the Sluisjesdijk.
- NAM-terrain, Spuizone and marshalling yard become available for transformation.

3
- Economic growth continues for more than 15 years
- Population growth for more than 15 years
- The sea level shows a substantial growth which corresponds to at least the middle value of the calculated numbers of Deltares (2018), which alarms companies on pier 2 for the risks and makes them move out of the Waalhaven.
- The lose of harbor activities on the whole Sluisjesdijk.

4a
- Economic declines for more than 10 years, resulting in less demand for offices
- Population declines for more than 10 years, resulting in less demand for the development of houses outside the existing urban centers
- Harbor loses global position, resulting in a focus on inland shipping and the newer, larger and more modern harbor basins.
- Paris Agreement is achieved, meaning the temperature rise remained below 2 degrees Celsius and CO_2 emissions are strongly reduced. The numbers for sea level rise would correspond with the RCP4.5 scenario of Deltares (2018).
- The sea level shows a substantial growth which corresponds to at least the middle value of the calculated numbers of Deltares (2018), which alarms companies on pier 1 for the risks and makes them move out of the Waalhaven.

4b
- Economic growth continues for more than 10 years
- Population growth continues for more than 10 years.
- Harbor maintains global position and container ships keep on growing, resulting in the Nieuwe Maas being too small and undeep to meet the changes. This results in a stop in dredging activities in the Nieuwe Maas.
- Paris Agreement is not achieved, meaning the temperature rise will be between 2 and 4 degrees Celsius. CO_2 emissions are not substantially decreased, which stimulates climate change. The numbers for sea level rise would correspond with the RCP8.5 scenario of Deltares (2018).
- The sea level shows a substantial growth which corresponds to at least the middle value of the calculated numbers of Deltares (2018), which alarms companies on pier 1 for the risks and makes them move out of the Waalhaven.

5
- Economy declines for more than 10 years
- Population declines for more than 10 years, resulting in less demand for the development of houses outside the existing urban centers
- Former piers show a constant process of loss and dynamic movement of land. When more than 20 percent of the original location of the piers changed, the tipping point is reached as the recovery of the piers would result in too much capital destroyment.
- Silting of head of piers. Due to the constant process of natural sedimentation, at one point the head of piers will be silted. The reaching of this tipping point would mean the piers are not accessible by boats, which is desired in the Steam Scenario. Making the water again deep enough for boats would mean: dredging. This would destroy the natural delta landscape as it developed over time due to changing currents and disturbances and therefore results in extreme capital destroyment.
- Tourism sector shows a substantial growth for more than 10 years thanks to the unique delta landscape.

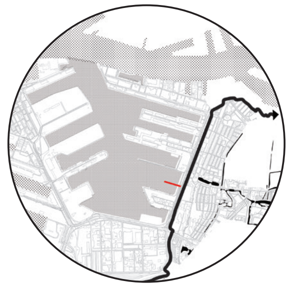
6
- Economic growth continues for more than 10 years
- Population growth continues for more than 10 years.
- Unaccessible Nieuwe Maas for inland shipping. As the dredging activities are stopped in phase 4b, the Nieuwe Maas slowly undeepens. Reaching this tipping point means the harbor's focus would remain globally and not on inland shipping. Making the Nieuwe Maas accessible for shipping again would result in a huge loss of capital.

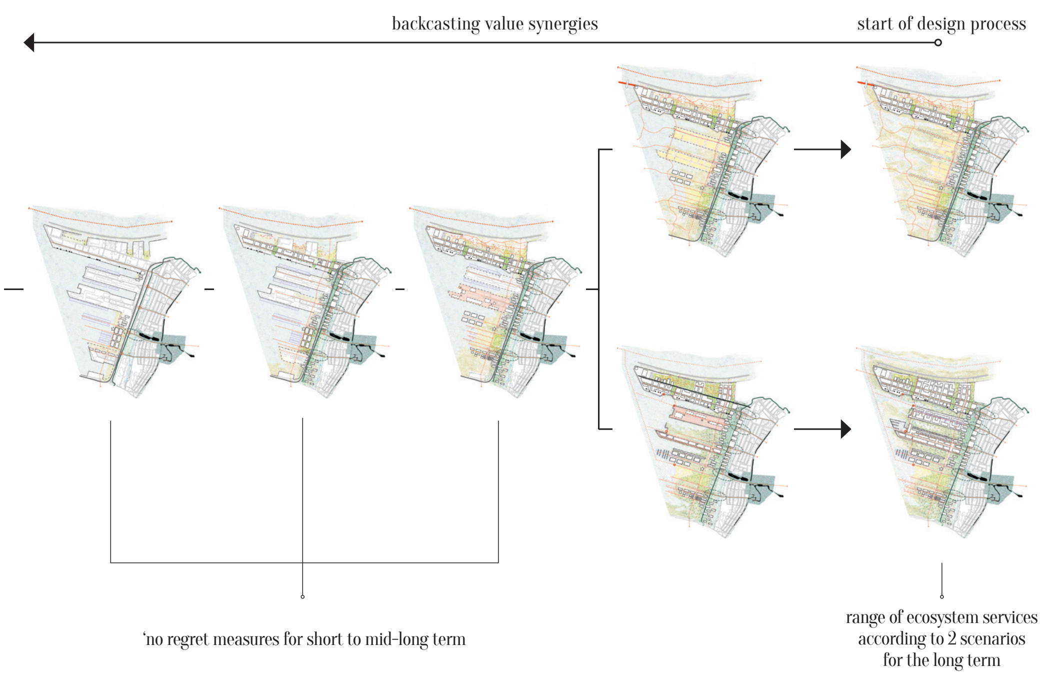
Phasing

The design process started with determining the range of ecosystem services for both scenarios The value synergies among both scenarios are important 'no matter what' and are therefore used to backcast the ecosystem services. This results in the 'no regret' measures for the short- and mid-long term (see figure 5.15). Besides the search for 'no regret' measures, the backcasting also provides a phasing strategy for implementation of the project. In this way, the design can be implemented in different phases, for which the partnership can be reconsidered between each phase.

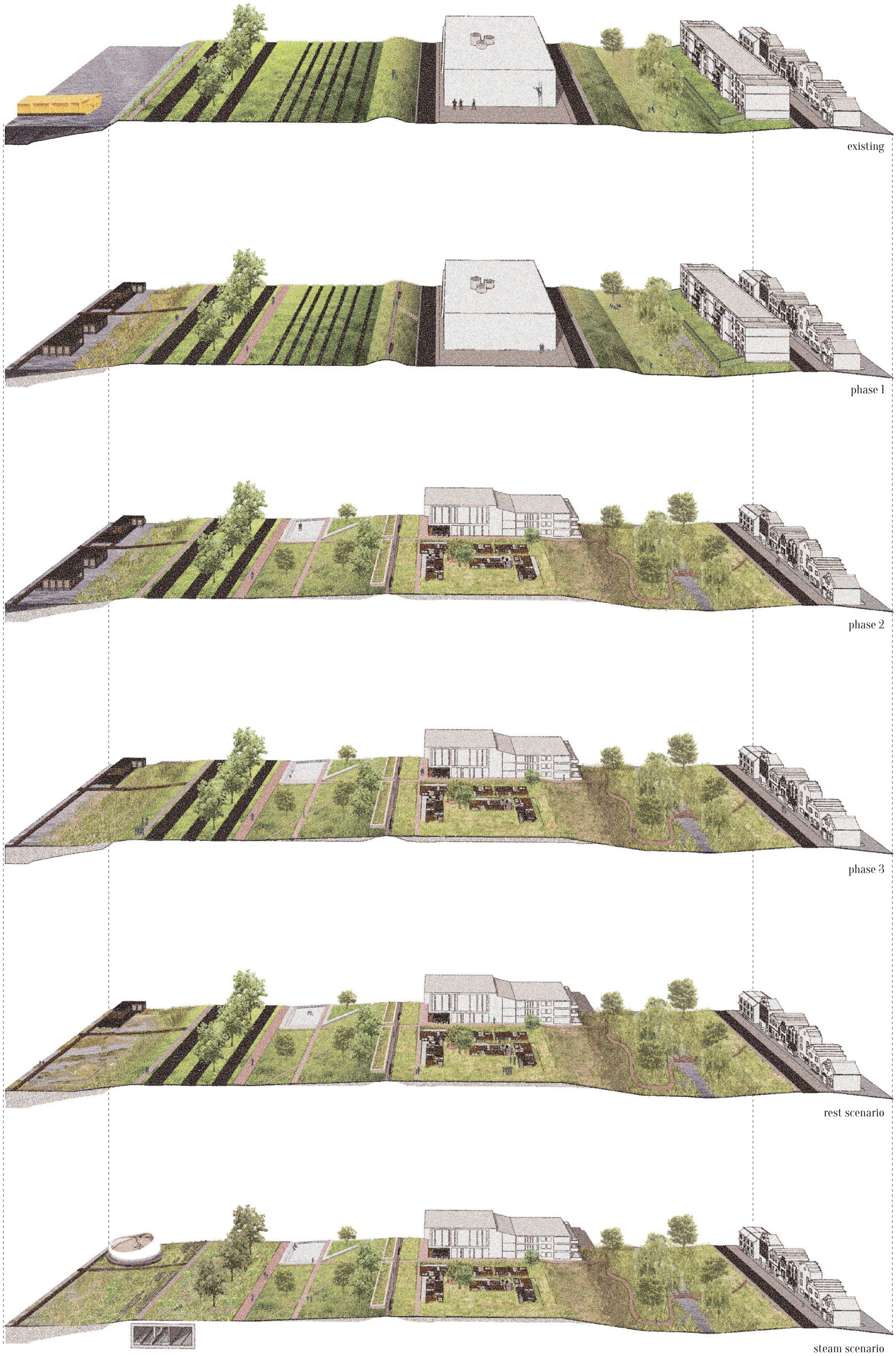
The sections in figure 5.16 show how the different phases result in a different spatial configuration of, in this case, the climate dike. The images show that the values can already be high in phase 2, showing how valuable the 'no regret' measures are in this case.

The following pages (figure 5.17 to 5.26) show the designs of the different phases.





▲ Figure 5.15 | Overview of phases (source: by author)



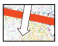
▲ Figure 5.16 | Phasing of the Climate Dike (source: by author)

Phase 4a

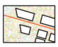
Spatial Conditions and Transformations to Consider

Due to the substantial growth of the sea level and the increasing risks this brings, the last companies on pier 1 move out of the Waalhaven.

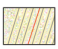
legend


The culvert with gate (klepduiker) is constructed at the entrance of the Waalhaven in this phase. This is a very low technical intervention and therefore not costly. From this moment in time, the sediment starts to settle more quickly.


The harbor functions and land use on pier 1 and 2 which were dependend on their relation with the water have now lost their function and the land on the piers become abandoned. As there is no direct space pressure, the quays can be removed in order to create a more natural landscape, creating a gradient between water and land.

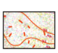

The piers where quays are already removed before will slowly grow due to sediment disposal, creating more land within the water.


After removement of the hard quays, pier 1 and 2 are now subjected to the dynamics of the river. The sea level rise until now has been moderate, so they are only flooded during extreme storms. This makes it possible to cultivate the land for saline agricultural purposes. The original peat landscape north of the river is being transformed to allow a higher ground water table to reduce soil subsidence and CO2 emissions and there is less financial support to import food. This makes the demand for local/regional food production high. Both piers can provide food which can be used locally.

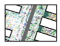

Sediment disposal areas which already have been growing for several decades become less and less wet. The area where this would happen first is the site between pier 4 and Waalhaven Zuid. The first types of aquaculture and wet and salt resistant crops are produced here.


As the buildings along the main road and the Sluisjeskade are well located for businesses, they attract companies, also because of the favourable settlement climate. There is no need to develop more office buildings or residential buildings as the existing buildings are sufficient and the existing urban areas with residential purposes are shrinking.


These floating buildings used to be floating offices which became less functional as they are located on a distance from primary infrastructure and the demand decreases. Therefore it is decided to transform the floating buildings into holiday houses. Pier 3 connects greatly to the Zuiderpark's major recreational routes and therefore this would strengthen the recreational elaboration of the area. The holiday park is located next to the city park and inside the delta landscape. This creates the ultimate experience for tourists to stay the night in the Dutch Delta Landscape.


The ecological zone and purifying landscape along the Nieuwe Maas is already providing high ecological and recreational values. The delta landscape is constantly subjected to the tides and growing due to sediment disposal. The sea containers improve the liveliness.

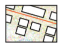
The following landscapes are providing the same values as described in the final state of the Rest Scenario as they are already completed in this phase:


The climate dike with the four identities

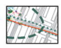

The buildings along the main road


The buildings on the middle and southern part of the Sluisjeskade

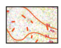

The harbor relicts on the southern part of the Sluisjeskade


The buildings on pier 4


The recreational routes in the tidal landscape


The connecting routes between the Waalhaven and the city


The connection between the Zuiderpark and the Waalhaven


The purifying and ecological tidal landscape with sea containers

▲ Figure 5.17 | Phase 4a (source: by author)

Phase 4b

Spatial Conditions and Transformations to Consider
Due to the substantial growth of the sea level and the increasing risks this brings, the last companies on pier 1 move out of the Waalhaven.

legend

The continuous growth of the Rotterdam Harbor results in increasing size of ships. This, together with the increasing risks of the deep Nieuwe Maas related to water safety and saline intrusion, the decision is made to stop dredging the Nieuwe Maas. The river will slowly increase its own nature values, which also provides opportunities for recreation. As the harbor activities which were dependent on their relation with the water are all moved out of the Waalhaven, the dredging in the harbour basin will also be fully stopped.

As the economy and population is constantly growing, the desire to maintain land for further economic and urban growth is crucial. Therefore, the quays located in erosion area are transformed into layered cultural tidal parks. This prevents the quays from erosion and also stimulates sediment disposal behind those piers in order to make the land grow naturally, which again could be used for further densification. In order to provide an attractiv, varied, cultural transition zone for pier 1 and 2, the spatial lay out should vary on different parts. Spatial lay outs of this type of quay could be stairs sloping downwards towards the water, a layered park with several plateaus on different heights or a hard quay with a lower located level next to it, located just above the water level. During daily, fortnightly or storm waves the lowest layers of these parks are flooded while the highest parts remain dry. In this way the relation of people to the water and their awareness of the delta dynamics is increasing, but still the water safety and maintenance of land is provided.

The southern part of pier 2 is subjected to erosion and as this pier has high flood risks it is heightened (landfill) with soil from dredging activities in the region. Due to increasing population and demand for urban expansions, this part of the pier is directly occupied by residential buildings. Some of the temporary functions which arised in the previous phase appear to be very successful and are integrated in the design.

Pier 1 is subjected to flood risks during extreme storms and therefore the harbor activities move out slowly. This is a process which takes time and in the meanwhile the area is occupied by other sectors. When buildings become abandoned some new initiatives can take place, similar to developments we have seen before in Katendrecht and the Merwe-Vierhavens. When buildings are being demolished and land is available, developers take their chance to adapt to the constantly rising demand for housing. They do this by organising creative, temporary and flexible types of housing, like tiny houses, which can be transported easily when the risks become too high. When an occasional storm event happens, those land-use types are more flexible to adapt to the water and are also less vulnerable in terms of economic damage.

The parts of the tidal, purifying park in the length of the river which are subjected to sediment disposal the longest (and are therefore the highest) are occupied for further expansion of the business district. The highly attractive business climate this location along the NIeuwe Maas provides is of high economic value.

The tidal nature in between the piers is already subjected to sediment disposal for a while and therefore becomes dryer and dryer. This creates opportunities to cultivate the land for recreational purposes. The tidal parks which are developed here provide green, public space for surrounding residential and office areas and connect people to the tidal dynamics.

As the sea level is rising rapidly and it's directing towards a sea level rise of 200 cm, extreme measures are taken to protect the area within the dikes. However, this risk also increases opportunities for improving recreational and natural values. The climate dike, which already is very wide and slopes downwards towards the main road will be extended towards the tidal nature. After reaching more than 100 cm sea level rise, the main road would become threatened by flood risks, which means a transformation would have to happen anyway. Therefore, this main road is constructed underground in this phase, providing space for the dike to extend towards the tidal city parks between the piers. This long and gradual slope from the top of the dike towards the water provides conditions for the development of a wide range of habitats as the subjection to tides, ground water level and salinity levels vary strongly. This intervention also completes the maximum value of connecting the city to the Waalhaven as there is one large dike park between them, providing the same values with the four identities as explained before.

The growing population demands for the development of residential houses, which will happen in a floating way near the floating offices and in the extension of pier 4.

As the desire for inhabitants to visit cool, recreational areas alongside the water increases, a beach will be constructed on the west side of the urban tidal park between pier 3 and 4.

Inhabitants of the Steam Scenario are more focused on intensive types of recreation (Deltaprogramma Rijnmond-Drechtsteden, 2011). Favourable locations for the development of such types of recreation are the intersection of the routes between the urban area and the Waalhaven and the dike park. By developing recreational amenities, inhabitants can be attracted towards the dikepark and finally to the Waalhaven.

The following landscapes are providing the same values as described in the final state of the Rest Scenario as they are already completed in this phase:

The Sluisjesdijk, functioning as a highly intensive business district

The green public parks in the business district

The green promenade in the business district

The harbor relicts on the southern part of the Sluisjeskade

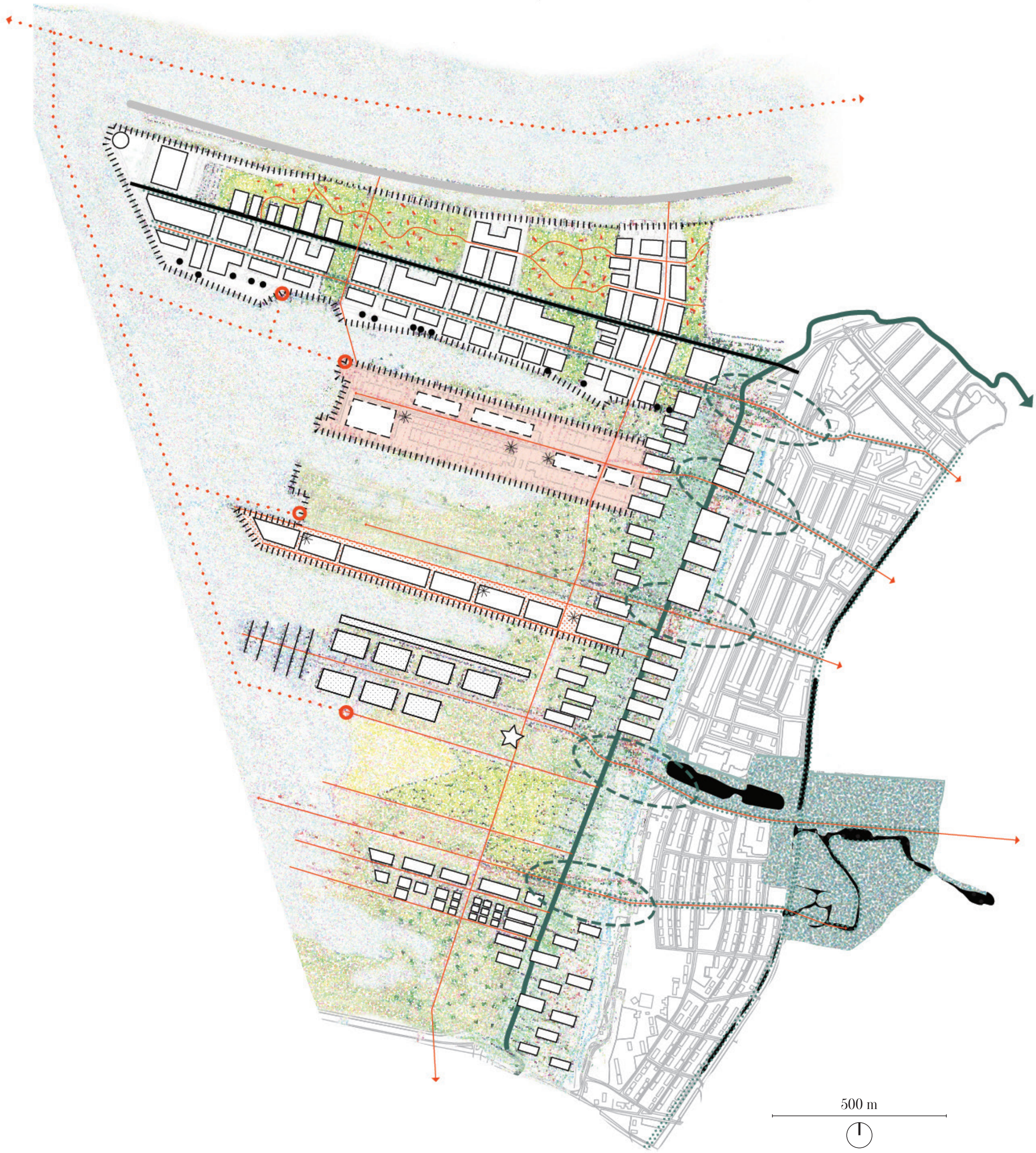
The recreational boat routes and mooring places

The ecological value of the tidal landscape

The connecting routes between the Waalhaven and the city

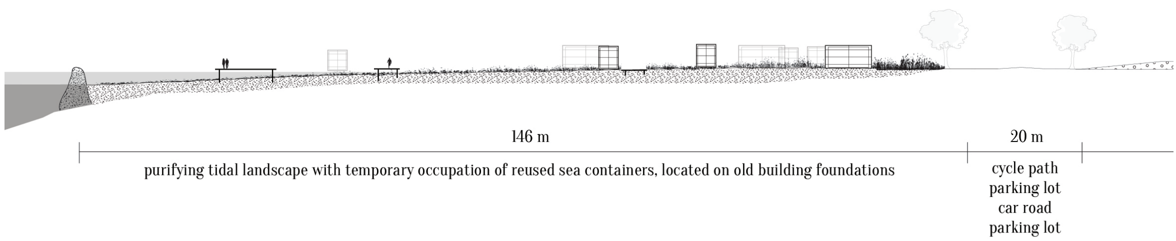
The connection between the Zuiderpark and the Waalhaven

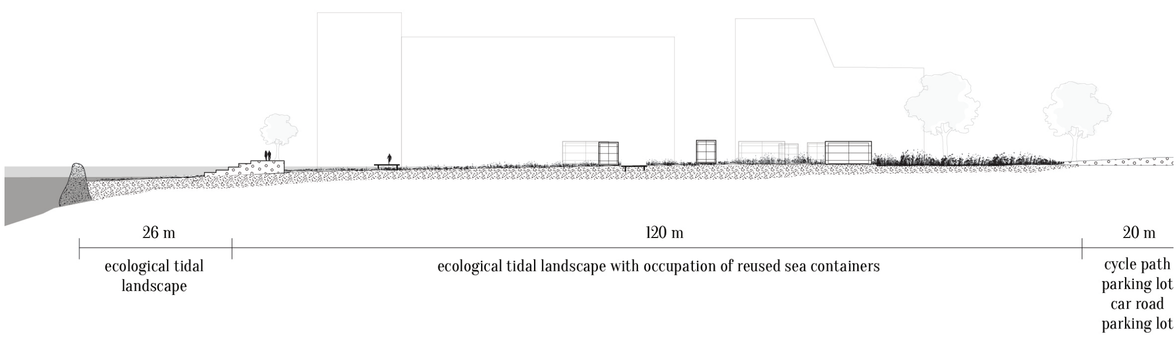
The buildings on pier 4.

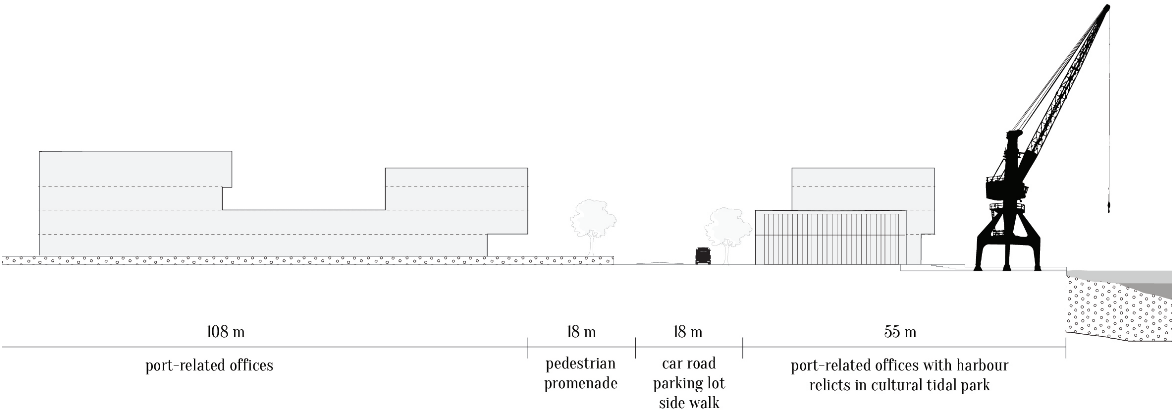


▲ Figure 5.18 | Phase 4b (source: by author)

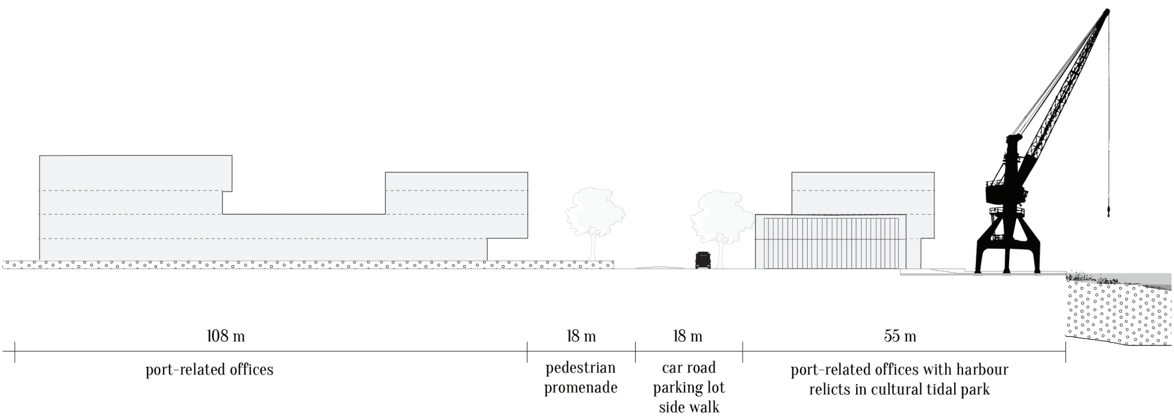
Sluisjeskade Phase 4a and 4b







▲ Figure 5.19 | Section Sluisjesdijk phase 4a (source: by author)



▲ Figure 5.20 | Section Sluisjesdijk phase 4b (source: by author)

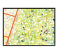
Phase 3

Spatial Conditions and Transformations to Consider

The population in the region is still growing and urbanization and densification is a trend. The economic damage for the harbor activities at pier 2 and 3 during a flood become too high and risky and therefore more and more companies leave those piers to find safer spots in the harbor seawards. Pier 1 is still in use, but as the business climate for the harbor in the Waalhaven becomes less due to the new developments and the growing ships some of the companies also decide to move slowly. In general pier 1 is safer than pier 2 and therefore still in function. Due to the developments in the middle part of the Sluisjeskade in the previous phase the southern part of the Sluisjeskade will now also be transformed and upgraded in relation to the middle part.

legend

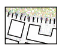

As Waalhaven Zuid is located in a sediment disposal area, the quays can be removed without the loss of land. This results in a gradient between water and land (water - mud flat - salt marsh - land) improving ecological conditions


As pier 3 lost its harbour function and therefore the mooring places in the water become available, the area between pier 3 and 4 can develop quickly. The floating offices which where located here and created the opportunity for sediment to settle faster are moved towards pier 3. This opens up the developed tidal nature underneath which have been developed naturally for several decades now. This land will be transformed into a tidal city park in combination with the bar and restaurant. On the higher grounds there will be intensive types of recreation, while the lower located (and more wet parts) create opportunities for improving biodiversity and extensive types of recreation. The park is combined with floating pathways towards the waterside reaching towards a recreational harbor, which makes the park better accessible within the wider context.


Pier 2 is subjected to flood risks during extreme storms and therefore the harbor activities move out slowly. This is a process which takes time. The transformation happens in the same way as explained for pier 1 in phase 4b.


Pier 1 is still in use for harbor activities and therefore also the mooring places. This part of the basin is still being dredged and tidal nature will not yet develop here.

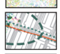
The following landscapes are providing the same values as described in the final state of the Rest Scenario as they are already completed in this phase:


The Sluisjesdijk, functioning as a highly intensive business district


The green public parks in the business district

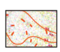

The harbor relicts on the southern part of the Sluisjeskade

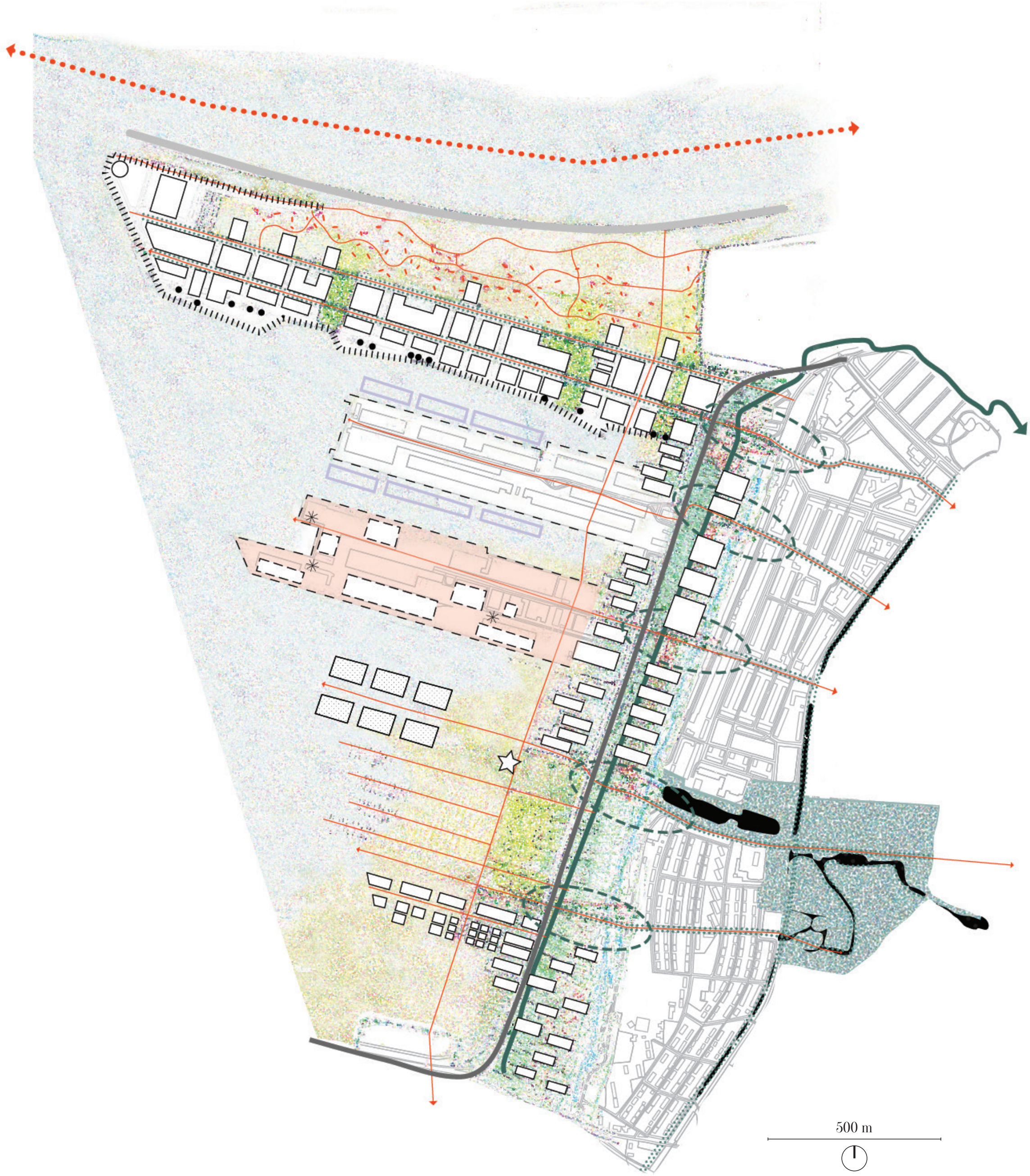

The ecological value of the tidal landscape


The connecting routes between the Waalhaven and the city


The connection between the Zuiderpark and the Waalhaven


The buildings on pier 4


The purifying and ecological tidal landscape with sea containers



▲ Figure 5.21 | Phase 3 (source: by author)

Phase 2

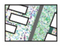
Spatial Conditions and Transformations to Consider

On the mid-long term the marshalling yard, Spuizone and NAM-terrain will lose its function and transformation of this terrain on both sides of the primary dike becomes possible (dS+V, Port of Rotterdam and DCMR, 2010). The middle part of the Sluisjeskade becomes totally available and some parts of the northern and southern part as well. The southern part of pier 4 becomes available. Pier 1, 2 and 3 are still in function

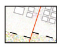
legend

The lower located Spui is a park on the east side of the Spuizone which is about +1.00 to +0.50 m NAP which will be developed into a wetland in this phase. It will create high recreational and natural values and is also able become a water storage area for water coming from the east during high river discharge. As the historical street Zuidhoek is a historical dike, it is located higher in the landscape which makes this possible without increasing flood risks. The park connects the primary dike and relating tidal parks to the larger ecological network. In order to make sure the park contributes to the relation between city and harbor, the houses on the west-side of the Zuidhoek are removed. This creates an open connection between the historical street and buildings which increases the attractiveness of the whole area. The wetland nature consists of water plants, herb- and flower rich grasslands and reed and rush which will differ in visual appearance compared to the tidal parks. It creates a natural parkish zone combined with wooden paths for inhabitants to stroll and experience the wetlands. During low water levels in dryer seasons, the nature can be managed naturally by allowing cattle into the area, which also improves the recreational values and food production. The zone can also be used to distribute rain water from the urban area in terms of peak rainfall. By increasing the ground water table in this area, the saline intrusion through ground water will be reduced.

In this phase the office park, being part of the climate dike, will be constructed. The Spuizone, now an industrial area located directly behind the primary dike, is +3.40 m NAP, which is 2.20 m lower than the primary dike. In this zone, which is about 50 m wide, landfilling will take place, making it as high as the primary dike to form a climate dike. For this to happen, dredged material from other harbor basins or the Nieuwe Waterweg is used to contribute to regional circularity. This dike is, due to its wideness, extremely strong and will not collapse during extreme storms. As the area within the dikes is relatively high here there is not that much sand needed. New offices in combination with residential buildings will be built on the climate dike. In the north, on the harbour side the buildings will be developed higher to create a view towards the harbour landscape. On the city side the buildings are sloping downwards to create a connection with the wetland park and the historical building line along the Zuidhoek. In the south: the buildings are spread into the landscape to create a more rural environment (reference: Funenpark, Amsterdam). A combination of residential and offices creates a lively and mixed living environment throughout the day. In between the buildings an urban agricultural food landscape will develop which will be available for both residents and workers to create connections between them. In the northern part, the focus will be more on vegetable gardens where people can cultivate their own food. Here, in relation to the already existing urban farming in Charlois (Westlandse Tuin) a food hub can develop along the Voornsestraat. On the dike a sustainable green house will develop, functioning as a local shop and restaurant where people can buy locally produced food or sell their own produced food for further distribution. In the southern part the focus will be more on orchards in combination with cattle, which has a more rural identity. This reflects to the agricultural identity the area used to know in the past and also relates to the green tuindorp (garden village) Wielewaal.



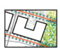
The area along the dike outside the dikes (former marshalling yard) will become a 'front side' of the whole combination of parks (tidal parks, climate dike park and wetland park) as it naturally becomes a connection zone between the buildings on the quays and the buildings on the dike. In this phase, it will be developed in such a way that it provides routes between harbor and urban area and creates possibilities for walking, cycling, sports, dog walking, etc. The paths are sloping downwards from the dike, located higher in the landscape until they attach to the promenade/street. This is to avoid costs in the future as in the next phase this land will be heightened with a gradual slope from the dike downwards to the harbor to strengthen the dike and create a foreland.



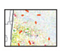
The southern part of pier 4 will be developed. As this whole pier is located in a sediment disposal area, the quays can be removed and the land and water will grow gradually together, forming a tidal landscape. Finally, when the water between pier 4 and Waalhaven Zuid is 'filled' with sediment and created new tidal land, the pier itself will also be subjected by the tides and will grow slowly together with the rising sea levels. New residential buildings will be developed on the south . The residential buildings will be build in a way that the ground floor first will be used in a temporal way, for example by demountable houses (sea containers which can be removed when the risks become too high) / tiny houses. After 2050, when the flood risks for this pier become too extreme, the temporal houses can be removed and reused somewhere else. The higher floors are now located on stilts and the tides can flow underneath and slowly dispose sediment until at one point the buildings are again located on land and safe for flooding.

Between pier 2 and 3 gradually a tidal park is developing due to sediment disposal. The buildings from dockworks (which are already build flood proof as the ground floor is an open parking lot) are now located in a tidal landscape.

Some parts of pier 2 are outdated and as they are also located on quite low land in a sediment disposal area the quays are removed. The soil from the pier will be gradually spread into the water, in combination with the area between pier 1 and 2. As this is a sediment disposal area the transition zone will grow slowly, together with the tides and rising sea level. The area between pier 1 and 2 will be developed with buildings in the same style as the Dockworks.

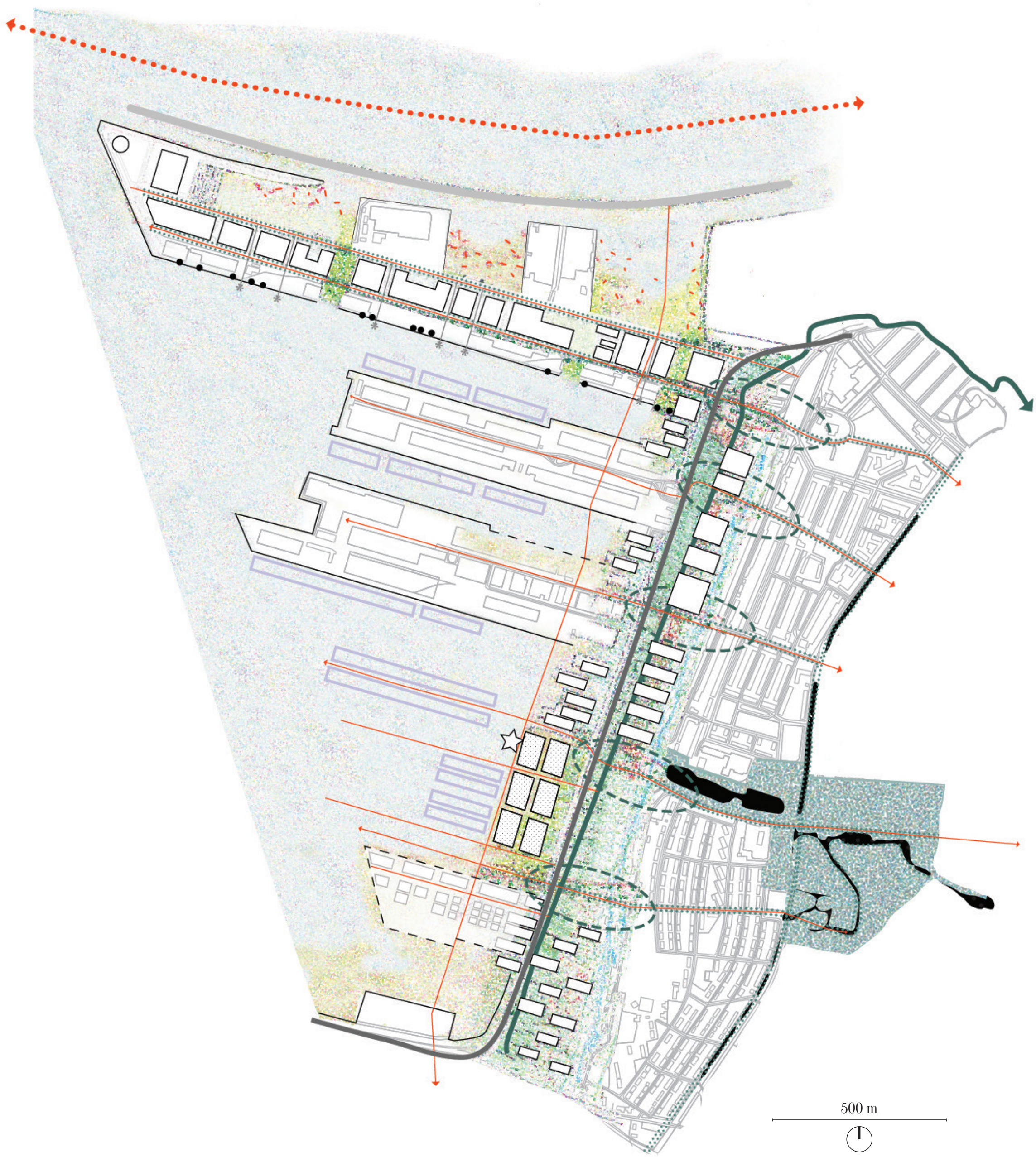


The land on the middle part and top of the Sluisjeskade will be heightened until +5.00 m NAP in order to deal with the possible sea level rise of 195 cm. This is necessary in this part of the harbor as this pier (together with the RDM terrain) have to funnel the sea water in order to not give it more space. The land will be developed directly with high density office buildings, functioning as a business card along the Nieuwe Maas. Three 'dry' green parks in the extension zone of the 3 small harbor basins connect naturewise with the tidal parks due to the green and gradual banks and functions as public space in the office area.



Areas on the northern part of the Sluisjeskade which lose their function will develop into an intertidal purifying landscape by removing the hard quays. In this phase, the area is already in temporary use with the sea containers as explained before. As those areas are sediment disposal areas, the banks between the water and the middle part of the Sluisjeskade can be green and gradual which can be used to connect the just developed office area with the temporal purifying landscape.

Some parts of the northern and southern part of the Sluisjeskade are still in use for harbor activities. The visibility towards these harbor areas increases strongly during this phase as the areas become surrounded by recreational, residential and work-related functions. This is of high value for the Port of Rotterdam in order to increase the cultural identity of Rotterdam as a Harbor City.



▲ Figure 5.22 | Phase 2 (source: by author)

Phase 1

Spatial Conditions and Transformations to Consider
Buildings between pier 1 and 2 and pier 2 and 3 are strongly outdated and create a visible and spatial boundary between the road and the water. As yet, piers 1 and 2 remain in function for the transhipment of cargo. The mooring places along pier 3 also remain in function, but in between those places there are already opportunities for short term developments. The northern part of pier 4 will lose its function on the short term and is available for transformation (dS+V, Port of Rotterdam and DCMR, 2010). Nowadays, the Spuizone is still functioning with businesses like graphic design, printshops and storage, but will slowly become available for transformation as it creates a huge boundary between city and harbor (Programmabureau NPRZ, 2013). The NAM-terrain is not yet available for transformation, but will follow soon (dS+V, Port of Rotterdam and DCMR, 2010).

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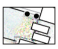
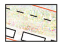


Empty land and remove quays between Sluisjesdijk and pier 1, pier 2 and 3, pier 3 and 4, the north side of pier 4 and between pier 4 and Waalhaven South. Create a transition zone between water and land by taking soil from the land and spread it into the water on quays between Sluisjesdijk and pier 1, pier 2 and 3 and the northside of pier 4. The land along the quays between pier 3 and 4 and pier 4 and Waalhaven Zuid have less space, so here dredged material should be added on the bottom of the basin to provide the gradual slope which is needed for tidal nature.

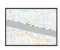
Develop floating offices in the water between pier 3 and 4 in combination with higher located walking paths and musselbanks in order to stimulate sediment disposal. There is still space available for ships in this part of the harbour and the land below the floating buildings will slowly increase, creating a natural gradient. Along pier 3, on the corner of the floating buildings a bar and restaurant will be developed, which attaches greatly to the pedestrian route coming from the Zuiderpark. This spot creates a great overview of the water, the harbor (activities along pier 3), new and innovative office developments (floating buildings), the development of tidal nature underneath and in between those buildings and food production (mussel banks in the harbour basin can be used to sell in the restaurant as local food).

The ground level of the buildings between pier 2 and 3 is already used for parking in the open air and in combination with the location and position of the buildings these dockworks provide a transparent building structure, creating visibility between the road and the water. The area between Sluisjesdijk and pier 1 will be developed in a similar way, where buildings can be build partly on land and partly in the water. However, here the quay is subjected to erosion. Therefore, a soft bank is not desired as this will be slowly taken away by nature. Therefore, a layered, cultural tidal park is developed, creating a recreational transition zone between land and water. This provides opportunities for people to get access to the water and can be, for example, used during lunch time to have a break with colleagues.



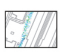
On the northern part of pier 4 new space becomes available for offices, which will be developed in east-west direction to connect to the new to developed route between Wielewaal and the harbour and attaches to the north-south route coming from the other piers. The buildings are build on poles reaching to +5.00 m NAP in order to deal with possible sea level rise of 195 cm by 2100.

The quays in the Kortenoordsehaven, Sint Janshaven and Robbenoordsehaven along the Sluisjesdijk are removed and the land will be transformed into a transition zone between land and water, perpendicular to the river. This will be combined with salt resistant purifying plants to reduce the pollution in the soil, caused by the petroleum storage in the past. During this process the land can be used for starters and creative industries housed in old sea containers which will be scattered around the landscape. The building foundations from existing buildings can be reused for this. While the soil is purifying, a temporary lively landscape creates opportunities for the Charlois' inhabitants to make use of the harbour landscape by starting their own business. In this way the land is used in a functional way on the short term and will on the long term provide a clean soil for further urban development. It also creates more diversion in the harbor landscape by introducing new types of businesses, like design offices, artist exhibitions, catering industry, etc. A representation of this transformation is represented in the sections on the next page.

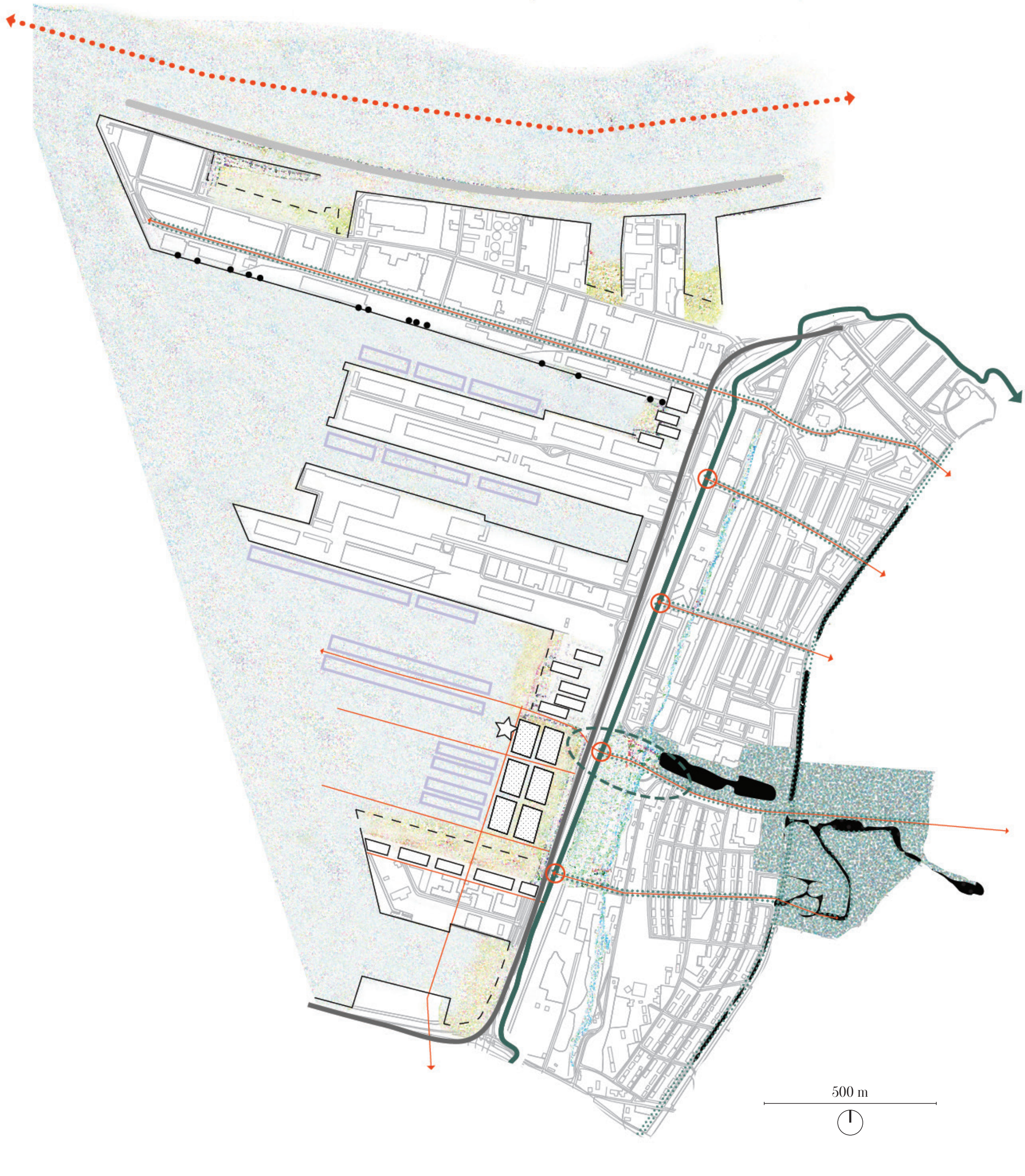


A length dam is developed in the length of the river Nieuwe Maas, creating an intertidal area between the river and the land where the currents and water speeds are lower, resulting in natural sediment disposal. This stimulates the growth of the tidal parks in the Kortenoordsehaven, Sint Janshaven and Robbenoordsehaven.

The location of the existing pedestrian bridge between the Zuiderpark and the Waalhaven near pier 3 is the starting point for the connection between the urban and harbor area. The area between the historical street Zuidhoek and the primary dike, which is now a soccer club and a day-care, will transform as being part of the Zuiderpark. The soccer club and day-care can remain on the same location, but the spatial characteristics will be developed as one identity in relation to the Zuiderpark. On the intersection between the historical road and the pedestrian, recreational route there is space available for new amenities which could develop in the same line as the soccer club, day-care and Zuiderpark. This will resolve the boundary which these areas create nowadays and create an interesting route towards the Waalhaven, stimulating recreation in the east-west direction towards the floating buildings and tidal park development.

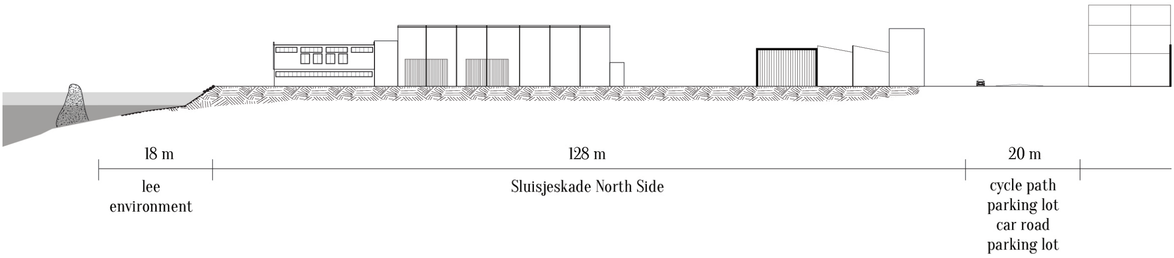


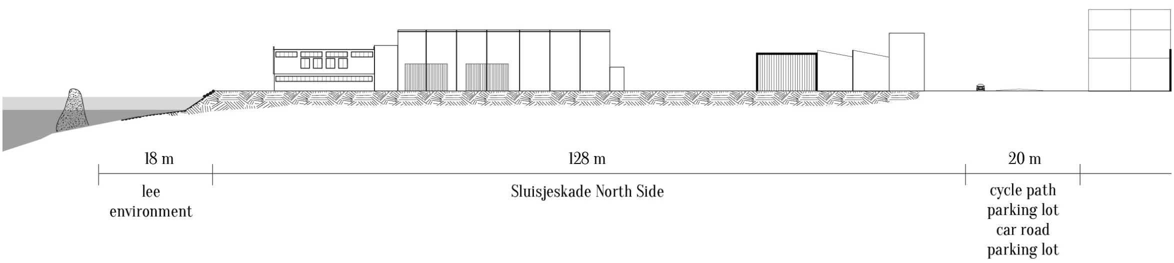
Between the Spuizone and the historical street (Zuidhoek) a water body will be dug, connecting this lower located area with the Blue Connection (Blauwe Verbinding). The water body consists of green, ecological river banks in order to improve nature values. In the phase 2, this zone will be transformed into a wetland city park for which this is the first step.

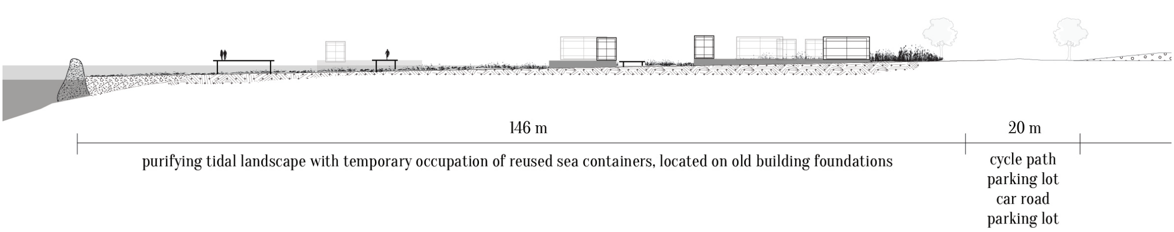


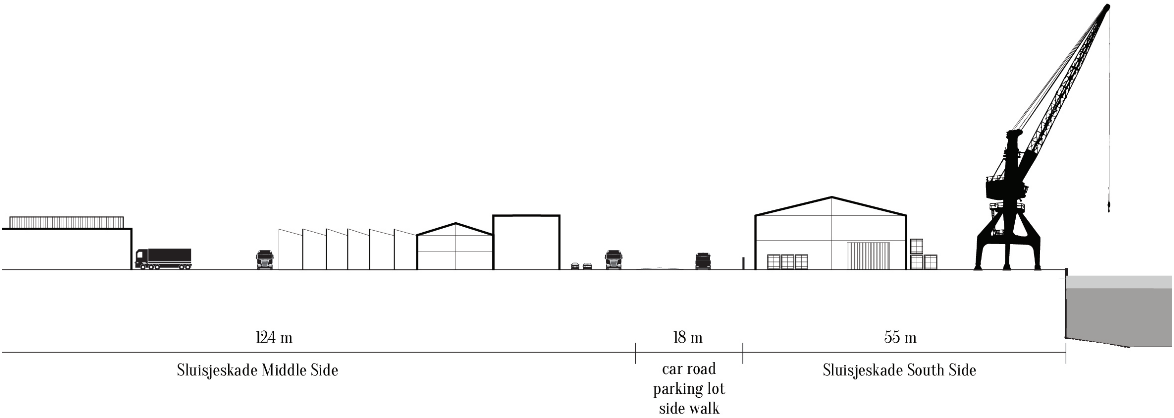
▲ Figure 5.23 | Phase 1 (source: by author)

Sluisjeskade Phase 1, 2 and 3

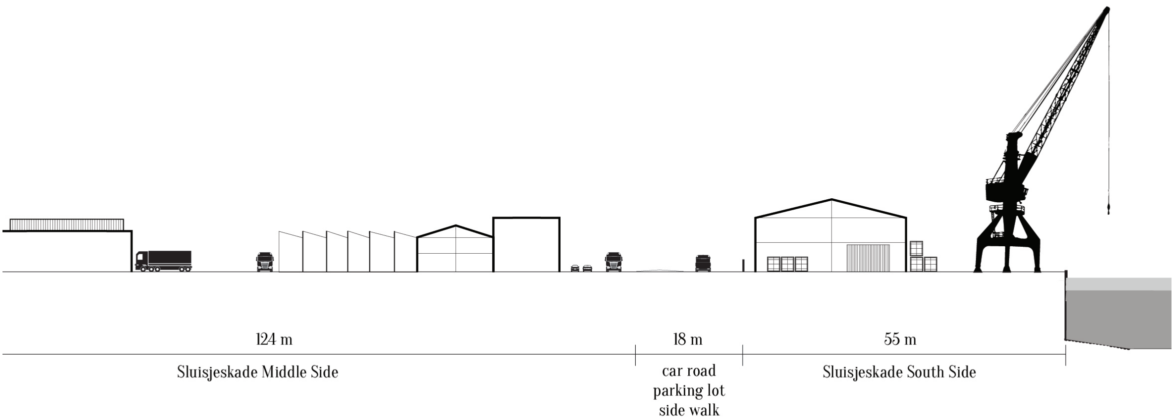




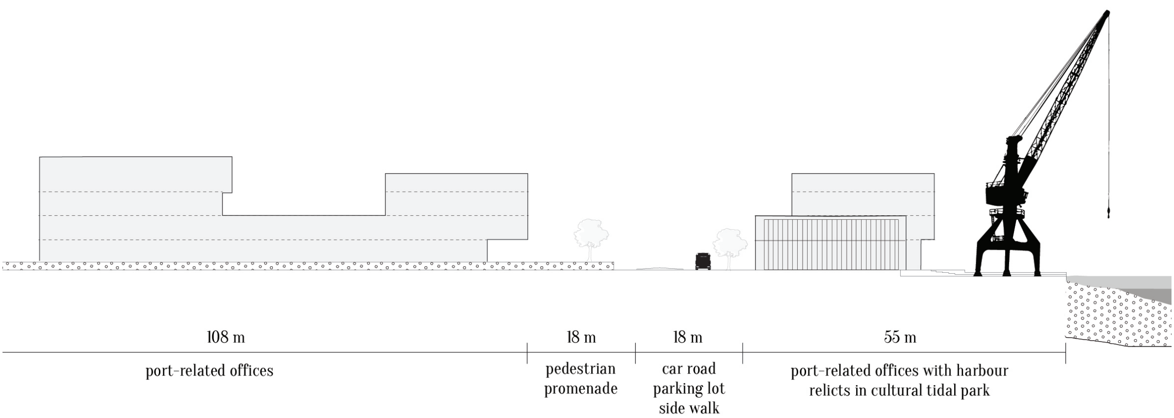




▲ Figure 5.24 | Section Sluisjesdijk phase 1 (source: by author)

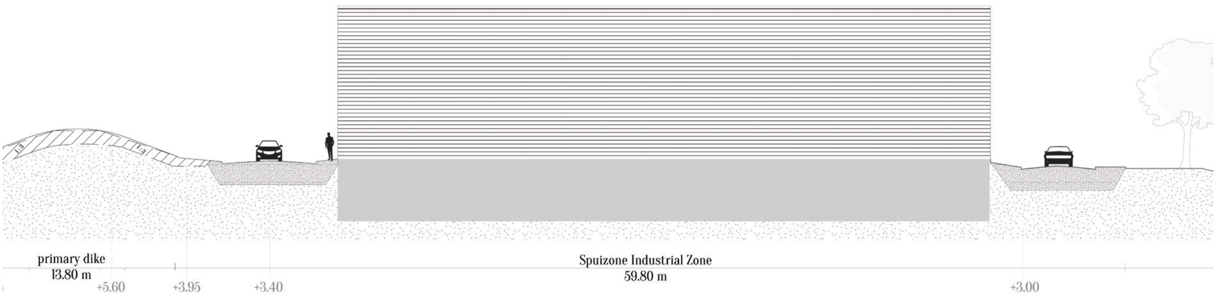


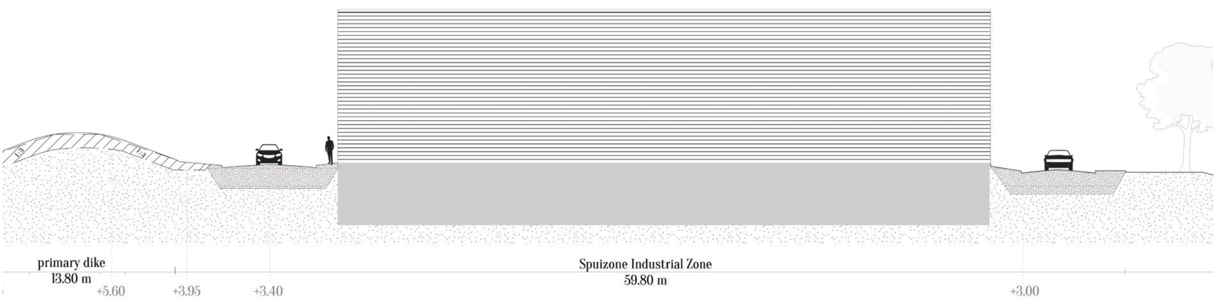
▲ Figure 5.25 | Section Sluisjesdijk phase 2 (source: by author)

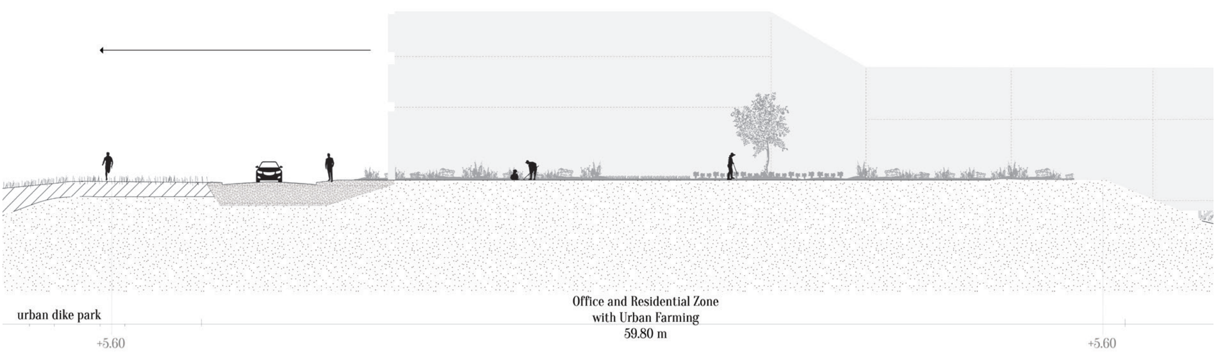


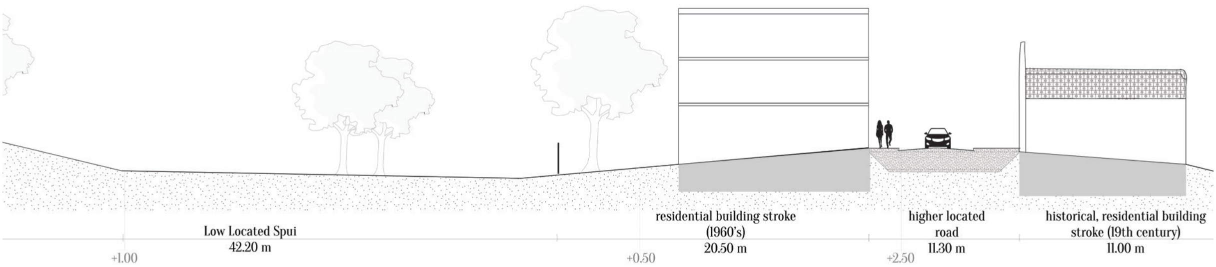
▲ Figure 5.26 | Section Sluisjesdijk phase 3 (source: by author)

Climate Dike Existing Situation, Phase 1 and Phase 2

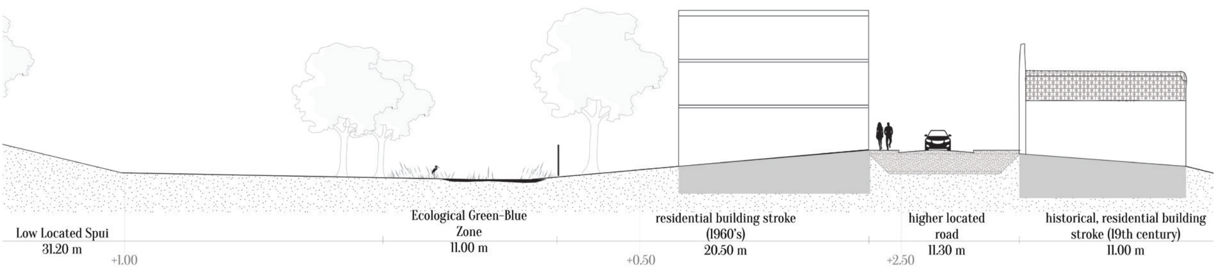




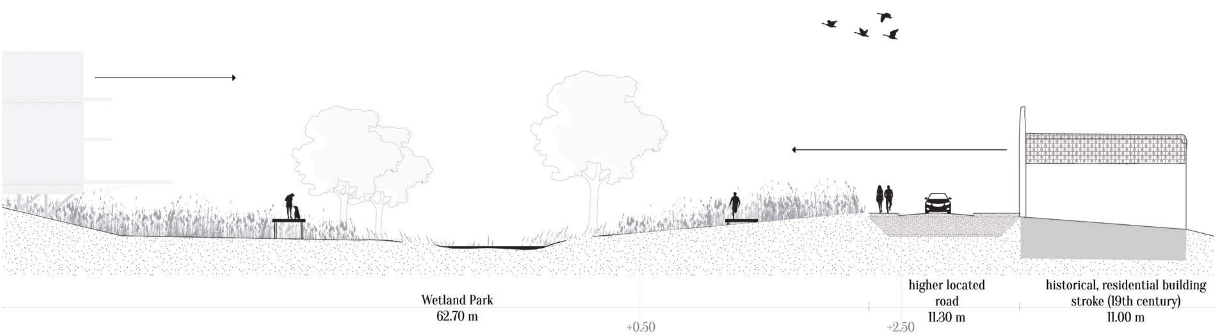




▲ Figure 5.27 | Section of existing situation Waalhaven Oost (source: by author)



▲ Figure 5.28 | Section of phase 1 Waalhaven Oost (source: by author)



▲ Figure 5.29 | Section of phase 2 Waalhaven Oost (source: by author)

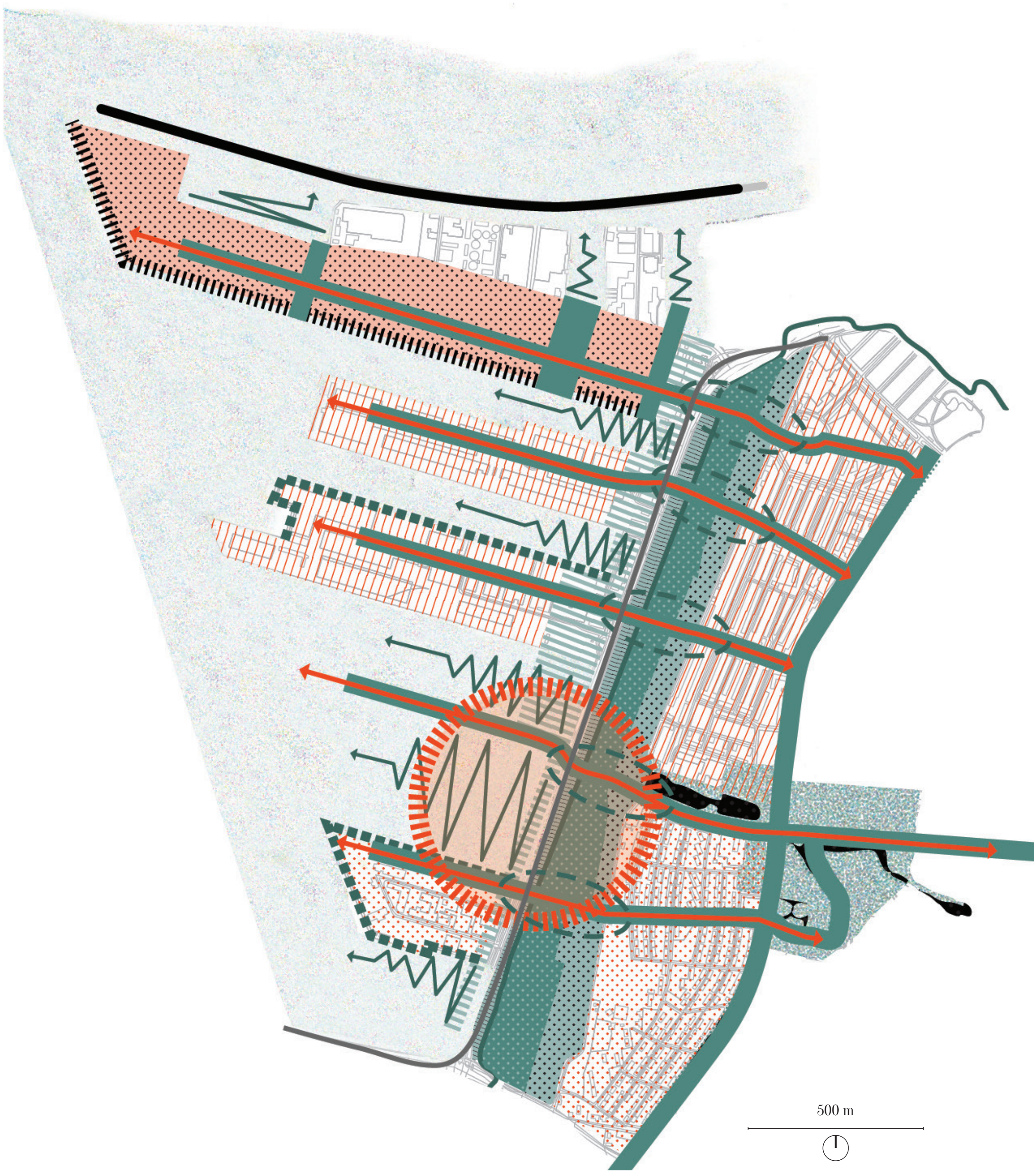
´No Regret´ Measures

The 'no regret' measures are related to the first three phases and represented in figure 5.32. The first three phases will be implemented on the short and mid-long term and will not result in the loss of capital for partners. Therefore, the recommendation is to strive towards the implementation of the 'no regret' measures, as they provide highest benefits no matter what. The 'no regret' measures are related to the urban fabric of the surrounding neighbourhoods, the recreational and ecological network and decreases risks. This together provides a robust, but adaptive spatial framework for the development of the Waalhaven on the short and mid-long term and can finally result in the previously described long-term states.

An example of a 'no regret' measure is represented in the human perspective in figure 5.31, which shows a short-term measure for the first phase. Compared to the current situation (figure 5.30), local tidal parks can provide high values for the harbor and office workers, while the harbor can still function properly.

▲ Figure 5.30 | Current Situation Sluisjeskade (source: by author)

▲ Figure 5.31 | Short-term local measure at the Sluisjeskade, providing high values for workers (source: by author)



legend

- extend existing routes from city towards harbour
- extend existing green structures to connect in the large scale ecological network
- connect to existing Zuiderpark
- wetland park, connected to Zuiderpark and part of climate dike
- heightened office park combined with urban farming as part of climate dike
- current primary dike, upgraded to climate dike
- city dike park with gradual slope towards primary dike
- intersections between east west routes and climate dike parks provide varied experience
- tidal city park with intensive types of recreation
- development of tidal nature
- quays which can be removed and transformed to green banks as they are located in sediment disposal area
- quays which have to be maintained and transformed into cultural tidal parks as they are located in erosion area
- dam in length of river to reduce erosion and stimulate sediment disposal
- landfill area which will be combined with offices
- transparent office development along main road
- spatial develoment of piers is related to urban tissue of Old Charlois
- spatial develoment of piers is related to urban tissue of Wielewaal

▲ Figure 5.32 | 'No regret' measures and robust, but adaptive spatial framework (source: by author)

6

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results

6.01. Provided Ecosystem Services

This section describes the provided ecosystem services for each phase and how it changes through time. This is done by investigating which surface, length or amount of each of the 26 subservices is provided in each phase. With this information the change of provided services is made clear and the preferred pathways can be defined. The section shows two examples of the provided services per phase and ends with a conclusion. The full results of all 26 subservices can be found in appendix 7 and a first overview in figure 6.1.

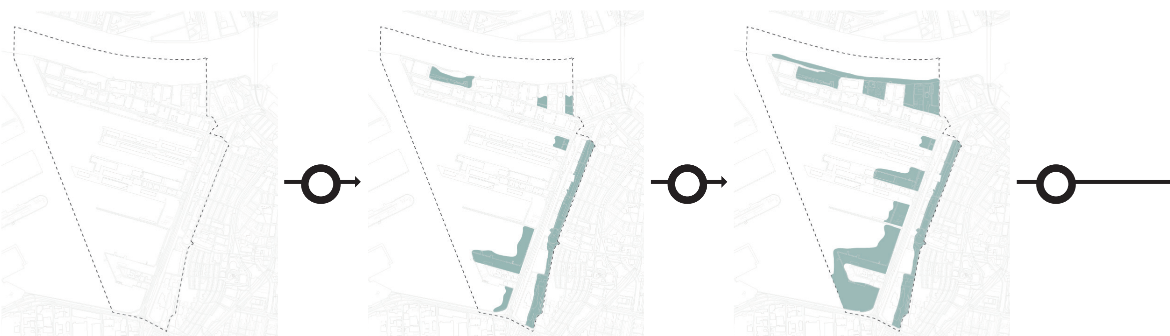
In the next phase, this information will be linked to the earlier described interest of the stakeholders, showing how their interest changes over time. With this information the consideration can be made to what extent stakeholders remain interested in the project and are willing to provide financial support.

▲ Figure 6.1 | Overview of spatial representations of provided ecosystem services per phase (source: by author)

Subservice 2.1 - Water Purification

Area that can provide this service: tidal areas (both mud flats and salt marshes)

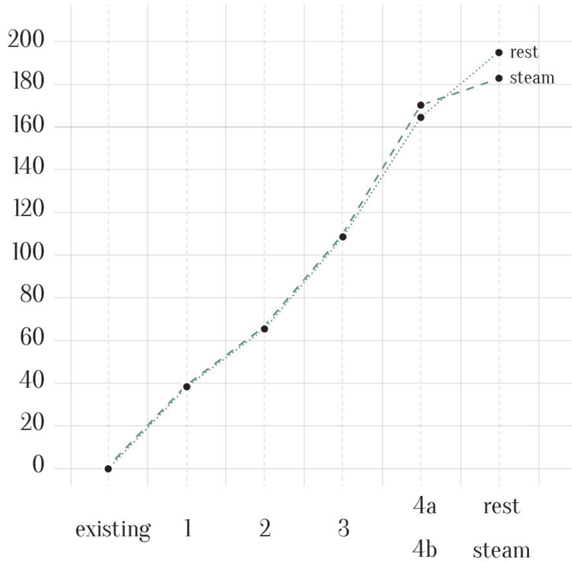
Key performance indicator: surface of tidal area in ha

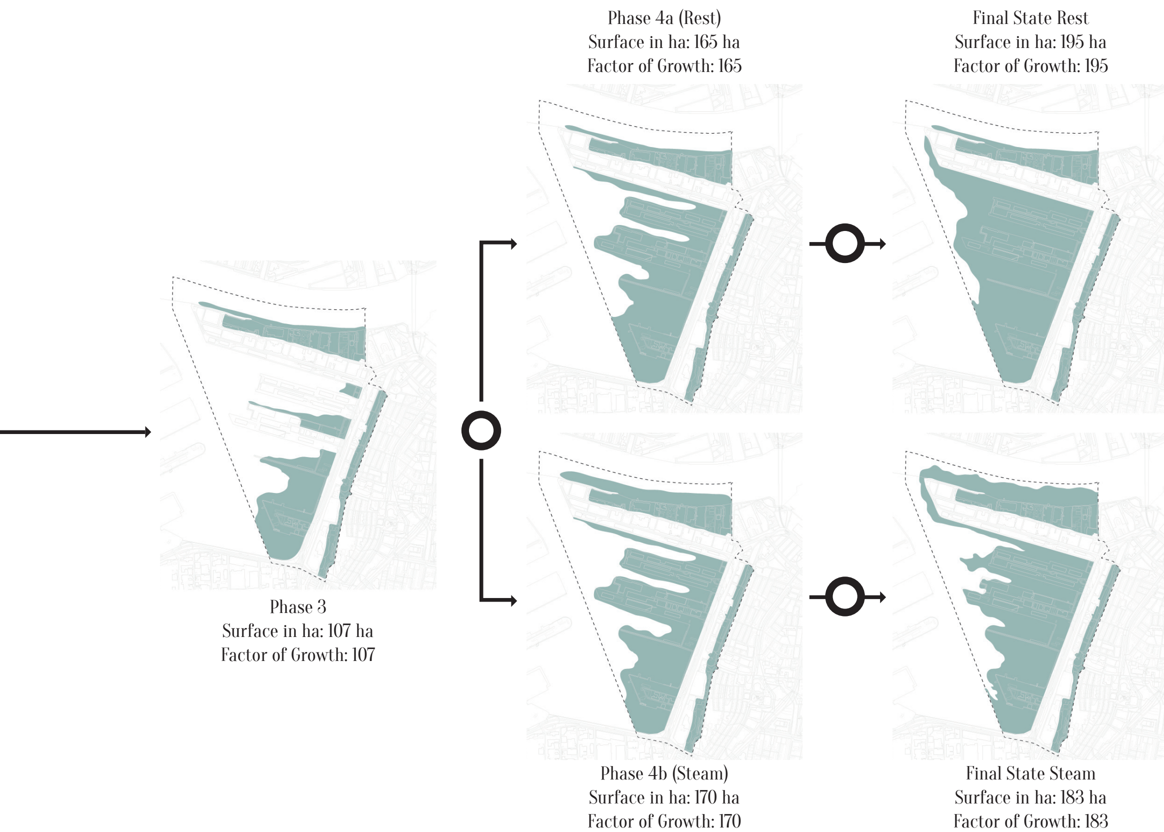


Existing Situation
Surface in ha: 0 ha

Phase 1
Surface in ha: 39 ha
Factor of Growth: 39

Phase 2
Surface in ha: 65 ha
Factor of Growth: 65


200
180
160
140
120
100
80
60
40
20
0
rest
steam
existing
1
2
3
4a
4b
rest
steam


Phase 4a (Rest)
Surface in ha: 165 ha
Factor of Growth: 165
Final State Rest
Surface in ha: 195 ha
Factor of Growth: 195
Phase 3
Surface in ha: 107 ha
Factor of Growth: 107
Phase 4b (Steam)
Surface in ha: 170 ha
Factor of Growth: 170
Final State Steam
Surface in ha: 183 ha
Factor of Growth: 183

Subservice 6.2 - Provide Green Business Settlement Climate

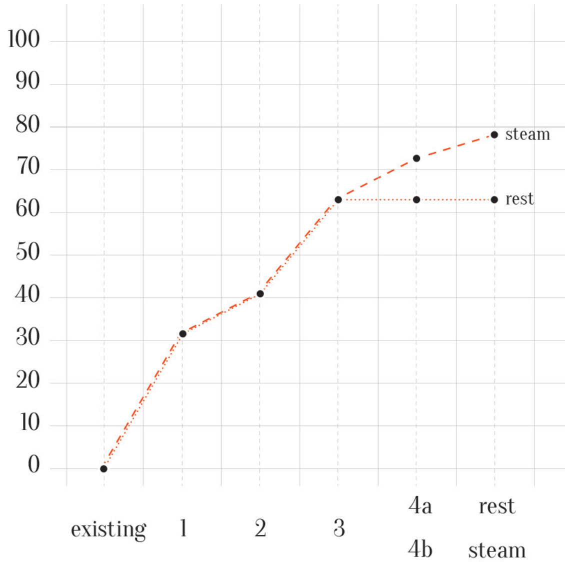
Area which can provide this service: All office or harbor area located next to tidal nature

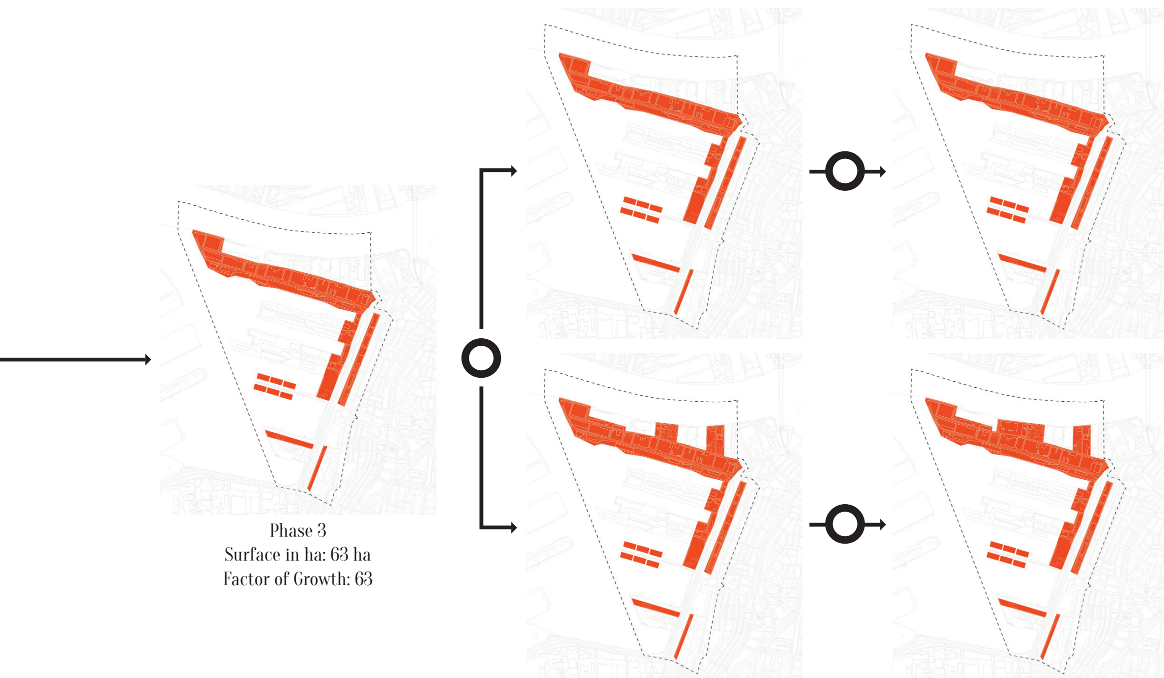
Key performance indicator: The surface of all land with offices or harbor area located next to tidal nature in ha

Existing Situation
Surface in ha: 0 ha

Phase 1
Surface in ha: 32 ha
Factor of Growth: 32

Phase 2
Surface in ha: 41 ha
Factor of Growth: 41





Phase 4a (Rest)
Surface in ha: 63 ha
Factor of Growth: 63

Final State Rest
Surface in ha: 63 ha
Factor of Growth: 63

Phase 3
Surface in ha: 63 ha
Factor of Growth: 63

Phase 4b (Steam)
Surface in ha: 73 ha
Factor of Growth: 73

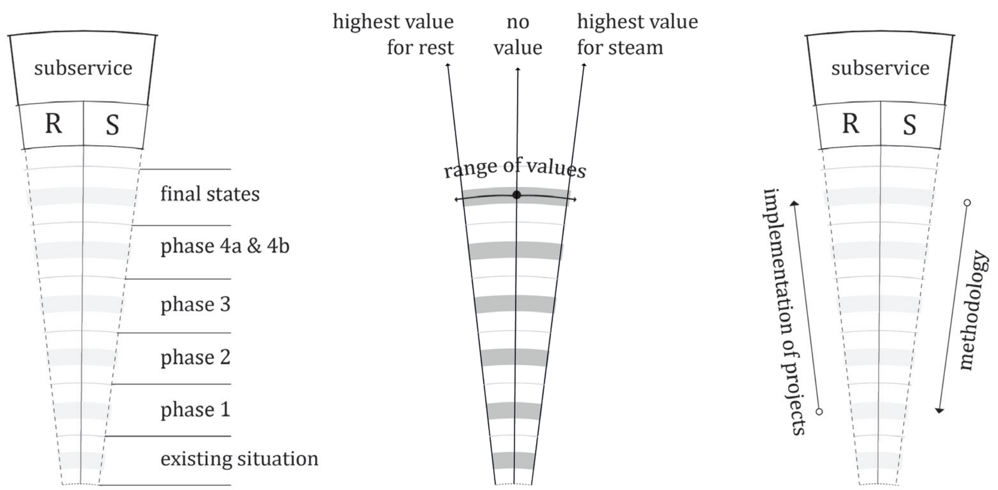
Final State Steam
Surface in ha: 78 ha
Factor of Growth: 78

6.02. Preferred Pathways

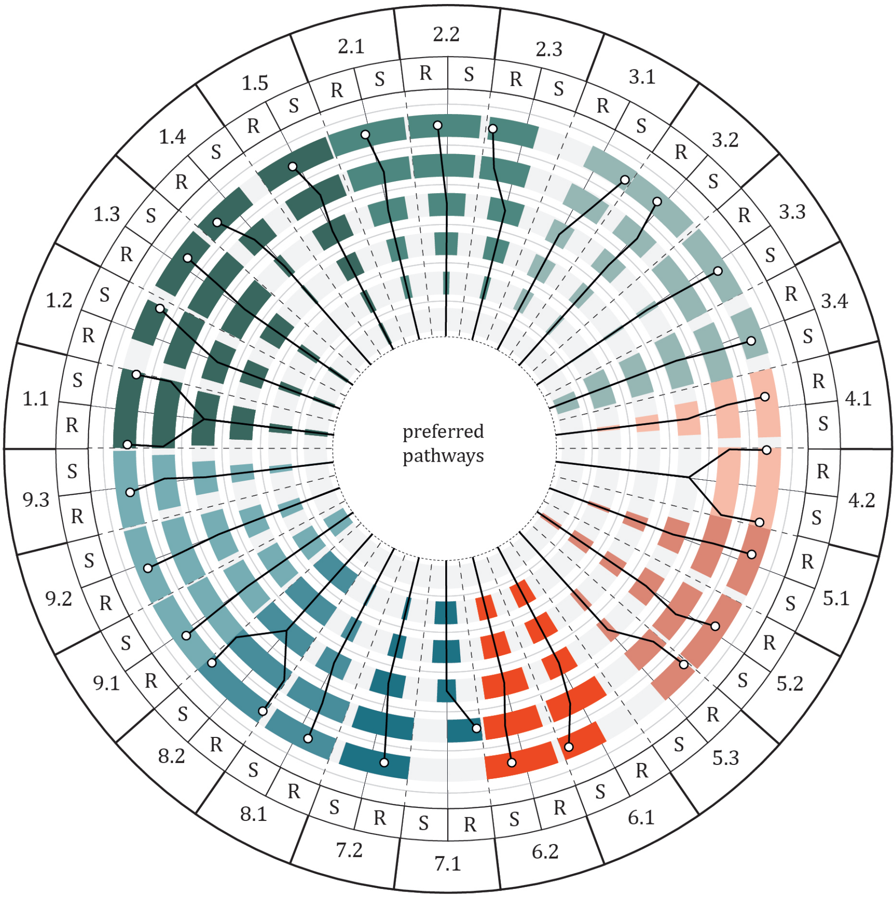
The results of the provided subservices for each phase of the process are summarised in the diagram in figure 6.3. This information is combined with a road map with the preferred pathway for each subservice. It shows whether the services is more provided in phase 4a or 4b and the final state of Rest or Steam.

For each of the subservices, the range of values provided by the ecosystem services are represented with the coloured bars. The center of each service represents zero value and the outsides of the service represents the highest value for Rest or Steam. The different phases of the diagram can be read from the inside, with the existing situation most close to the center and the final states on the outer sides of the diagram. As explained before, the methodology works from the long-term back to the short term, which is in this diagram from the outside towards the center. The implementation of the projects (the general timeline from now until 2100) can be read from the center to the outside. The diagram is therefore applicable for both the methodology and the implementation of projects. An explanation of how to read the diagram is represented in figure 6.2.

The diagram only shows a conclusion of the results and the preferred pathways for each of the subservices. It does not say anything yet about the preffered pathways for each specific stakeholder. This information will be used in the next part of this thesis where the provided values are related to the interest of the stakeholders. This will finaly conclude in a preferred pathway for each stakeholder.



▲ Figure 6.2 | Explanation to read the diagram in figure 6.3 (source: by author)



legend

1. Relate City to the River
- 1.1 – Attractive landscape for visitors (day-trips / recreation)
- 1.2 – Recreation: water sports
- 1.3 – Recreation: fishing
- 1.4 – Tourism: holidays
- 1.5 – Accessibility of water / coastal zone

2. Increase Natural Values and Biodiversity
- 2.1 – Water Purification
- 2.2 – Refugia for migratory and resident species
- 2.3 – Transition zone between land and water providing migration routes

3. Provide Educational Environment
- 3.1 – Awareness of living and working in a delta
- 3.2 – Awareness of coastal dynamics by visitors
- 3.3 – Characteristic landscape: improving identity of Rotterdam as Delta region
- 3.4 – Characteristic landscape: improving cultural identity of Rotterdam as Harbour City

4. Increase Water Safety
- 4.1 – Reduce water depth to reduce currents and waves
- 4.2 – Protection of the existing dikes by creating foreland, resulting in less maintenance costs

5. Food Production
- 5.1 – Fish Production
- 5.2 – Shellfish Production
- 5.3 – Crop Production

6. Basis for Urban Development
- 6.1 – Increasing Land and Real Estate Values
- 6.2 – Provide green business settlement climate

7. Contribute to Regional Circularity
- 7.1 – Reuse of coarse residual material
- 7.2 – Reuse of sediment flows

8. Provision of Fresh Water
- 8.1 – Reduce saline intrusion by surface water
- 8.2 – Reduce saline intrusion by ground water

9. Climate Regulation
- 9.1 – Temperature Regulation
- 9.2 – Air Quality Regulation
- 9.3 – Carbon Sequestration

R — Rest Scenario

S — Steam Scenario

—o pathway providing highest benefits obtained from ecosystem services

▲ Figure 6.3 | Summary of provided ecosystem services per phase and related preferred pathways (source: by author)

PART III

evaluating interests and ecosystem services through time

7

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dynamic equilibrium for human and nature

7.01. Comparing Interest and Provided Ecosystem Services

This section evaluates to what extend partners maintain their interest in the project over time when reaching specific tipping points. It relates the interest of the partners to the preferred pathways, as explained in the previous chapter. For these conclusions the services which are of high interest (assessed with 5) are considered as these are providing highest benefits for that specific partner. By comparing the different preferred pathways for the services with highest interest, conclusions can be drawn what could be the most preferred pathway for the partner. This does not mean the stakeholder has a choice for the direction of the pathway, as the direction towards the scenarios depends on the uncertainties, the reaching of the tipping points.

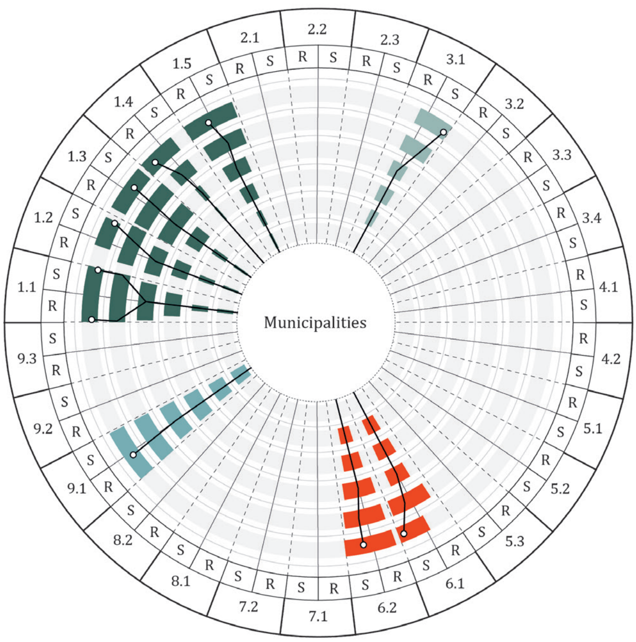
Municipalities - Short and Mid-Long Term

As explained before, for the Municipalities the desired ecosystem services change over time. Until phase 3 the short-term assessments are taken into account. For phase 4a, 4b, the final state of Rest and the final state of Steam the long-term assessments are considered. For the long-term interest the consideration is made whether the interest meets the provided service in both scenarios.

For the short and mid-long term interests the most important services for the Municipalities are the ones which are represented in figure 7.1. On the short and mid-long term it is not clear yet how the interest will change. Therefore, the interests as how they are taken into account now and also how they would evolve on the long-term.

1. Relate city, river and harbor
The results and diagram show that this service is already extensively provided in the first 3 phases. As this relates people to the river, the development of the project in these phases is already contributing to the objective of the Municipality to make the river function as a main, green public space. Therefore, the Municipality is obtaining high values on the short and mid-long term. With the current interests the benefits would be similar in both scenarios as 1.2 and 1.3 provide higher benefits in Steam and 1.4 and 1.5 higher benefits in Rest.

3. Provide Educational Environment
The interest to increase the awareness of living in a Delta (subservice 3.1) obtains quite high benefits in the first phases. With the current interests the preferred pathway would direct extremely towards Steam.



▲ Figure 7.1 | Interest and preferred pathways for Municipalities on short and mid-long term (source: by author)

6. Basis for Urban Development
On the short and mid-long term, the Municipality is expecting a large growth in economy and population. As the analysis shows the values of both subservices is increasing in the first three phases. Therefore, the project is increasing the values for this ecosystem service on the short and mid-long term. The interest in this service is now high as the Municipality expects the economy and population to grow on the long-term, which relates to the Steam Scenario.

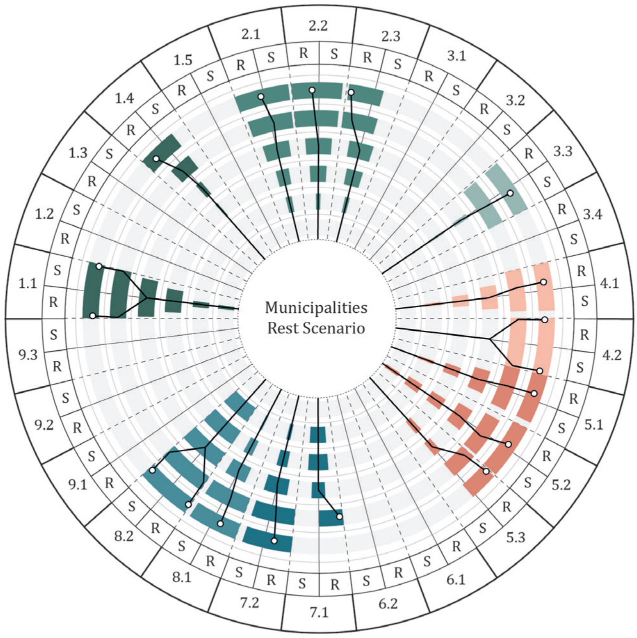
9. Climate Regulation
This service is already provided in the existing situation and first phases. This is because, besides nature, the water regulates the temperature as well and covers a large part of the basin. The service increases in the Rest Scenario as there will be more unpaved area.

Municipalities - Long-Term

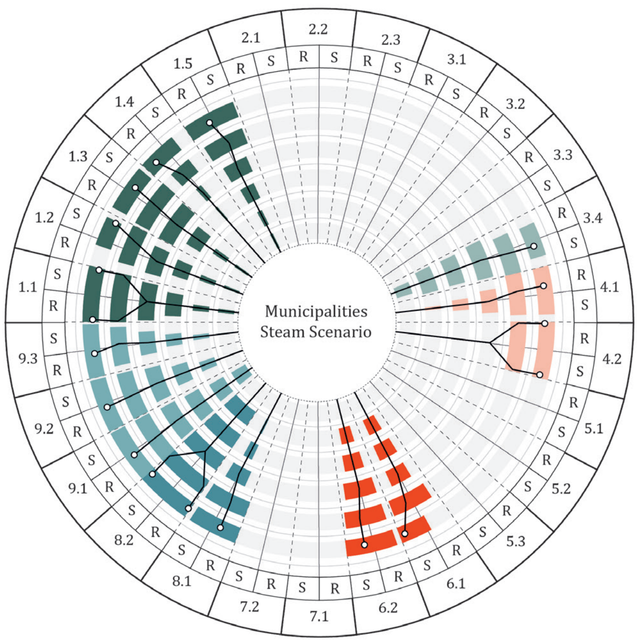
For the long term the ecosystem services of highest interest for the Municipality are strongly related to the scenarios as their main objective is to provide a good quality of life for inhabitants. This means, to name an example, when the project is leaning towards the Rest Scenario and the desire of inhabitants to produce their own food is increasing, the interest of the Municipality to provide the ecosystem service of food production would also increase. Therefore, the relative value of each phase in the long term process is high for the Municipality as its desires are adjusted over time.

The long-term diagram for Rest in figure 7.2 shows that the services where the Municipalities are interested in also provide highest values in the Rest Scenario. The long-term diagram for Steam in figure 7.3 shows that the preferred pathways are higher in phase 4b than in 4a. However, in the final state the pathways often slightly direct towards the Rest Scenario.

The preferred pathway for the Municipalities in the Rest Scenario is the 4a-Rest pathway. In the Steam Scenario this is the 4b-Rest pathway.



▲ Figure 7.2 | Interest and preferred pathways for Municipalities in Rest Scenario (source: by author)



▲ Figure 7.3 | Interest and preferred pathways for Municipalities in Steam Scenario (source: by author)

Port of Rotterdam - Short and Mid-Long Term

For the Port of Rotterdam the desired ecosystem services change over time. Until phase 3 the short-term assessments are taken into account. For phase 4a, 4b, the final state of Rest and the final state of Steam the long-term assessments are considered. For the long-term, the consideration is made whether the interest meets the provided service in both scenarios.

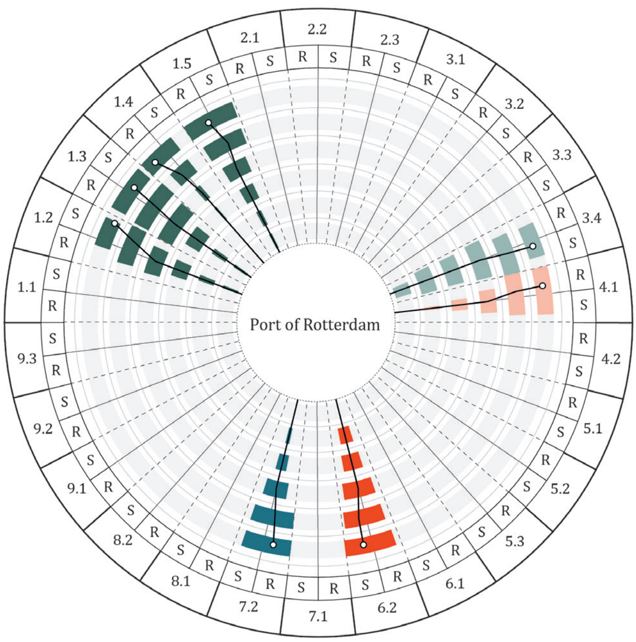
For the short and mid-long term interests the most important services for the Port of Rotterdam are the ones which are represented in figure 7.4. On the short and mid-long term it is not clear yet how the interest will change. Therefore, the interests as how they are now are considered and also how they would evolve on the long-term.

1. Relate city, river and harbor
Comparing the increase of factors of growth which this service provides shows that the service is already extensively provided in the first 3 phases, which is when the harbor is still (partly) functioning in the Waalhaven. This means that the visibility of the harbor activities increase on the short and mid-long term, providing values for the Port of Rotterdam. With the current interests the benefits would be similar in both scenarios as 1.2 and 1.3 provide higher benefits in Steam and 1.4 and 1.5 higher benefits in Rest.

3. Provide Educational Environment
The highest interest of the port within this ecosystem service is the improvement of the cultural identity of Rotterdam as a Harbor City. The analysis shows that this service increases in the first phase, decreases slightly in the second phase compared to phase 1, but is still increased compared to the existing situation, and increases again in the third phase. It is interesting to observe that, however the port is slowly transforming and moving out of the harbor basin, the values for increasing the identity of Rotterdam as a Harbor are still increasing. This is mainly happening due to the improved accessibility of the coastal zone and the water and therefore the visibility of the harbor activities.

4. Increase Water Safety
Reducing water depth to reduce currents and waves decreases flood risks outside the dikes and is therefore an important ecosystem service for the port. This value increases extremely through time as it is dependent on sediment disposal which takes time. Therefore, on the short term, the port will only obtain little values from this service.

6. Basis for Urban Development
For the Port of Rotterdam it is important to keep the values for settling businesses in the Waalhaven high as the harbor is slowly transforming and businesses would move in relation to that. Therefore, the improving of a green and pleasant business climate could work as an objective for

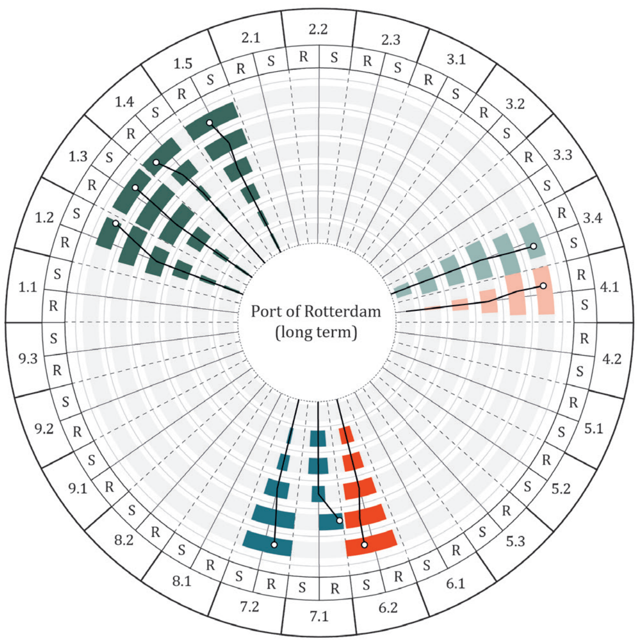


▲ Figure 7.4 | Interest and preferred pathways for Port of Rotterdam on short to mid-long term (source: by author) companies to stay or settle, which is favourable for the harbor. As the analysis shows, the values of both subservices is increasing and already quite high in the first three phases.

7. Contribute to Regional Circularity
The reuse of sediment is of high value, as the port's dredging activities provide a lot of material which has to be processed. The reuse of this material for the faster development of tidal parks is therefore benefitting the Port. This subservice already has increasing values in the first three phases and therefore benefits the port on the short and mid-long term.

Port of Rotterdam - Long-Term

For the long term the ecosystem services of highest interest for the Port of Rotterdam are the ones represented in figure 7.5. The diagram shows that the subservices for increasing water safety (4.1) and contribute to regional circularity (7.1 and 7.2) provide higher values in the Rest Scenario. Relating people to the river and creating awareness of the cultural identity of Rotterdam as a Harbor City are providing more values in Steam. In general the preferred pathways would direct towards the Steam Scenario: 4b - Steam.



▲ Figure 7.5 | Interest and preferred pathways for Port of Rotterdam on long-term (source: by author)

Province of Zuid-Holland

For the Province of Zuid-Holland the most important services are the ones which are represented in figure 7.6.

1. Relate city, river and harbor
Both subservices do not provide that many values on the short-term. The values increase extremely in phase 4a and 4b and then mainly in phase 4b. However, the final state of Rest provides more values than Steam.

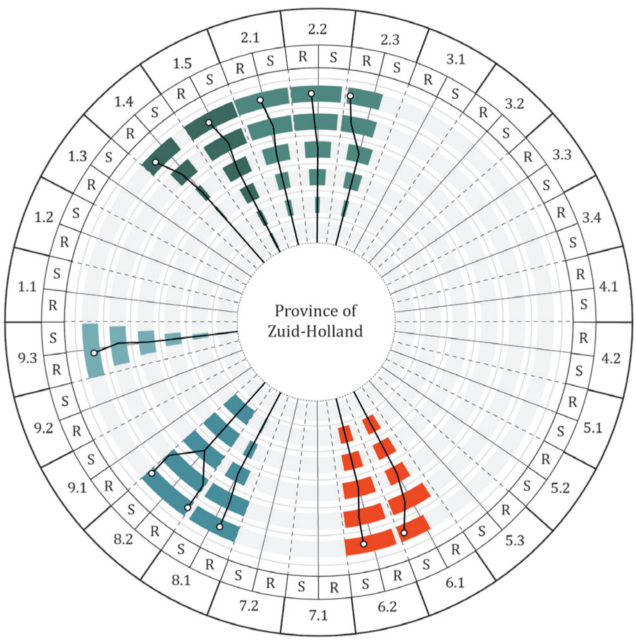
2. Increase Natural Value and Biodiversity
The values these three subservices provide are increasing in every phase and therefore already providing high values on the short and mid-long term. On the long-term the highest values are provided in the Rest Scenario.

6. Basis for Urban Development
Increasing land and real estate values and provide a green business settlement climate are important for the province as the province aims for the development of an attractive settlement climate for both businesses and residents. Both values are provided on the short-term and increase extremely in the Steam Scenario.

8. Provision of Fresh Water
The subservice of decreasing saline intrusion through ground water is already provided on the short-term. Decreasing saline intrusion through surface water increases on the long-term and is mainly addressed in the Rest Scenario.

9. Climate Regulation
In the province, CO2 emissions are a big problem due to peat oxidation in the polders. CO2 sequestration by salt marshes can compensate this problem partly and is therefore important for the province. It is mainly provided in phase 4b and the Rest Scenario.

The preferred pathway for the Province of Zuid-Holland is 4b-Rest. This means when we reach tipping point 4b the values will increase slightly for the province, but after that also the province would obtain most benefits from the Rest Scenario.



▲ Figure 7.6 | Interest and preferred pathways for the Province of Zuid-Holland (source: by author)

Rijkswaterstaat

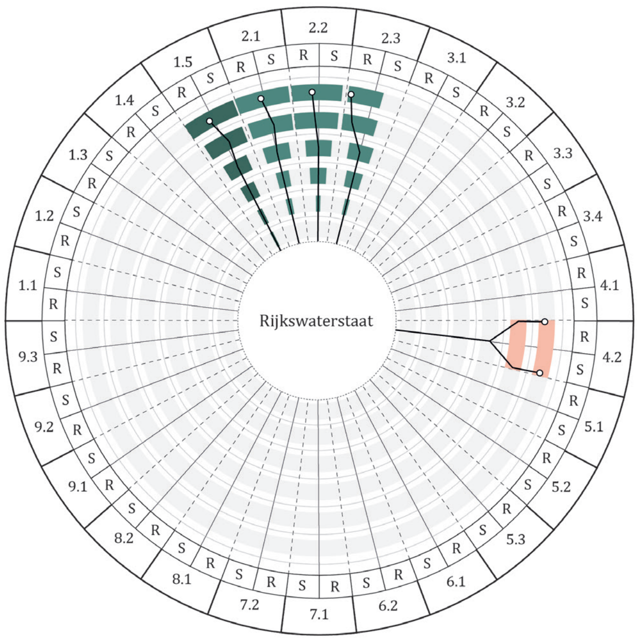
For Rijkswaterstaat the most important services are the ones which are represented in figure 7.7.

1. Relate city, river and harbor
The provided values for this subservice is almost similar in both scenarios. However, the pathway directs slightly to 4b and in the final state to Rest.

2. Increase Natural Value and Biodiversity
The values these three subservices provide are increasing in every phase and therefore already providing high values on the short and mid-long term. On the long-term the highest values are provided in the Rest Scenario.

4. Increase Water Safety
The subservice to protect dikes with a foreland is important for Rijkswaterstaat as they take care of the maintenance of the dikes. This value is provided from the point in time the sea levels start to rise faster. From this point, the dikes are sometimes directly subjected to the water, for example during extreme storms. At the time this point is reached, the tidal parks have developed to such an extent that it immediately provides the values and this is similar in both scenarios.

The preferred pathway for Rijkswaterstaat is 4a-Rest. This means that to obtain most values from tidal parks would mean an acceptance of socio-economic decline.



▲ Figure 7.7 | Interest and preferred pathways for Rijkswaterstaat (source: by author)

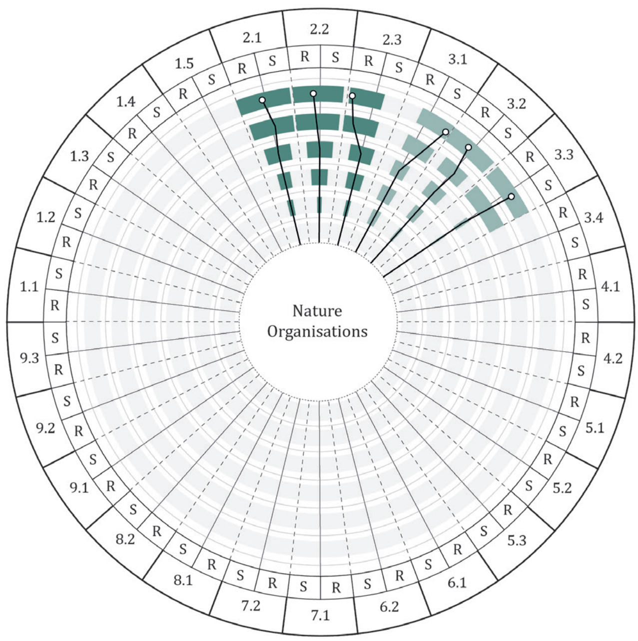
Nature Organisations

For Nature Organisations the most important services are the ones which are represented in figure 7.8.

2. Increase Natural Values and Biodiversity
By comparing the different growth factors of each phase the conclusion can be drawn that the interest of the Nature Organisations is higher in the Rest Scenario for all three subservices. The most extreme growth in the provision of these services takes place between phase 3 and 4a.

3. Provide Educational Environment
For subservices 3.1 and 3.3 the benefits for Nature Organisations are highest in the Steam Scenario. For subservice 3.2 the benefits are higher following the pathway towards the Rest Scenario. It It is interesting to see that apparently for this service, nature organisations would obtain higher benefits when economy grows. This can be explained as to create awareness for nature you need to connect people to nature. Higher densities of businesses or dwellings in combination with tidal nature therefore creates higher awareness than a highly ecological tidal landscape with mainly recreational purposes. Therefore, the overall direction of the pathway for this service would lean towards Steam.

Comparing the different preferred pathways for the subservices results in a slight direction towards the Rest Scenario in the final state. It appears that apparently making people aware of the value of nature is higher in the Steam Scenario, which makes the values do not differ much between both scenarios. The final preferred pathway for Nature Organisations is 4b-Rest.



▲ Figure 7.8 | Interest and preferred pathways for Nature Organisations (source: by author)

Deltaprogram Rijnmond-Drechtsteden

For the Deltaprogram the most important services are the ones which are represented in figure 7.9.

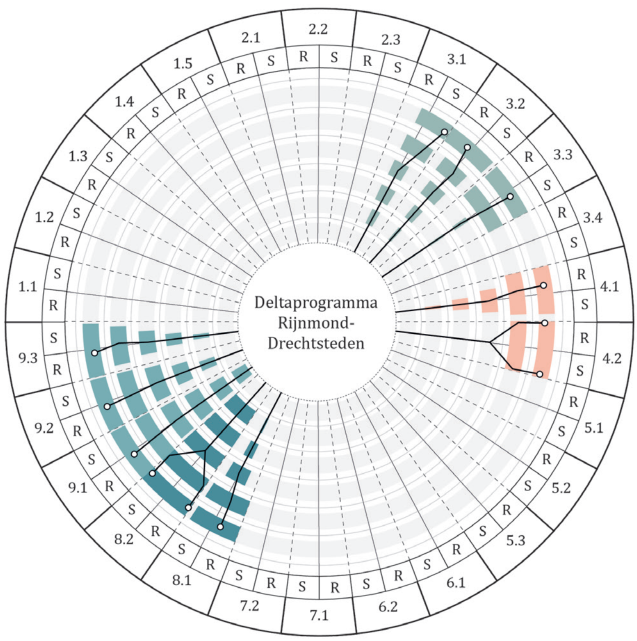
3. Provide Educational Environment
For the Deltaprogram it is important for people to be educated about the risks of living in a delta. If they are well prepared they might take personal measures to protect themselves against flood risks or be prepared for possible evacuations. The provided ecosystem services are higher in the Steam Scenario for both subservice 3.1 and 3.3. For subservice 3.2 the service is higher in 4b and then directs towards Steam.

4. Increasing Water Safety
Increasing water safety is for subservice 4.1 most provided in Scenario Rest and for subservice 4.2 the provided services are similar in both scenarios. This results in the fact that the interest of the Deltaprogram for this service would be higher in the Rest Scenario.

8. Provision of Fresh Water
For the subservice to reduce saline intrusion through surface water (8.1) the benefits are highest in the Rest Scenario. For saline intrusion through ground water (8.2) the benefits remain the same throughout the whole proces, so is similar in both scenarios. Therefore, also for the provision of fresh water the interest of the Deltaprogram is highest in the Rest Scenario.

9. Climate Regulation
Within the ecosystem service of climate regulation, the three subservices would all provide the highest benefits in the Rest Scenario. However, the results does not differ much from the Steam Scenario, which would also deliver relatively high values.

The preferred pathway for the Deltaprogram is 4b-Rest.



▲ Figure 7.9 | Interest and preferred pathways for the Deltaprogram Rijnmond-Drechtsteden (source: by author)

Zuid Hollands Landschap

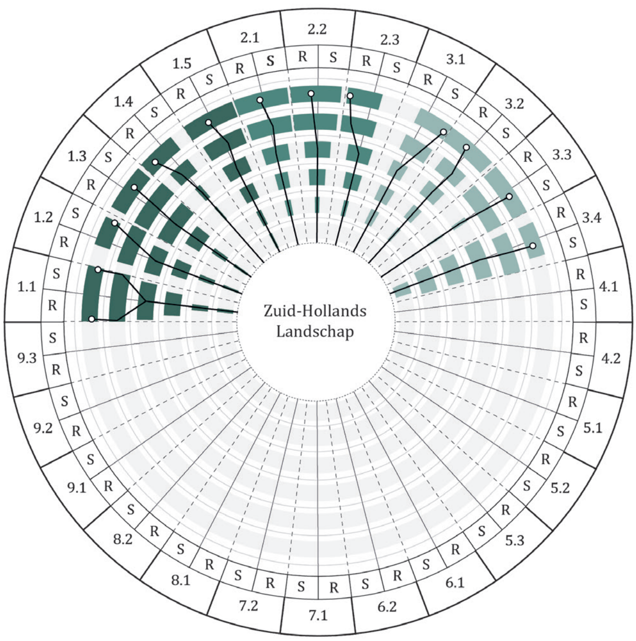
For the Zuid-Hollands Landschap the most important services are the ones which are represented in figure 7.10.

1. Relate city, river and harbor
The interest of connecting people to nature differs for the five subservices. For 1.1 the interest remains the same in both scenarios, for 1.2 and 1.3 the interest would increase in the Steam Scenario and in 1.4 and 1.5 the interest would increase in the Rest Scenario.

2. Increase Natural Values and Biodiversity
By comparing the different growth factors of each phase the conclusion can be taken that the interest of the Zuid-Hollands Landschap is higher in the final state of the Rest Scenario for all three subservices. It directs slightly towards 4b for subservice 2.2 in the phase before the final state. The most extreme growth in the provision of these services takes place between phase 3 and 4a. In

3. Provide Educational Environment
For subservice 3.2 the benefits for Zuid-Hollands Landschap are highest in the Rest Scenario. For subservices 3.1, 3.3 and 3.4 the benefits are higher following the pathway towards the Steam Scenario. For all subservices, the value is higher in 4b than in 4a.

The preferred pathway for the Zuid-Hollands Landschap is 4b-Rest.



▲ Figure 7.10 | Interest and preferred pathways for Zuid-Hollands Landschap (source: by author)

Water Boards

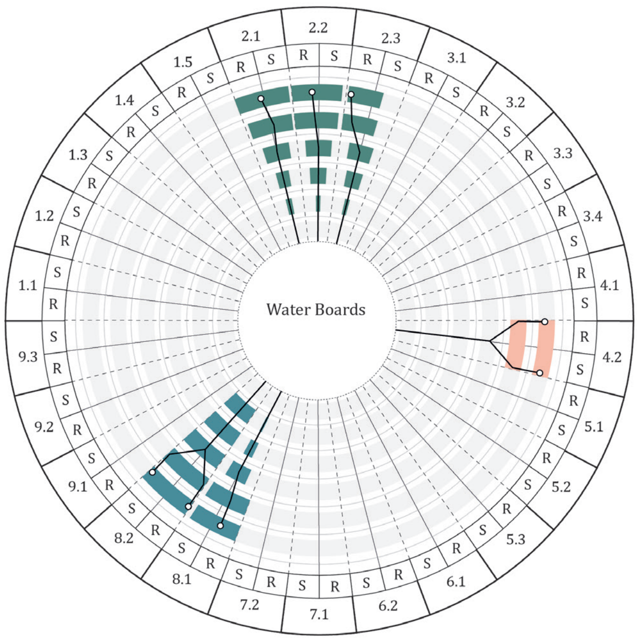
For the Water Boards the most important services are the ones which are represented in figure 7.11.

2. Increase Natural Values and Biodiversity
For all three subservices the interest of the Waterboards is higher in the Rest Scenario. It directs slightly towards 4b for subservice 2.2 in the phase before the final state. The most extreme growth in the provision of these services takes place between phase 3 and 4a.

4. Increasing Water Safety
The subservice to protect dikes with a foreland is important for Water Boards as they take care of the maintenance of the dikes. Increasing water safety is for subservice 4.2 similar in both scenarios. This value is provided from the point in time the sea levels start to rise faster. From this point, the dikes are sometimes directly subjected to the water, for example during extreme storms. At the time this point is reached, the tidal parks have developed to such an extent that it immediately provides the values and this is similar in both scenarios.

8. Provision of Fresh Water
For subservice 8.1 the benefits are highest in the Rest Scenario and for subservice 8.2 the benefits remain the same throughout the whole proces, so is similar in both scenarios. Therefore, for the provision of fresh water the interest of the Waterboards is highest in the Rest Scenario.

The preferred pathway for the Water Boards is 4a-Rest. This means that to obtain most values from tidal parks would mean an acceptance of socio-economic decline.



▲ Figure 7.11 | Interest and preferred pathways for Water Boards (source: by author)

Rotterdam Climate Initiative

For the Rotterdam Climate Initiative the most important services are the ones which are represented in figure 7.12.

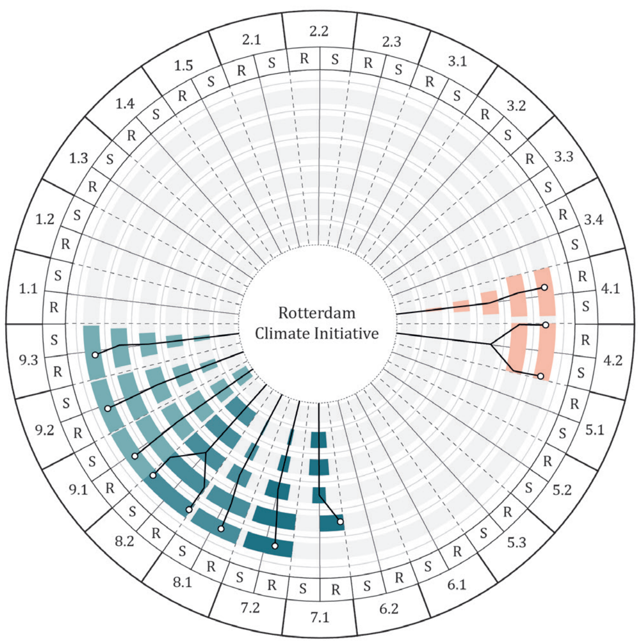
4. Increasing Water Safety
Increasing water safety is for subservice 4.1 most provided in Scenario Rest and for subservice 4.2 the provided services are similar in both scenarios. This results in the fact that the interest of the Climate Initiative for this service would be higher in the Rest Scenario.

7. Contribute to Regional Circularity
Subservice 7.1 to reuse coarse residual material provides higher values for the Climate Initiative in the Rest Scenario as more quays are being transformed and therefore available for reuse. The provided values for this service stops after phase 4a, which makes this a service providing values for the short and mid-long term. For subservice 7.2 the interest for the Climate Initiative to obtain this service is higher in the Rest Scenario.

8. Provision of Fresh Water
For the subservice to reduce saline intrusion through surface water (8.1) the benefits are highest in the Rest Scenario. For saline intrusion through ground water (8.2) the benefits remain the same throughout the whole proces, so is similar in both scenarios. Therefore, also for the provision of fresh water the interest of the Climate Initiative is highest in the Rest Scenario.

9. Climate Regulation
Within the ecosystem service of climate regulation, the three subservices would all provide the highest benefits in the Rest Scenario. However, the results does not differ much from the Steam Scenario, which would also deliver relatively high values.

Alltogether, this results in the overall consideration that the Climate Initiative would obtain highest benefits while directing towards the Rest Scenario. The preferred pathway therefore is 4a-Rest.



▲ Figure 7.12 | Interest and preferred pathways for the Rotterdam Climate Initiative (source: by author)

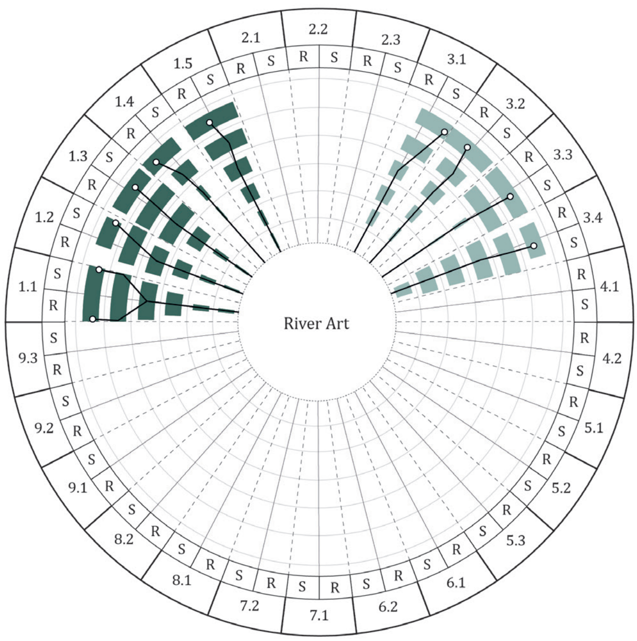
River Art

For River Art the most important services are the ones which are represented in figure 7.13.

1. Relate city, river and harbor
For subservice 1.1 the interest remains the same in both scenarios, for 1.2 and 1.3 the interest would increase in the Steam Scenario and in 1.4 and 1.5 the interest would increase in the Rest Scenario. The focus of River Art is to develop art pieces in the water or along the coast. As all of the five subservices are able to improve this objective in a similar way, the interest of River Art would not change in the different pathways. In both Rest and Steam the interest would remain the same.

3. Provide Educational Environment
For subservice 3.2 the benefits for River Art are highest in the Rest Scenario. For subservices 3.1, 3.3 and 3.4 the benefits are higher following the pathway towards the Steam Scenario. For all subservices, the value is higher in 4b than in 4a.

River Art would obtain highest benefits while directing towards the Steam Scenario. The preferred pathway is 4b-Steam. However, in the final state, the values in the Rest Scenario relatively high as well.



▲ Figure 7.13 | Interest and preferred pathways for River Art (source: by author)

7.02. Evaluating Preferred Pathways

In this section, the preferred pathways of the different partners are compared to find out what the similarities and conflicts are. For this, the stakeholders with the same preferred pathways are grouped and critically reflected.

4a (towards Rest) - Rest Pathway

Partners with 4a-Rest as preferred pathway are:
- Municipalities in Rest-Scenario
- Rijkswaterstaat
- Water Boards
- Rotterdam Climate Initiative

Evaluation
This pathway directs directly towards the Rest Scenario, which means towards socio-economic decline and moderate climate change. This could mean that when the mentioned partners want to obtain highest benefits from tidal nature they should rather accept economic decline.

4b (towards Steam) - Rest Pathway

Partners with 4b-Rest as preferred pathway are:
- Municipalities in Steam-Scenario.
- Province of Zuid-Holland
- Deltaprogram Rijnmond-Drechtsteden
- Zuid-Hollands Landschap
- Nature Organisations.

Evaluation
It is an interesting fact that the Municipalities in the Steam Scenario have a preferred pathway towards the final state of the Rest Scenario. Apparently, without designing for it, the Rest Scenario often still provides higher values on the extreme long-term. For example if we look at main service 9 (climate regulation), this service is considered as being more important in the Steam Scenario in general and therefore the design solutions are adjusted to provide this service. However, these results show that still the Rest Scenario provides higher values while the design solutions are less directed to provide this service. This example is also applicable for service 1, 4 and 8 (as the diagram in the previous section shows). The reason why the Province, the Deltaprogram, the Zuid-Hollands Landschap and the Nature Organisations obtain higher benefits in 4b than in 4a is due to their interest in main service 3 (provide educational environment) or 6 (basis for urban development). It appears that, making people aware of the value of nature is higher in the Steam Scenario. This can be explained as in the Steam Scenario, more people work and live in the delta landscape and are therefore more connected to it. This is the reason why nature organisations, the Zuid-Hollands Landschap and the Deltaprogram have a preferred pathway towards 4b. For the Municipality and the Province this is due to their interest in main service 6: basis for urban development. The preferred pathway of all partners finally directs towards Rest. The preference for the direction towards 4b instead of 4a is not extremely magnificent. As explained before, the values for the services these partners are interested in, are also relatively high in phase 4a.

4a (towards Rest) - Steam Pathway

No partners consider this pathway as the most preferred one.

4b (towards Steam) - Steam Pathway

Partners with 4b-Steam as preferred pathway are:
- Port of Rotterdam
- River Art.

Evaluation
River Art would obtain highest benefits while directing towards the Steam Scenario. However, in the final state, the values in the Rest Scenario are relatively high as well. This is the same for the long-term benefits for the Port of Rotterdam.

Concluding Results

As this evaluation shows provides the final state of the Rest Scenario more values for most partners than the Steam Scenario. However, many of these partners would prefer to first direct to 4b (towards Steam) and then direct back to the Rest design, which would mean a loss of capital. Therefore, the following options are possible:

1. The pathway directs towards 4b, but after that the economy starts declining extremely and climate change becomes less extreme (for example due to new produced knowledge and inventions). This would result in a loss of capital as tipping point 4b has already passed. The partners with the preferred pathway 4b-Steam would obtain highest benefits as it follows their preferred pathway. However, it also results in a loss of capital as some investments made in phase 4b does not function in the Rest Scenario. In this option, you could divide the costs in such a way that those stakeholders invest more in the projects as they also obtain highest benefits.
2. The pathway directs towards 4a and after that follows to the final state of the Rest Scenario. This means that the Municipalities in Rest Scenario, Rijkswaterstaat, Water Boards and the Rotterdam Climate Initiative obtain highest benefits as it follows their preferred pathway. This means they would also invest most in the interventions. Partners whose preferred pathway is 4b - Rest obtain still relatively high benefits in 4a and highest benefits in the final state of Rest. This means this would be the second group to invest in the interventions.

In both options the Port of Rotterdam and River Art obtain lowest benefits and would therefore also invest least in the interventions. However, for the Port of Rotterdam it could be considered to accept a decline in urban development in the Waalhaven in order to provide higher values in the harbor basins which are still in use, such as the Maasvlakte. Directing towards the Rest Scenario would mean the values in the Waalhaven itself are lower. However, as it increases water safety and can contribute to regional circularity to a great extent, it can increase the ecosystem services on the regional scale for the Port of Rotterdam. For example, because it could prevent the functioning harbor basins from flooding and can foresee in the processing of dredged material from those basins for the development of tidal parks in the Waalhaven. Therefore, the pathway towards Rest might be even more valuable on the long-term.

The results underpin the argument to maybe not constantly seek for economic growth as on the long-term it reduces the ecosystem services. Less partners will benefit from economic growth on the long-term as it reduces crucial values such as water safety. In the first part of this thesis it is explained that the awareness for the natural capital is rising, which results in eco-based solutions. However, the institutional influences on these solutions are still high. Providing economic benefits on the short-term 'wins' from the possible ecosystem services the eco-based solutions can provide on the long-term as the benefits for decision-makers often have to be within reach of their governing period. The testing of the backcasting method could bring awareness for the natural capital to a next level. It makes decision-makers aware of the value of nature and that it could go beyond economic growth. In the extremely complex Rotterdam Region the risks for continuing with hard measures and manipulating the delta landscape are too high. Why is the economic pressure on this vulnerable region this high? Do we need a natural disaster before we take serious measures? However the Steam results show that economic growth could go together with soft measures, it still does not provide as many services as in the Rest Scenario. Therefore, an acceptance of economic decline to improve the quality of life and reduce the risks of the uncertain future might be necessary.

7.03. Evaluating Urban, Regional and Territorial Effects through Time

This section evaluates on the effects through time in relation to space: the urban, regional and territorial scale. In the text, the numbers refer to the images in figure 7.14, representing the elements how to obtain most values from tidal nature.

Short-Term Effects

The values of the long-term strategy and phasing of the Waalhaven for the local surroundings are extensively addressed in chapter 4 and 5 of this thesis. On the short-term when the harbor is still present, the interventions in the Waalhaven improve the green business settlement climate, connect the neighborhoods to the Waalhaven, increase awareness of living in the Delta, improve natural and recreational values, provide space for leisure, reduce saline intrusion through ground water and regulates the climate which improves health. These ecosystem services have a direct effect on the inhabitants of the neighborhoods, the workers in the harbor and the flora and fauna in the harbor basin (1).

The 'no regret' measures already provide a strong connection between the basin and the Zuiderpark by connecting recreational routes and tidal and fresh nature. Since 2018 the Blue Connection is finished: an integral connection between the Zuiderpark in Rotterdam, a landscape park in Rhoon and Dordrecht. It improves recreational routes, ecological connections, the water quality and functions as water storage area. As explained before, the water system of the Blue Connection is extended to the wetland park in the climate dike. Therefore, the interventions not only improve the water quality for the wetland park itself, but also functions as a climate buffer in relation to the Blue Connection (4). The climate dike as a whole connects the Waalhaven with the surrounding neighborhoods, which completely integrates the Waalhaven in the recreational and natural network (3). This will not only improve the accessibility of the Waalhaven, but also the other way around. As more recreationalists will visit the Waalhaven, the Blue Connection becomes more attractive from the west side as well (4). For increasing urban and regional natural values, the interventions are extremely important as they connect tidal and fresh nature. This provides species to migrate between water and land and therefore extends their migration routes and habitat. The Waalhaven is now integrated in an ecological and recreational network which extends to Dordrecht, the natural park the Biesbosch and even further (3 & 4). On the short-term, the interventions would already contribute on a regional scale, as dredged material from the rivers and harbor basins can be reused in the tidal parks and therefore do not have to be processed.

The method of inverting ecosystem services through time to use it as a design instrument in order to obtain most values from it, is tranferable to other eco-based projects. The case-study of the Waalhaven functioned to test the method. When more of these kind of case-studies would become reality along the Nieuwe Maas, the interventions would be able to function together, providing higher values for the direct surroundings (1).

Mid-Long Term Effects

On the mid-long term, when the small scale local projects are increasing in size and values, the ecosystem services are enforcing each other. For example, protecting the primary dike along the Waalhaven would prevent this specific dike to collapse, but a structural undeepening of the harbor basins and river will reduce the pressure on the whole primary dike system (2). Another ecosystem service which increases strongly on the long-term and regional scale is the provision of fresh water by reducing saline intrusion. On the mid-long term the sea levels start to rise and river discharges become more extreme, which increases saline intrusion. By that time, the local scale initiatives are already enforcing each other and together the undeepening would result in a reduced saline intrusion through surface water (2).

Long-Term Effects

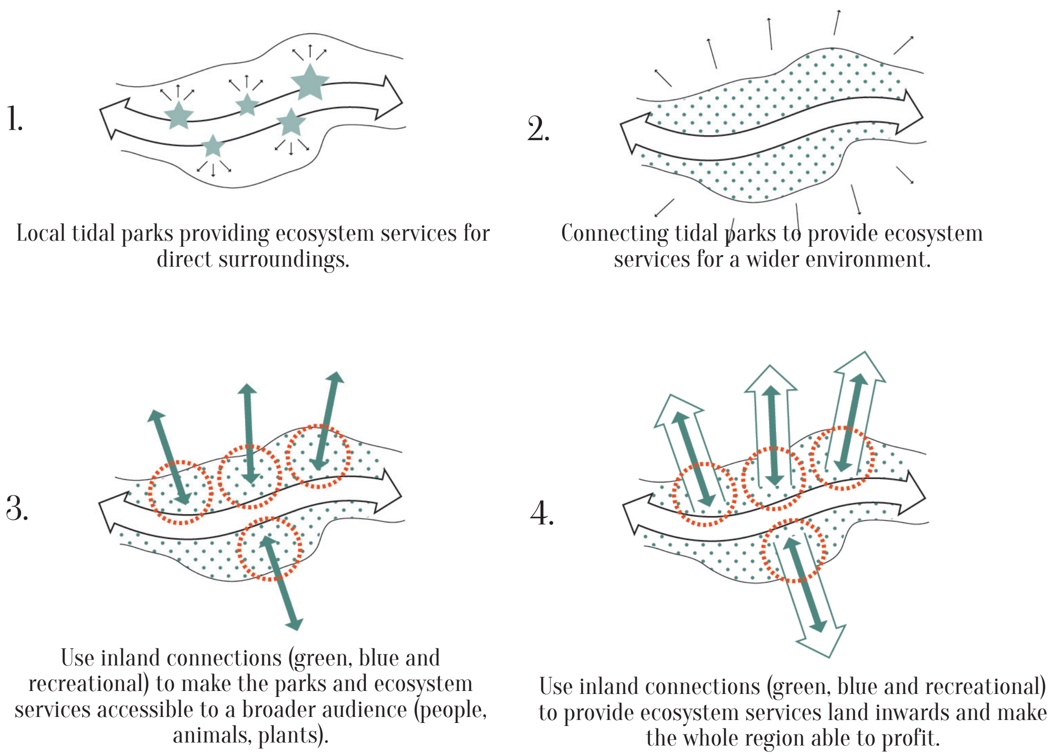
The ecosystem services of water safety and access to fresh water, which start to be profitable on the mid-long term, increases even more on the long-term. Risks are reduced and therefore the economic growth would be stimulated in a sustainable way. This could attract businesses, jobs and inhabitants and would therefore boost the economy (2). It would not only reduce risks for the region, but would benefit the nation in general. This is because for example the water inletpoint near Gouda would be less threatened by saline intrusion. As this inlet point is important for the provision of fresh water for large parts of the Netherlands, it benefits all.

This thesis describes the method in relation to the Nieuwe Maas, but as explained before, it is transferable. When other nations with tidal rivers along the North Sea, such as the Thames river in the UK, the Elbe river in Germany and the Seine river in France, would use the method to develop tidal nature as well, the values would increase to a territorial scale. On the short-term and local scale, tidal parks does contribute to climate mitigation by CO_2 sequestration in the salt marshes and wetlands by reducing CO_2 emissions caused by peat oxidation. However, this is only a drop in the ocean. Climate change is a phenomena which cannot be resolved with small scale measures. Nations should work together to really make a difference. Therefore, I would recommend to apply the method on a territorial scale to set conditions for serious climate mitigation.

Together with that, the sediment capturing in the rivers increases the quality of the water that ends up in the North Sea. Together with the territorial improvement of ecology and biodiversity this would result in more healthy seascapes. It would reduce hypoxia areas and algae blooms and therefore improve marine life.

Conclusion

By applying the 'Turning the Tide' method at the same time on a regional and even territorial scale, the ecosystem services would enforce each other. Small scale interventions on the short-term provide high benefits locally. However, to really make a difference on the long-term, in relation to water safety, saline intrusion, climate mitigation and therefore a good quality of life for future generations, the method should be applied in the whole North Sea Estuary.



▲ Figure 7.14 | Tidal nature providing highest values (source: by author)

conclusions

Conclusions

The manipulation of the delta landscape in the Rotterdam region, to meet the economic desire of society, resulted in a degradation of ecosystem services. Each eco-based design, such as 'the River as a Tidal Park', being the case-study for my thesis, is subjected to a wide range of environmental, societal and political risks. Considering the extremely uncertain projected risks for increasing sea levels and more extreme river discharges after 2050, the river does not provide the flexibility the future demands. After the implementation of relatively short term and local scale initiatives the project is still subjected to these uncertainties. This makes the final values it can produce in the future uncertain and might conflict with long term and large scale projects. Therefore, it might result in a loss of capital for partners as the project appears to be unsustainable. Accordingly, this thesis investigates the possible extension of 'the River as a Tidal Park'. It aims for developing an adaptive framework to ensure the desired objectives for 2100 will be achieved and costs and benefits are distributed more evenly among stakeholders through time and space. The hypothesis which will be tested is to what extend the value of ecosystem services can be inverted in time to use it as a design instrument in relation to decision-making processes, in order to obtain most values from it. The research question which leads this thesis is:

How can the concept of 'Nature as a New Economy' be used for the development of an adaptive design for the spatial transformation of the fluvial zone of the Nieuwe Maas considering the uncertain future?

The question is tackled by 1) investigating the uncertainties of the region until 2100 and how they are affecting the project of the River as a Tidal Park, 2) investigating the range of ecosystem services tidal parks are able to provide and how they would contribute to future problems, 3) investigating the desired values for the stakeholders to achieve with the project until 2100, 4) discover value synergies in terms of ecosystem services beween two future scenarios (related to socio-economic and climate change) in order to find 'no regret' measures, 5) investigating the effects on the spatial lay out through time in terms of the provision of ecosystem services by reaching design specific tipping points and 6) define the change of interest for stakeholders over time in order to distribute costs and benefits more even among them.

The concept of 'Nature as a New Economy' is in this thesis used to develop an adaptive design for the spatial transformation of the coastal zone of the Nieuwe Maas considering the uncertain future. It is used in the way that the whole research takes the desired ecosystem services for 2100 as a starting point for planning and design. The range of ecosystem services which should be provided in the two scenarios are taking into account most plausible uncertainties. By finding value synergies between both scenarios, the 'no regret' measures are determined. These measures provide ecosystem services on the short term and do not result in a loss of capital on the long term. It is unclear what moment in time uncertainties are affecting the project, but the adaptive framework provides guidelines for decision-makers to take action when specific tipping points are reached. The desired ecosystem services future generations need, is provided by following the framework. By relating the provided ecosystem services through time with the desired ecosystem services for the partners, the interest of them after reaching specific tipping points is clarified. This could result in the choice of stakeholders to stop investing in the project, as they expect to obtain less ecosystem services in the future. However, it could also work as an objective to increase financial support as the benefits will increase. As chapter 6 shows, the value of most ecosystem services are increasing after the tipping points are reached, this last example would probably be the case. This would increase financial support for the project and could therefore attract new partners as they observe the ecosystem services that are provided could also benefit them.

By showing and quantifying the value of nature - the ecosystem services - the project could be provided with a model of revenue in order to make sure the project can be extended until 2100. The increasing financial support through time makes that the tidal parks are able to provide more ecosystem services which are able to cope with and decrease the risks related to the uncertain future.

In this way, the framework and method developed by 'Turning the Tide' is providing decision-makers with a language to give insight in the benefits for them on the long term, is increasing the financial support for the project and will reduce the risks

for future generations. This thesis provides a backcasting method which is transferable in other eco-based projects to increase ecosystem services over time. It makes decision-makers aware of the value of nature and that it could go beyond economic growth.
Nature can be the economy itself, which is the new value for producing economic growth. Soft measures demand for more space and less intensive use of land for urban- and harbor development and agriculture. For nature to be the new economy, the current generation should make this space available. We should not wait for a disaster to happen as the consequences might be extremely harmful for future, or even current, generations. With these words I would like to encourage the argument to partly accept possible economic decline in this extremely vulnerable region.

By applying the 'Turning the Tide' method at the same time on a regional and even territorial scale, the ecosystem services would enforce each other. Small scale interventions on the short-term provide high benefits locally. However, to really make a difference on the long-term, in relation to water safety, saline intrusion, climate mitigation and therefore a good quality of life for future generations, the method should be applied in the whole North Sea Estuary.

Lessons Learned

The methodology of designing by looking into the desired ecosystem services for the two scenarios results in a very broad perspective of how tidal nature can contribute to society. Following the thoughts of the two different scenarios results in a shift of thinking, which does not just follow the most probable future. During the research and design process I noticed sometimes I wanted to define for the scenarios which ecosystem service is most important within that scenario. However, do the people who live in that scenario also consider it as important? Because if they do not, they won't develop ecosystems providing this particular service, while I now think they would. For example, the Steam Scenario describes that increasing biodiversity with nature development will be the least important type of land use by 2100 as it makes place for urban development, harbor activities and agriculture. In order to have a sustainable economic development, biodiversity is crucial, for example in terms of pollination needed for food production. However, society in the Steam Scenario would not rather provide nature for improving biodiversity as they do not consider it as important. In this way, the way of thinking from me now might be different from the decision-makers in the future. This scenario-thinking is an important skill I used and developed during the writing of this thesis.

Another important aspect, which I mainly developed during the internship at the Municipality, is the influence of political values on nature development. As described before, nature is often subordinate to economic development as the development of urban areas, harbors, quays, shipping routes seems economically more profitable. Within the project team of the River as a Tidal Park, the value of nature is, of course, clear and awareness of the benefits society can obtain from tidal parks is high. However, the project team is dependent on external financial support, meaning the partners have to transfer the awareness of the value of nature to possible contributors. An example of how this is done is by the implementation of small scale parks, which are financially feasible on the short term, to show what value it can bring. With this 'first generation' of parks the interest among decision-makers is rising and now a 'second generation' of parks is in its design phase, which are of a larger scale and pursue higher ambitions. This way of creating interest by implementing projects works to attract new stakeholders. The outcomes of the thesis can function as a method to increase interest among stakeholders, not approaching it from today's perspective, but from that of the future. By showing the stakeholders how the tidal parks can benefit them, considering the approaching risks related to socio-economic change and climate change, in the future. The thesis aims of showing the urgency for stakeholders to support the program now, as otherwise it would result in destroying capital for them in the future. By combining the two methods to increase awareness among stakeholders, resulting in possible financial support on the short term, the project would be able to come into an accelerated phase. The understanding of the influence of political values on nature development and finding ways to use this in a sustainable way is a great value I developed during the thesis.

Internship at the Municipality of Rotterdam

The development of the research and design of this thesis went hand in hand with my internship at the Municipality of Rotterdam. This section describes the value of the thesis for the Municipality.

Focus of Future Objectives of the Program
The project of the River as a Tidal Park, of which the Municipality is a main partner, started in 2013 and the first generation of parks is or will be developed until 2020. The collaboration contract of the program runs until 2020, which makes it crucial to think about future partnerships and related objectives of the program. The seven objectives which are defined in 2013 have to be reconsidered for which this thesis provides the first steps. The thesis reflected on the existing objectives provided by the implemented and planned tidal parks, resulting in an overview of the provided values. Some of the objectives appeared to be addressed less than others. Nowadays, some ecosystem services might not be considered important. The method provided by this thesis gives insight in the importance of the services on the long-term and therefore the changing interests over time. The project's objectives have to be adjusted after each generation of parks as the demands and desires of the partners and population of the region change and new insights could provide new values for future parks. In the years after the start of the project already a lot changed, for example in terms of society's awareness of climate change. Therefore, reflection on the existing objectives is important for the future development of the project. The analysis of possible services the tidal parks can provide and the regional analysis showed that the tidal parks can resolve more problems, which are mainly long term, than the program addresses now. In the thesis this resulted in a change of importance of existing objectives and resulted in the addition of two new objectives. The thesis therefore provides insight in the importance of some of the values in specific scenarios (such as food production), due to future uncertainties (such as increasing water safety) and values which are not addressed yet, but become of great importance (such as climate regulation) (Oosterholt, 2019). In the autumn of 2019 a new direction for the approaching UPG program (Uitvoeringsprogramma Groen), running from 2020-2024, for the project of the River as a Tidal Park will be determined (de Groot, 2019). A recommendation is to use the input of the thesis for the actualisation of the existing objectives and the proposal of new-to-consider objectives as they become important in the future.

Involvement and Interest of Partners
Together with this consideration of future objectives of the program, the involvement and interest of the partners is important. During the latest meetings of the partnership (Kernteamoverleg Rivier als Getijdenpark, 2019) some partners pronounced their concerns about certain values provided by the parks in which they invest which does not meet the desires of this specific partner. To name an example: nature organisations invest in parks in the highly urban area of Rotterdam which in the end become very cultural with mainly recreational purposes, functioning as a base for further densification. The nature organisations would prefer tidal parks which are more natural, providing natural values and increasing biodiversity, but still they do invest in the cultural parks not providing the services they desire. The difference in ambitions, desires, demands and objectives by each stakeholder are logical and crucial, but it is important to be aware of this in order to distribute the costs and benefits fairly among stakeholders (Oosterholt, 2019). The thesis provides insight in the desires and interest of the existing partners and how the project developed according to this. Furthermore, the ecosystem service assessment shows how the values each stakeholders obtains in the different phases change over time. In this way, a direction towards a certain scenario can already result in a recommended change of costs and benefits among stakeholders as the expected values for stakeholders might change. This could result in a more sustainable partnership for the long term in which each stakeholder agrees with the distributed costs and benefits.

Insight in Nature's Value
As explained before, the value of nature on the long term is often undeRestimated by decision-makers, resulting in a lack of nature-inclusive projects in economically valuable regions. The project of the River as a Tidal Park aims for including nature more in the future development of the river Nieuwe Maas, but sometimes finds conflicts when it comes to financing the projects. The ecosystem service assessment shows the economic value of the implementation of tidal nature in the Waalhaven. This represents the value nature can provide on the long term and functions as a common language between decision-makers. By the assessment of this design, providing ecosystem services, partners which are not involved yet can recognize the values of nature and can decide to invest in the project as well. The attracting of new partners and contributors could result in increased financial support which makes the implementation of tidal parks more feasible.

Long Term Development of Short Term Implementations
The short term implementation of tidal parks are often seen as a final status, providing values for the direct surroundings. However, this thesis shows that the dynamics of the changing climate, of the changing socio-economic state of the region and of the rivers' hydrodynamics demand for projects

which are constantly evolving through time and are able to adapt to these landscapes of flux. The tidal parks can never be 'finished' in such a dynamic landscape. The methodology which this thesis follows, by working backwards from 2100 to now, result in 'no regret' measures which are not destroying capital within each plausible future. The problem that this thesis addresses is outreaching the municipality on itself. It does give insight in how they can contribute to this huge future transition and not become the victim of the regional dynamics when the tidal parks for example cannot keep up with the speed of rising sea levels. The methodology provides a sustainable way of thinking, a new approach to develop tidal nature and create supporting capacity.

For Further Research

The usual way of designing is to first analyse the expected future trends and then design with the intention that the design can deal with these changes. However, after implementation of a design, there will always be unexpected uncertainties. The project 'Turning the Tide' considers scenarios until 2100 which covers two plausible futures related to socio-economic and climate change. By defining the most crucial ecosystem services in each scenario and search for value synergies, the short term design will be able to transform towards both scenarios without a loss of capital. Therefore, I would say that the methodology makes sense and works. However, due to limited time, only two scenarios are considered. This does cover the full range of variables considering climate change and socio-economic change, but due to a different combination of those variables in crowd and warm the outcomes shall be different. Therefore, the research and design does not give a full overview of the correct value synergies and therefore of the final short term design. For further research I would recommend to investigate the other two scenarios, define the desired ecosystem services, search for the synergies and adjust the short term 'no regret measures' to be sure the design is able to adapt to the plausible futures.

Besides that, for the research I used an actual report of the Deltascenarios from 2017, which did not yet took into consideration the increasing speed and rise of the sea level. The Deltascenarios take into account a maximum sea level rise of 85 cm until 2100, while the new numbers from Deltares (October 2018) define a possible sea level rise of 300 cm. For the research and design I used the newest numbers for sea level rise, but as they were not developed in new socio-economic scenarios the relation between those two variables, as how I used them, might be not scientific. For example, due to the new numbers for sea level rise, there is a discussion if it would be even possible to stay in the west part of the Netherlands by 2100, as the risks become too extreme. For the thesis I took as an assumption that society does not leave the region completely and that the developed ecosystems provide services for the population in 2100. However, the outcome of this deep uncertainty only becomes visible after 2050, which might result in the fact that new measures have to be taken to remain safe.

With the assessment of ecosystem services how it is used in this thesis, it does indicate to what extend the interest of stakeholders increases or decreases over time, but does not show the exact value of the provided services. In order to use the concept of 'Nature as a New Economy' to a great extend, the adding of economic values to the provided services is needed. This could give insight in the monetized value for each stakeholder in each phase as it functions as a common language through time. With this information, the project could be evaluated using a cost-benefit analysis. With this evaluative framework the costs of implementation can be compared with the (monetized) benefits for each stakeholder, showing the absolut value. Drawing these kind of conclusions would increase the interest of stakeholders even more as the absolut value is quantified and works as an objective for change. It could also be used to improve the fair-share between the partners.

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appendix

Appendix 1 – Analysis of Tools to Assess Ecosystem Services

The concept of nature as a new economy is outreached through the development of several tools to assess ecosystem services. Two tools, which are commonly used in planning and design practices, are the Dutch TEEB tool (2013) and the British B£ST tool (2018) are analysed to understand in what way ecosystem services are assessed in planning and design before.

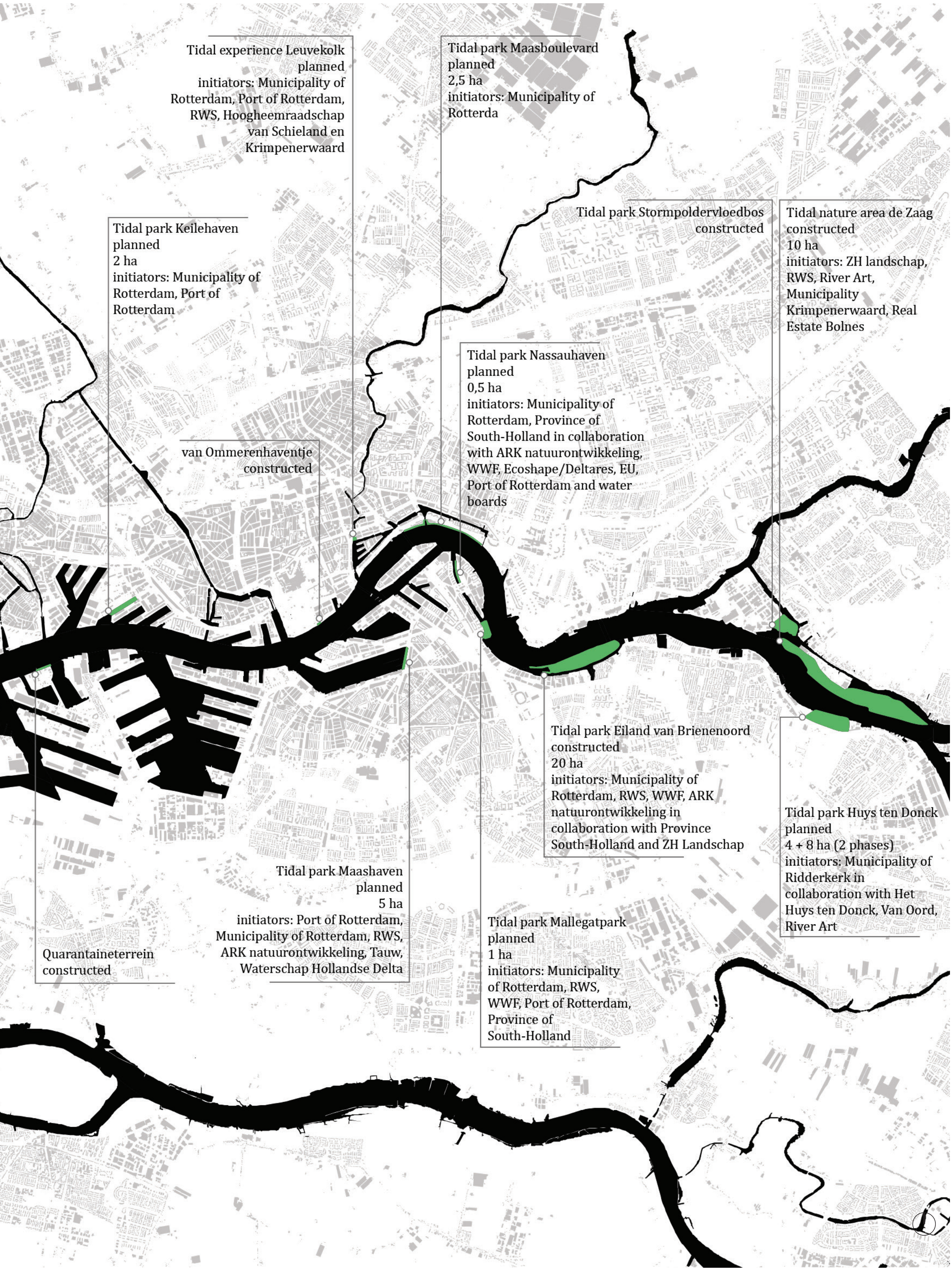
TEEB is a Dutch tool, meaning The Economics of Ecosystems and Biodiversity, originated in 2013 and developed by the Ministry of Economic Affairs and Infrastructure & Environment. The aim of the tool is to function as a method to recognize and monetize the benefits of Blue Green Infrastructure (BGI). This will result in investments that are economically more profitable when including blue and green elements in a project (Gomez, 2016; TEEB, 2011). The TEEB tool works with six different categories in values obtained from BGI, namely health, energy consumption, value of housing, social cohesion, water management and recreation and leisure. Each category requires specific data in order to be able to assess the economic benefits related to the project. To explain the operation of the TEEB tool, an example from the health category will be described, showing the assessment of reduced healthcare costs due to a greener environment. By adding green, the number of patients is reduced, resulting in a decrease of health costs. The required data are 1) the number of inhabitants in a sample of 3.14 km^2 and 2) the percentage of km^2 new green space in the same area. Maas et al. (2009) defined that due to a 1% increase in greenery, the amount of patients per 1000 people is reduced by factor 0.835. The calculation of the reduction of patients can be done by (number of people living in a radius of 1 km from the improved greenery/1000) x (percentage of greenery improved) x 0,835. Multiplying this with the average health cost per patient per year results in the saved money on healthcare costs due to a greener environment (Bruno, 2018). The calculation of those savings before the (re)development of public space can work as an incentive for the development of greenery instead of, for example, paved area.

B£ST is a tool for valuing the benefits of BGI as well, but then more specifically in how they can contribute in sustainable stormwater management. Stormwater management is shifting in perspective from simply providing drainage to one that manages stormwater on the surface. This change requires a broader range of actors to be involved than just the engineers, including landscape architects and urban planners. B£ST emphasizes how this shift to Sustainable Drainage Systems (SuDS) can contribute in providing a broad range of benefits on all levels, besides just the reduction of flood risk (Ciria, 2017). The benefit categories B£ST considers are air quality, amenity, biodiversity and ecology, building temperature, carbon reduction and sequestration, crime, economic growth, education, enabling development, flexibility, flooding, ground water recharge, health and wellbeing, pumping waste water, rain water harvesting, recreation, tourism, traffic calming, treating waste water and water quality (Ciria, 2016). The tool looks into which ecosystem services are affected by the whole sustainable drainage system and therefore does not focuses on individual components of the system. It can be properly used throughout the design processes as several design simulations can be compared to discover the most valuable option (Susdrain, 2017). In order to explain the operability of the B£ST tool an example of how a SuDS scheme can improve air quality and therefore reduce health treatment will be explained. This assessment can be best compared with the assessment of the reduction of the amount of patients due to a greener environment, taken as an example from the TEEB tool. This makes it easy to compare both tools. Firstly B£ST asks the user to estimate the local existing air quality, which is needed to later evaluate and define the likely impact. The reduction in air pollution is calculated through the following formula: (number of trees and area of vegetative SuDS) x (average pollution removal level). The tool calculates vegetation and their impact according to their size. There is distinction made in the amount of annual pollutant uptake of NO2, SO2, O3 and PM-10 related to small, medium and large size trees. This allows the tool to calculate the economic value of the improvements. This is done through linking it to the monetary values of air quality benefits coming from the UK government's air quality economic assessment methodology (Defra, 2013), which is based on the damage to health avoided from reductions in air pollution (Ciria, 2016).

Comparing the assessment of ecosystem services through both tools it stands out that the B£ST tool is way more specific than the TEEB tool. However TEEB seems to focus on BGI in general while B£ST only focuses on drainage systems, B£ST is way more comprehensive as it relies more on site specific data. It also recognizes that the benefits of the drainage systems can extend beyond the urban context, while most of the TEEB indicators focus only on urban areas (Moncrieff, 2018). B£ST considers more benefit categories and is also more specific in the calculation of the improvement of air quality as it considers several air quality parameters and makes a distinction in the size of the trees and their uptake of pollutants in the air. Besides that, B£ST aims for planning and designing sustainable drainage systems which are more flexible and adaptable than traditional piped drainage systems. When climate changes or knowledge is advanced, the systems can be added to or even abandoned relatively cheaply and easy, which makes them in a way adaptable to uncertainties. B£ST also investigates on the impact of uncertainty in the values being used and applied through the application of a simple user defined estimate of confidence (Ciria, 2016).

Appendix 2 - Analysis and Assessment of Constructed and Planned Tidal Parks

Location of Constructed and Planned Tidal Parks



▲ Overview of constructed and planned tidal parks in the Nieuwe Maas (source: by author)

Analysis of Characteristics of Constructed and Planned Tidal Parks

Tidal Parks \ Characteristics	Park Surface	Planned / Constructed	Spatial Characteristics Original River Bank
1. Eiland van Brienenoord	20 ha	constructed	natural – cultural
2. Groene Poort noord	2,9 ha	planned	natural – cultural
3. Groene Poort Zuid	20 ha	constructed	natural – cultural
4. Huys ten Donck	12 ha	planned	natural – cultural
5. Keilehaven	2 ha	planned	natural – cultural
6. Leuvekolk	t.b.d.	planned	natural – cultural
7. Maasboulevard	2,5 ha	planned	natural – cultural
8. Maashaven	5 ha	planned	natural – cultural
9. Mallegatpark	1 ha	planned	natural – cultural
10. Nassauhaven	0,5 ha	planned	natural – cultural
11. van Ommerenhaventje	0,1 ha	constructed	natural – cultural
12. Quarantaineterrein	0,5 ha	constructed	natural – cultural
13. Stormpoldervloedbos	8,5 ha	constructed	natural – cultural
14. Vijfsluizerhaven	5 ha	constructed	natural – cultural
15. Wilhelminahaven	2,5 ha	planned	natural – cultural
16. de Zaag	10 ha	constructed	natural – cultural

design principles

park in outside bend · park in inside bend · park in length of the river · park perpendicular to the river · park as an island · park in harbor basin

Level of Nature and Culture of Park	Design Principles for creating Tidal Nature	Natural Conditions for Tidal Nature	Relation to Urban Density / Accessibility	Main Initiators
natural cultural	—	salt brackish fresh	low high	Municipality of Rotterdam, Rijkswaterstaat, WWF, ARK
natural cultural		salt brackish fresh	low high	Municipality of Maassluis, Rijkswaterstaat, Province of South-Holland
natural cultural		salt brackish fresh	low high	Rijkswaterstaat, Port of Rotterdam, WWF, Municipality of Rotterdam
natural cultural		salt brackish fresh	low high	Municipality of Ridderkerk
natural cultural		salt brackish fresh	low high	Municipality of Rotterdam, Port of Rotterdam
natural cultural		salt brackish fresh	low high	Municipality of Rotterdam, Port of Rotterdam, HHSK, Rijkswaterstaat
natural cultural		salt brackish fresh	low high	Municipality of Rotterdam
natural cultural		salt brackish fresh	low high	Port of Rotterdam, Municipality of Rotterdam, Rijkswaterstaat, ARK, Tauw, Water Board Hollandse Delta
natural cultural		salt brackish fresh	low high	Municipality of Rotterdam, Rijkswaterstaat, WWF, Port of Rotterdam, Province of South-Holland
natural cultural		salt brackish fresh	low high	Municipality of Rotterdam, Rijkswaterstaat, Province of South-Holland
natural cultural	—	salt brackish fresh	low high	Municipality of Rotterdam
natural cultural	—	salt brackish fresh	low high	Municipality of Rotterdam
natural cultural	—	salt brackish fresh	low high	Municipality of Krimpen aan den Ijssel, SH Landscape, Rijkswaterstaat
natural cultural		salt brackish fresh	low high	Municipality of Schiedam, Rijkswaterstaat, ARK
natural cultural		salt brackish fresh	low high	Municipality of Schiedam, Rijkswaterstaat
natural cultural	—	salt brackish fresh	low high	SH Landscape, Rijkswaterstaat, RiverArt, Municipality of Krimpenerwaard, Real Estate Bolnes

▲ Characteristics of implemented and planned parks (source: by author)

Assessment of Constructed and Planned Tidal Parks on Provided Ecosystem Services

Tidal Parks \ Main Goals and related Values	Relate City to River		Increase Natural Value	Educational Environment	
	Recreation	Accessibility of the Water	Increasing Biodiversity	Awareness of Living in the Delta	Playground to get acquainted with Nature
1. Eiland van Brienenoord	+	+	++	+	+
2. Groene Poort Noord	+	++	+	+	+
3. Groene Poort Zuid	0	0	++	+	0
4. Huys ten Donck	+	++	+	+	0
5. Keilehaven	++	++	+	++	0
6. Leuvekolk	++	++	0	+	0
7. Maasboulevard	++	+	+	++	+
8. Maashaven	++	++	++	++	++
9. Mallegatpark	0	0	++	+	0
10. Nassauhaven	+	0	++	+	0
11. van Ommerenhaventje	+	++	0	++	0
12. Quarantaineterrein	++	++	0	++	++
13. Stormpoldervloedbos	+	0	+	+	0
14. Vijfsluizerhaven	0	0	++	+	0
15. Wilhelminahaven	++	++	++	+	+
16. de Zaag	+	+	++	+	0
Ecosystem Service Assessment	19	19	21	21	8
Objective Assessment	**19**		**21**	**16**	

Increase Water Safety	Food Production		Basis for Urban Development		Closing Regional Cycles	
Protection of the Dikes	Generate Fishing Spots	Production of Edible Plants and Animals	Increased Land and Real Estate Value	Cost-Saving through decreased Maintenance	Reuse of Restflows	Labs or Testcase provide Knowledge Production
0	+	0	+	0	0	0
+	+	0	+	0	0	0
+	0	0	0	0	++	+
0	+	0	+	0	0	0
0	0	0	++	0	0	0
0	0	0	+	0	0	0
++	0	0	++	+	+	+
0	+	0	++	+	+	0
+	0	0	0	+	0	0
0	0	0	++	+	0	0
0	0	0	+	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	+	0	0
0	+	0	0	+	0	0
0	+	0	+	0	0	0
5	6	0	14	6	4	2
5	**3**		**10**		**3**	

▲ Ecosystem services provided by constructed and planned parks, including their assessment (source: by author)

Appendix 3 - Problem Analysis Nine Ecosystem Services

1. Relate city, river and harbor

Lack of Recreational Facilities along the River
On regional scale in general there is a lack of recreational facilities in the coastal zone of the river. More landinwards there are several recreational areas and mainly here and along the sea coast there are a lot of recreational possibilities. Along the Nieuwe Maas there are some long distance routes but they lack in the south. Also the recreational facilities are only focused on hotels and bungalows here.

The main problem in the relation between the city and the river is the fact that between the recreational routes and urban areas, the harbor is located. This creates a wide boundary and reduces the attractivity for people to visit the river.

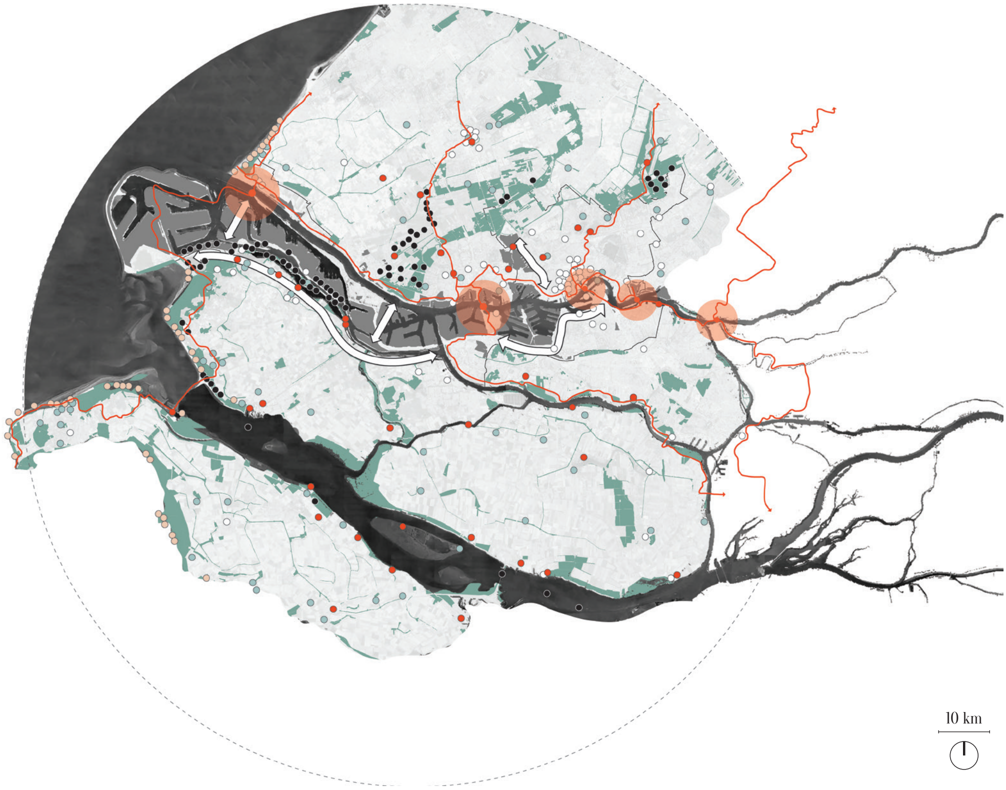
Lack of Access to Green Public Space
However the river Nieuwe Maas is located in the center of the city of Rotterdam, still the map shows the inhabitants here have extremely insufficient access to green. On the next page a zoom in to this area shows the recreational possibilities of this part of the city.

legend
- recreational zones
- long distance recreational routes
- campings and bungalow parks
- hotels and hostels
- beach entrance
- outside water recreation
- recreational harbour
- industrial / harbour zone
- river crossing point
- missing links regional network
- built environment
- water

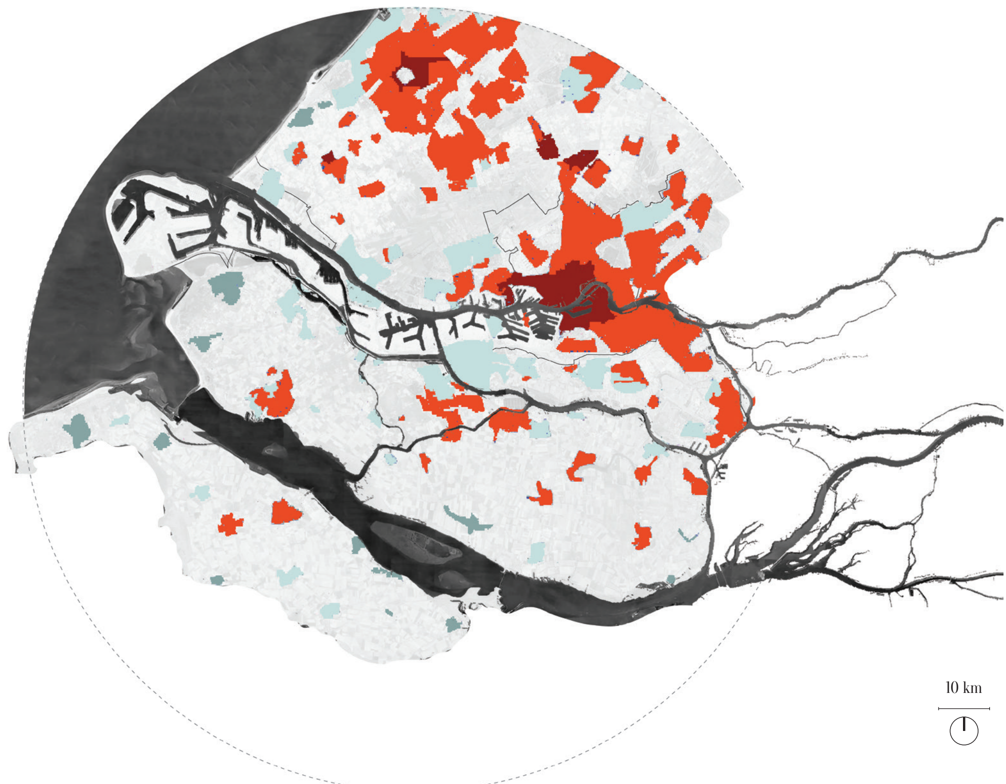
legend
- extremely insufficient
- insufficient
- sufficient
- extremely sufficient
- built environment
- water

▲ River Bank Maasboulevard (source: Google Streetview)

▲ River bank along Het Park (source: Google Streetview)



▲ Lack of recreational facilities along the river (source: by author)



▲ Lack of access to green public space (source: by author)

2. Increase Natural Values and Biodiversity

Manipulation of Nature

Centuries ago the natural river Merwede was a dynamic river, subjected to the dynamics of both the North Sea as the Rhine-Meuse Estuary (Palmboom, 1990). It was a tidal landscape with a braided river structure and a dynamic gradient from sweet to salt, providing a wide variety of habitats for flora and fauna. Since one and a half century the character of the river extremely changed: the river is largely canalised and the natural slope is transformed into hard quays, functioning for industrial activities, ports, residential areas and embankments (Stikvoort et al., 2002).

Degradation of Nature Types

What stands out on a regional scale is the fact that the main nature zones are located along the large waters, except for the coastal zone of the Nieuwe Waterweg and Nieuwe Maas, which is due to the harbor and urban development. Due to the manipulation, the river lost a large part of its nature types and therefore its function as habitat area for flora and fauna (Stikvoort et al., 2002).

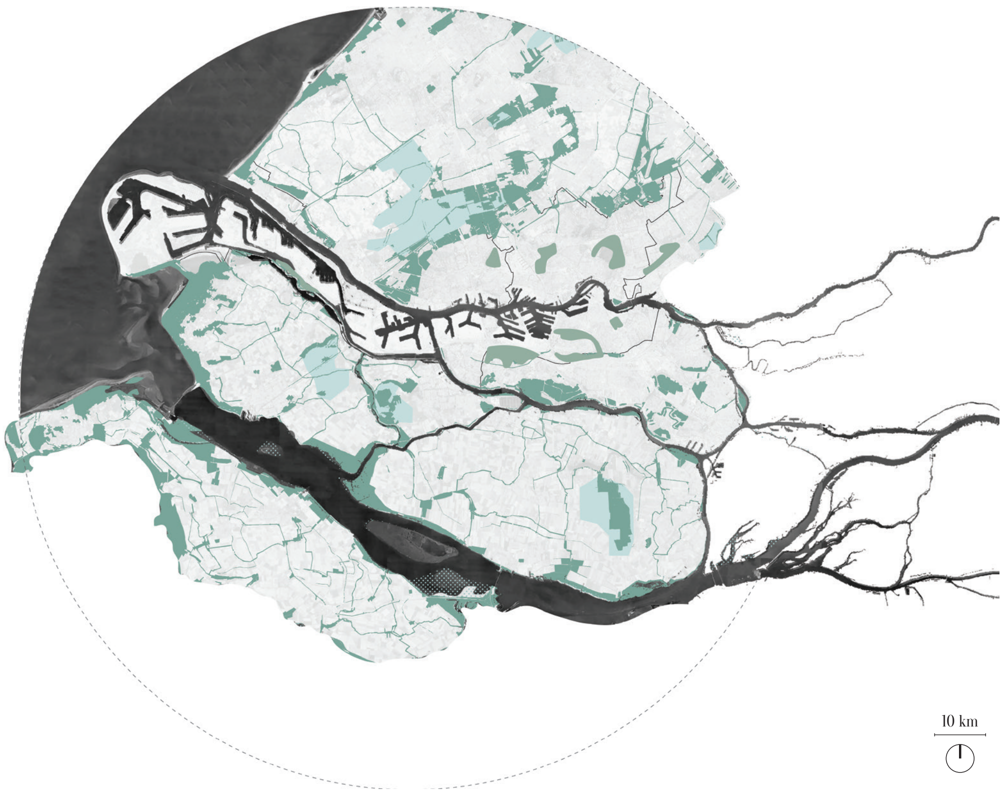
On a city scale it stands out that there are quite some green corridors in the city. However, still, the river banks are mainly (70 percent) hard and grey. This means, the existing green within the city is not connected to the water, but is almost always blocked by hard quays. This does not improve ecological qualities, as there is no transition zone between land and water.

legend

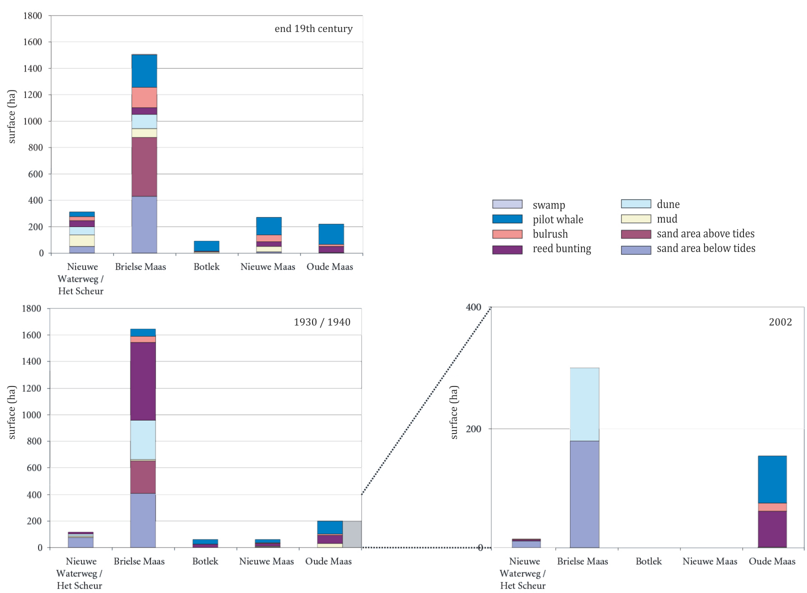
- nature zones
- woodland bird zones
- water related nature zones
- built environment
- water

▲ Hard quay in Rijnhaven (source: by author)

▲ Hard quay Kop van Zuid (source: by author)



▲ River is not connected in the ecological network (source: by author)



▲ Degradation of nature types of the Nieuwe Maas through time (source: Stikvoort et al., 2002)

Lack of Ecological Qualities along the River Banks

On a city scale it stands out that there are quite some green corridors in the city. However, still, the river banks are mainly (70 percent) hard and grey. This means, the existing green within the city is not connected to the water, but is almost always blocked by hard quays. Those hard quays are not beneficial for ecology as it only provides habitats for water species or species which can create a habitat attached to the quay, like some types of oysters or mussels.

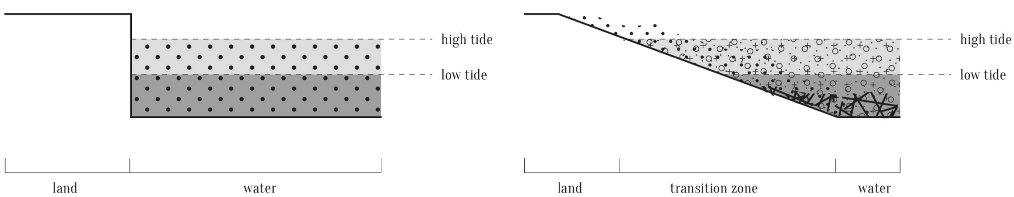
Transition zones between land and water are crucial as they provide different types of water depth which attracts different types of species.

legend

- grassland
- forest
- crop field
- horticulture
- sport field
- parks and gardens
- line of trees
- hedge
- built environment
- water

legend

- soft river banks
- hard river banks
- built environment
- water



▲ Lack of transition zones between land and water (left). Transition zones improve ecological values (right) (source: by author)

▲ Lack of ecological qualities along the river bank (source: by author)

▲ 70 percent of the river banks are hard and paved (source: by author)

3. Provide Educational Environment

The Rotterdam Region with the river Nieuwe Maas is transformed and manipulated that much due to natural and human actions that it now hardly does not contain nature types.

The map above shows a projection of the current river bed of the Nieuwe Waterweg and the Nieuwe Maas on the Delta Landscape of 1649 to illustrate the drastic changes.

In the 19th and 20th centuries the Netherlands thought it would be possible to control the urbanization process of the delta landscape completely. The landscape became subjected to the needs of the human society, through land making, urbanisation and flood defense (zuiderzeeworks and deltaworks). These flood defense works contributed in a spectacular economic growth of the whole country (Meyer and Nijhuis, 2016). The natural and human processes, which formed the Rotterdam Region as how we know it today, are described on the following page. The maps in this timeline are taken from the Landschappelijk Raamwerk report (Strootman Landschapsarchitecten and de Urbanisten, 2016)

Due to the constant process of providing water safety for the region the cultural landscape has changed. The lower map shows the remaining relicts which are still visible in the landscape. North of the river we can find the peat landscape, which is very open and wet. This is why there are a lot of linear ditches which are perpendicular to the larger waterways. Here we can also find the foreland polders (aanlandpolders) which are located in between the old Maasdijk and the Nieuwe Waterweg. Some of them, like the ones in Rotterdam and Schiedam are now built, but the one near Hoek van Holland is still partly polder. In general this landscape is located about 2 or 3 meters below sea level.

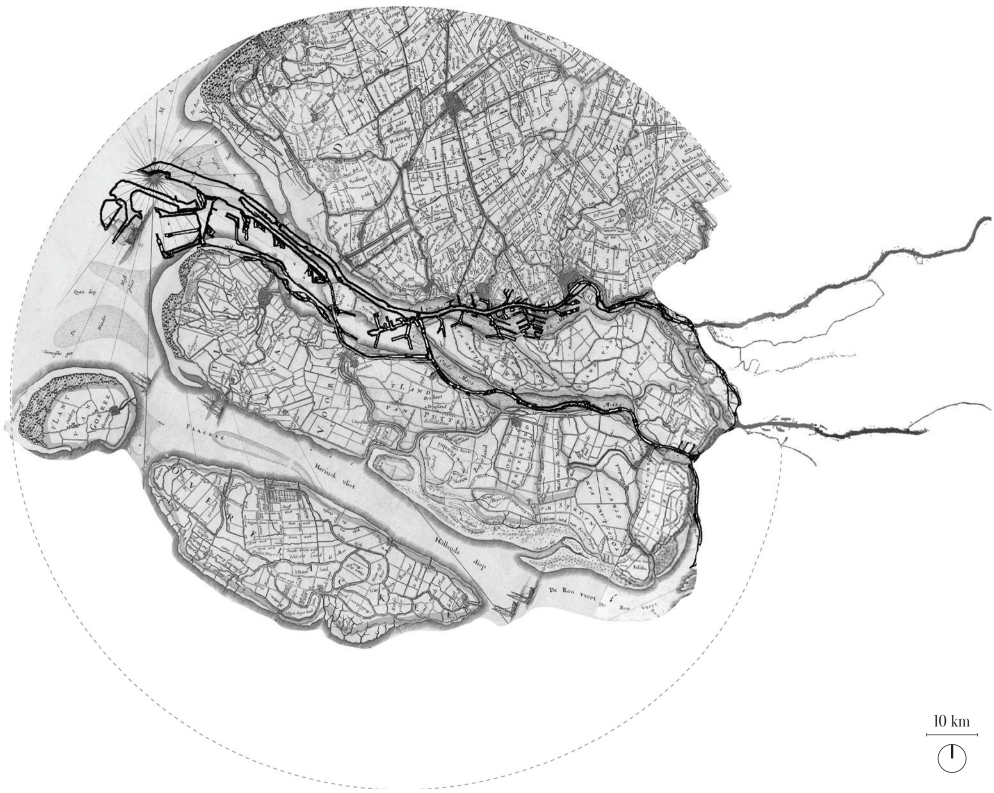
South of the river there is the sea clay landscape which is totally different of structure. This landscape is not linear, but more structured in blocks and with ring dikes. The oldest polders in between these dikes are the lowest, about 1,5 to 2 meter below sea level. Younger polders, which had less time to settle down, are located about 0,5 meter below sea level.

legend

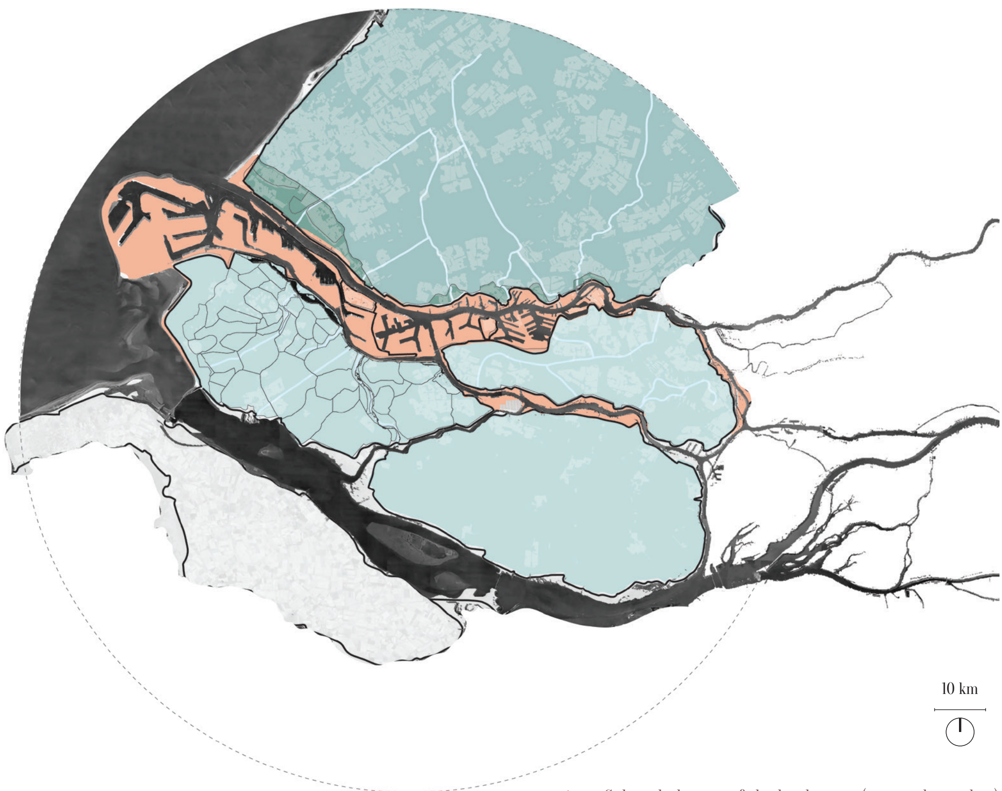
- clay soils
- peat soils
- sandy soils
- newer polders between historical dikes and primary dikes
- inland, fresh water ways
- historical ring dikes
- water

▲ The Bonnenpolder near Hoek van Holland is a foreland polder (aanlandpolder) constructed in 1850 (source: Google Streetview)

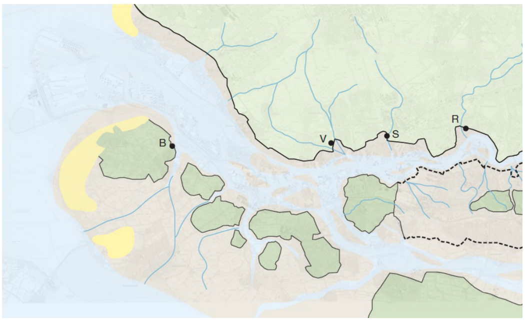
▲ Old ring dikes in sea clay landscape south of the river (source: Google Streetview)



▲ Manipulation of the Delta landscape (source: by author)

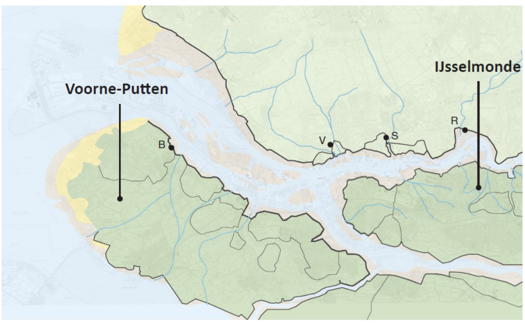


▲ Cultural identity of the landscape (source: by author)



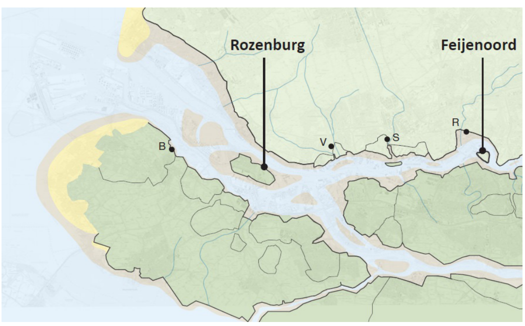
1380

The dynamic delta near Rotterdam consists of peat area in the north and sea clay in the south. Inhabitants occupy the landscape and due to dug ditches and removed peat the peat landscape settles. People protect themselves in the north through a continuous dike (Maasdijk) with dams in the creek mouths, where later the cities of Vlaardingen (V), Schiedam (S) and Rotterdam (R) rise. In the south, people occupy the higher islands in the tidal landscape, protecting themselves with ringdikes around each island.



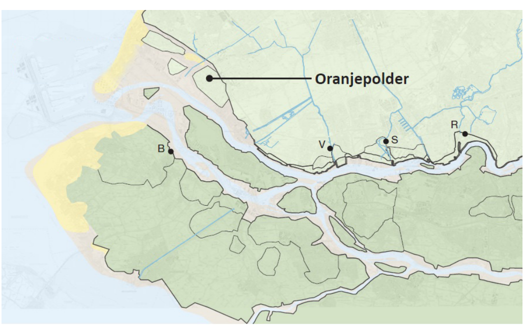
1570

Due to climate change and sea level rise, more and more sediment is disposed in the tidal landscape. This results in more land in front of the dikes in the north. This land near the cities is occupied and transformed into useable polders for the cities. In the south, the sea clay polders are extended with new polders, finally ending up with islands grewing together. Those larger polders are surrounded with new dikes, resulting in larger indike areas, like Voorne-Putten and Ijsselmonde.



1690

The landscape outside the dikes is still subjected to the dynamics of the tides, resulting in more and more sediment disposals. In some areas, like Rozenburg and Feyenoord, this results in new islands which then are surrounded by ringdikes.



1850

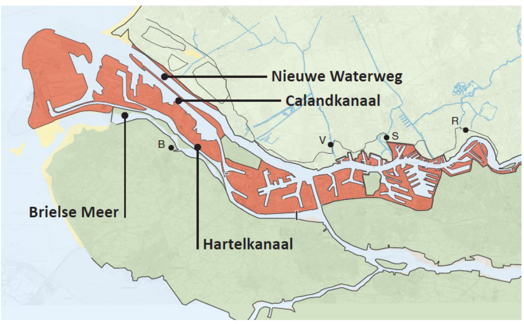
Due to more and more construction of polders and sediment disposal the river mouth moves seawards. This also results in the growth of Rozenburg, which finally splits up the river. Two seperate rivers now transport the water to the sea: the Brielse Maas (south) and the Scheur (north). The sediment areas in front of the Maasdijk are made into polders (Oranjepolder) and also the land in front of the cities.

1890

In 1872 the increasing sediment disposals in the river mouth became obstructing for the shipping traffic, so the decision was made to dug a new canal: the Nieuwe Waterweg. Rotterdam profits from this and starts with the development of a harbor and industrial area.

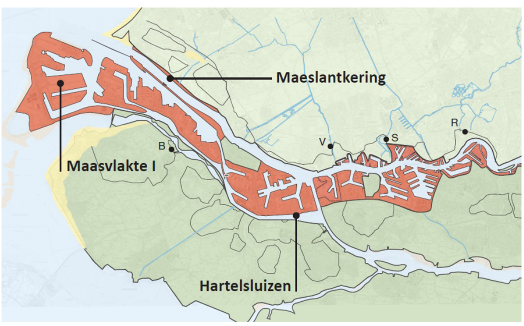
1940

Thanks to the Nieuwe Waterweg, Rotterdam's harbor starts to grow, as well in the north as the south of the river. In this period, harbors like the Maashaven and Waalhaven are constructed. The Rozenburg island grows to its maximum surface. This also results in the consolidation of the Brielse Maas.



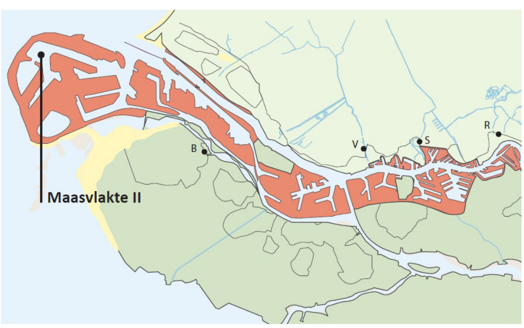
1971

After WO II, the expansion of the harbor goes fast. In 1950 the Brielse Meer becomes indike area and large harbor basins, like the Calandkanaal and Hartelkanaal, are dug and used since 1971. The island Rozenburg (Europoort) and a large part of Ijsselmonde are transformed into harbor area, which is all outside the dikes. Only some small villages within the harbor area, like Pernis and Rozenburg, are protected by dikes. When the Maasvlakte I is constructed in 1973, the harbor starts to move seawards.



2008

Since 1953 the Deltaworks are constructed along the whole coast of the Netherlands, to protect the whole country against flooding. The Europoortkering is the last part of these national works. Besides strenghtening of the dikes, the Maeslantkering in the Nieuwe Waterweg and the Hartelkering in the Brielse Maas (both constructed in 1997). The harbors close to the cities are losing their function.



2015

After the construction of the Maasvlakte I, the Maasvlakte II is constructed, taking more and more land of the sea. In total the new harbor area is about 2000 ha.

▲ Development of the delta through time (source: Palmboom, 1990, modified by author)

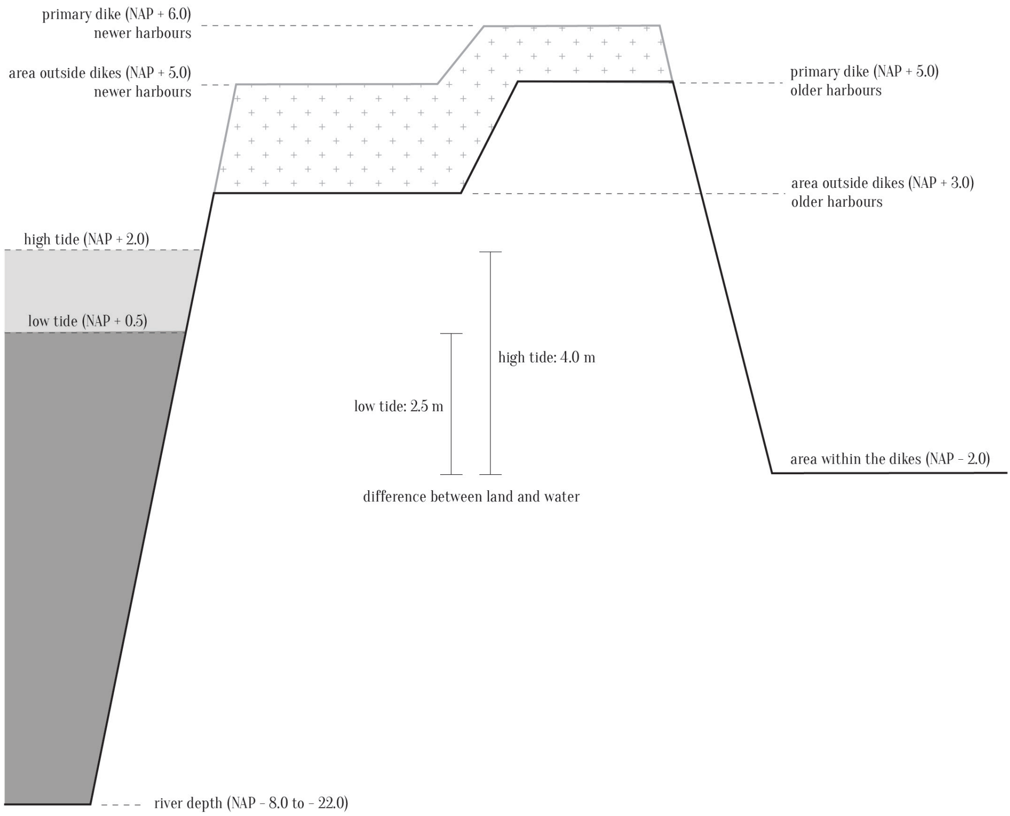
4. Increase Water Safety

Water safety is a huge problem in the region. Due to the constant manipulation of the delta through time we dug our own grave as the risks become bigger. The difference between the water levels outside the dikes and the land where we live is already 2.5 meters during low tide and 4 meters during high tide. The land outside the dikes is located much higher (5 to 7 meters above the land inside the dikes) and is in this way protected against the water.

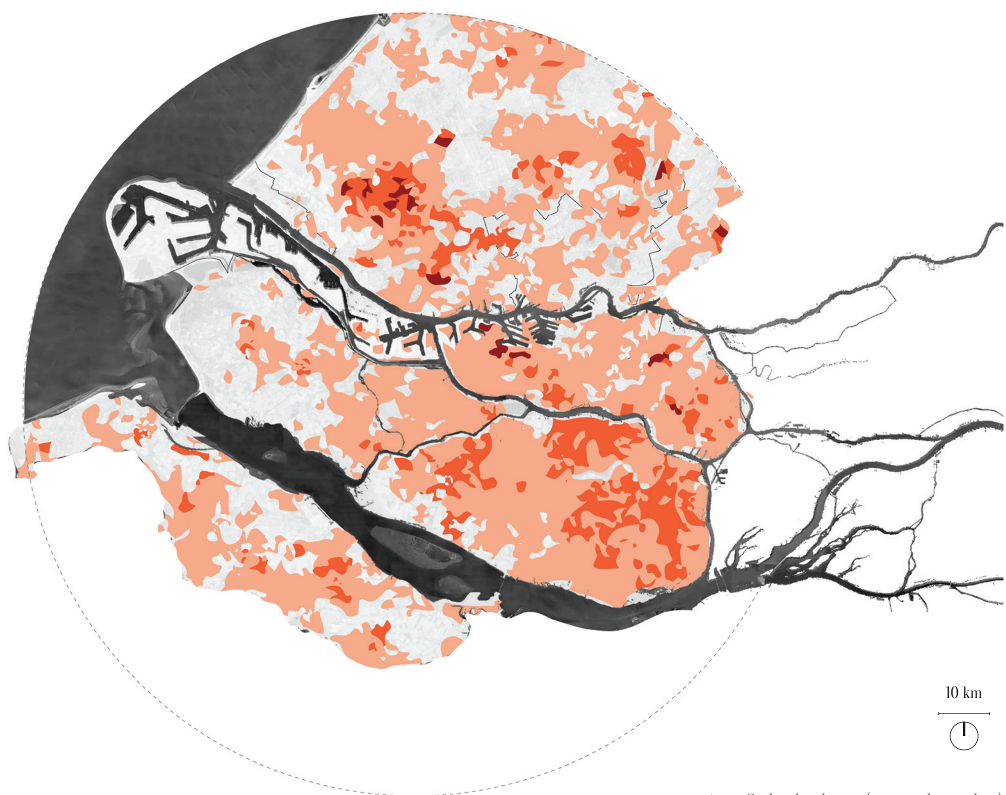
As we need dry land to live and to produce food we have always drained the polder landscape. Especially the peat landscape, which is saturated with a lot of water, settles extremely due to draining. The problem of soil subsidence is therefore exacerbating the problem of water safety. The areas which are most vulnerable for soil subsidence are visible in the lower map.

legend

- little soil settlement - < 2 mm
- significant soil settlement since may 2015 - 2 to (
- significant soil settlement since october 2016 - 2
- extreme soil settlement - > 6 mm



▲ Height difference between area within and outside the dikes (source: by author)



▲ Soil subsidence (source: by author)

At some points the dikes are located very close to the river water, which increases the risks as the dikes are constantly subjected to tides and storm waves. This increases the erosion of the dikes and therefore decreases the water safety land inwards.

The Dutch have always protected themselves against the water by dike systems, sluices, dams and through drainage of the polders. This resulted in the fact that the polders became lower and lower and therefore also the risks when a dike collapse become bigger and bigger. The lower map shows the water depth when a primary dike collapse. This will not happen all at the same time but depends on which dike collapses. As some dike rings have a higher protection rate (see upper map) it does not necessarily mean that the lowest zones in the landscape have the highest water depth during a flood.

Flood Risks

Until now they took into account the Land Height Levels for Building (uitgiftepeilen) of +3,00 m NAP behind the Maeslantkering and +4,50 m NAP in front of the Maeslantkering. The Maeslantkering is designed for 60 cm sea level rise and a Rhine river discharge of 17000 - 18000m3/s. The starting point is to close the Maeslantkering once a year to not conflict with the harbor activities, with a maximum of 3 times a year. This is exceeded when the sea level rises with 1 meter. Taking into consideration the expected sea level rise, new Land Height Levels for Building (uitgiftepeilen) are defined, which take into account the two most extreme scenarios (Rest and Steam) for 2100, which is 35 and 85 cm sea level rise). The G+ scenario (the average of these extremes) is the starting point, meaning 60 cm sea level rise in 2100. These uitgiftepeilen take into account 60 cm sea level rise so it means the areas below these levels are risk areas. The map with flood risks which corresponds with this existing management is represented in the lower map.

The numbers for sea level rise, coming from the scenarios as described before, come on top of the +3,00 NAP (in front of Maeslantkering) and +4,50 NAP (behind Maeslantkering). The maps for both scenarios (2100) are represented on the following pages.

legend

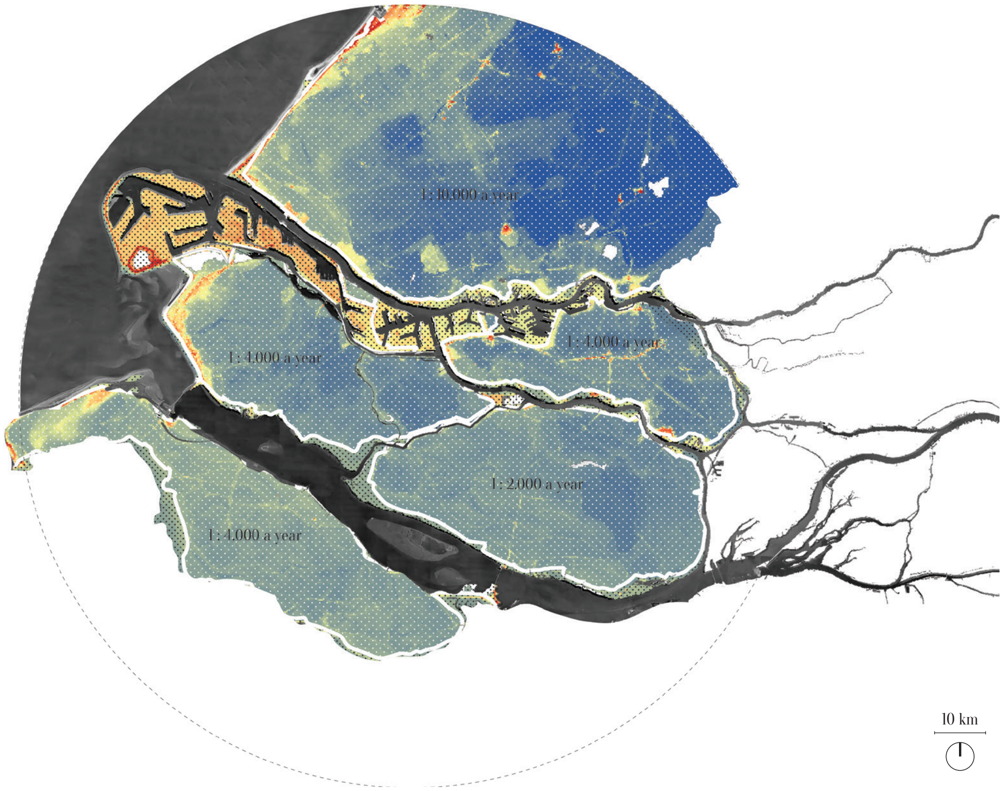
10 m + NAP
-6 m + NAP
primary dike
area within dikes
area outside dikes
water

legend

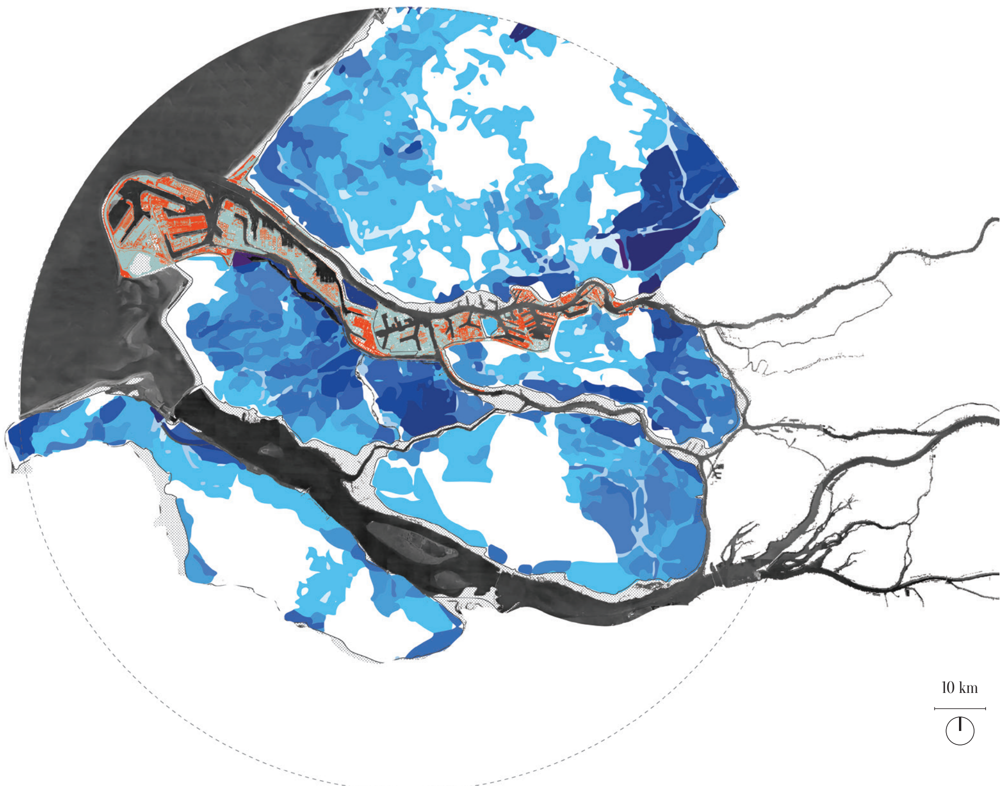
> 6.0 m water depth if primary dike collapses
4.0 - 6.0 m water depth if primary dike collapses
2.0 - 4.0 m water depth if primary dike collapses
1.0 - 2.0 m water depth if primary dike collapses
0.5 - 1.0 m water depth if primary dike collapses
< 0.5 m water depth if primary dike collapses
flood risk areas
'safe' areas for flooding
primary dikes
built environment
water

	In front of Maeslantkering	Behind Maeslantkering	Flood risk 2100
Basis +	+ 5.50 NAP	+ 3.90 NAP	1:4000
Basis	+ 5.10 NAP	+ 3.60 NAP	1:1000

Scenario	Numbers for sea level rise (cm)	Uitgiftepeil	
		Behind kering (+ NAP)	In front of kering (+ NAP)
Rest 2050	25	3,25	4,75
Steam 2050	30	3,30	4,80
Steam+ 2050	45	3,45	4,95
Rest 2100	100	4,00	5,50
Steam 2100	200	5,00	6,50
Steam+ 2100	300	6,00	7,50



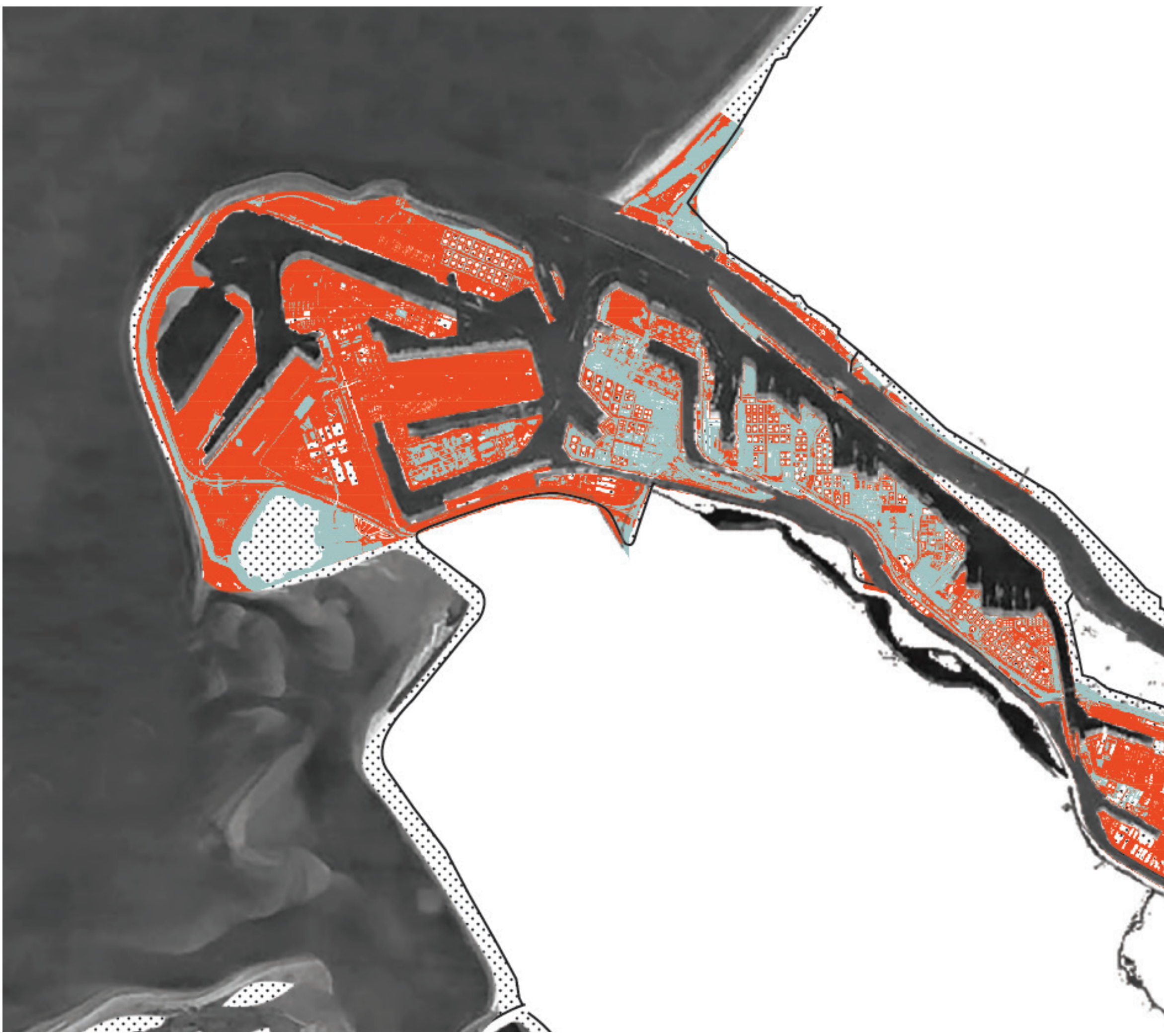
▲ Protection of low located polders by dikes with varied protection rates (source: by author)

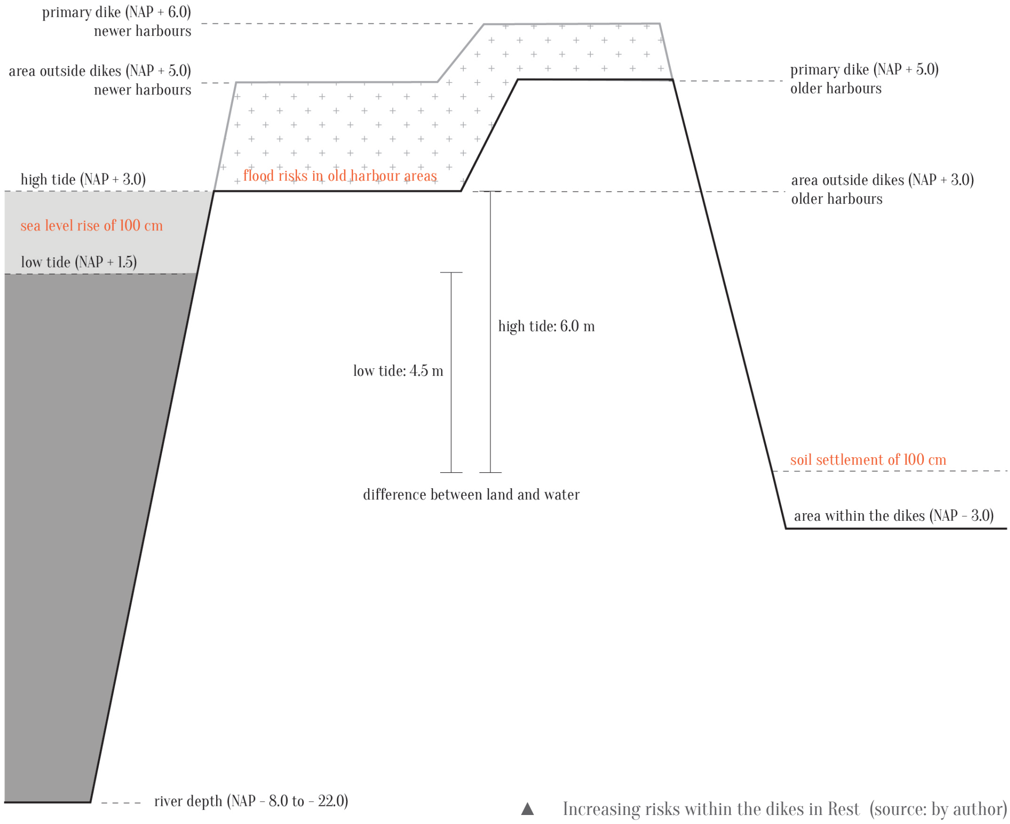


▲ Regional flood risks within and outside the dikes (source: by author)

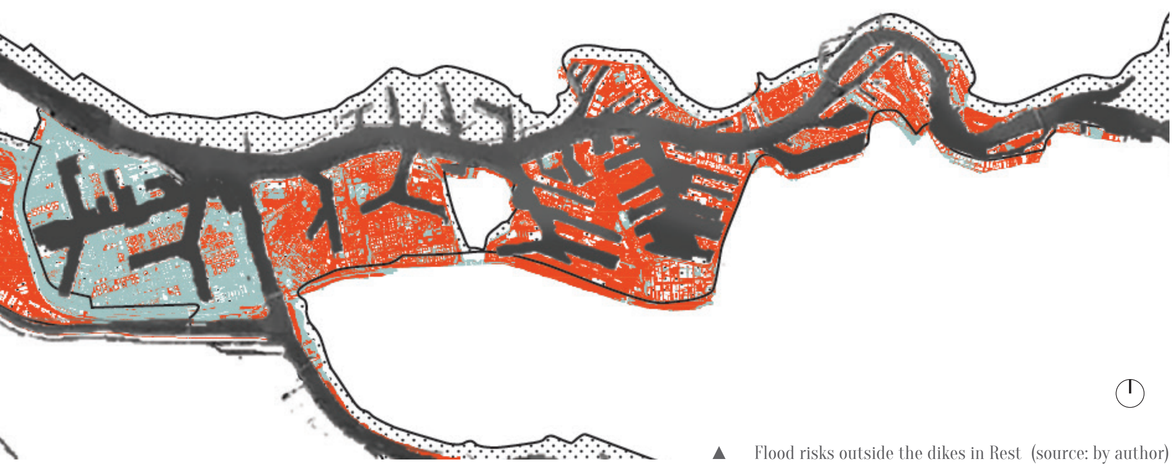
Problem increases in Rest Scenario
In the Rest Scenario the sea level will rise with about 1.0 meter. As explained before, due to constant draining of the polders the soil settles. Taking this both into account results in an increasing difference between river / sea water level and cultivated land of 140 cm. During low tide this results in a difference between land and water of 3.90 meter and during high tide of 5.40 meter.

In the area outside the dikes this also results in increasing flood risks. The increasing sea level of 1.0 meter results in flood risks in the areas which are indicated in red in the map below.





▲ Increasing risks within the dikes in Rest (source: by author)



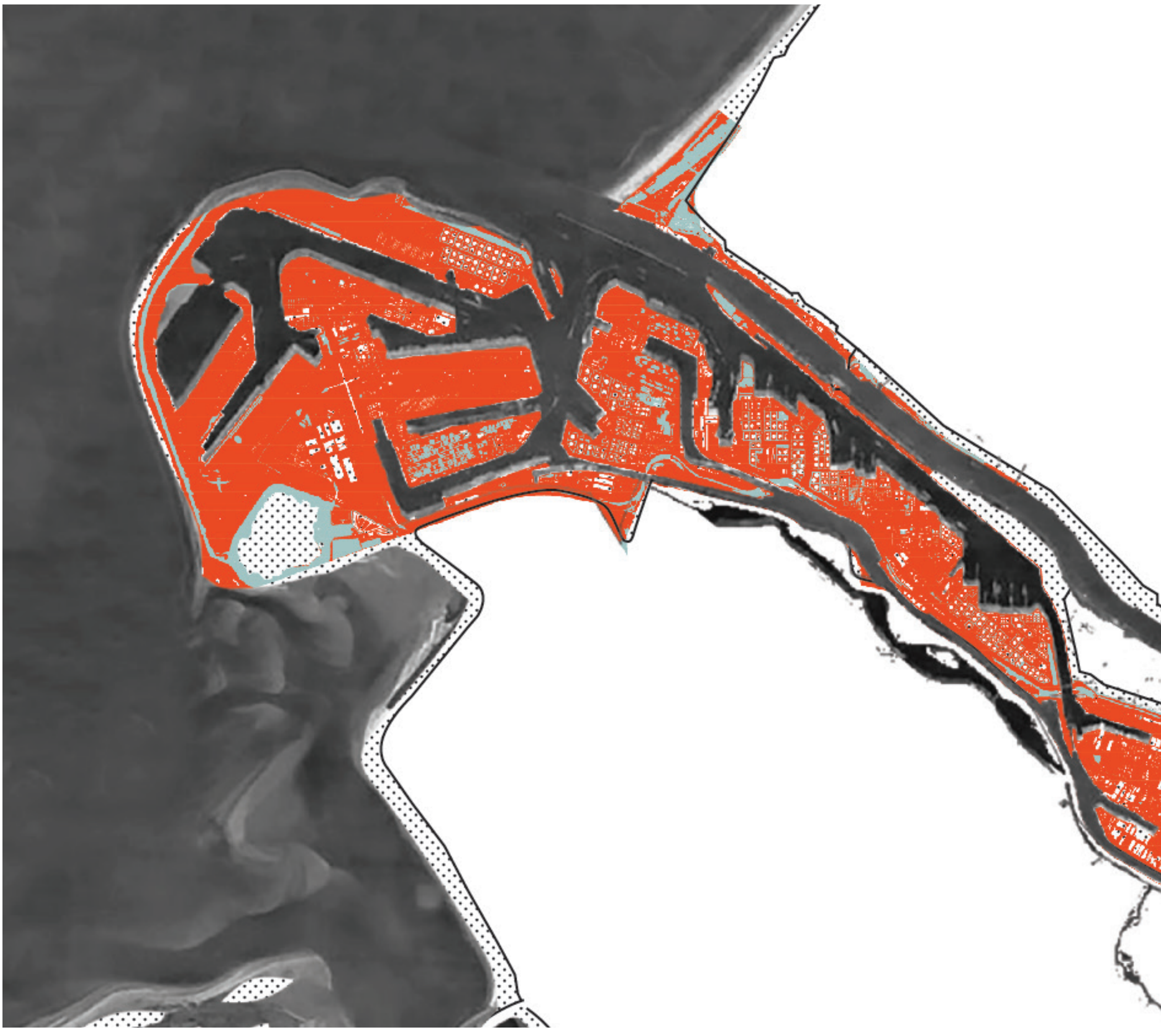
▲ Flood risks outside the dikes in Rest (source: by author)

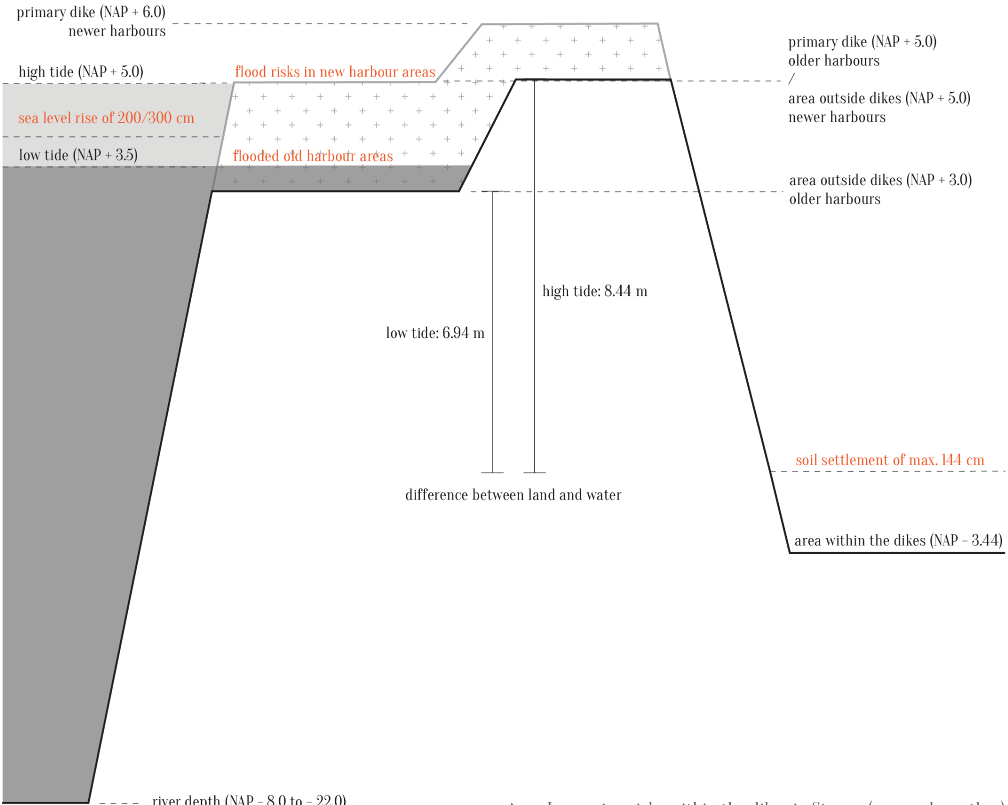
Problem increases in Steam Scenario

In the Steam Scenario the sea level will rise with 2.0 meters. In this scenario the risks for soil subsidence are even bigger as we need to pump the water more and more out of the polders as the difference between land and water is bigger. This results in increasing soil subsidence. Taking this into account results in an increasing difference between river / sea water and cultivated land of 240 - 340 cm in 2100. During low tide this results in a difference between land and water of 4.90/5.90 meter and during high tide of 6.40/7.40 meter.

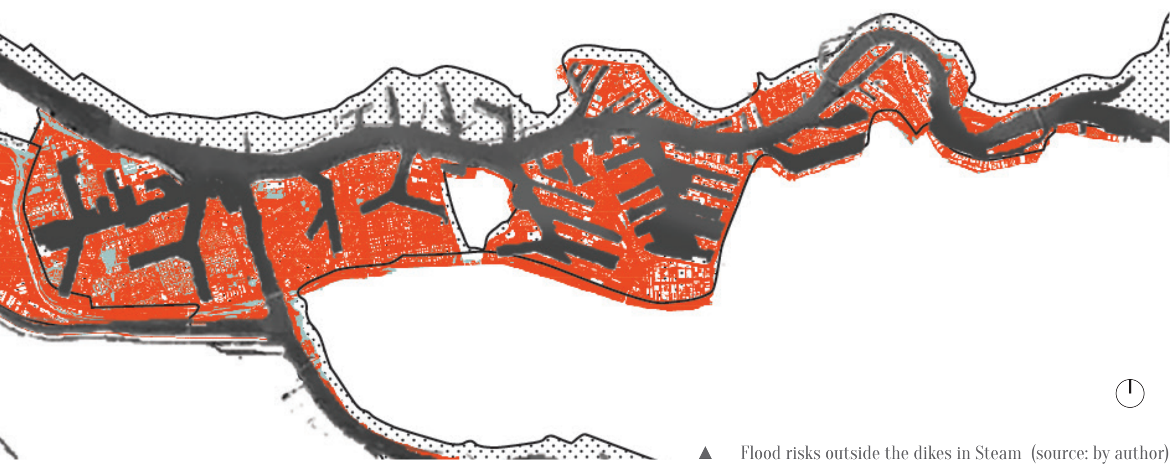
With this difference you can imagine that by trying to keep the land behind the dikes dry for agricultural use the problems are more and more increasing as the pumps have to work harder to get the water from the extremely low polders to the extremely high river.

In the area outside the dikes this also results in increasing flood risks. A sea level rise of 2.0 meter results in flood risks in the areas which are indicated red in the map below, which is almost the whole harbor.





▲ Increasing risks within the dikes in Steam (source: by author)



▲ Flood risks outside the dikes in Steam (source: by author)

5. Food Production

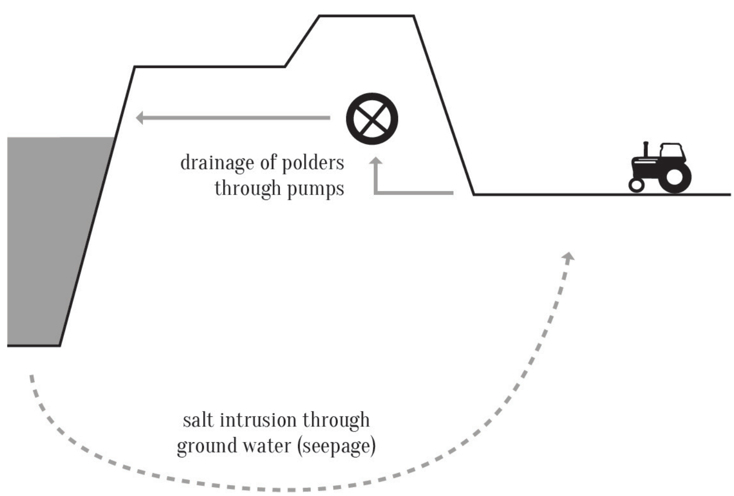
The food production in this region is very much under pressure due to the low location of the fields in the landscape. Due to our constant process of drainage the land is located much lower than the surface water which makes the necessity to pump more intensively crucial to keep the land dry for agriculture. This difference between land and water also increases the salt intrusion through ground water (seepage).

The approaching sea level rise and constant soil subsidence increases both problems. Keeping the land dry demands with more and more drainage which than again increases the soil subsidence. This soil subsidence results in oxidation of the peat landscape, which increases CO_2 emissions and therefore stimulates climate change. The intruding salt through ground water results in a bad water quality for farming, which the crops cannot stand.

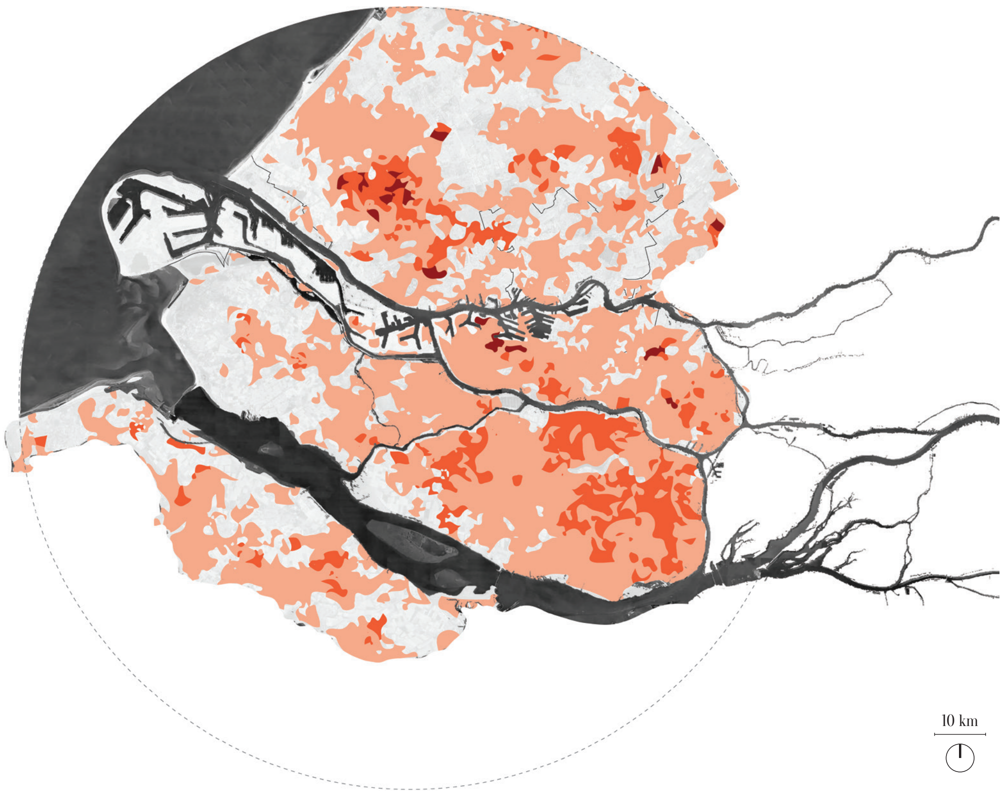
The question is if it will be still feasible to keep draining the land as it increases the problems for food production, increases water safety problems and increases CO_2 emissions.

legend

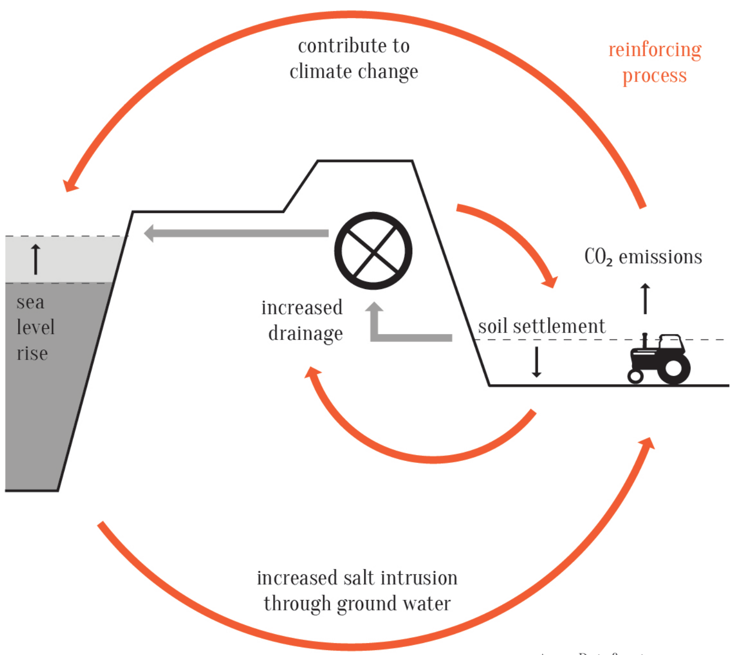
- little soil settlement - < 2 mm
- significant soil settlement since may 2015 - 2 to (
- significant soil settlement since october 2016 - 2
- extreme soil settlement - > 6 mm



▲ Existing process of drainage in order to use the polders for agriculture and urban development (source: by author)



▲ Soil subsidence (source: by author)



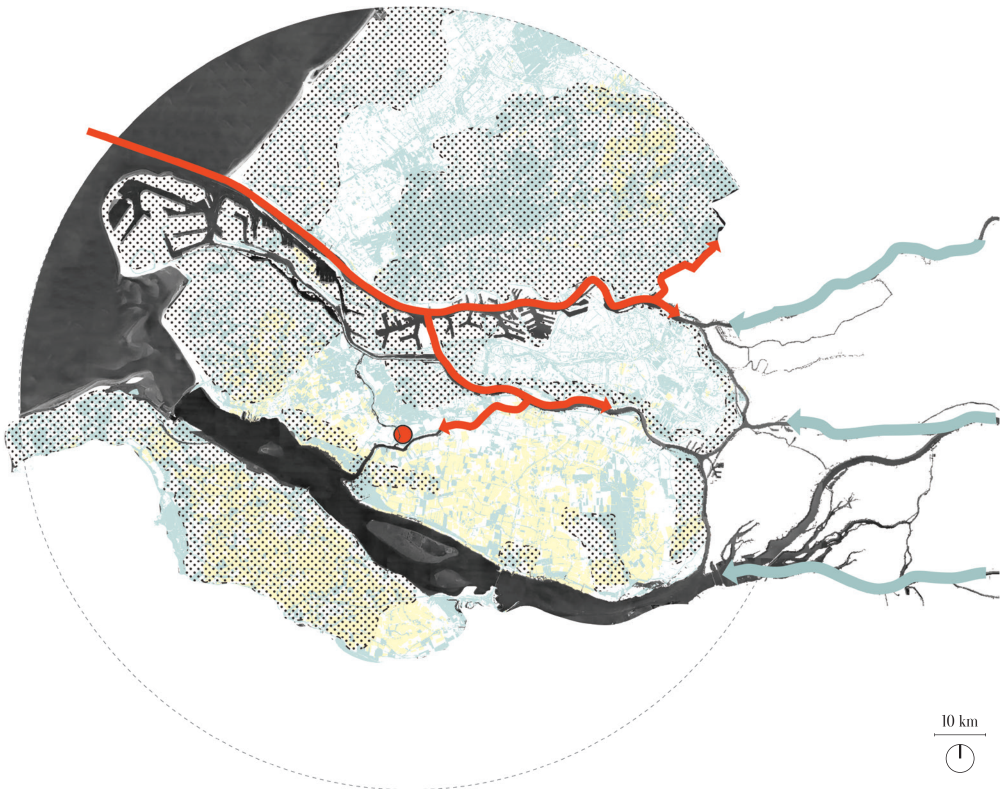
▲ Reinforcing process (source: by author)

The upper map shows the locations of the salt intrusion through ground water. Those locations can be found mainly along the coast and the rivers and sea arms. Also the peat landscape north of the river is vulnerable for salinization.

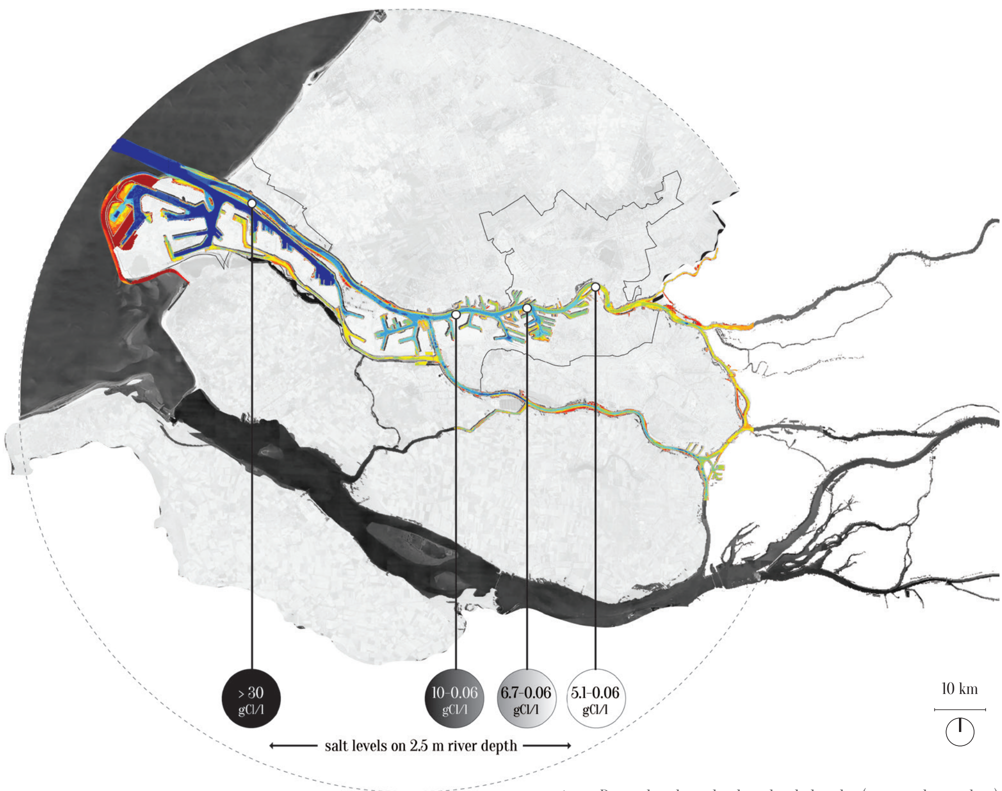
Providing food in the river can provide more food security in the future. Food like fish, shellfish and plants can be cultivated in the river. However, they all demand for different water depths and salinity levels. The lower map shows the difference in river depth and salinity levels within the river. This information will be used and further explained in the regional strategy.

▲ Water mills in the Dutch Landscape have always functioned to drain the polders and make them dry enough for agricultural and urban settlements, for example this one from the polder Oud-Mathenesse. Later these water mills are replaced for more modern pumps (source: J. Rozema)

▲ Peat Landscape in Midden-Delfland is drained for agricultural purposes (source: Zuid-Hollands Landschap)



▲ Saline intrusion, affecting food landscapes (source: by author)



▲ River depth and related salt levels (source: by author)

6. Basis for Urban Development

Nowadays, in this region the cities of Rotterdam and The Hague are the most dense areas, see figure below. The region attracts more and more people and when we take a look at the trends until 2040, see the map in the right lower corner, those areas are the areas with the highest demand for new housing development as well. In Rotterdam a necessity of 50.000 new houses until 2040 is expected, which will be mainly located in the city center and along the river bank of the Nieuwe Maas. This means the already grey and dense zones will become more grey and more dense. The challenge which goes together with this is not only to realise new housing, but also to provide a favourable and attractive living environment with enough green public space.

legend ▶

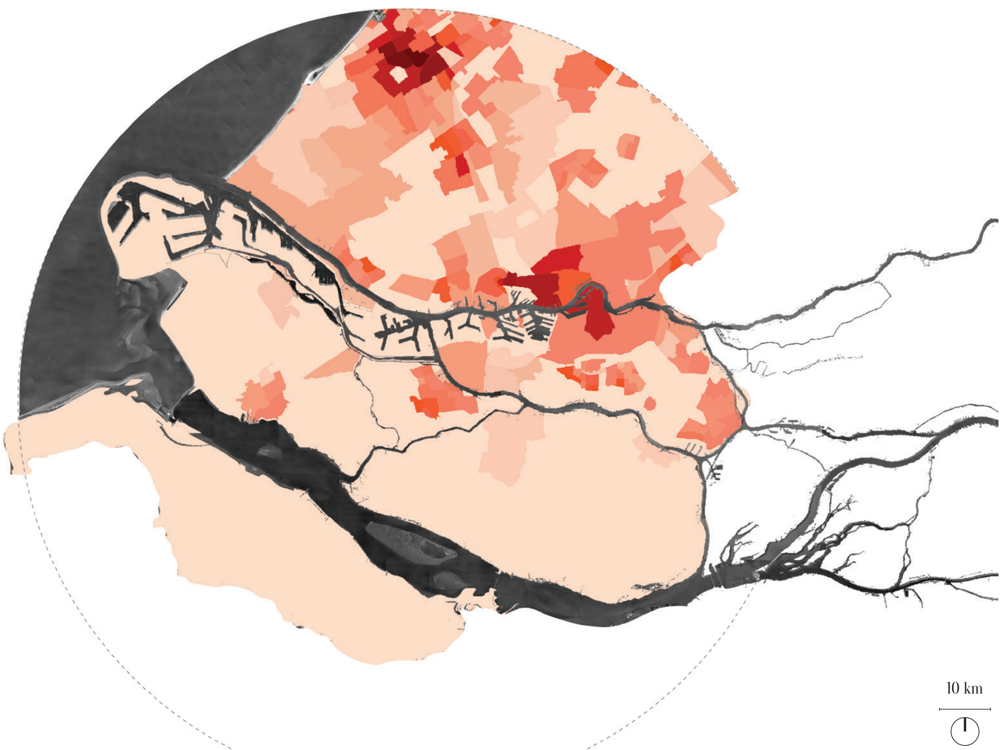
- 3000 + houses
- 1500 + houses
- 200 + houses
- built environment
- water

legend ◀

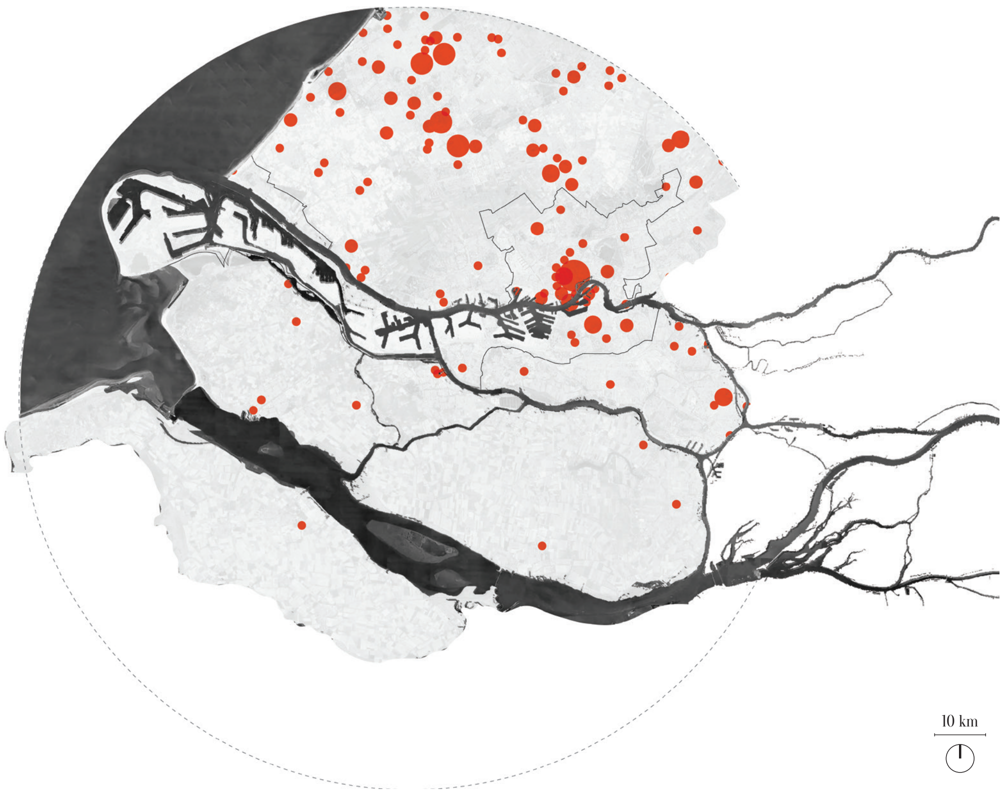
- high demand for housing development
- medium demand for housing development
- low demand for housing development
- \+ higher supply than demand

legend ▼

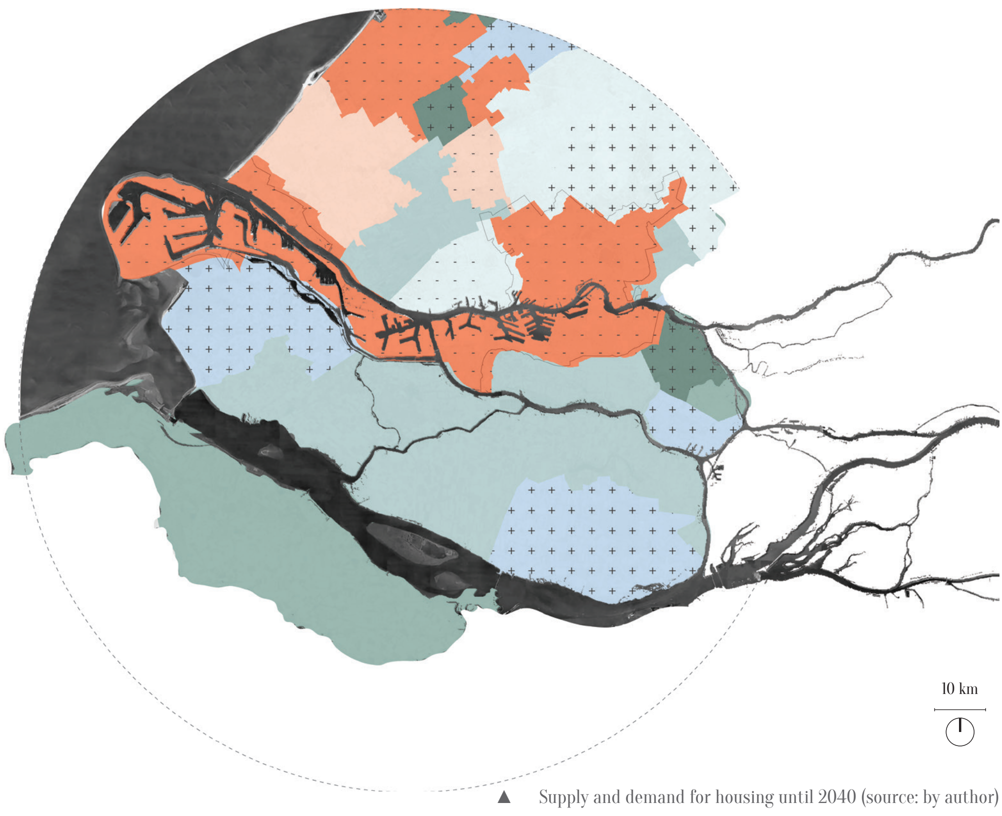
- highest population density
- lowest population density
- water



▲ Urban densities (source: by author)



▲ Building agenda (source: by author)



▲ Supply and demand for housing until 2040 (source: by author)

From 2040, there is no data of how the population within the region will develop exactly. This is where the scenarios become important, as they describe the two most extreme plausible futures for 2100.

The Rest Scenario describes that the population in the region will shrink. More and more job opportunities are settling in the east and south of the Netherlands, which makes these regions more attractive for inhabitants than Rijnmond-Drechtsteden. This creates less pressure on space and higher real estate values. As the mindset in the Rest Scenario has changed to a very sustainable and aware society, people live more close to each other to not have high consequences for the environment. They prefer small, local communities in centers where people move mainly by bike and foot.

The Steam Scenario takes into account a population of Rijnmond-Drechtsteden which doubles in size. This is mainly due to the favourable climate compared to other regions and the economic success. The cities grow more and more together, as people seek for cooler living environments, instead of the warm and crowded city centers. These centers become extremely dense with a high pressure on public green space. In Rotterdam a concentration of densification is visible along the river bank, as this is the most cool living environment.

legend

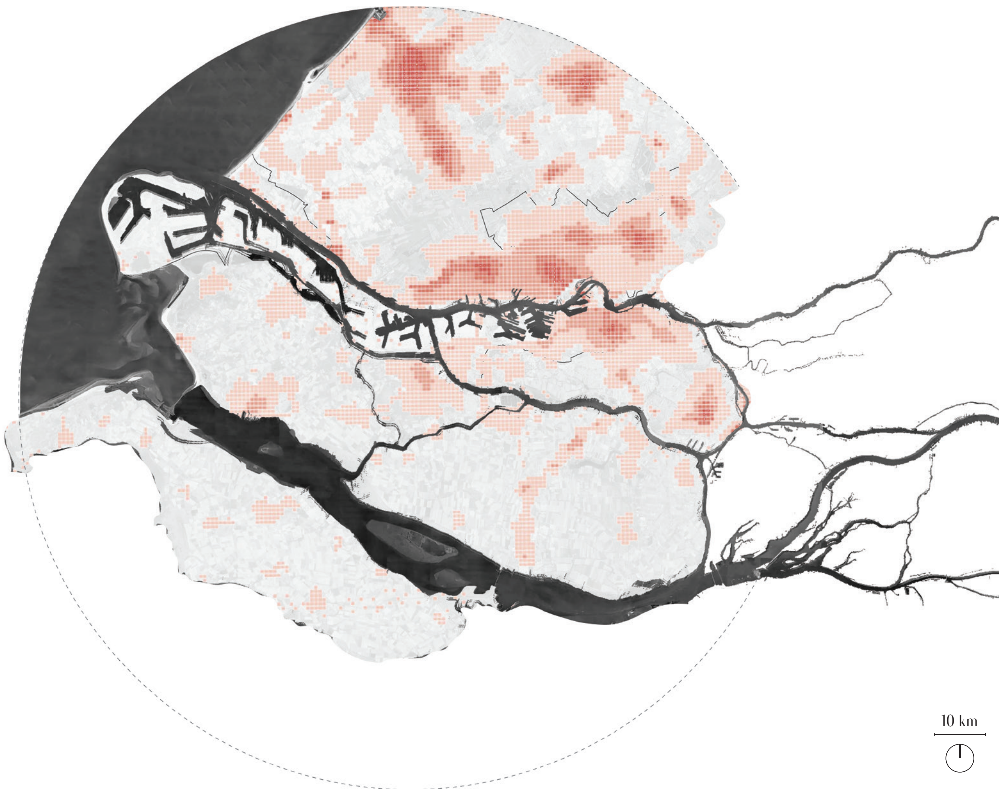
highest population density

lowest population density

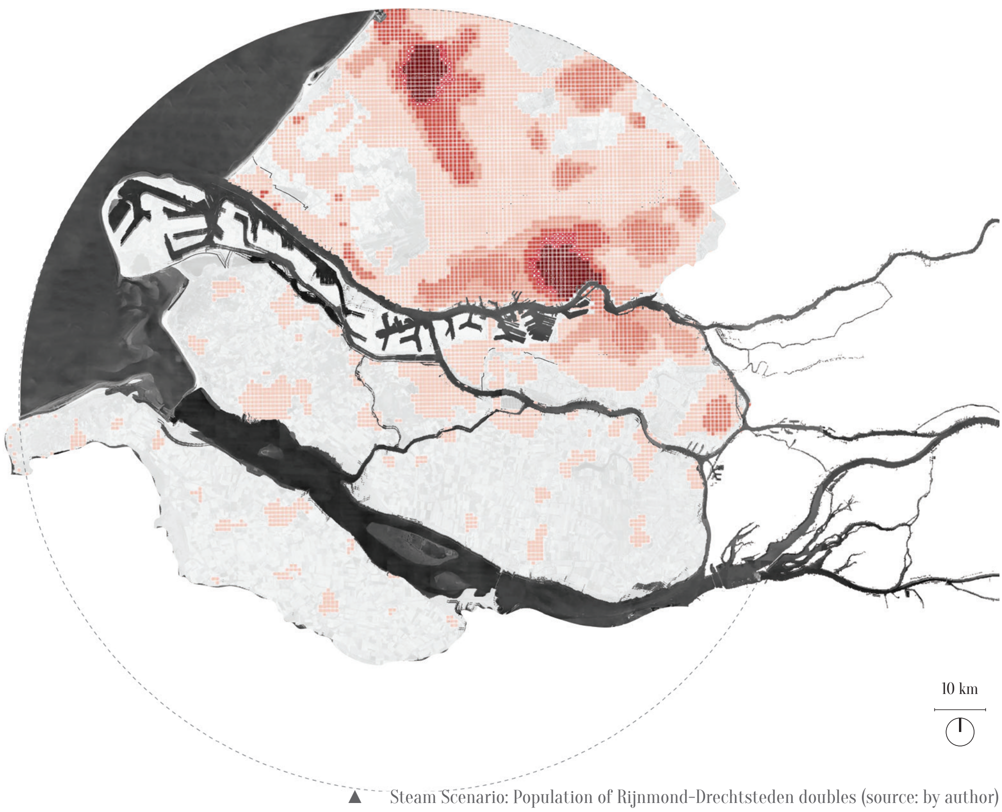
water

▲ Urban Development along old harbor basin at Katendrecht (source: by author)

▲ Most of the high rise buildings in Rotterdam are located along the river bank (source: by author)



▲ Rest Scenario: Population of Rijnmond-Drechtsteden shrinks (source: by author)



▲ Steam Scenario: Population of Rijnmond-Drechtsteden doubles (source: by author)

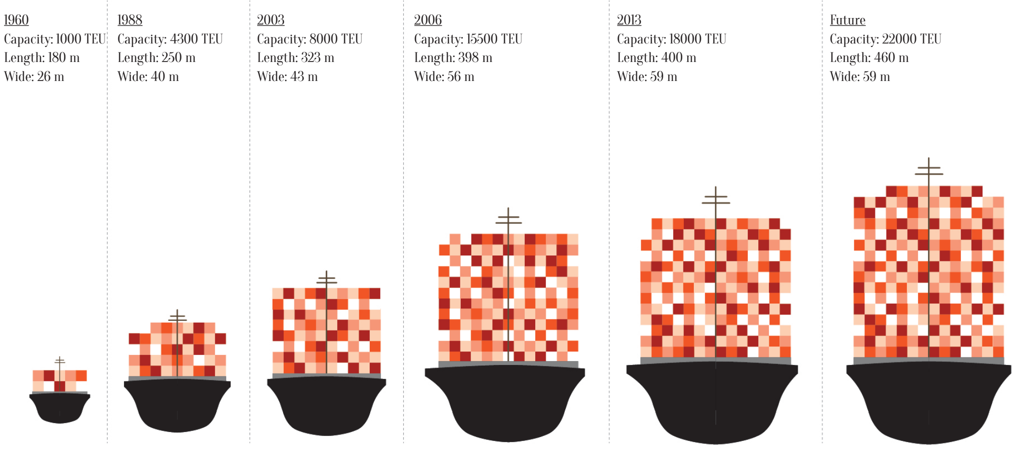
7. Contribute to Closing Regional Cycles

In the Rhine-Meuse Estuary the sediment origins from as well the North Sea as the rivers. As the Nieuwe Maas is the receiving end of the Rhine-Meuse Estuary and the only open connection with the North Sea sediment settles here in the most extreme way, namely more than 3.0 cm a year. In other parts of the estuary, for example in the Oude Maas, the average river bed changes with a decrease of 3.0 cm a year. This eroding process started since the closure of the Haringvliet when constructing the Delta Works.

To maintain the Nieuwe Waterweg and Nieuwe Maas deep enough for shipping, the river and harbor basins are constantly dredged. Since the construction of the Maasvlakte 2 the dredging activities became even more extreme as the new harbor area changed the currents and therefore the sediment influx.

Ninety percent of the total amount of dredged material is clean and deposited at sea. However, a part of this material is transported back to the river mouth due to natural processes (Veelen et al, 2018). Taking into acount the perspective that ships will become bigger and the rivers have to become deeper, more and more dredging activities have to take place in the future.

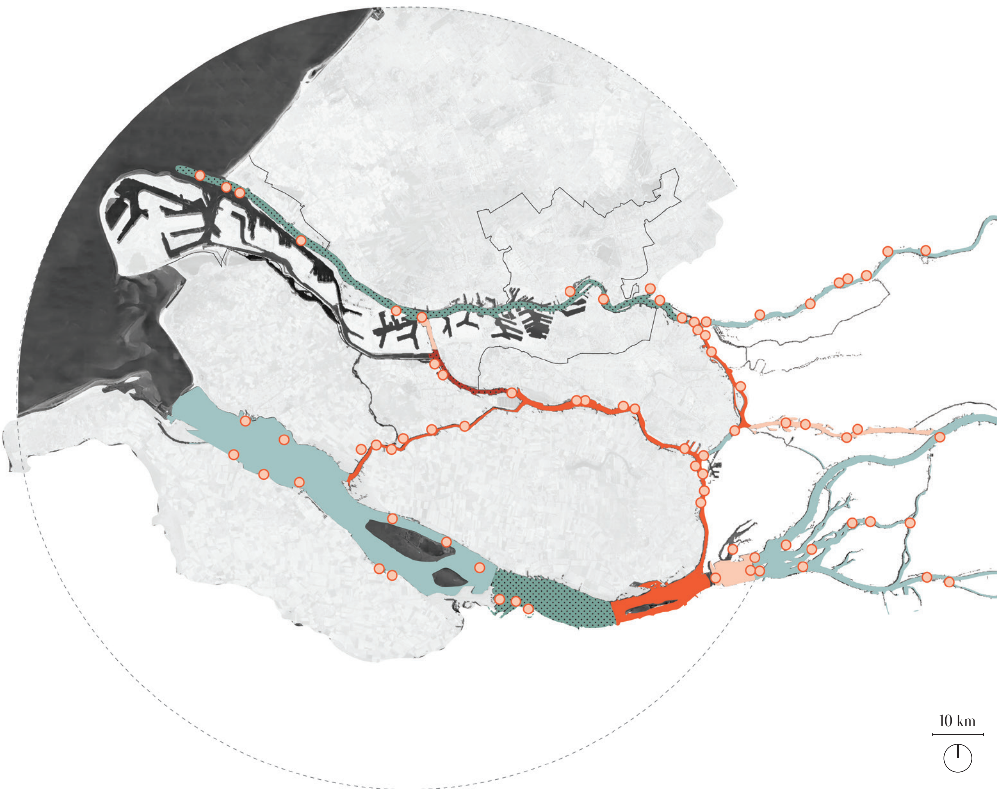
At the same time, the region also has to deal with a lack of sand and sediment, for example for port- and urban development and for flood safety. It is not very efficient to first dredge the material to the North Sea and then have to transport it back or find other resources because the material is needed.



▲ Increasing size of ships through time (source: by author)

▲ Dredging activities in the Nieuwe Maas (source: Port of Rotterdam)

▲ The Maashaven in Rotterdam is an example of an harbor which, due to its location in the outside bend of the river, never have to be dredged (source: de Graaf)



▲ Sedimentation and erosion in the Delta (green is sedimentation and red is erosion) (source: by author)

▲ Sedimentation and erosion in the Nieuwe Maas (green is sedimentation and red is erosion) (source: by author)

8. Provision of Fresh Water

The open connection of the Nieuwe Waterweg and Nieuwe Maas has, besides the water safety issues, another disadvantage: salinization. This process of a build up of salt in surface water and soil results in a lack of fresh water for agriculture and drinking purposes. The salt water intrudes into the land in two ways: through the surface- and the ground water.

Salinization through surface water happens via the rivers. This process aggravates when the sea level rises and when the river discharge is low. Last summer for example did the extreme drought and extremely low river discharge cause problems for farmers and nature areas.

Salinization through ground water happens in the form of seepage. This process aggravates when the sea level rises and the soil settles and will be further explained in the food production section.

legend

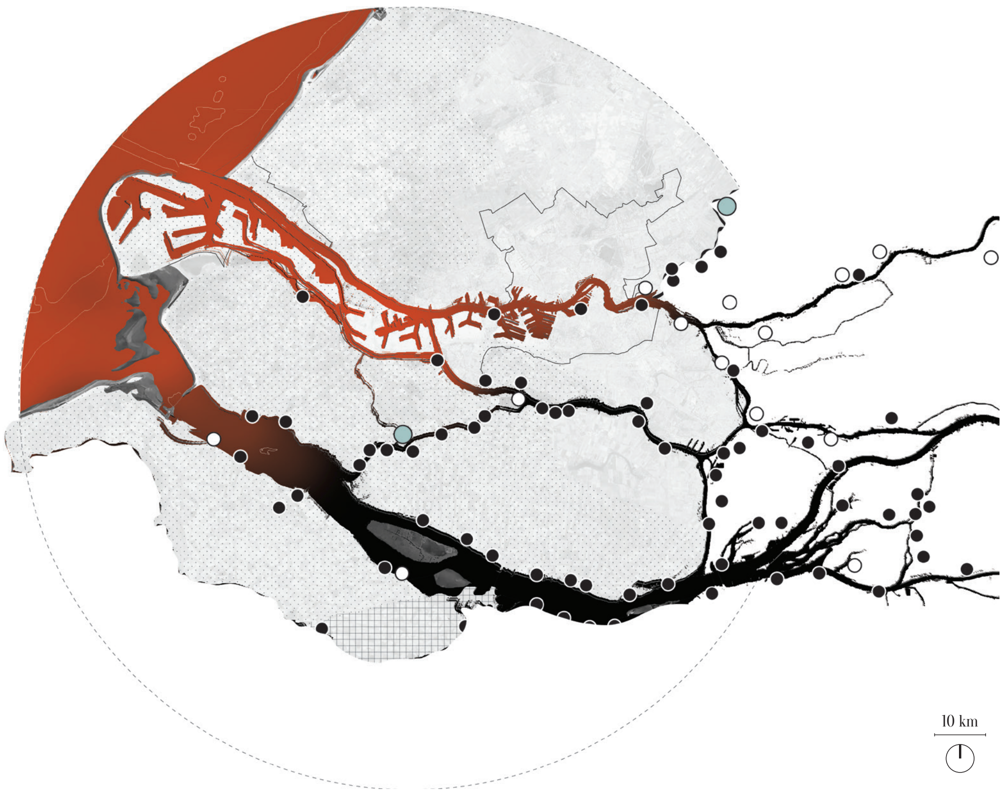
- salt water
- fresh water
- fresh water point for agriculture
- fresh water point for drinking water
- most crucial fresh water point
- fresh water dependant on Hollands Diep / Haringvliet
- fresh water dependant on Volkerak / Zoommeer
- built environment
- water

legend

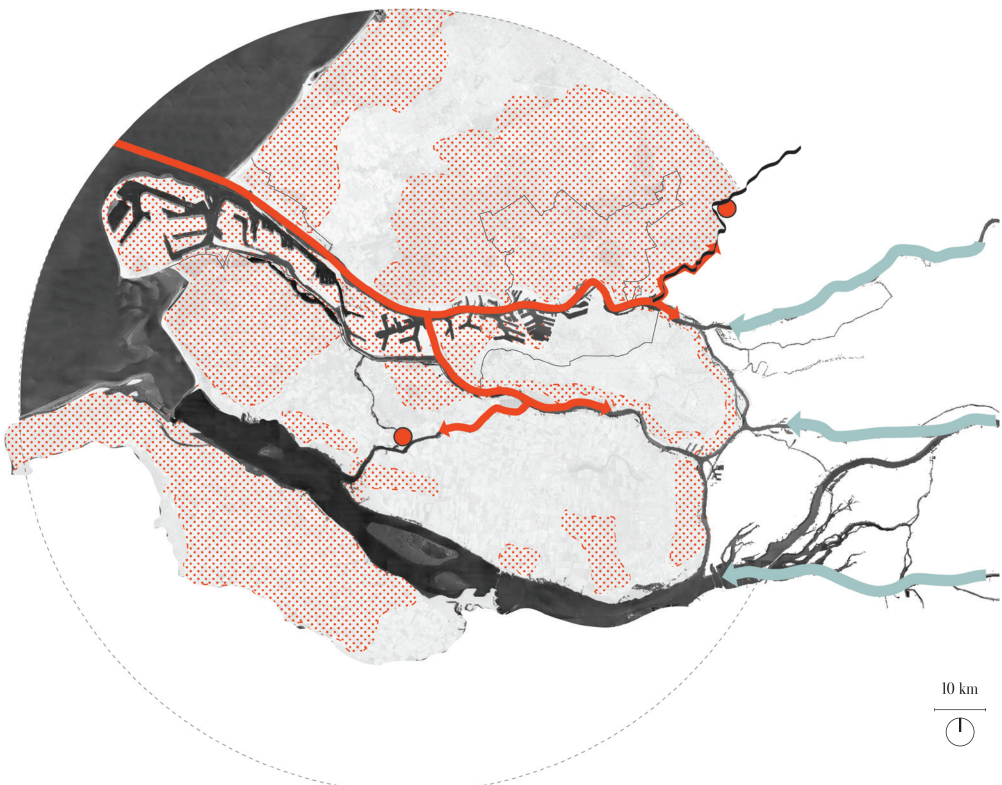
- salt intrusion by rivers
- salt intrusion by ground water
- river discharge
- threatened fresh water point
- built environment
- water

▲ Extremely low water levels in rivers upstream last summer cause salinization problems downstream (source: ANP)

▲ The Aaldijk near Spijkenisse is an example where you can see the height difference between the tidal waters (outside the dikes) and the boezem land (inside the dikes), causing brackish seepage in agricultural area (source: Google Streetview)



▲ Saline intrusion through surface water threatening inlet points for fresh water (source: by author)



▲ Saline intrusion through ground water (source: by author)

9. Climate Regulation

An important part of climate change is temperature rise, which will be 1-2 degrees in the Rest Scenario and 2-4 degrees in the Steam Scenario. This, together with the fact that cities become more dense and grey (which absorbs the heat / heat island effect), results in very warm cities. The average difference between a city center and the surrounding landscape can even become 7 degrees. The heat map in figure shows the most warm areas in the region and also illustrates how green areas, like the Kralingse Plas in Rotterdam bring cooling.

legend

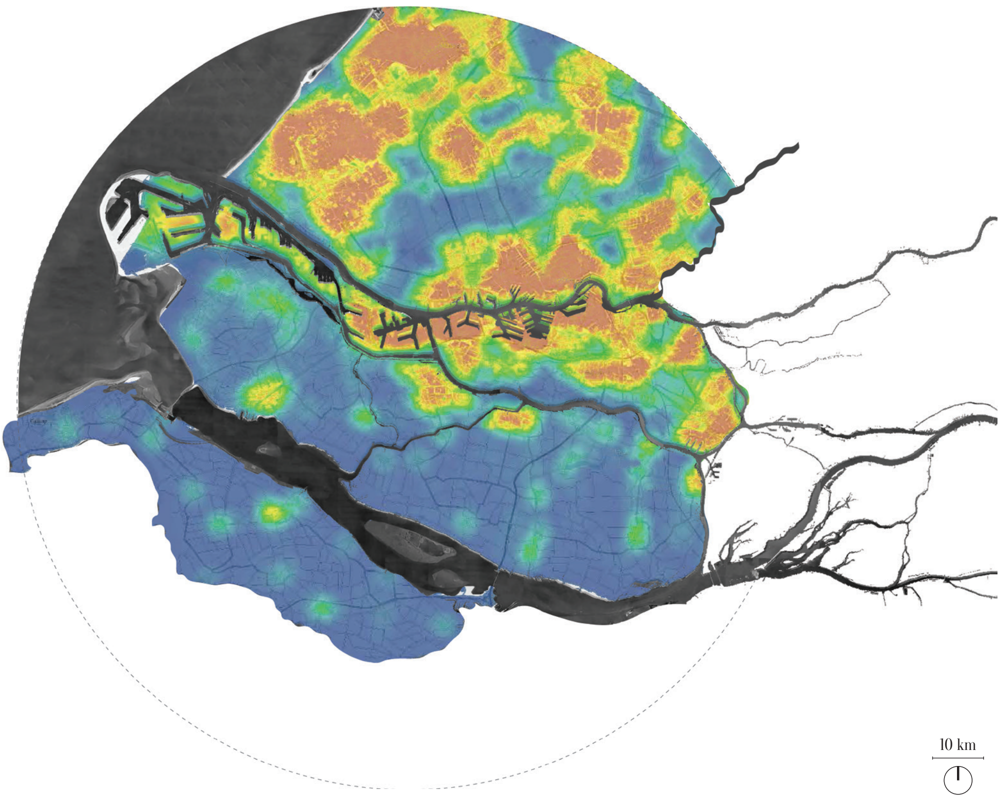
average temperature in non-urban area - 2.8 degrees

average temperature in non-urban area - 0 degrees

water

▲ Demand for cool, green areas, like the Kralingse Plas, to deal with heat stress in the city (source: Metro)

▲ The air quality in Rotterdam is the worst from the Netherlands, mainly caused by traffic, industries and from external resources (source: Architectenweb)

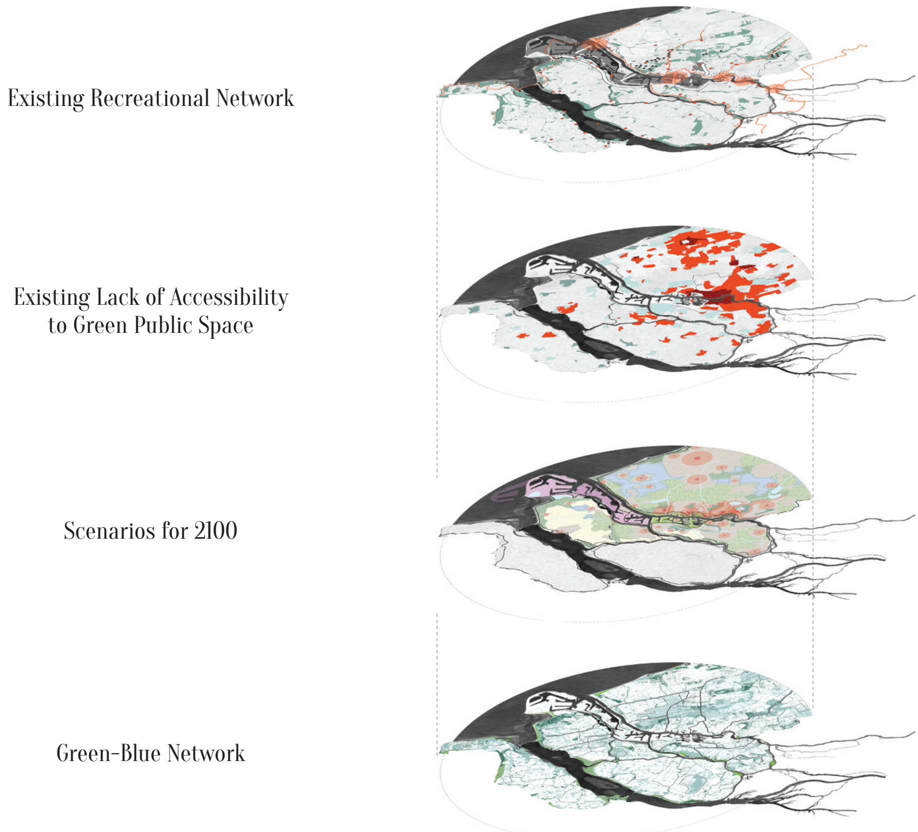


10 km

▲ Heat map (source: by author)

Appendix 4 - Ecosystem Service Strategies Regional

1. Relate city, river and harbor

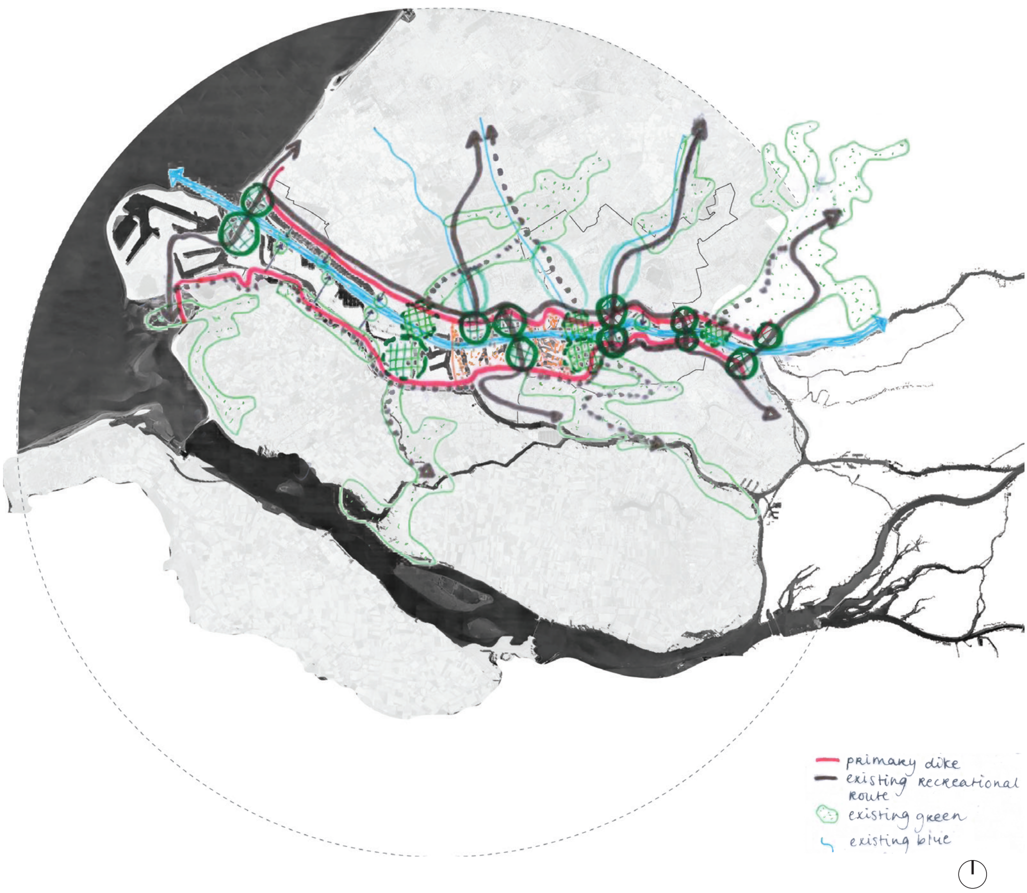


Tidal parks can function as attractive city parks to create a connection between the city and the river. The transition zone between land and water can be used for recreational activities, like walking, fishing, playing, sports, etc. and can also create access to the water which makes recreational facilities on the water better accessible.

The regional recreational network is crucial to make sure the tidal parks provide most recreational values. Without connecting it in the contextual network the parks are less accessible and therefore provide less values for the wider context. The existing structures will be used to define the focus points for tidal parks within the area outside the dikes

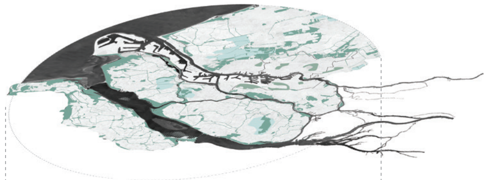
Design Rules to Relate the City to the River

- Use the intersection between river and existing recreational routes to develop recreational tidal city parks (first priority).
- Use existing recreational routes in combination with existing green-blue network to create recreational connections in the wider context between the river and the tidal parks.
- Use proposed recreational connections to develop recreational tidal city parks and connect the whole river in the wider context (second priority).
- Improve the existing green-blue network and recreational network in urban area by adding recreational and natural value in order to attract visitors from the hinterland to the river and tidal parks.
- Transformation of the harbor functions in the Botlek and Waal-Eemhaven creates opportunities to create a large scale recreational or tourism park with possibilities for daytrips or holidays and overnight stays.
- Improve relation between existing recreational routes and the river by providing small scale tidal parks in the urban area and harbor which is still in function to improve continuity of recreation along the river bank.

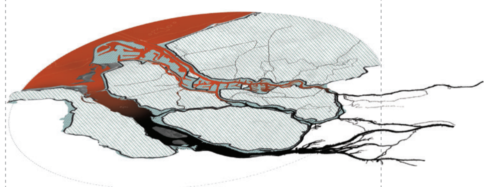


2. Increase Natural Values and Biodiversity

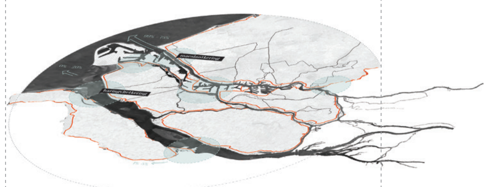
Existing Ecological Network



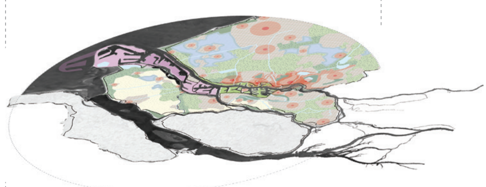
Delta Dynamics providing difference between
Tidal and Fresh Nature



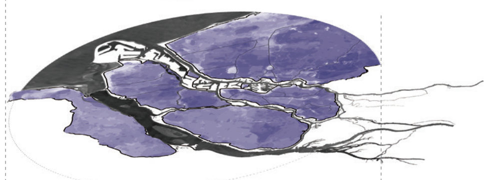
Existing Water System creates Boundaries
for Species to Migrate



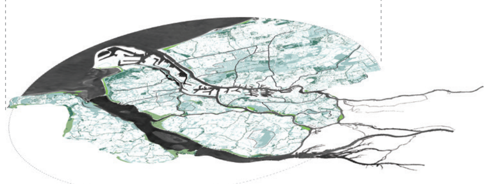
Scenarios for 2100



Opportunities for Giving Land back to Nature



Green-Blue Network



Tidal parks can provide a transition zone between land and water which provides different types of habitats for species (due to different water depth, different vegetation). The parks can function as stepping stones for migration routes along the river or can function as a transition zone to migrate between water and land.

In order to function as a migration route along the river the river bank outside the dikes will be transformed into natural banks as far as possible. In the Botlek and Waal Eemhaven, this will be elaborated to the full extent. In the other parts of the harbor small locations for stepping stones will be investigated. The river structures landinwards function as points where tidal parks can provide the entrance between water and land. This connects fresh and tidal water nature to provide a wide combination of habitats in the region.

Design Rules to Increase Natural Values and Biodiversity

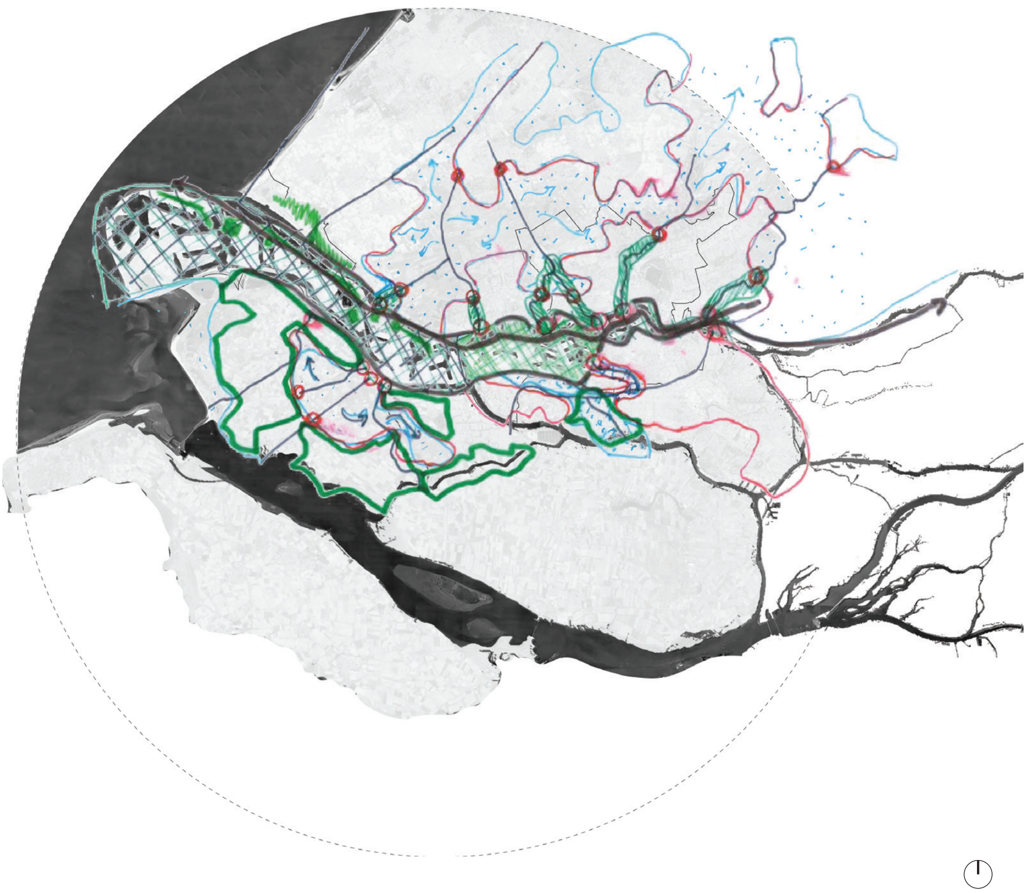
Let nature find its own way in the Waal and Eemhaven to restore the natural tidal landscape and let the dynamics of the delta form the landscape. This provides a large tidal habitat area for migrating species between sea and rivers.

Provide small scale tidal stepping stones in the harbor area which is still in function to create stepping stones for migration between the marine and terRestrial habitats.

Use existing inner city rivers to improve natural values along the banks and provide a connecting migration route between tidal and fresh nature.

Upgrade water management points in order to make them suitable for species to pass.

Stop draining the polder landscape to restore wetlands and give fresh water nature the freedom to flourish. The peat landscape north of the river can grow slowly. This landscape can also be used to store river water in times of high river discharge (combination with water safety).



3. Provide Educational Environment

Relicts of the Historical Landscape as Base for providing an Educational Environment

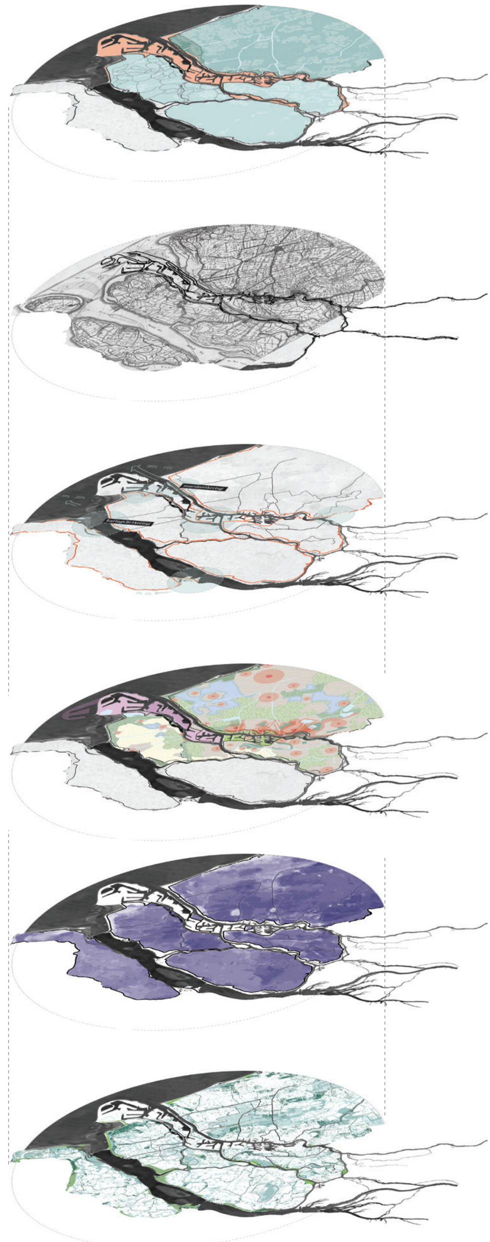
Historical Delta provides Inspiration to create Awareness of Living in the Delta

Existing Water System with Primary and Secondary Dikes

Scenarios for 2100

Opportunities for Giving Land back to Nature

Green-Blue Network



Tidal parks can provide a transition zone between land and water which can connect people more to the tides and dynamics of the delta. Nowadays, the often hard quays and non accessible river banks does not allow people to experience the fact that they are living in the delta. Creating more destinations along the river attracts people to the river and the tides. Providing tidal parks in between the primary dikes (which are often well used recreational routes) and the river connects people directly to the delta. Tidal nature is originally the type of nature which could be found in the historical delta. By developing tidal parks along the river bank, people become more aware of living in the delta as they are subjected to the tides. The base for this strategy to increase awareness of living in the delta is two sided:

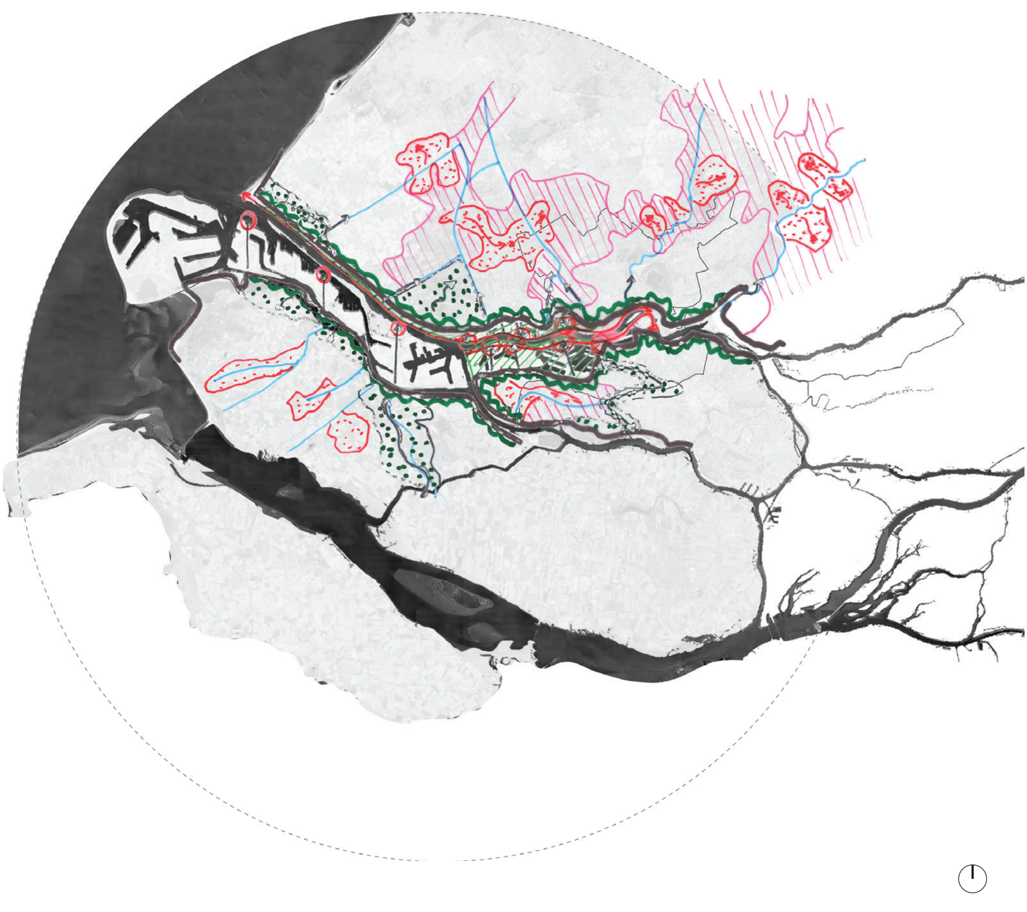
1. Bring people to the river / tides / delta
2. Bring the river / tides / delta to the people

1. Create destinations along the river bank, provide routes along and to the river bank, develop the primary dike as a destination which make people experience the delta from the dike (also due to the height difference between outside and inside dikes the difference between the delta landscape and the hinterland can be experienced well here)

2. Let the tides in in the area outside the dikes to connect the primary dike (where the people are) directly to the tidal landscape. Besides that, the historical landscape with old dikes is used to let the tides come into the land. In certain areas, this brings the tides further land inwards and can therefore also create awareness there. This also improves the cultural identity of the region as it gives old dikes again the function of a dike. Provide water detention zones along the inland rivers to let the fresh tides in during peak rainfall or high river discharge which increases awareness of the fact that people live in the receiving end of an estuary.

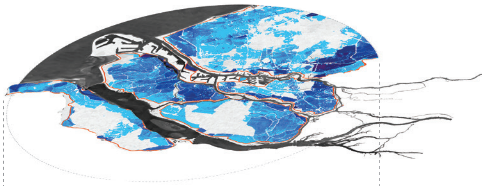
Design Rules to Relate the City to the River

- Where possible restore the tidal influence in the area outside the dikes to connect the dike directly to the delta dynamics
- Develop continuous routes along the river in order that people can have access to the whole river bank without interruptions
- Develop destinations on the river bank to attract people from the primary dikes and hinterland to the water and tides.
- Develop the primary dike itself as a destination with tree structures and street furniture to experience the difference between the dynamics of the natural delta and the hinterland.
- Restructure primary dikes to provide more land outside the dikes and let the tides in, which increases awareness for risks coming from the sea. (note: conflicts with water safety and salinity intrusion)
- Create zones along inland rivers to let the 'fresh tides' in when needed. Fresh tides can be seen as water during high river discharge or peak rainfall which increases river water levels and creates risks. Providing space for this water creates awareness land inwards (around the detention zones), because people become aware of the effects of living in the receiving end of the Rhine-Meuse Estuary (awareness of river water). The location for these zones come from the combination of the Green-Blue Network and the map for opportunities for giving land back to nature.
- Maximum zone to restore fresh tides. The location of this zone is related to the land use types grassland and nature, as these types are the ones which are available for change according to both scenarios for 2100.

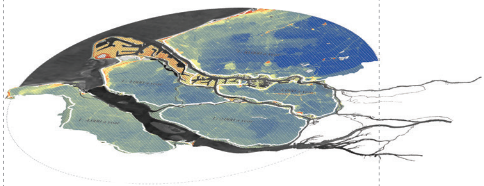


4. Increase Water Safety

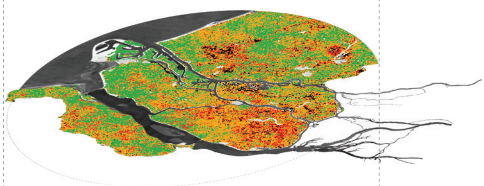
Water Depth within the Dikes in case a Primary Dike Collapses



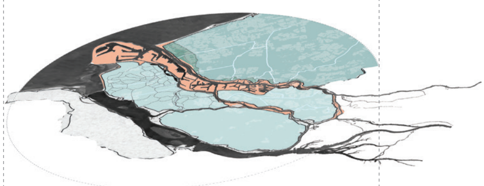
Existing Water Safety Management



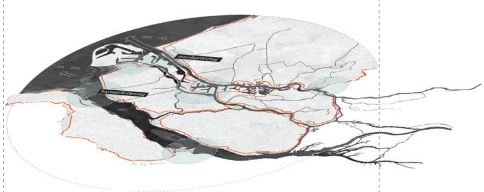
Soil subsidence Increases Water Safety Problems



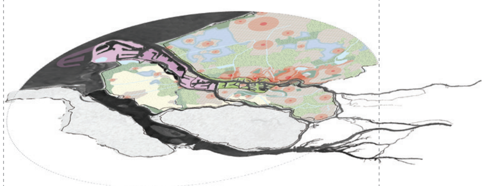
Historical Dike Structures can become Functional in the New Water System



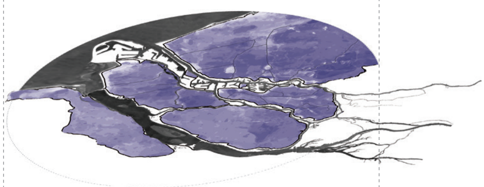
Existing Water System



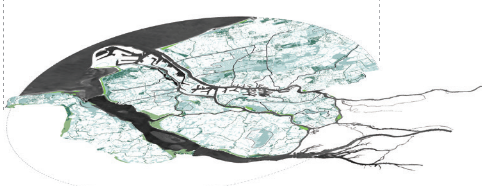
Scenarios for 2100



Opportunities for Giving Land back to Nature



Green-Blue Network



Tidal parks can contribute in creating more water safety by slowing down the water speed and reduce the intensity of waves and tides. This reduces flooding and protects the existing dikes from eroding. The regional strategy for increasing water safety provided by tidal parks is four sided:

1. Create a fore land in front of the primary dikes. This slows down the tides and waves and therefore protect the dikes which makes them more safe.
2. Slow down the water in general by reducing river water depth in order to reduce storm waves entering the quays/land and create floodings.
3. Create intertidal wetlands behind the primary dikes to stimulate sediment disposal and create more stable and wide (climate) dikes
4. Create water detention zones along the inland rivers to temporary store the water during peak rain fall or during high river discharge, which can be reused in periods of drought

Design Rules to Increase Water Safety

Botlek and Waal-Eemhaven: tranformation of harbor creates possibility to create large scale tidal river bank to protect primary dike

Stimulate development of tidal nature in zone between primary dike and river in order to protect primary dikes

Create intertidal zones in between dikes to stimulate sediment disposal and create more solid and wide (climate) dike structures to protect the hinterland

Investigate on developing the same intertidal zones in areas within the old dike structures which are occupied by urban strctures (where possible develop)

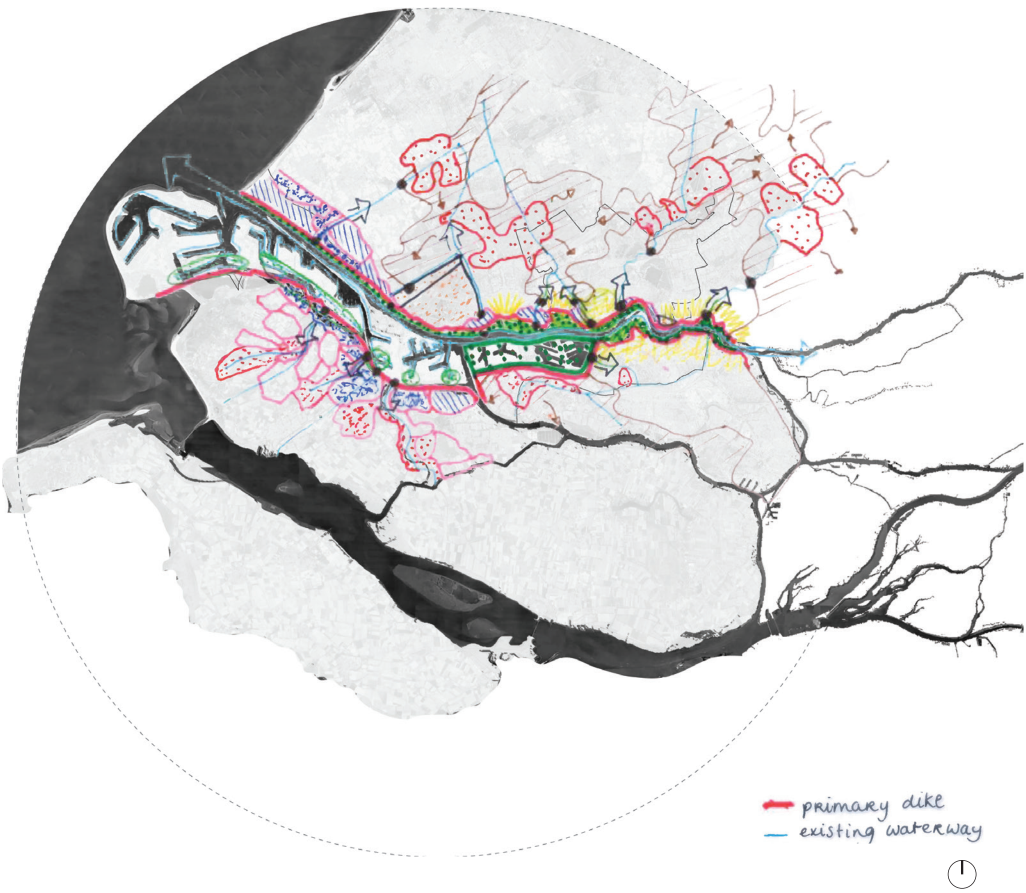
Existing higher structures in the landscape (e.g. secundary dikes) which can be used to develop intertidal zones behind primary dikes to strenghten primary dikes

Investigate on opportunities in functioning part of the harbor next to primary dikes to develop (small scale) tidal parks to create a foreland for primary dikes and therefore protect them.

Use existing water management points to create the possibility to let fresh water into the inland rivers during high river discharge to release pressure on the area outside the dikes and the primary dikes.

Flood detention zones along inland rivers to temporary store the water during high river discharge or heavy rainfall. Later this water can be reused in dry periods or it can be absorped/infiltrate in the soil. The location for these zones come from the combination of the Green-Blue Network and the map for opportunities for giving land back to nature.

Maximum zone to take from cultivation and give back to nature as it is non-built and mainly grassland and nature. By giving this land back to nature, the peat soil can slowly grow back due to Restoration and sediment disposal. After a few decades this zone will be higher than the built areas and functions as a huge dike in which cities are lower locatd islands. The cities will become more safe, but people can also occupy the higher grounds and live in an unique Restored peat landscape.



5. Food Production

River Depth and Salinity Levels influencing Types of Nature to Produce in the River

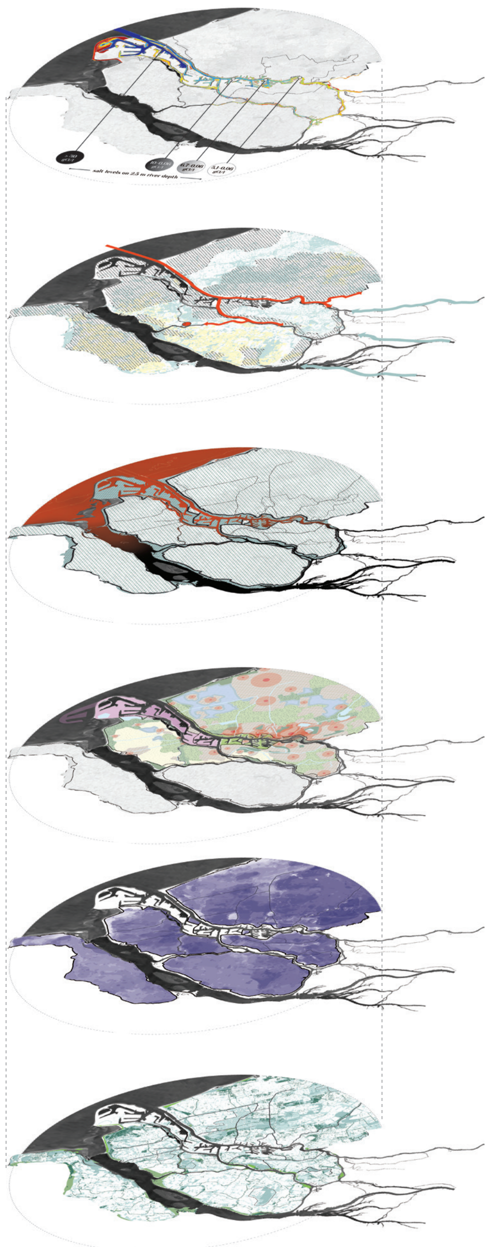
Salinity through Ground Water affecting Food Landscapes

Delta Dynamics influencing types of Food Production

Scenarios for 2100

Opportunities for Giving Land back to Nature

Green-Blue Network



First of all, tidal parks and wetlands can reduce soil subsidence and therefore salt intrusion through ground water by stimulating sediment disposal. They can also provide space for the production of new types of food, like fish, meat, shellfish and plant production. As tidal parks in the Nieuwe Maas are close to urban development this can provide local food which can be directly consumed by inhabitants. It can be maintained by farmers and sold in local shops or maintained by inhabitants itself and used directly. For this strategy the river depth and salt levels of the river are very important as they define the types of food which can be produced. The different types of food, as they will be explained in the regional strategy, are spelled out after the strategy.

The zones which are affected by salinity intrusion through ground water and are no vulnerable zones for flooding have to transfer their production to salt resilient crops. In the areas which are vulnerable for flooding and have to be given back to nature, this will be combined with food production.

Design Rules to provide Food Production

Cropfields and grasslands which are affected by salinization through ground water have to switch to salt resistant crops (food type 5: potato, quinoa, grasshopper, chicken, crake, grey goose, lamb)

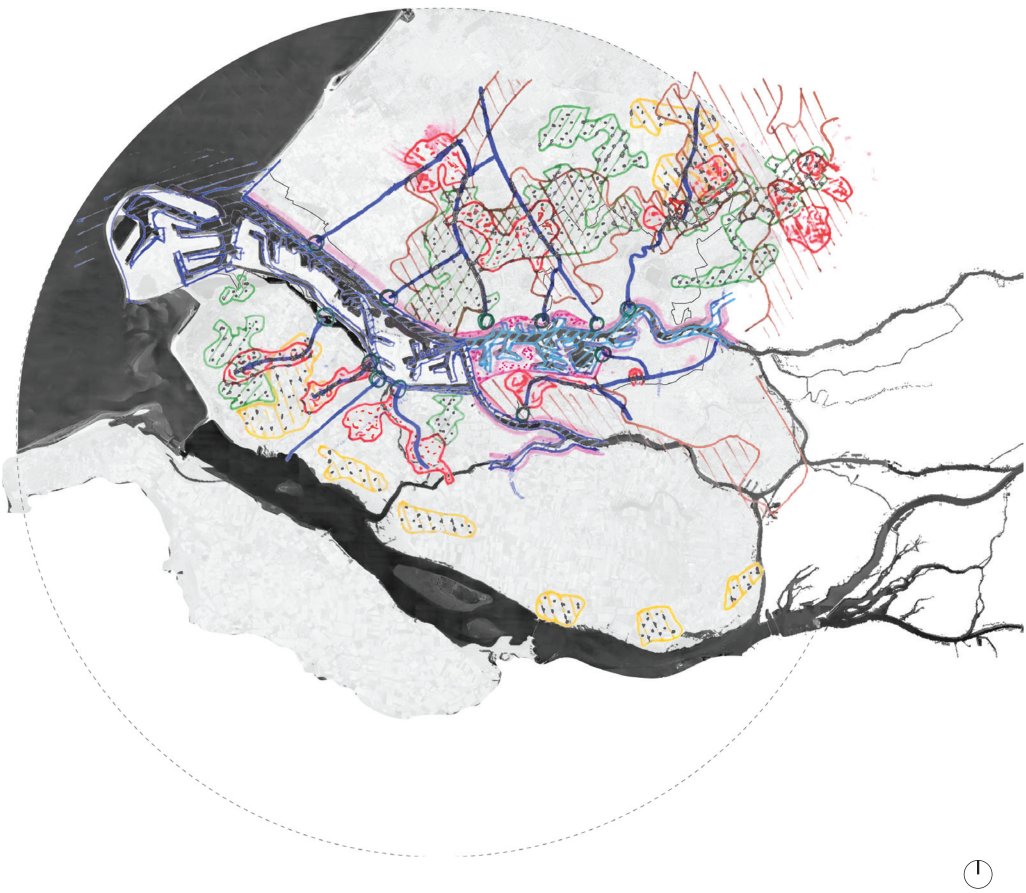
First areas to increase water level on land have opportunities for food production for shallow fresh water (food type 1)

Use existing inner city rivers to improve natural values along the banks and provide a connecting migration route between tidal and fresh nature.

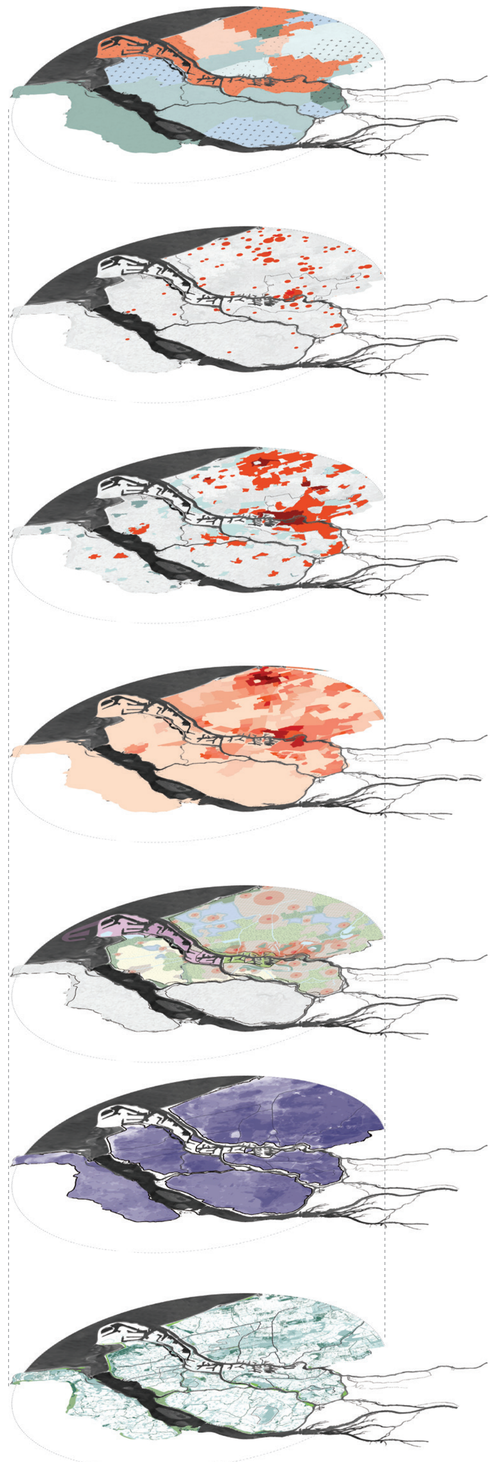
Upgrade water management points in order to make them suitable for species to pass.

Stop draining the polder landscape to restore wetlands and give fresh water nature the freedom to flourish. The peat landscape north of the river can grow slowly. This landscape can also be used to store river water in times of high river discharge (combination with water safety).

Crop field zones are maintained organic and with flower and herb rich zones around and in between the fields to provide biodiversity, pollination and natural dissease and pest control.



6. Basis for Urban Development



Housing Supply and Demand until 2040

New Urban Development Locations

Existing Lack of Accessibility
to Green Public Space

Existing Population Density

Scenarios for 2100

Opportunities for Giving Land back to Nature

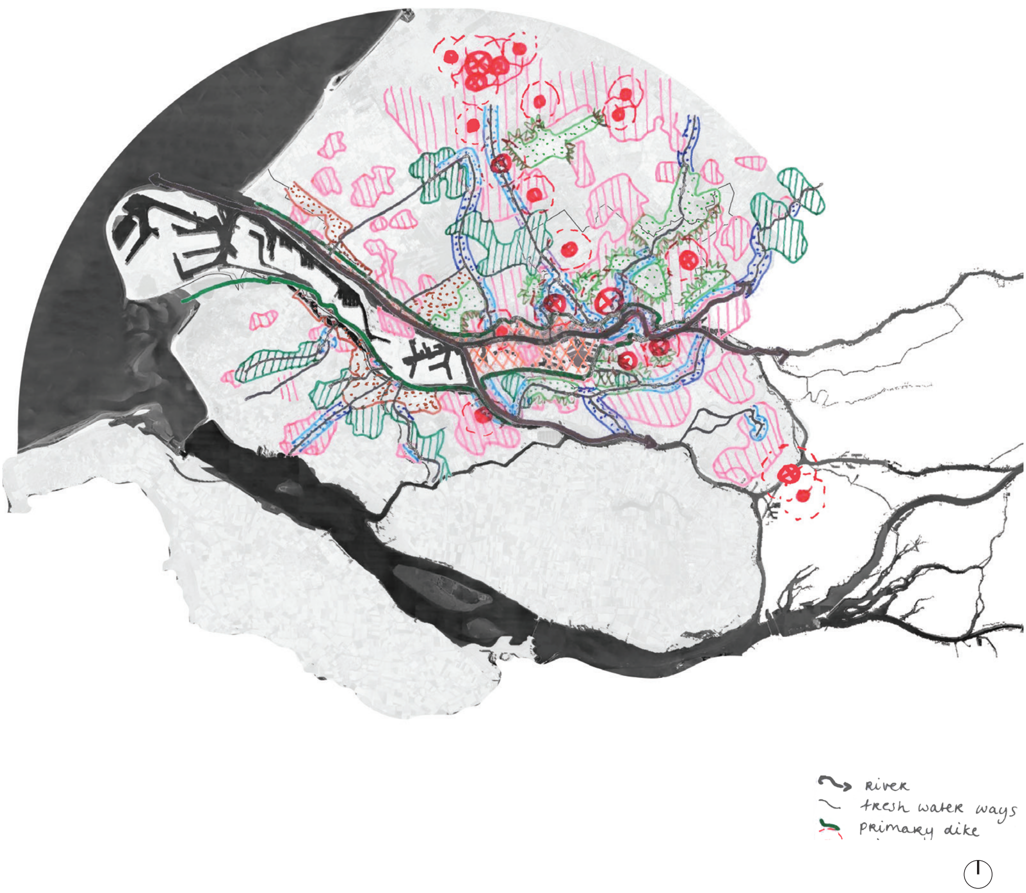
Green-Blue Network

As the analysis shows, the river and its banks are attractive areas for urban development. Tidal parks along the river bank can provide green, public space in existing cities and can therefore improve its land values. Development of tidal parks in or close to the city can also go together with new urban development as it can provide an unique living environment where people can live in adaptive and flood proof housing within the tidal landscape.

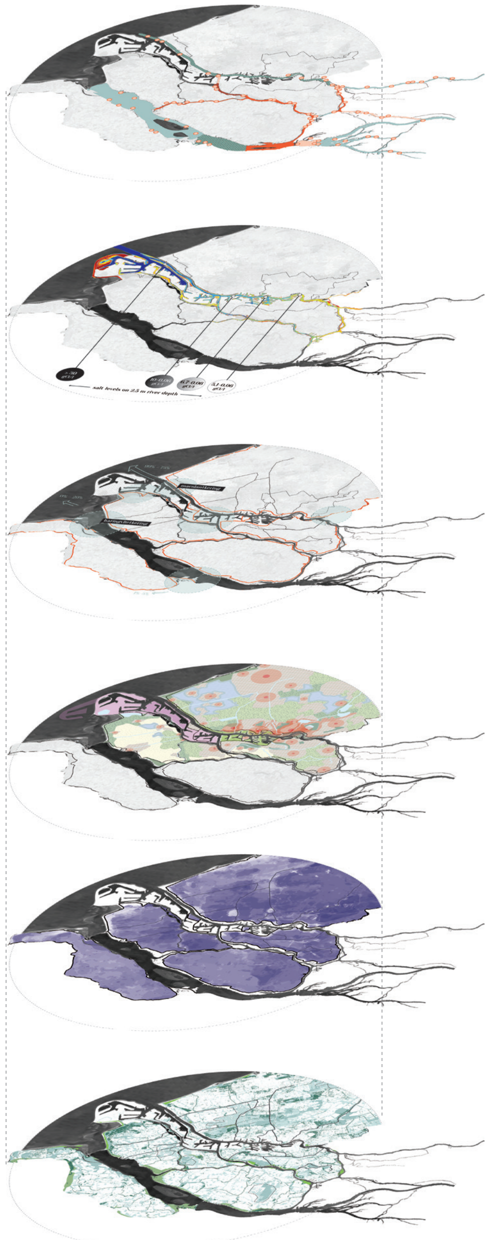
The regional strategy firstly focuses on improving land values by improving existing green and blue structures. It also takes the opportunity to combine other services provided by wetlands and tidal parks with new urban development. For example, intertidal zones behind the primary dikes which create robust climate dikes to improve water safety can go together with new urban development.

Design Rules for Basis for Urban Development

- Existing urban centers are first locations where densification takes place. From here, the expansion will take place towards the surroundings.
- Upgrading urban riverfronts with natural and recreational values increases land values for urban surroundings
- Existing urban areas will densify until 2050 and keep on densifying in Steam Scenario.
- New urban development locations in area outside the dikes as the harbor in this area will transform in both scenarios. The area will develop first in the Waalhaven, as this is the harbor most close to the existing city.
- New urban development locations directly behind primary dikes, in combination with robust and wide climate dikes
- First areas to increase water level on land (to provide more water safety) are opportunity areas for water rich rural housing development outside the existing cities.
- Possible urban development locations along waterways in rural area, which can be developed in case of high space pressure in existing cities
- Upgrade existig parks and lakes in urban area with natural an recreational values to increase land values for urban surroundings.



7. Contribute to Regional Circularity



Sediment and Erosion Processes

River Depth which Influences Sediment Influx

Existing Water System to Transport
River Water Inland

Scenarios for 2100

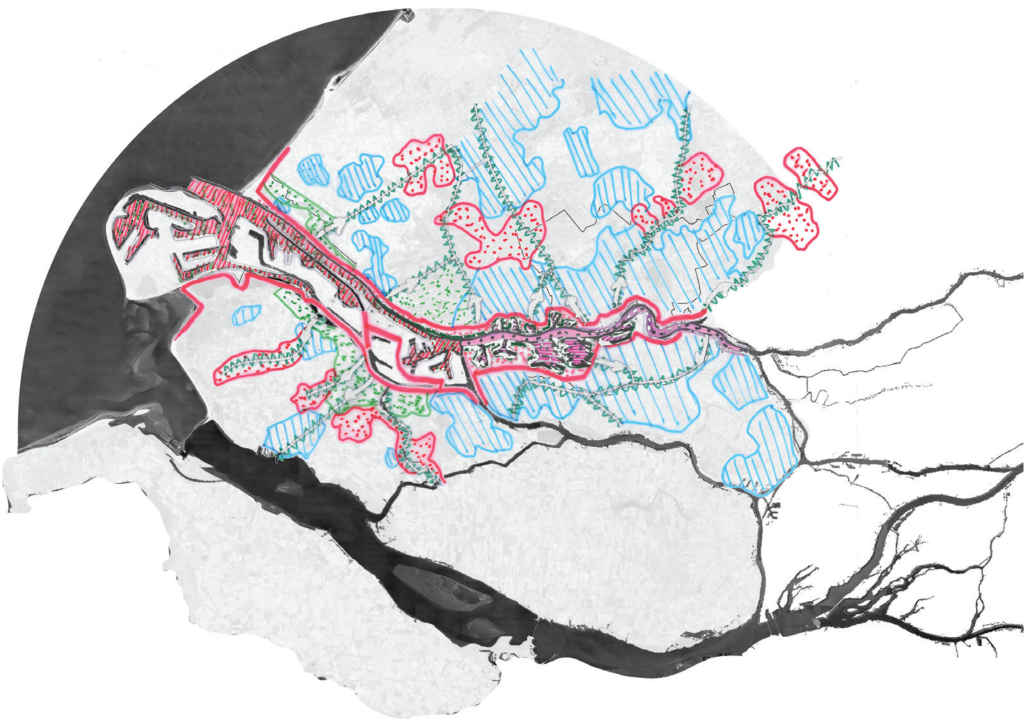
Opportunities for Giving Land back to Nature

Green-Blue Network

The strategy for contributing to regional circularity focuses mainly on the sediment cycle. The natural sediment influx in the rivers and harbor basins will be used. In areas like the Nieuwe Waterweg, where the sediment is not demanded, the dredging activities continue, but the dredged material can be reused in the construction of tidal parks. Within some older harbor basins which have to be transformed, the sediment influx can take place in a natural way, without dredging.
Besides the use of the natural sediment disposals, the strategy focuses on reusing coarse residual material of old quays and demolished buildings in urban environment. This material can be used for the development of dams or other artificial structures within new tidal parks.

Design Rules to contribute to regional circularity

- When harbor activities allow it (in Steam Scenario): stop dredging the Nieuwe Maas to stimulate sediment fixation and naturally undeepen the river
- Sediment fixation in harbor basins along the Nieuwe Maas to naturally develop tidal nature
- Reuse clean sediment coming from the Nieuwe Waterweg, Scheur and harbor basins (dredging material) for new tidal parks or to improve dikes, for example to relocate dikes or to make them wider
- Reuse of river sediment along inland rivers in areas which first should be given back to nature (see 'water safety') to heighten up the land. This can be combined with nature development and production of biomass for energy production.
- Reuse sea influx of sediment directly behind primary dikes to create a wide and relatively high stroke of land behind the primary dikes which provides water safety and works as an alternative for the continuous process of heightening up the dikes. This can be combined with nature, agriculture or housing.
- tidal water quays / fresh water quays: Reuse coarse material of old quays to create artificial structures in areas which are transformed into tidal parks
- Reuse coarse residual material of urban areas which are demolished or transformed within new tidal parks
- Deep salty water in Nieuwe Waterweg, Scheur and harbor basins can be used for seaweed production for energy
- Shallow salty water in Nieuwe Maas and harbor basins can be used for sea grass production for energy
- Use tidal influence along tidal river for energy production. Combine with reuse of coarse residual material.
- + + Reuse plant Rests of tidal parks and green banks as biomass for energy



8. Provision of Fresh Water

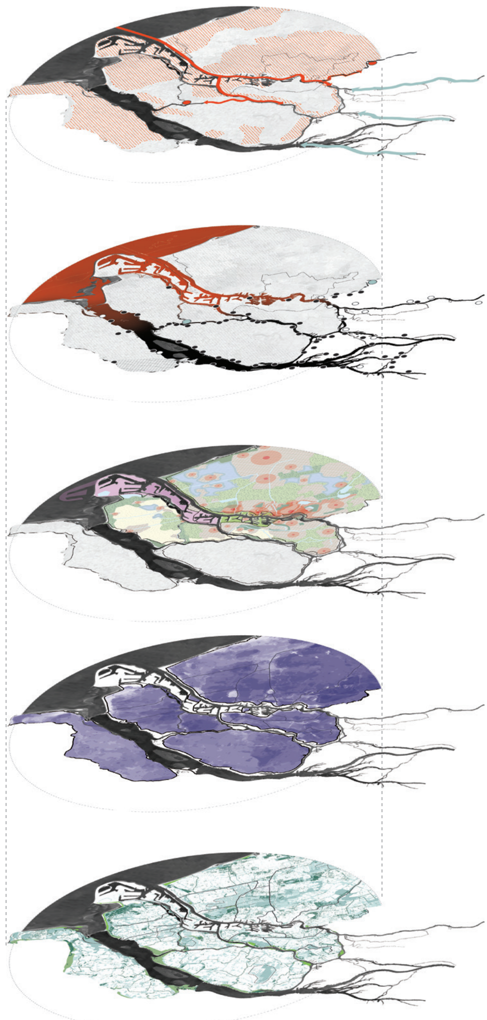
Salinization through Ground Water (Seepage)

Salinization through Rivers

Scenarios for 2100

Opportunities for Giving Land back to Nature

Green-Blue Network



The strategy for contributing to regional circularity focuses mainly on the sediment cycle. The natural sediment influx in the rivers and harbor basins will be used. In areas like the Nieuwe Waterweg, where the sediment is not demanded, the dredging activities continue, but the dredged material can be reused in the construction of tidal parks. Within some older harbor basins which have to be transformed, the sediment influx can take place in a natural way, without dredging.
Besides the use of the natural sediment disposals, the strategy focuses on reusing coarse residual material of old quays and demolished buildings in urban environment. This material can be used for the development of dams or other artificial structures within new tidal parks.

Design Rules for provision of fresh water

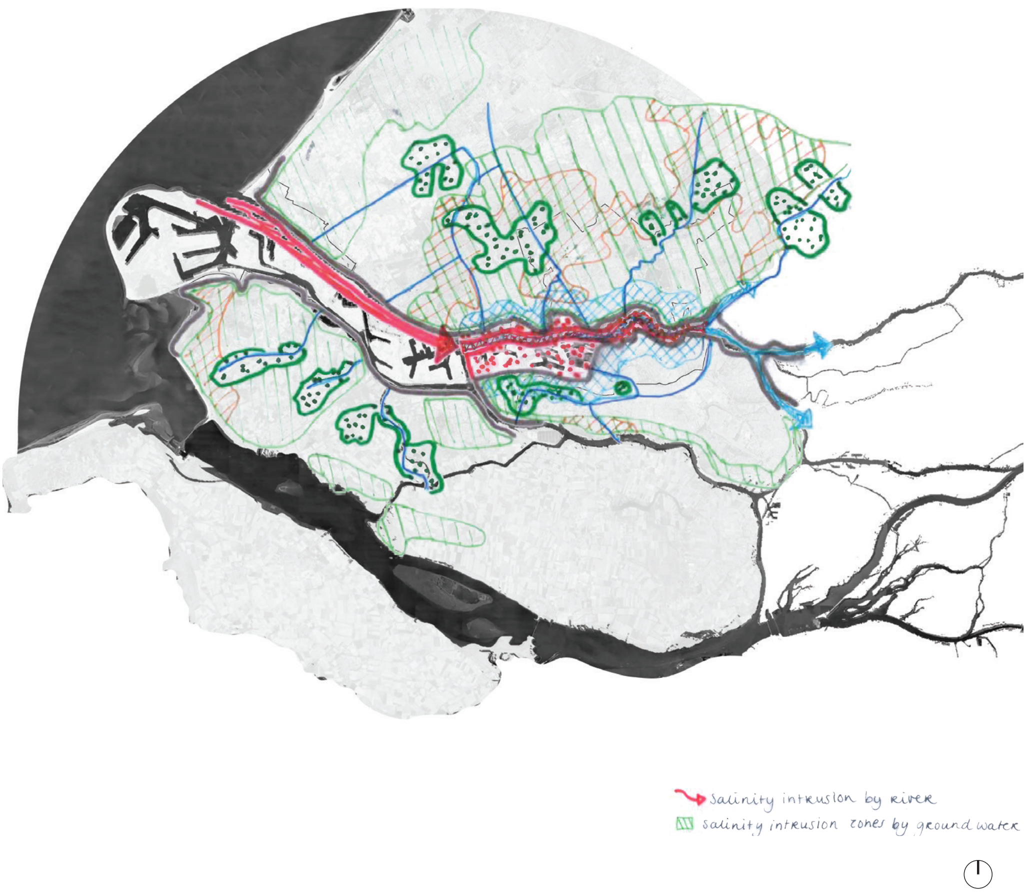
When harbor activities allow it (in Steam Scenario): stop dredging the Nieuwe Maas to stimulate sediment fixation and naturally undeepen the river. This decreases water speed and currents and therefore decreases salinity intrusion

Develop tidal nature along Nieuwe Maas to decrease height difference between areas inside and outside the dikes and therefore decrease salt seepage coming up in the areas within the dikes

Decrease of salinity intrusion through ground water due to the two measures described above.

Maximum possible area (within salinity intrusion zone by ground water) to give back to nature in order to increase the ground water table and land level (through sedimentation disposal), resulting in decreasing salt seepage coming up.

Water retention along inland rivers in areas to give back to nature first (see water safety). These zones can store fresh water during peak rainfall and high river discharge and can be reused within agriculture and nature areas in times of drought.



9. Climate Regulation

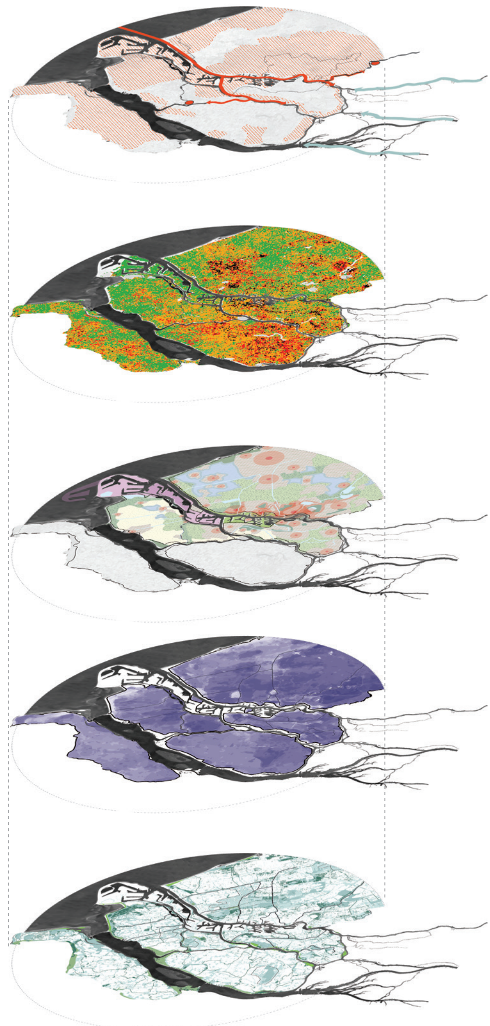
Salinization through Ground Water (Seepage)

Salinization through Rivers

Scenarios for 2100

Opportunities for Giving Land back to Nature

Green-Blue Network



The strategy for contributing to regional circularity focuses mainly on the sediment cycle. The natural sediment influx in the rivers and harbor basins will be used. In areas like the Nieuwe Waterweg, where the sediment is not demanded, the dredging activities continue, but the dredged material can be reused in the construction of tidal parks. Within some older harbor basins which have to be transformed, the sediment influx can take place in a natural way, without dredging.
Besides the use of the natural sediment disposals, the strategy focuses on reusing coarse residual material of old quays and demolished buildings in urban environment. This material can be used for the development of dams or other artificial structures within new tidal parks.

Design Rules for Climate Regulation

 Combine the primary dikes with tree structures to capture SO2, NOx, CO2 and fine dust, coming from ships and harbor activities.

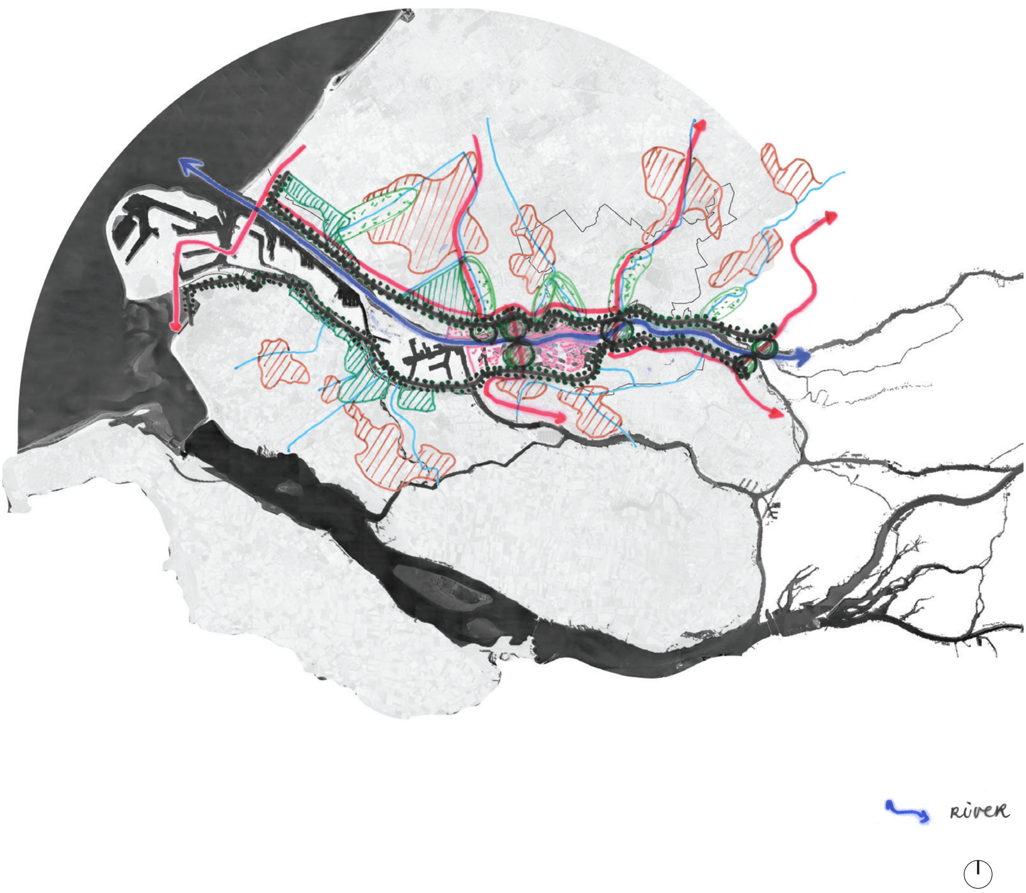
 Create intertidal zones behind the primary dikes combined with aluvial willow foRest to capture SO2, CO2, NOx and fine dust coming from ships, harbor and roads along dikes.

 Develop reed and rush structures in brackish zone along river to capture SO2, NOx, CO2 and fine dust. Reed and rush is the only upgoing type of plant which can grow in a salty environment.

 Reduce extreme CO2 emissions produced by peat oxidation caused by soil subsidence by giving these zones back to nature and increase the ground water level.

 Develop ecological banks along inner city rivers (Green-Blue structures) to reduce heat stress. Where possible it can be combined with reed and rush or alluvial willow foRest to improve the air quality.

 Use interconnections between recreational routes and river (close to the city center) to create possibilities for inhabitants to get access to the water. This can create cool and recreational zones where people can escape from the cities' warm and crowded climate.



Appendix 5 - Ecosystem Service Strategies Waalhaven

In order to make sure the final strategies for each scenario take into account the services society desires in 2100 a maximisation method is applied for each of the nine ecosystem services, see figure 7.30. Each strategy represents the maximal outcome of how nature would be able to provide that specific service in the Waalhaven.

1. Relate city, river and harbor

City park functioning as a connecting zone between city and harbor

Give the city a 'face' towards the city park

Extend existing routes in the city to the harbor

Extend large scale cycle network to make the water better accessible

Extend large scale boat network to connect the whole city to the Waalhaven

Create local pedestrian routes along the water to create accessibility

Create tidal parks in the water close to the city to bring people closer to the water

Make the water suitable for water recreation (swimming, water sports, fishing)

Connect tidal park to the Zuiderpark to profit from recreation and visitors in the park

2. Increase Natural Value and Biodiversity

Let nature develop a gradient in the water through sediment disposal, creating different habitats for species

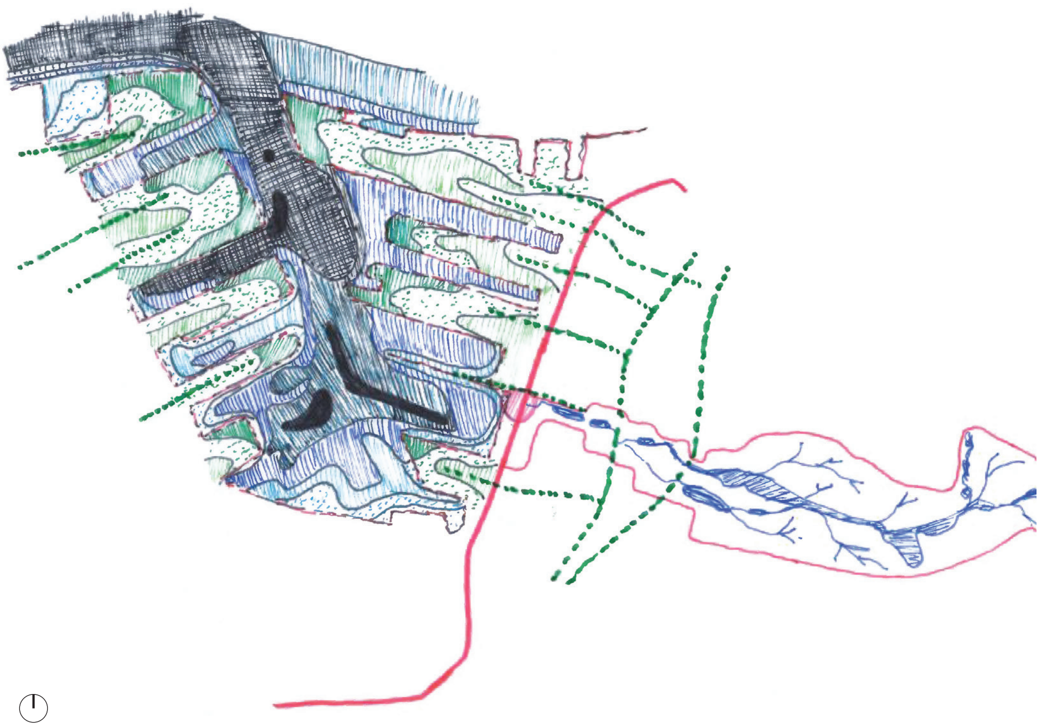
Stop managing existing quays so that they will be slowly demolished by nature

Let nature develop a gradient o land through erosion, resulting in a varied gradient between land and water

Make sure the water management point allows species to migrate between salt/tidal nature and fresh nature

Develop regional dikes around the Zuiderpark and let the fresh water flow freely

Connect ecological structures within and outside the dikes



3. Provide Educational Environment

- Make quays which are not accessible accessible to connect people to the water and create awareness of living in the Delta.
- Already accessible quays are the first quays to develop a transition zone between land and water
- Create a transition zone between land and water to increase awareness of living in the Delta.
- Improve connectivity between city and harbor
- Strenghten identity of the harbor by building on to existing characteristics (large units, blocks, eastwest connections, straight lines)
- Strenghten identity of the city in contrast with the harbor by building on to existing characteristics (small units, linear, north-south connections, organic lines)
- Maintain monuments and improve their accessibility and visibility to improve cultural identity.
- Restructure primary dikes to provide opportunities to let the tides in and provide more delta dynamics close to inhabitans (note: conflicts with water safety and salinizatio)
- Develop destinations on the riverbank to attract people to the water

4. Increase Water Safety

Maintain RDM terrain and Sluisjeskade to funnel the water and do not give the rising sea level and tidal influence more space as this will only increase the risks

Give back to nature first
(area is already at high risk)

Give back to nature second
(area is at risk at 35 cm sea level rise)

Give back to nature third
(area is at extreme risk at 85 cm sea level rise)

Give back to nature fourth
(area is at risk at 85 cm sea level rise)

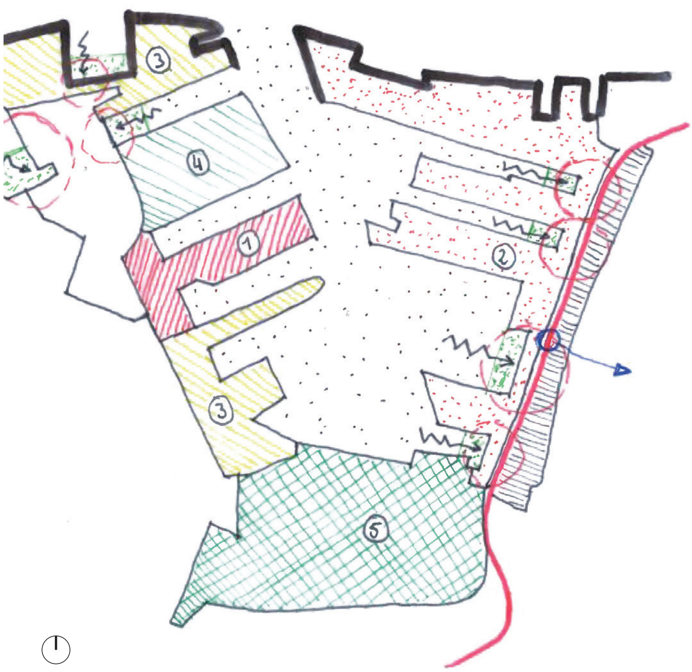
Give back to nature fifth
(area is NOT at risk at 85 cm sea level rise)

Create tidal parks in front of primary dikes to reduce waves and currents and protect the dike from erosion

Create intertidal zone behind primary dike to stimulate sediment disposal and create a solid and wide climate dike

Create tidal nature in harbor basin to reduce waves and currents and protect the whole hinterland

During high river discharge: create the possibility to let the fresh water into the inland river to reduce pressure on zones outside the dikes



5. Food Production

Deep salty water provides foodtype 1

Undeep salty water provides foodtype 7 and possibilities for aquaculture producing animals

Undeep salty water provides foodtype 7 and possibilities for aquaculture producing plants

Salty river banks providing foodtype 8 and possibilities for aquaculture producing plants and animal production on land (crake, grey goose and chicken)

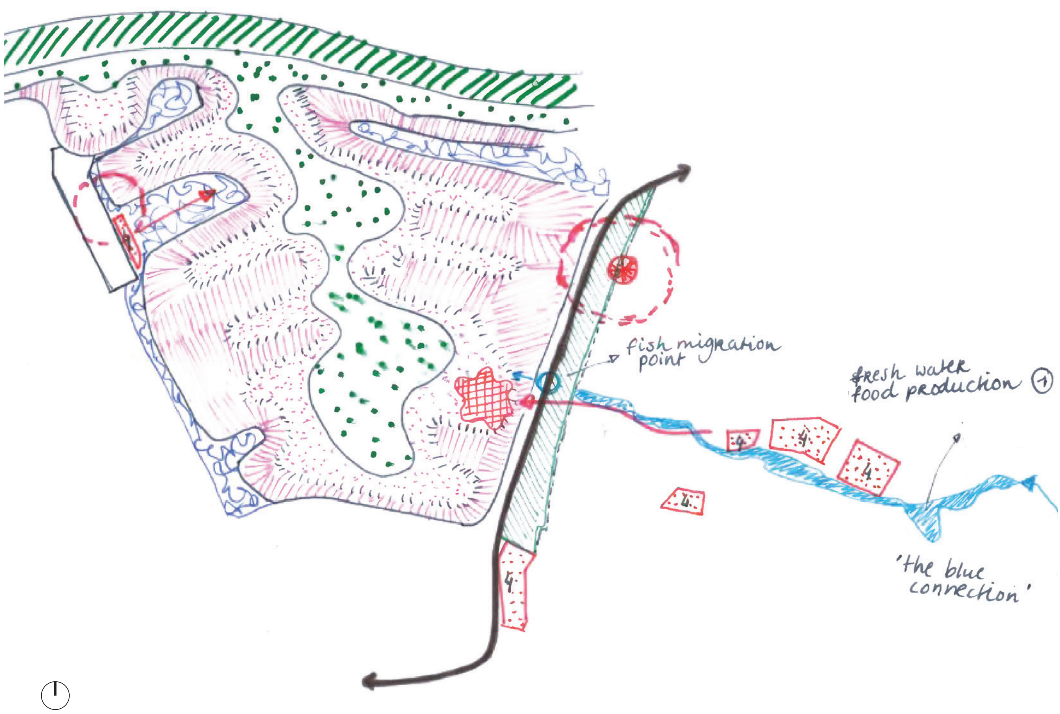
Salty land for salty agriculture and allotment gardens providing foodtype 5

Intertidal area behind primary dike is first combined with aquaculture and then regular farming

Existing allotment gardens

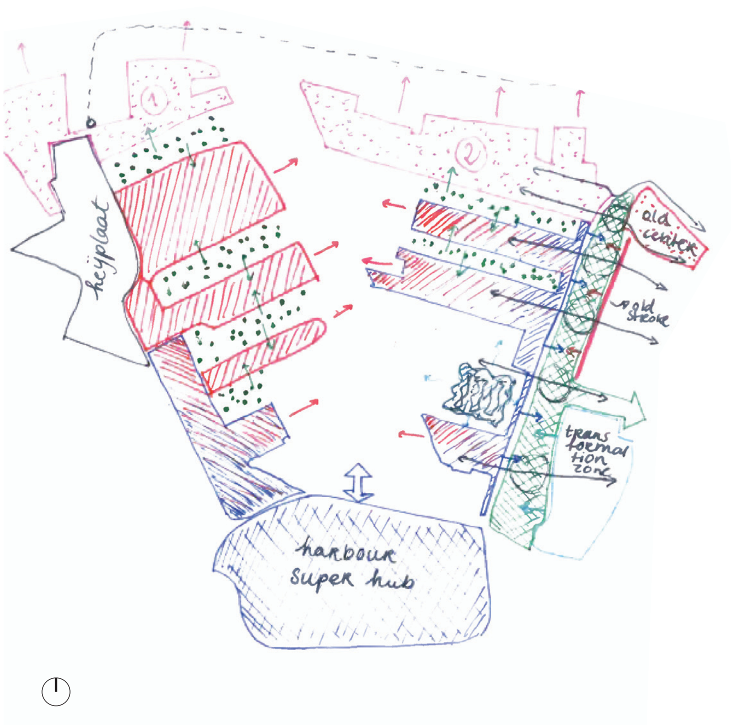
Foodhub Charlois with existing urban farming area

Innovative aquaculture project as a landmark for the area



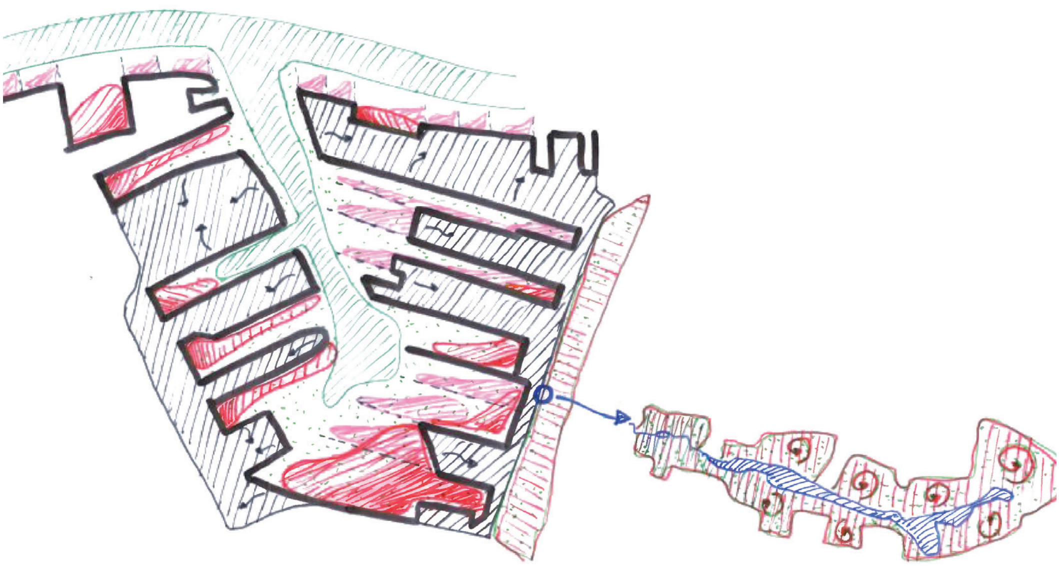
6. Basis for Urban Development

- Existing harbor company area is upgraded to superhub due to excellent location
- Upgrading existing business centers along the Nieuwe Maas, becoming a business card for the area
  - (1) Businesses for manufacturing, education, technology, innovation, design, research
  - (2) Businesses for innovation, knowledge institutes, maritime services, starters
- New housing locations (quiet, along the water)
- Combined working / living environment in which the gradient shows the focus on work or living
- Intertidal park behind primary dike functioning as city park providing values for new and existing urban development by increasing land values.
- Embed new urban areas within existing context
- Focus of amenities / recreation to connect the new harborcity with Charlois
- Position urban transformation zone towards city park
- Tidal parks in former harbor basin increasing surrounding land and building values
- Floating houses in large part of former harbor basin and as attractive area between new harbor city and Zuiderpark



7. Contribute to Regional Circularity

- Use existing sediment disposal locations to develop tidal parks
- When quays are demolished, reuse coarse residual material for dams to catch more sediment
- New dams built with reused material to catch sediment
- New catched sediment to reuse regionally or to develop tidal parks in the Waalhaven
- Use height difference of quays and tidal influence on land to produce energy
- Deep water: seaweed production for energy
- Undeep water: seagrass production for energy
- Sediment catchment within the dikes by transporting water inland



8. Provision of Fresh Water

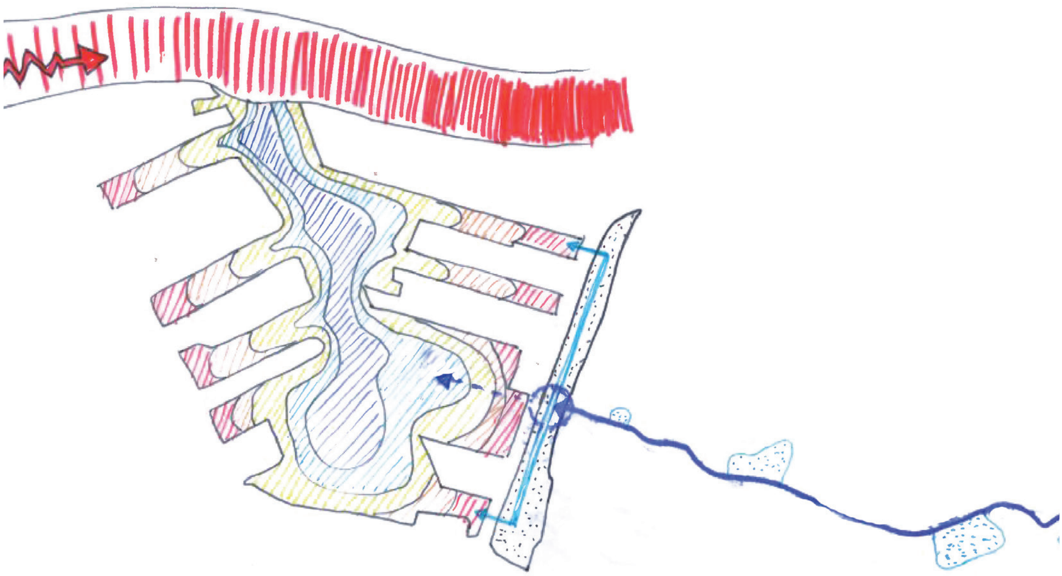
Make the river Nieuwe Maas as undeep as possible with a gradient from deep (west) to undeep (east) to decrease water speed and currents and decrease salinity intrusion

Develop a gradient from deep to undeep within the harbor basin to decrease water speed and currents and decrease salinity intrusion

Develop seepage ditch to catch he salt seepage so it won't intrude in the land and affect nature and agriculture. Zone around this ditch will be brackish.

Fresh water supply through the 'Blauwe Verbinding' meaning 'Blue Connection' coming from the Oude Maas.

Retention zones for fresh water coming from the Blauwe Verbinding in areas with higest potential to give back to nature to reuse in times of drought



9. Climate Regulation

Intertidal zone behind primary dike combined with luvial willow foRest to capture S02, C02, N0x and fine dust coming from ships, harbor and traffic

Tree structures along harbor basins to 'steer' the wind to the warm city

Give land back to water and combine with tidal nature to provide cool structures for future urban development

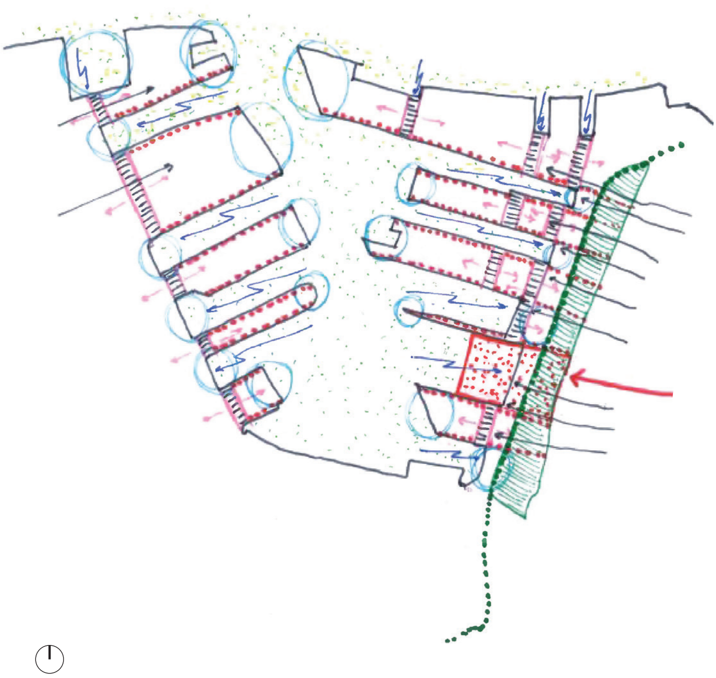
Use interconnecton between recreational route and water to develop a recreational tidal park and attract people to the water to provide a cool climate

Combine primary dikes with tree structures to capture S02, N0x, C02 and fine dust

Create continuous routes from the city to the water to give access to the cooler climate

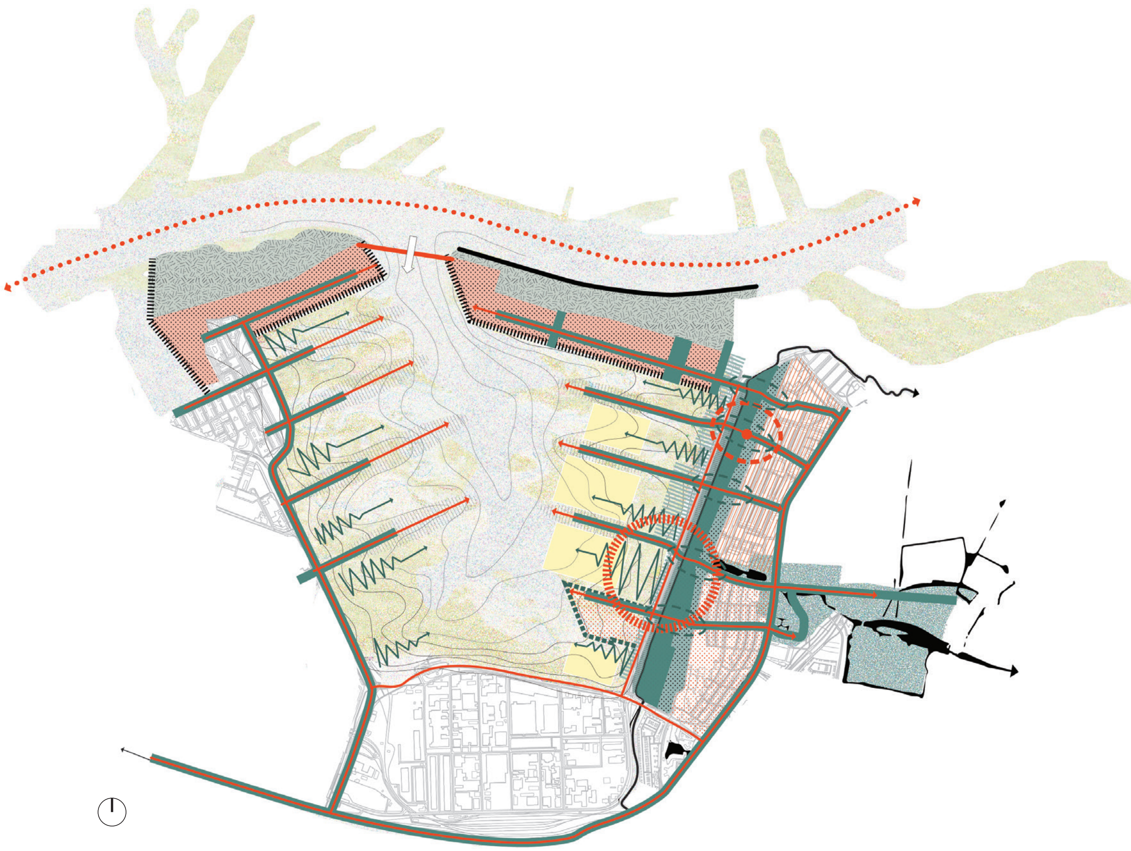
Create tidal parks on ends of pier and harbor basins to create transition zones from land to water to connect people to the cool water

Combine water with reed and rush (which is the only upgoing type of plant which can grow in salty waters) to capture S02, N0x, C02 and fine dust



Appendix 6 - Waalhaven Scenario Strategies

Rest Scenario Strategy



legend

- extend existing routes from city towards harbour
- extend existing green structures to connect in the large scale ecological network
- connect to existing Zuiderpark
- wetland park, connected to Zuiderpark and part of climate dike
- heightened office park combined with urban farming as part of climate dike
- current primary dike, upgraded to climate dike
- city dike park with gradual slope towards primary dike
- intersections between east west routes and climate dike parks provide varied experience
- tidal city park with intensive types of recreation
- development of tidal parks
- quays which have to be maintained and transformed into cultural tidal parks as they are located in erosion area
- dam in length of river to reduce erosion and stimulate sediment disposal
- landfill area which will be combined with offices
- transparent office development along main road
- spatial develoment of piers is related to urban tissue of Wielewaal
- holiday / tourism houses along wooden paths in tidal landscape, providing unique holiday experience
- local food production where inhabitants can grow their own food. Different types of food production in water and on land, related to the salt gradient, the ground water level and the subjection to the tides.
- culvert with gate (klepduiker), providing conditions to leave the water in the basin during low tide which increases sediment disposal.
- purifying tidal park with reuse of sea containers, providing a clean soil to improve ecological values and the occupation of the sea containers by creative and catering industry and starters improves liveliness
- Nieuwe Maas is still in use for inland shipping
- use existing urban farming project in the city to create a foodhub in the intertidal park, creating opportunities for inhabitants to sell their locally produced food or buy it from their neighbours

On the next page a more extensive version of the legend can be found. The numbers in the text refer to the nine ecosystem services which are considered in this thesis.

1. Relate city, river and harbor
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3. Create an educational environment
4. Increase water safety
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6. Function as a basis for urban development
7. Contribute to regional circularity
8. Provision of fresh water
9. Climate Regulation

Excavation of pier to create a tidal park in the length of the river, protecting the higher zone behind from increasing curents, waves, stormtides, etc (4). The constant subjection to tides stimulates sediment disposal, which can be used to make the land grow naturally (7). The zone also functions as a habitat area for long distance migration of species in the river (2). Combined with reed and rush to purify air from NOx, SO2, CO2 and fine dust coming from shipping in the Nieuwe Maas (9). It also creates a transition zone from land improving the relation between people and water (1) and increase the awareness of living in a delta (3). For the Sluisjesdijk and RDM terrain it provides an attractive, green business climate (4).

Connect existing green structures in the city to the Waalhaven area to create ecological corridors between the tidal and the fresh nature (2). These structures also provide a direction to recreation as the routes guide visitors towards the Waalhaven (1). This improves the accessibility of the Waalhaven and the tidal nature and therefore would create more awareness for the risks of the water (3)

As this part of the harbor basin is located in the outer bend of the river a dam in the length of the river is necessary to prevent the tidal nature from erosion (4). Behind this dam a sheltered zone will arise where sediment can dispose (7) and species can find their habitat (2). The dam can be used for recreation (1) to fully experience the tidal dynamics (3). To construct the dam, the coarse residual material of the quays can be reused (7).

As this part of the harbor basin is located in the inner bend of the river, the tidal nature is subjected to natural sediment disposal (7), which can be used to extend the tidal nature and provide habitats for migrating species (2). It also protects the land behind against flooding as it creates a foreland which reduces waves (4).

Use the natural sediment disposal in the harbor (7) to create a gradient in the bottom of the basin towards land. This gradient, providing varieties in salinity levels, ground water table and subjection to tides, creates opportunities for different types of habitats for species (2) and the mudflats and salt marshes are able to sequestrate CO2 (9). It also reduces saline intrusion through surface water as it pushes back the salt transporting on the bottom of the basin (8). The landscape can be combined with wooden, higher located, paths to provide opportunities for extensive recreation (1) and connect visitors to the tidal landscape (3).

Stop managing quays which results in a slow process towards a gradient between land and water. Near quays subjected to sedimentation the land will gradually grow and near quays subjected to erosion the land will slowly dissapear in the water. At the point the quay starts to erode or flood due to sea level rise, the quay is disassembled so that the coarse residual material can be reused (7). The gradient between land and water which finally arises create opportunities for improving biodiversity (2), reduce saline intrusion (8) and the mud flats and salt marshes are able to sequestrate CO2 (9). As the area will grow together with the previous measure, the area can also function as extensive recreation area (1) and to connect visitors to the tidal landscape (3)

Development of a wetland between the primary dike and the historical building line of the Zuidhoek. Water coming from the Waaltje (fresh water river) through the Blauwe Verbinding (Blue Connection) in the Zuiderpark can be let into this area. This improves nature values and connects the primary dike and relating tidal parks to the larger ecological network (2). Besides that, it can function as a climate buffer, providing opportunities to infiltrate rain water in times of peak precipitation (4) and functions as cool zone for the neighbouring urban areas (9). By increasing the ground water table in this area, the saline intrusion through ground water will be reduced (8). It also improves recreational values (1) and increases real estate and land values (6).

Different types of food production (5) in water and on land, related to the salt gradient, the ground water level and the subjection to the tides. This can be combined with energy production with seagrass and -weed, to provide food and energy for the neighbourhood and stimulate the circular economy (7). The structures of food and energy production in the water, such as vegetation or oyster banks, reduces water speed and currents (4) and allows sediment to settle more quickly (7). As this fastens the process, the gradient between water and land is reached faster, resulting in refugia for migrating species (2) and the reduction of saline intrusion (8).

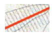
By stopping the dredging activities in the harbor, the natural process of the development of a delta landscape will start. As explained before, this results in natual sediment disposal, but will also allow vegetation to arise naturally. The difference in salt levels, ground water table and subjection to tides results in several types of vegetation, such as pioneer vegetation, vegetation for mudflats, saltmarshes and the banks. The vegetation will adapt naturally when the temperature increases or the sea level rises. The plants and nature types increase biodiversity (2), enforce the sedimentation process (7), reduce currents and water speeds (4), sequestrate CO2 and increases air quality by capturing NOx, SO2 and fine dust (9).

Develop a recreational city park which creates large scale connections in the recreational network (1) (by connecting water recreation to the recreation of the Zuiderpark). This park increases water safety (4) as it protects the primary dike from erosion caused by storm waves (which is a risk at +1.00 m sea level rise), improves biodiversity as the hard quays are transformed into green banks (2), increases surrounding land and real estate values, improves the business settlement climate (6) and provide an educational environment as it connects people to the tidal dynamics, increasing their awareness of living in the delta (3).

Use existing urban farming project in the city to create a foodhub in the intertidal park, creating opportunities for inhabitants to sell their locally produced food or buy it from their neighbours (5). This improves relations between the neighbours and makes people aware of the productive capacity of the water in relation to tidal nature (3). As this concept shortens the food chain it stimulates circular economy (7).

Heightened land with soil coming from dredged areas in functioning shipping routes or harbor basins (7). This land needs to be maintained and made flood resilient in order to funnel the water and provide more water safety in the harbor basin (4). Opening up the entrance of the harbor basin would provide more space for the increasing sea water levels and therefore would increase the risks. After this process a business district will be developed on the heightened part with innovative companies, knowledge institutes and maritime services which is already the focus of this area. In current plans this is already the focus. The proposed developments in the Waalhaven provide a more favourable business climate (6) due to the green environment and the increased water safety, resulting in the opportunity for long term contracts for the businesses.

In the tidal landscape behind the length dam (in the length of the Nieuwe Maas) sea containers can be reused for temporary use (7). The containers can be placed on the existing building foundations from the Sluisjeskade, as there is no financial capacity to remove them and this use gives them a second life. The sea containers are designed to be very solid, resistant to water, salt, changing climates, etc. and are therefore very sustainable in this dynamic and temporary landscape. The containers can be used by small companies, starters, artists, function as a test lab for innovation, exposition space, conference rooms, etc. The containers function as harbor relicts in the landscape to remind people of the former use of this area, resulting in increasing cultural identity of Rotterdam as a Harbor City (3). The whole landscape, where nature and harbor merge, is of great recreational value and relates people to the water (1).

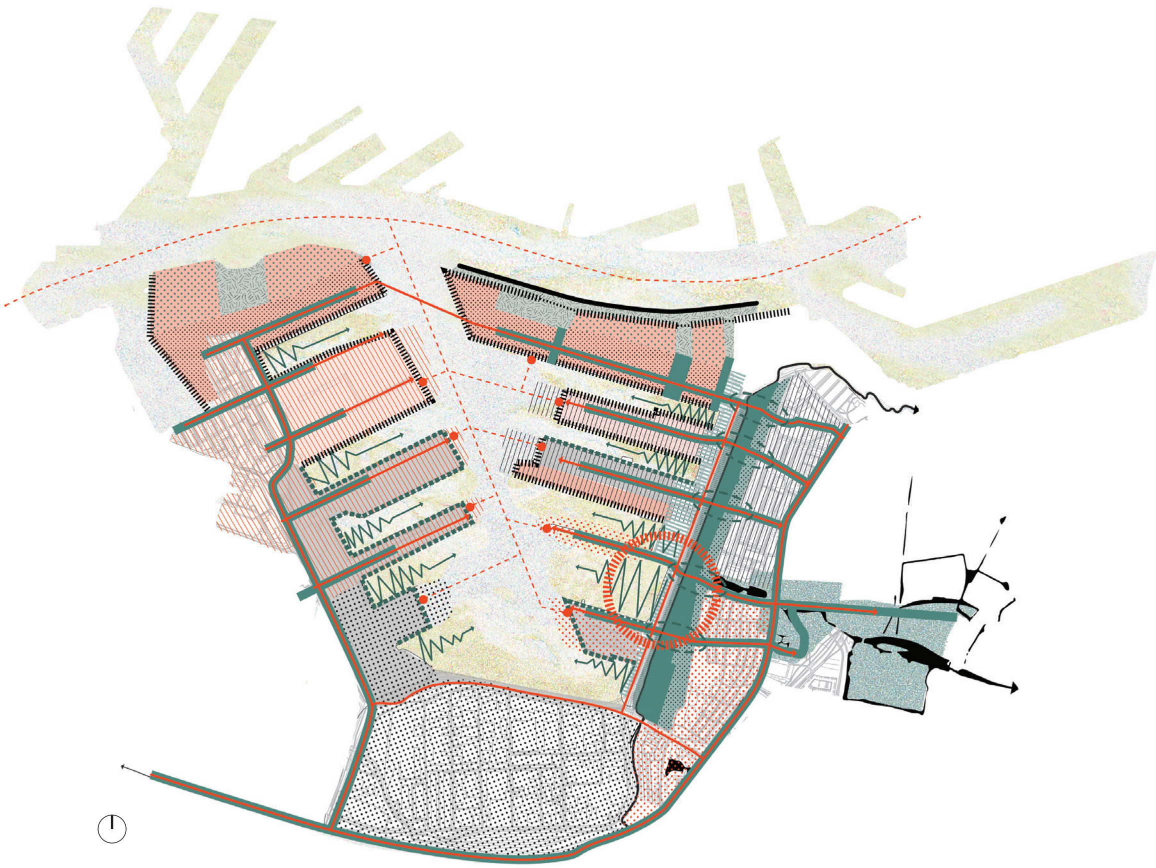


Development of holiday / tourism houses along wooden paths on the location of the original piers, where the landscape is still higher than the Rest of the landscape. These routes are connected to the main routes coming from the urban area and therefore relates people to the water (1). It provides an unique experience in the real Dutch Delta Landscape, educating foreigners about the dutch way of coping with increasing risks related to water (3). Besides attracting tourists, the houses can also be used by locals as a second house, providing a great living environment close to nature, where they can produce their own food. The type of buildings are adjusted to the type of landscape, which could be on poles, floating or fixed on land.

Focus on offices along the main road of which some of the existing ones are already built in a flood resilient way. The new ones will be build with flood resilient ground levels (4) as this area will be subjected to flood risks during heavy storms when the sea level rises with +1.00 m. The buildings can be combined with residential homes. The proposed developments in the Waalhaven provide a more favourable business climate (6) due to the green environment and the increased water safety, resulting in the opportunity for long term contracts for the businesses.

The land directly behind the primary dike is already quite high compared to the Rest of the area within the dikes. In order to strengthen the dike this land will be heightened and form a wide climate dike (4). The industrial zone which is there now will be transformed into new offices which provide a more transparent urban tissue to improve the connections between the city and the Waalhaven. The area in between those buildings can be used for urban farming (5). As the routes coming from the city are extended through the wetland area, over the climate dike, towards the Waalhaven, the whole area is functioning as one city park, increasing land and real estate values (6), regulate the temperature (9), improve the relation to the river (1) and the connectivity to subjection to tides (3). The historical north-south strokes are still there, but does not form a boundary anymore.

Steam Scenario Strategy



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- current primary dike, upgraded to climate dike
- city dike park with gradual slope towards primary dike
- intersections between east west routes and climate dike parks provide varied experience
- tidal city park with intensive types of recreation
- development of tidal parks
- quays which have to be maintained and transformed into cultural tidal parks as they are located in erosion area
- tidal parks which can be closed off during high risks with a gradual slope towards a more 'dry' green public park
- dam in length of river to reduce erosion and stimulate sediment disposal
- landfill area which will be combined with offices
- land which is purified by tidal nature and grew due to sediment disposal and is now occupied for offices
- transparent office development along main road
- spatial develoment of residential buildings on piers, related to urban tissue of Wielewaal
- spatial develoment of residential and office buildings on piers, related to urban tissue of old Charlois
- spatial develoment of office buildings on piers, related to urban tissue of Waalhaven Zuid
- spatial develoment of residential buildings on piers, related to urban tissue of Heijplaat
- accessibility of head of piers by recreational and daily transport on water
- recreational pedestrian and cycling bridge, connecting the Waalhaven in the large scale recreational network
- quays which are subjected to sediment disposal and can be removed and turned into tidal parks without the risks of losing land
- areas which are flooded on the short term (10-20 cm sea level rise), become land fill sites (constructed with soil coming from dredging activites within the functioning parts of the harbour) and are occupied for residential use
- areas which are flooded during spring tide and extreme storms create an unique living environment with higher constructed buildings and infrastructure and water squares which are flooded during high tide
- areas which are low located in a sediment disposal area and grew gradually over time, which finally provides a safe, higher located site available for urban development

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Quays which are subjected to erosion by the river, but are desired to maintain fixed to make sure the water will be funnelled to provide water safety in the harbor basin (4) or to stimulate sediment disposal behind those piers (7). The quays will be transformed into cultural tidal parks in the form of stairs or other layered designs providing opportunities for people to access the water side (1). This will create a recreational transition zone between water and land where people can experience the tides (3). The cultural tidal parks can also be combined with small nature interventions, such as pools which sometimes flood and where species can find their habitat (2). A reference project for this is the tidal park design for the Keilehaven in Rotterdam.

Land fill sites, constructed with soil coming from dredging activites within the functioning parts of the harbor, such as the Maasvlakte (7). This land already is subjected to flood risks with 10-20 cm sea level rise, which will happen on the short term. The land needs to be maintained and made flood resilient to funnel the water and provide more water safety in the harbor basin (4). After this process a business district will be developed on the heightened part with innovative companies, knowledge institutes and maritime services which is already the focus of this area. In current plans this is already the focus. The proposed developments in the Waalhaven provide a more favourable business climate (6) due to the green environment and the increased water safety, resulting in the opportunity for long term contracts for the businesses.

After this process a business district will be developed on the heightened part with innovative companies, knowledge institutes and maritime services which is already the focus of this area. In current plans this is already the focus. The proposed developments in the Waalhaven provide a more favourable business climate (6) due to the green environment and the increased water safety, resulting in the opportunity for long term contracts for the businesses.

Use the natural sediment disposal in the harbor (7) to create a gradient in the bottom of the basin towards land. This gradient, providing varieties in salinity levels, ground water table and subjection to tides, creates opportunities for different types of habitats for species (2), increases water safety as it reduces currents and waves (4) and the mudflats and salt marshes are able to sequestrate CO2 (9). It also reduces saline intrusion through surface water as it pushes back the salt transporting on the bottom of the basin (8). The landscape can be combined with wooden, higher located, paths to provide opportunities for extensive recreation (1) and connect visitors to the tidal landscape (3).

Land which is at least +3.50 m NAP, meaning that with 200 cm sea level rise it will be +1.50 m NAP, so with high tide it will stil be dry (as the water will be on +3.10 - +3.20 m NAP). During spring tide and storm waves, the pier will be flooded, so therefore the buildings and roads are constructed 1.50 m higher than the pier ground level (4). During spring tide, an unique living environment will arise where the whole pier is flooded, leaving water in the provided water squares in the middle of the pier. As the roads and buildings are build higher, the people are still able to access their houses and continue life. This all together increases the awareness of living in the delta (3), connects people to the water (1) and increases real estate values due to the unique housing location (6). As described in the previous measure, the middle of the piers subjected to spring tides are transformed into water squares. These squares are filled with water during spring tide which increases awareness among inhabitants and can function as a safe playground for children to get acquinted with nature (3). Besides that, the water which remains in the squares for a while will regulate the temperature on the pier (9). It also increases land and real estate values as the water squares can be designed as high quality public space (6).

Quays which will be removed and transformed into a green bank (2) as they are in a sediment disposal area and will therefore not result in a loss of land. The coarse residual material of the quays can be reused in the length dam in the river Nieuwe Maas (7).

The piers of which the quay is removed (see previous measure) are lower located in the landscape and will therefore flood at one point. The land of the pier will slowly spread into the water, forming a gradient where sediment disposal will result in a slow growing of land (7). In the period that it isn't flooded yet, the existing buildings remain and will gradually move out. This can be combined with start-ups in sea containers or tiny houses which can easily be transported when the risks become too high. When the piers get flooded and the sediment starts to dispose, new buildings on poles can be build on +5.00 m NAP (4). The land will slowly grow underneath the houses and at one point the tidal nature and ground level of the houses will grow together. A layer of about 1.5 meters have to be disposed before this happens which will take several decades and can be fastened by planting vegetation. After this process, the houses are located on the heightened land, being safe for flooding. As the land below the buildings will be untouched by humans it will provide natural values and increase biodiversity (2).

Connect existing green structures in the city to the Waalhaven area to create ecological corridors between the tidal and the fresh nature (2). These structures also provide a direction to recreation as the routes guide visitors towards the Waalhaven (1). This improves the accessibility of the Waalhaven and the tidal nature and therefore would create more awareness for the risks of the water (3)

The tidal zones in between the piers will be developed into tidal city parks, providing high recreational values (1), increase awareness by connecting people to the water (3), increase land and real estate value and improve the business climate (6), regulate the temperature of surrounding built environment (9) and could create small-scale opportunities for urban farming (5). The tidal nature in these areas also create a foreland for the primary dikes as these zones are located most close to the dike. When the sea level rises with more than 100 cm, the water would reach to the dike and the tidal nature is able to reduce currents and storm waves and therefore would prevent the dike from erosion (4).

Development of a wetland between the primary dike and the historical building line of the Zuidhoek. Water coming from the Waaltje (fresh water river) through the Blauwe Verbinding (Blue Connection) in the Zuiderpark can be let into this area. This improves nature values and connects the primary dike and relating tidal parks to the larger ecological network (2). Besides that, it can function as a climate buffer, providing opportunities to infiltrate rain water in times of peak precipitation (4) and functions as cool zone for the neighbouring urban areas (9). By increasing the ground water table in this area, the saline intrusion through ground water will be reduced (8). It also improves recreational values (1) and increases real estate and land values (6).

Develop a recreational city park which creates large scale connections in the recreational network (1) (by connecting water recreation to the recreation of the Zuiderpark). This park increases water safety (4) as it protects the primary dike from erosion caused by storm waves (which is a risk at +1.00 m sea level rise), improves biodiversity as the hard quays are transformed into green banks (2), increases surrounding land and real estate values, improves the business settlement climate (6) and provide an educational environment as it connects people to the tidal dynamics, increasing their awareness of living in the delta (3). Part of the tidal city park which is most close to the water will be combined with a beach and recreational harbor. This connects the Waalhaven in the large scale recreational network of the whole city in relation to the Zuiderpark (1).

The land directly behind the primary dike is already quite high compared to the Rest of the area within the dikes. In order to strengthen the dike this land will be heightened and form a wide climate dike (4). The industrial zone which is there now will be transformed into new offices which provide a more transparent urban tissue to improve the connections between the city and the Waalhaven. The area in between those buildings can be used for urban farming (5). As the routes coming from the city are extended through the wetland area, over the climate dike, towards the Waalhaven, the whole area is functioning as one city park, increasing land and real estate values (6), regulate the temperature (9), improve the relation to the river (1) and the connectivity to subjection to tides (3). The historical north-south strokes are still there, but does not form a boundary anymore.

Focus on residential buildings located in the calm atmosphere of the water and tidal landscape, providing a quiet living environment in the dense and crowded city (6). The buildings are adjusted to the type of land and level of vulnerability (4).

Focus on offices along the west side of the primary dike of which some of the existing ones are already built in a flood resilient way. The new ones will be build with flood resilient ground levels (4) as this area will be subjected to flood risks during heavy storms when the sea level rises with +1.00 m. The buildings can be combined with residential homes. The proposed developments in the Waalhaven provide a more favourable business climate (6) due to the green environment and the increased water safety, resulting in the opportunity for long term contracts for the businesses. On top of the climate dike, on the location where an outdated industrial zone is located now, new offices will be build. These offices are more transparent to guide the routes coming from the city, through the wetland park, into the Waalhaven.

In the Steam Scenario the transport over water becomes extremely important as the city is very dense and crowded and transport on land is time consuming. Therefore it is needed to keep the head of the piers accessible for boats. This improves the relation of people to the river (1) and also strengthens the cultural identity of Rotterdam as a Harbor City (3).

Appendix 7 – Results: Provided Ecosystem Services per Phase

1.1 Attractive landscape for visitors (day-trips / recreation)

Area which can provide this service: The whole project site (limited to 500 m distance from accessible area for people as this is the zone which is still perceptible for people (Gehl, 2017)).

Key performance indicator: surface of accessible and perceptible attractive landscape in ha

Existing Situation
Surface in ha: 52 ha

Phase 1
Surface in ha: 78 ha
Factor of Growth: 1.5

Phase 2
Surface in ha: 208 ha
Factor of Growth: 4

1.2 Recreation: Water Sports

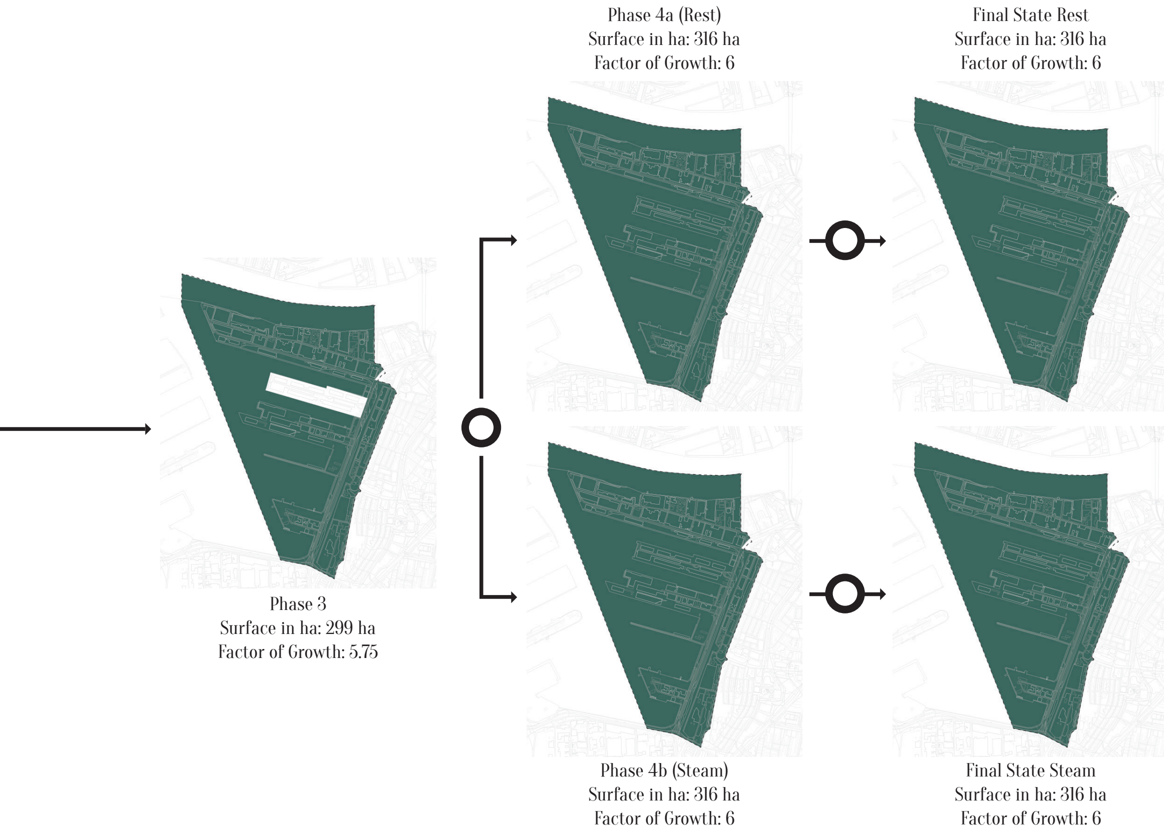
Area which can provide this service: all water not used for harbor activities and shipping

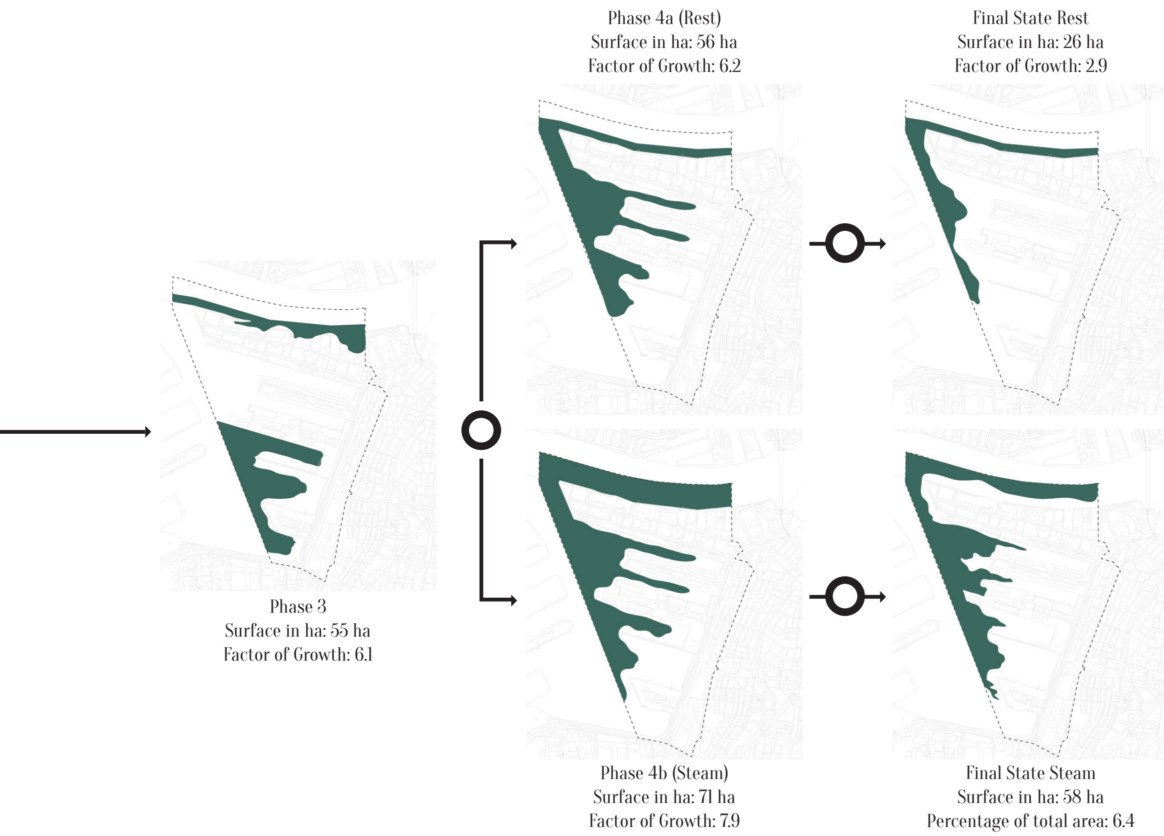
Key performance indicator: water surface not used for harbor activities and shipping in ha

Existing Situation
Surface in ha: 9 ha

Phase 1
Surface in ha: 15 ha
Factor of Growth: 1.7

Phase 2
Surface in ha: 30 ha
Factor of Growth: 3.6


Phase 4a (Rest)
Surface in ha: 316 ha
Factor of Growth: 6
Final State Rest
Surface in ha: 316 ha
Factor of Growth: 6
Phase 3
Surface in ha: 299 ha
Factor of Growth: 5.75
Phase 4b (Steam)
Surface in ha: 316 ha
Factor of Growth: 6
Final State Steam
Surface in ha: 316 ha
Factor of Growth: 6

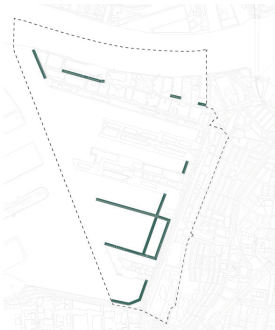

Phase 4a (Rest)
Surface in ha: 56 ha
Factor of Growth: 6.2
Final State Rest
Surface in ha: 26 ha
Factor of Growth: 2.9
Phase 3
Surface in ha: 55 ha
Factor of Growth: 6.1
Phase 4b (Steam)
Surface in ha: 71 ha
Factor of Growth: 7.9
Final State Steam
Surface in ha: 58 ha
Percentage of total area: 6.4

1.3 Recreation: Fishing

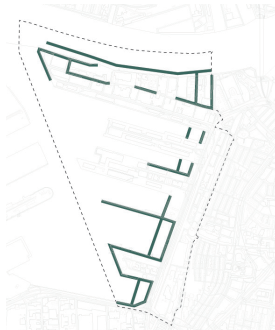
Area which can provide this service: hard quays, piers and paths next to water

Key performance indicator: length of hard quays, piers and paths in m

Existing Situation
Length in m: 1650 m



Phase 1
Length in m: 3400 m
Factor of Growth: 2.1



Phase 2
Length in m: 7700 m
Percentage of total area: 4.7

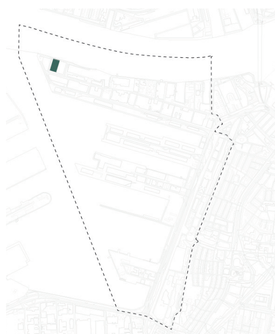
1.4 Tourism: Holidays

Area which can provide this service: area provided for holiday houses / overnight stays

Key performance indicator: amount of accomodations

Existing Situation
Amount: 0

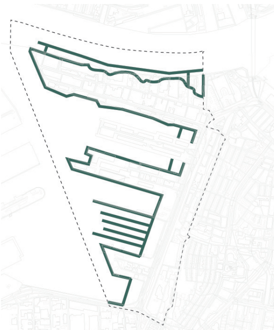
Phase 1
Amount: 0
Factor of Growth: 0



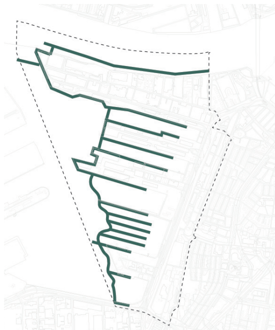
Phase 2
Amount: 70
Factor of Growth: 70

Phase 4a (Rest)
Length in m: 10.750 m
Factor of Growth: 6.5

Final State Rest
Length in m: 10.200
Factor of Growth: 6.2



Phase 3
Length in m: 12.000 m
Factor of Growth: 7.3



Phase 4b (Steam)
Length in m: 12.050 m
Factor of Growth: 7.3

Final State Steam
Length in m: 10.400 m
Factor of Growth: 6.3

Phase 4a (Rest)
Amount: 286
Factor of Growth: 286

Final State Rest
Amount: 646
Factor of Growth: 646

Phase 3
Amount: 106
Factor of Growth: 106

Phase 4b (Steam)
Amount: 220
Factor of Growth: 220

Final State Steam
Amount: 220
Factor of Growth: 220

1.5 Accessibility of water / coastal zone

Area which can provide this service: coastal zone, piers, quays, paths which are accessible for people

Key performance indicator: length of accessible coastal zone, piers, quays, paths in m

Existing Situation
Length in m: 1650 m

Phase 1
Length in m: 3400 m
Factor of Growth: 2.1

Phase 2
Length in m: 7700 m
Factor of Growth: 4.7

2.1 Water Purification

Area which can provide this service: tidal areas (both mud flats and salt marshes)

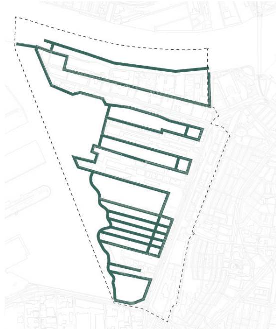
Key performance indicator: surface of tidal area in ha

Existing Situation
Surface in ha: 0 ha

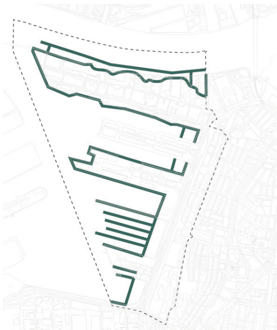
Phase 1
Surface in ha: 39 ha
Factor of Growth: 39

Phase 2
Surface in ha: 65 ha
Factor of Growth: 65

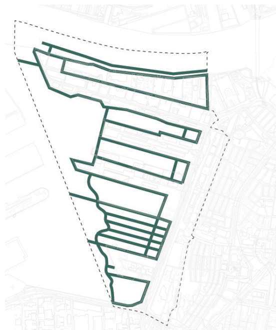
Phase 4a (Rest)
Length in m: 16.300 m
Factor of Growth: 9.9



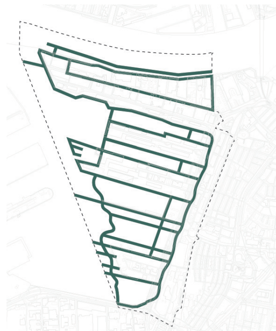
Final State Rest
Length in m: 18.100 m
Factor of Growth: 11



Phase 3
Length in m: 12.000 m
Factor of Growth: 7.3



Phase 4b (Steam)
Length in m: 17.400 m
Factor of Growth: 10.5



Final State Steam
Length in m: 17.700 m
Factor of Growth: 10.7

Phase 4a (Rest)
Surface in ha: 165 ha
Factor of Growth: 165

Final State Rest
Surface in ha: 195 ha
Factor of Growth: 195

Phase 3
Surface in ha: 107 ha
Factor of Growth: 107

Phase 4b (Steam)
Surface in ha: 170 ha
Factor of Growth: 170

Final State Steam
Surface in ha: 183 ha
Factor of Growth: 183

2.2 Refugia for migratory and resident species

Area which can provide this service: all tidal nature and un-dredged water

Key performance indicator: surface of tidal nature and un-dredged water in ha

Existing Situation
Surface in ha: 0 ha

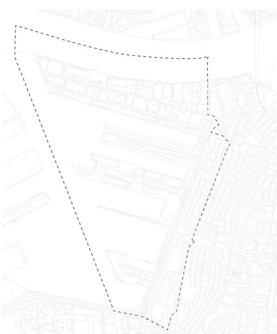
Phase 1
Surface in ha: 47 ha
Factor of Growth: 47

Phase 2
Surface in ha: 92 ha
Factor of Growth: 92

2.3. Transition zone between land and water providing migration routes

Area which can provide this service: gradual and green river banks connecting to land and water

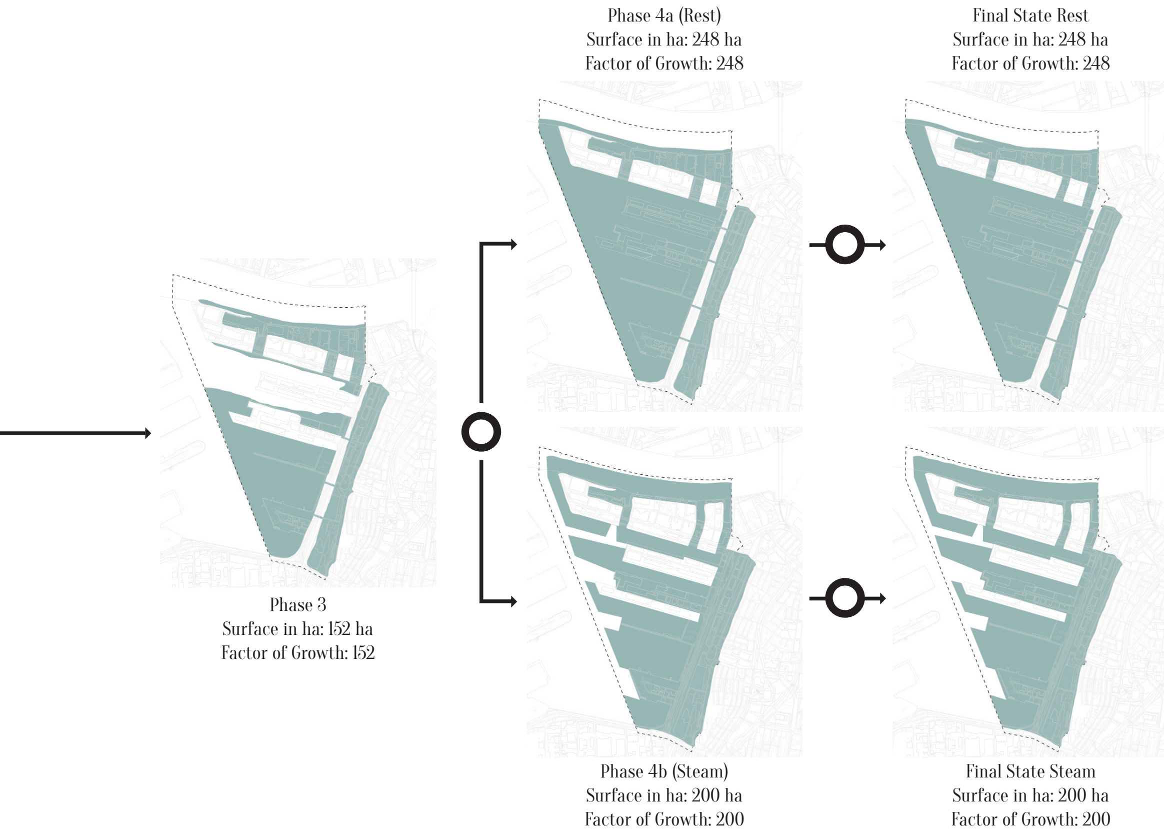
Key performance indicator: length of gradual, green banks which connect land and water in m

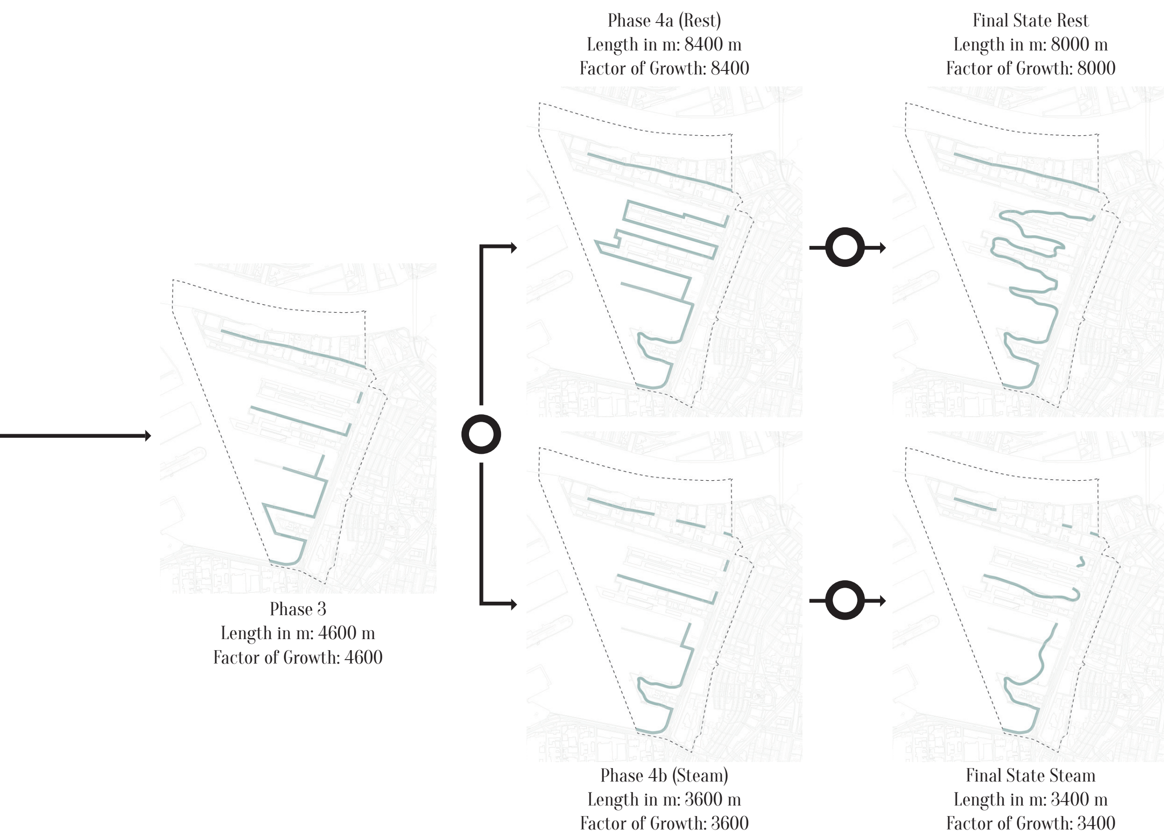


Existing Situation
Length in m: 0 m

Phase 1
Length in m: 1700 m
Factor of Growth: 1700

Phase 2
Length in m: 3400 m
Factor of Growth: 3400


Phase 4a (Rest)
Surface in ha: 248 ha
Factor of Growth: 248
Final State Rest
Surface in ha: 248 ha
Factor of Growth: 248
Phase 3
Surface in ha: 152 ha
Factor of Growth: 152
Phase 4b (Steam)
Surface in ha: 200 ha
Factor of Growth: 200
Final State Steam
Surface in ha: 200 ha
Factor of Growth: 200


Phase 4a (Rest)
Length in m: 8400 m
Factor of Growth: 8400
Final State Rest
Length in m: 8000 m
Factor of Growth: 8000
Phase 3
Length in m: 4600 m
Factor of Growth: 4600
Phase 4b (Steam)
Length in m: 3600 m
Factor of Growth: 3600
Final State Steam
Length in m: 3400 m
Factor of Growth: 3400

3.1 Awareness of living and working in a delta

Area which can provide this service: residential and office / harbor area located in or directly next to an intertidal area

Key performance indicator: surface of urban area located in or directly next to an intertidal area in ha

Existing Situation
Surface in ha: 0 ha

Phase 1
Surface in ha: 38 ha
Factor of Growth: 38

Phase 2
Surface in ha: 57 ha
Factor of Growth: 57

3.2 Awareness of coastal dynamics by visitors

Area which can provide this service: coastal zone, piers, quays, paths which are accessible for people and located next to tidal nature or culture

Key performance indicator: length of coastal zone, piers, quays, paths which are accessible for people and located next to tidal nature or -culture in m

Existing Situation
Length in m: 0 m

Phase 1
Length in m: 3000 m
Factor of Growth: 3000

Phase 2
Length in m: 7300 m
Factor of Growth: 7300

Phase 4a (Rest)
Surface in ha: 53 ha
Factor of Growth: 53

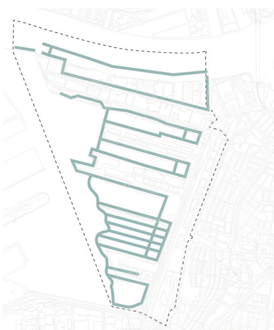
Final State Rest
Surface in ha: 48 ha
Factor of Growth: 48

Phase 3
Surface in ha: 56 ha
Factor of Growth: 56

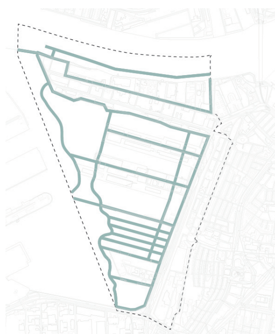
Phase 4b (Steam)
Surface in ha: 100 ha
Factor of Growth: 100

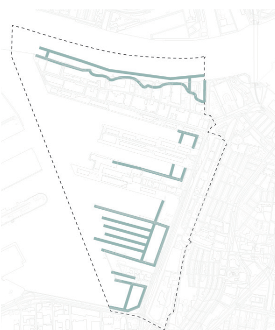
Final State Steam
Surface in ha: 108 ha
Factor of Growth: 108

Phase 4a (Rest)
Length in m: 10250 m
Factor of Growth: 10250

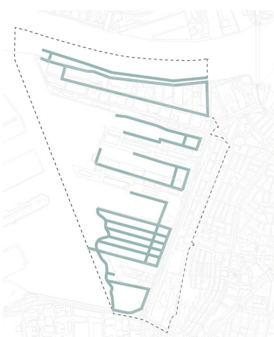


Final State Rest
Length in m: 18100 m
Factor of Growth: 18100

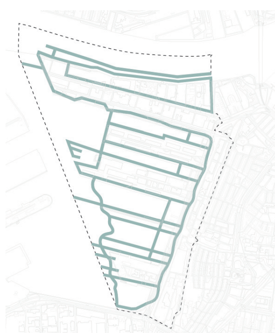




Phase 3
Length in m: 8800 m
Factor of Growth: 8800



Phase 4b (Steam)
Length in m: 11500 m
Factor of Growth: 11500

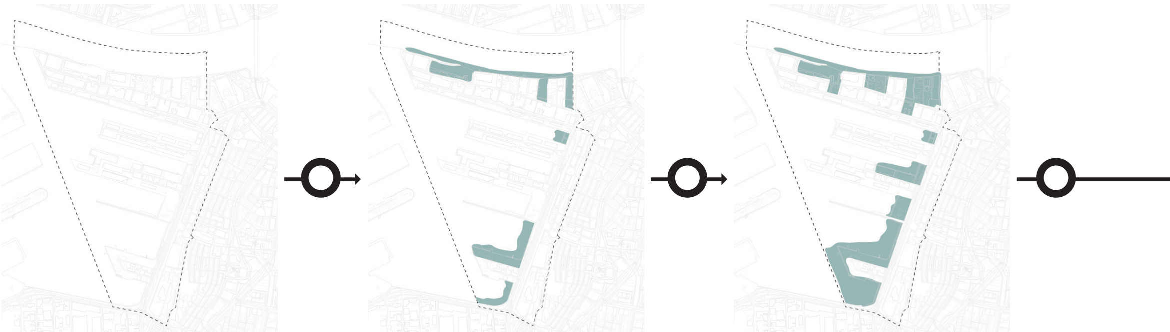


Final State Steam
Length in m: 17700 m
Factor of Growth: 17700

3.3. Create a characteristic landscape by improving cultural identity of Rotterdam as Delta region

Area which can provide this service: All area with delta characteristics (tidal water, tidal nature)

Key performance indicator: surface of characteristic delta landscape in ha



Existing Situation
Surface in ha: 0 ha

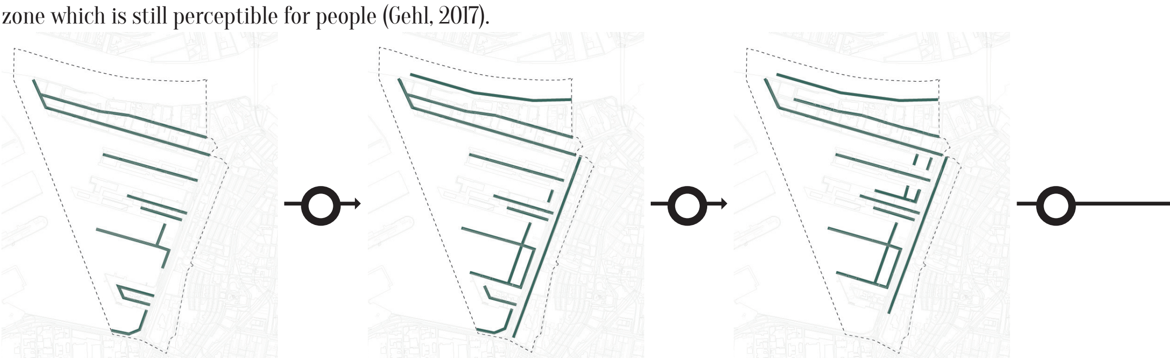
Phase 1
Surface in ha: 15 ha
Factor of Growth: 15

Phase 2
Surface in ha: 30 ha
Factor of Growth: 30

3.4 Create a characteristic landscape by improving cultural identity of Rotterdam as Harbor City

Area which can provide this service: All area where harbor activities or relicts of the harbor are visible, taking into account that this would be visible from 500 m distance from accessible area as this is the zone which is still perceptible for people (Gehl, 2017).

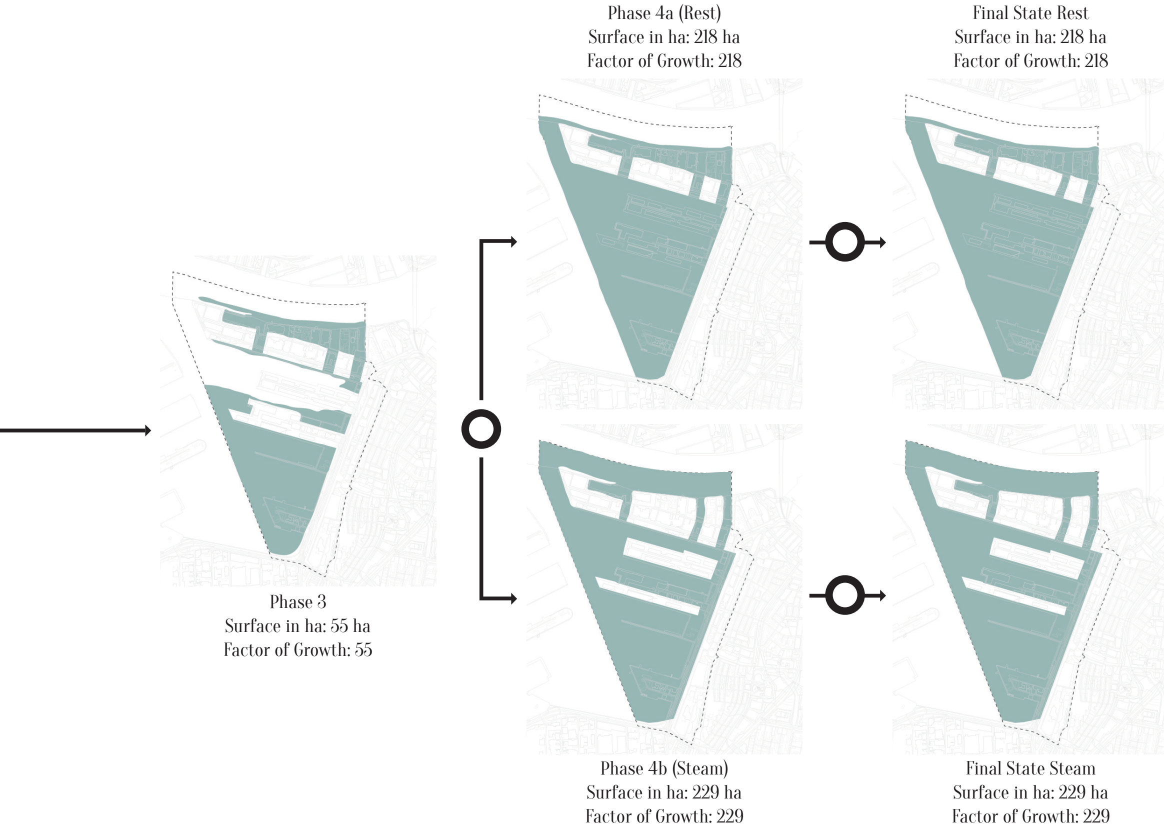
Key performance indicator: Surface of area where harbor activities or relicts are visible in ha

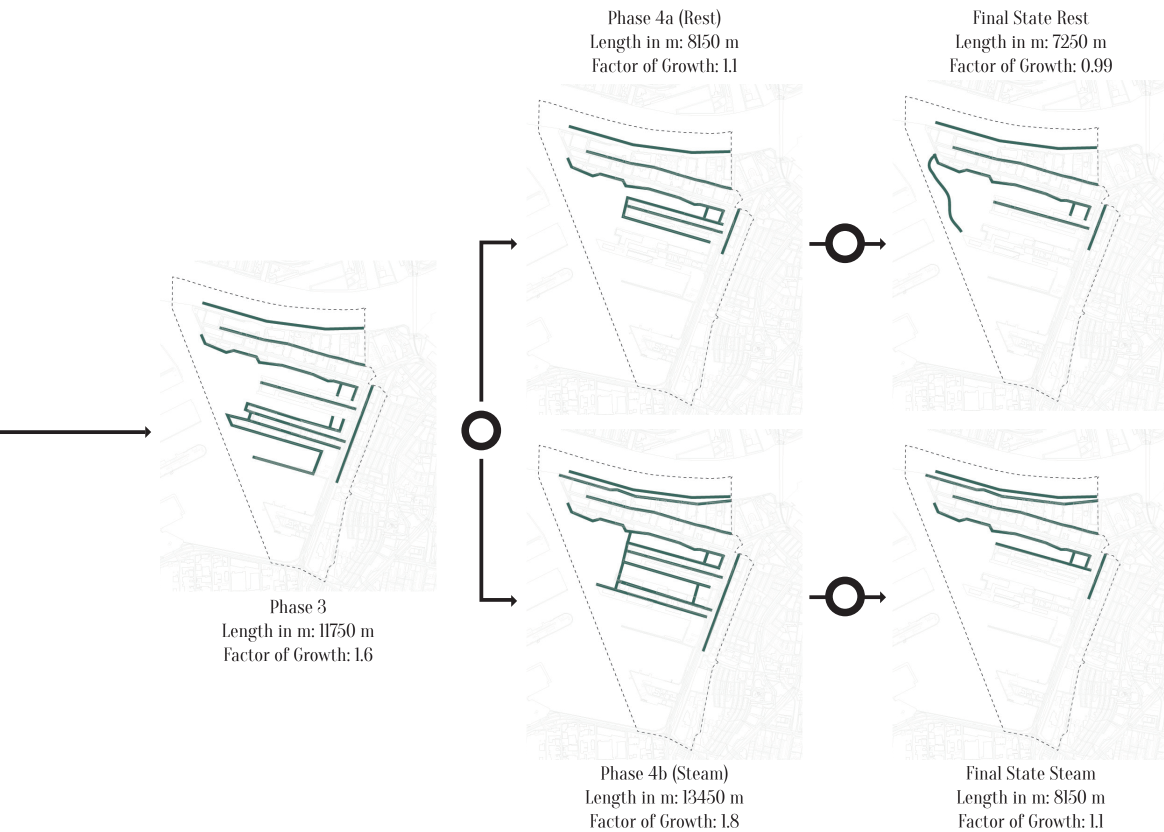


Existing Situation
Length in m: 7350 m

Phase 1
Length in m: 11550 m
Factor of Growth: 1.6

Phase 2
Length in m: 11140 m
Factor of Growth: 1.5

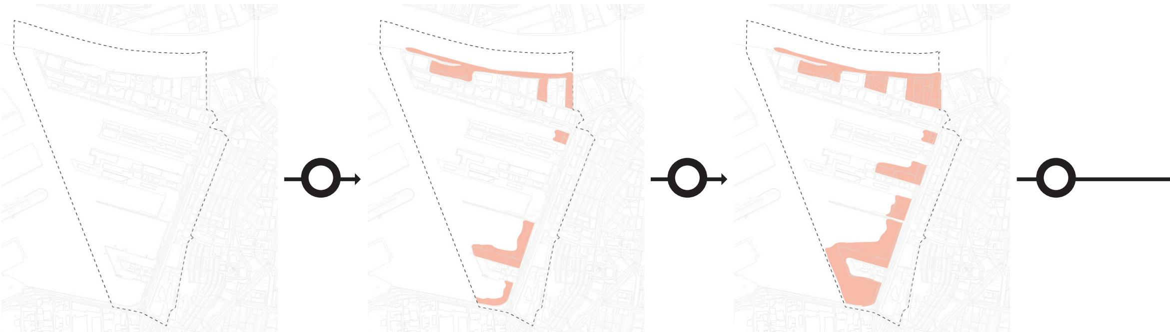

Phase 4a (Rest)
Surface in ha: 218 ha
Factor of Growth: 218
Final State Rest
Surface in ha: 218 ha
Factor of Growth: 218
Phase 3
Surface in ha: 55 ha
Factor of Growth: 55
Phase 4b (Steam)
Surface in ha: 229 ha
Factor of Growth: 229
Final State Steam
Surface in ha: 229 ha
Factor of Growth: 229


Phase 4a (Rest)
Length in m: 8150 m
Factor of Growth: 1.1
Final State Rest
Length in m: 7250 m
Factor of Growth: 0.99
Phase 3
Length in m: 11750 m
Factor of Growth: 1.6
Phase 4b (Steam)
Length in m: 13450 m
Factor of Growth: 1.8
Final State Steam
Length in m: 8150 m
Factor of Growth: 1.1

4.1. Reduce water depth to reduce currents and waves

Area which can provide this service: deep water where dredging activities are stopped and un-deepening is happening.

Key performance indicator: surface of deep water where dredging activities are stopped in ha



Existing Situation
Surface in ha: 0 ha

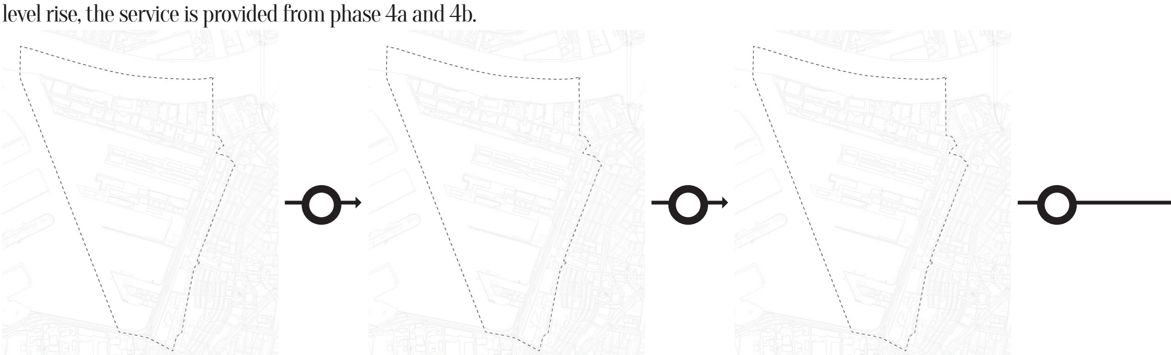
Phase 1
Surface in ha: 33 ha
Factor of Growth: 33

Phase 2
Surface in ha: 62 ha
Factor of Growth: 62

4.2. Protection of the existing dikes by creating foreland, resulting in less maintenance costs

Area which can provide this service: primary dikes which are protected by heavy waves and tides due to the development of tidal nature in front of the dike. As the sea water level only reaches the dike from +1.00 m sea level rise, the service is provided from phase 4a and 4b.

Key performance indicator: length of dike which is extra protected due to a foreland in m

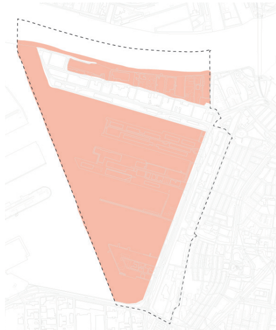


Existing Situation
Length in m: 0 m

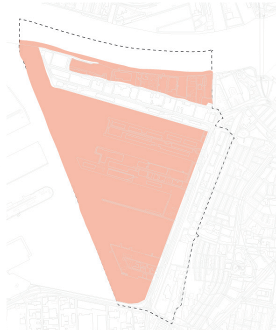
Phase 1
Length in m: 0 m
Factor of Growth: 0

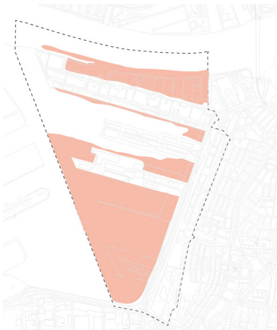
Phase 2
Length in m: 0 m
Factor of Growth: 0

Phase 4a (Rest)
Surface in ha: 214 ha
Factor of Growth: 214

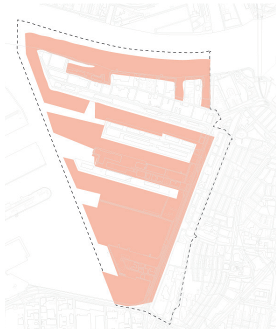


Final State Rest
Surface in ha: 214 ha
Factor of Growth: 214

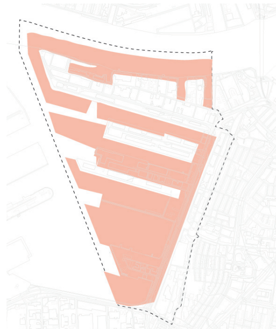




Phase 3
Surface in ha: 118 ha
Factor of Growth: 118



Phase 4b (Steam)
Surface in ha: 156 ha
Factor of Growth: 156



Final State Steam
Surface in ha: 156 ha
Factor of Growth: 156

Phase 4a (Rest)
Length in m: 1800 m
Factor of Growth: 1800

Final State Rest
Length in m: 1800 m
Factor of Growth: 1800

Phase 3
Length in m: 0 m
Factor of Growth: 0

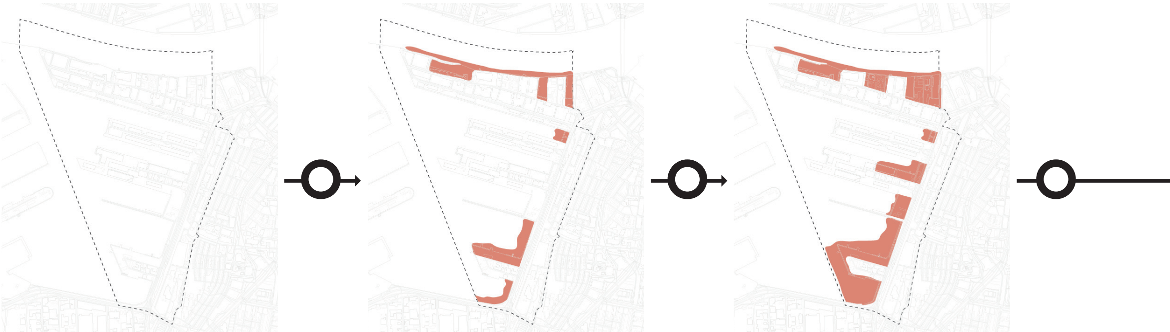
Phase 4b (Steam)
Length in m: 1800 m
Factor of Growth: 1800

Final State Steam
Length in m: 1800 m
Factor of Growth: 1800

5.1 Fish Production

Area which can provide this service: As fish is disturbed by dredging and shipping activities, the water area which is un-dredged and where natural processes start to take place can provide this service.

Key performance indicator: surface of water where dredging does not take place in ha



Existing Situation
Surface in ha: 0 ha

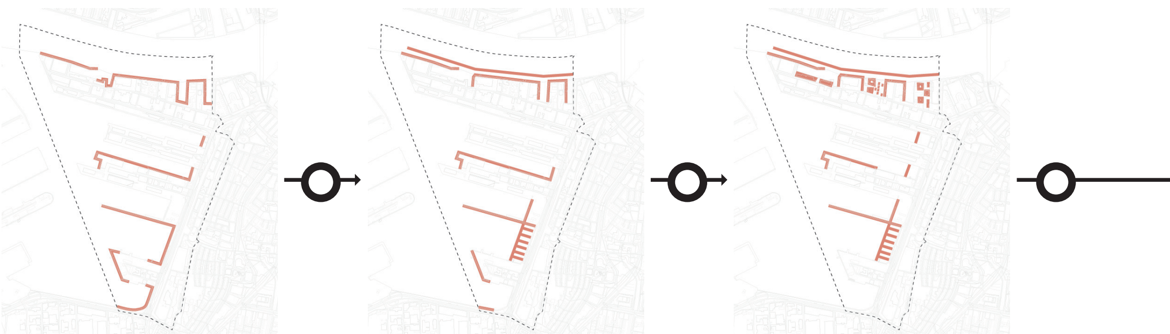
Phase 1
Surface in ha: 33 ha
Factor of Growth: 33

Phase 2
Surface in ha: 62 ha
Factor of Growth: 62

5.2 Shellfish production

Area which can provide this service: hard structures in an intertidal zone, functioning as habitat for the shellfish

Key performance indicator: All hard structures, such as paths, gradual hard quays, old building foundations, structures below floating houses, dams, located in intertidal area in m



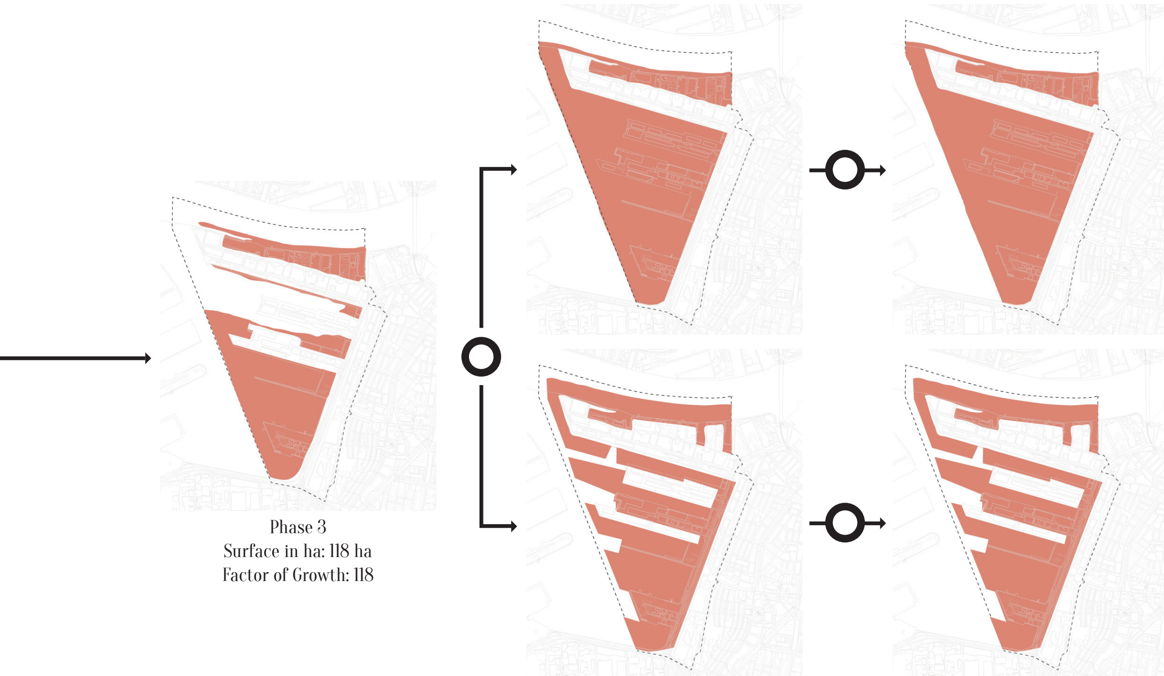
Existing Situation
Length in m: 4300 m

Phase 1
Length in m: 7300 m
Factor of Growth: 1.7

Phase 2
Length in m: 7700 m
Factor of Growth: 1.8

Phase 4a (Rest)
Surface in ha: 214 ha
Factor of Growth: 214

Final State Rest
Surface in ha: 214 ha
Factor of Growth: 214



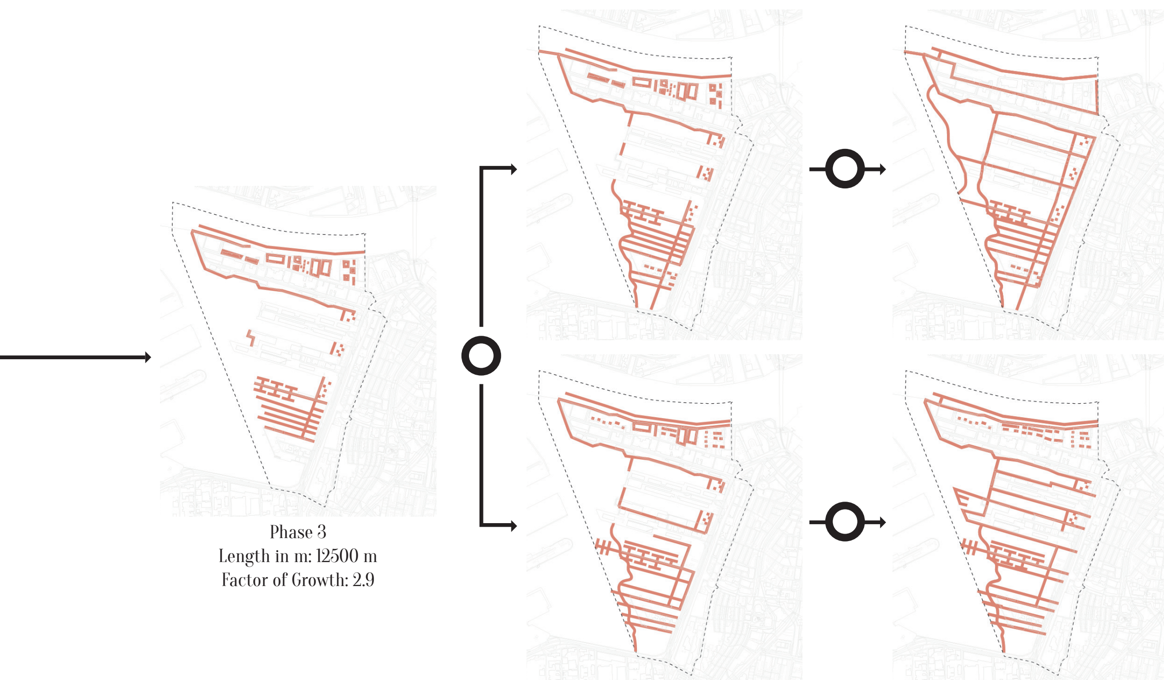
Phase 3
Surface in ha: 118 ha
Factor of Growth: 118

Phase 4b (Steam)
Surface in ha: 156 ha
Factor of Growth: 156

Final State Steam
Surface in ha: 156 ha
Factor of Growth: 156

Phase 4a (Rest)
Length in m: 17400 m
Factor of Growth: 5.1

Final State Rest
Length in m: 23600 m
Factor of Growth: 5.5



Phase 3
Length in m: 12500 m
Factor of Growth: 2.9

Phase 4b (Steam)
Length in m: 19500 m
Factor of Growth: 4.5

Final State Steam
Length in m: 23000 m
Factor of Growth: 5.3

5.3 Crop Production

Area which can provide this service: Land which is not permanently flooded and available for production of food crops

Key performance indicator: Land which is not permanently flooded and available for production of food crops in ha

Existing Situation
Surface in ha: 0 ha

Phase 1
Surface in ha: 0 ha
Factor of Growth: 0

Phase 2
Surface in ha: 7 ha
Factor of Growth: 7

6.1 Increasing Land and Real Estate Values

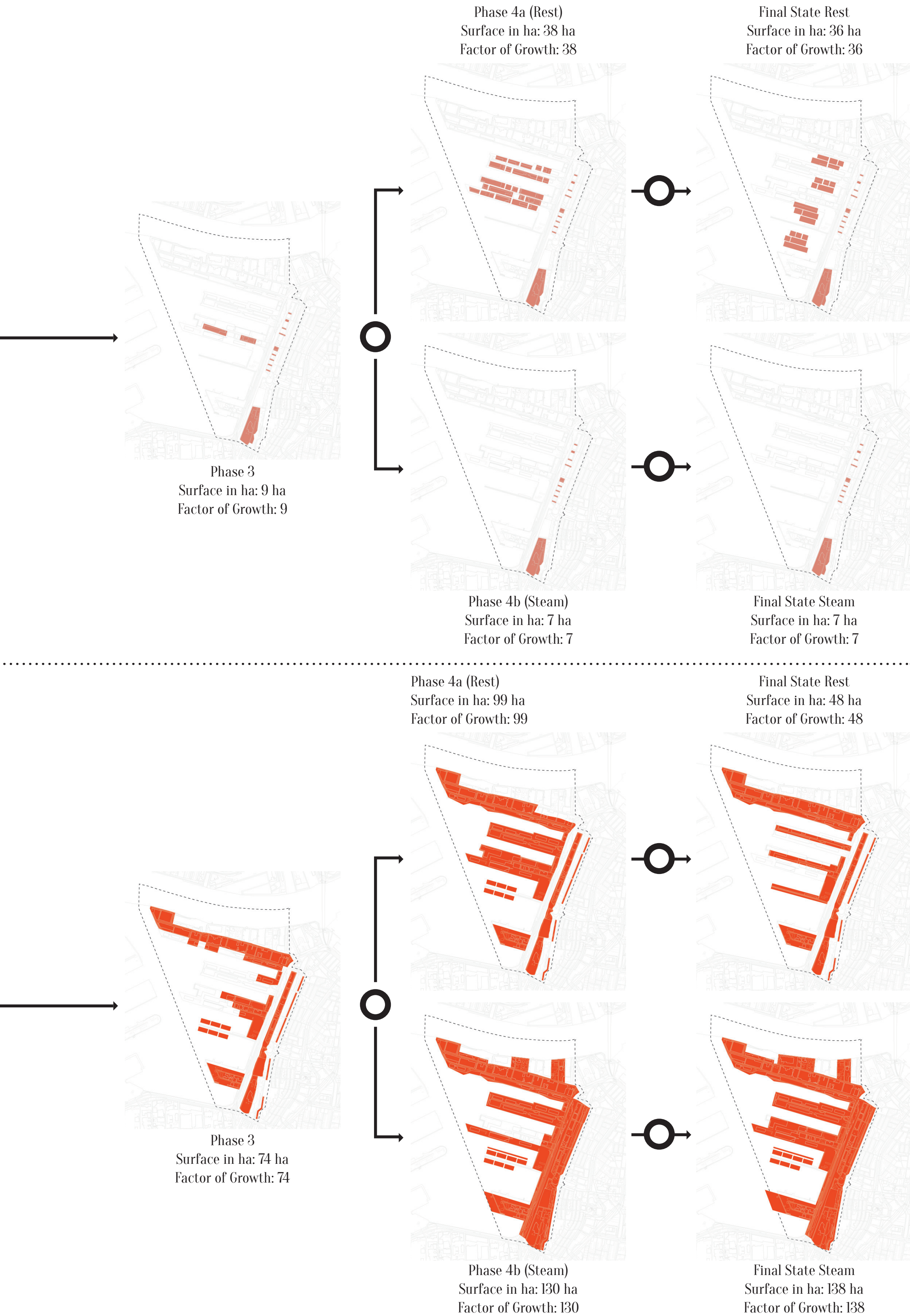
Area which can provide this service: All built parcels (real estate values) and parcels of land (land values) located next to tidal nature

Key performance indicator: The surface of all built and empty parcels of land located next to tidal nature in ha

Existing Situation
Surface in ha: 0 ha

Phase 1
Surface in ha: 58 ha
Factor of Growth: 58

Phase 2
Surface in ha: 75 ha
Factor of Growth: 75


Phase 4a (Rest)
Surface in ha: 38 ha
Factor of Growth: 38
Final State Rest
Surface in ha: 36 ha
Factor of Growth: 36
Phase 3
Surface in ha: 9 ha
Factor of Growth: 9
Phase 4b (Steam)
Surface in ha: 7 ha
Factor of Growth: 7
Final State Steam
Surface in ha: 7 ha
Factor of Growth: 7
Phase 4a (Rest)
Surface in ha: 99 ha
Factor of Growth: 99
Final State Rest
Surface in ha: 48 ha
Factor of Growth: 48
Phase 3
Surface in ha: 74 ha
Factor of Growth: 74
Phase 4b (Steam)
Surface in ha: 130 ha
Factor of Growth: 130
Final State Steam
Surface in ha: 138 ha
Factor of Growth: 138

6.2 Provide Green Business Settlement Climate

Area which can provide this service: All office or harbor area located next to tidal nature

Key performance indicator: The surface of all land with offices or harbor area located next to tidal nature in ha

Existing Situation
Surface in ha: 0 ha

Phase 1
Surface in ha: 32 ha
Factor of Growth: 32

Phase 2
Surface in ha: 41 ha
Factor of Growth: 41

7.1 Reuse of Coarse Residual Material

Area which can provide this service: All hard straight and hard gradual quays which are removed of which the coarse residual material can be reused. This service can only be provided once, when the quay is removed.

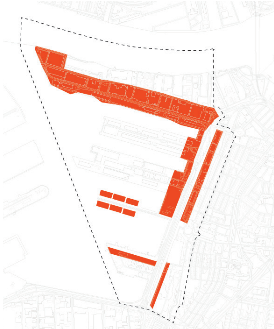
Key performance indicator: Length of all hard straight and hard gradual quays which are removed in m

Existing Situation
Length in m: 0 m

Phase 1
Length in m: 1700 m
Factor of Growth: 1700

Phase 2
Length in m: 2100 m
Factor of Growth: 2100

Phase 4a (Rest)
Surface in ha: 63 ha
Factor of Growth: 63



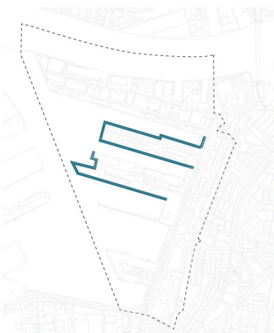
Final State Rest
Surface in ha: 63 ha
Factor of Growth: 63

Phase 3
Surface in ha: 63 ha
Factor of Growth: 63

Phase 4b (Steam)
Surface in ha: 73 ha
Factor of Growth: 73

Final State Steam
Surface in ha: 78 ha
Factor of Growth: 78

Phase 4a (Rest)
Length in m: 3100 m
Factor of Growth: 3100



Final State Rest
Length in m: 0 m
Factor of Growth: 0

Phase 3
Length in m: 1400 m
Factor of Growth: 1400

Phase 4b (Steam)
Length in m: 0 m
Factor of Growth: 0

Final State Steam
Length in m: 0 m
Factor of Growth: 0

7.2 Reuse of Sediment

Area which can provide this service: Sediment can be captured in areas where no dredging takes place and which is subjected to tidal influence, so in these areas the sediment can be reused for the development of tidal parks.

Key performance indicator: surface of tidal nature and un-dredged water in ha

Existing Situation
Surface in ha: 0 ha

Phase 1
Surface in ha: 33 ha
Factor of Growth: 33

Phase 2
Surface in ha: 62 ha
Factor of Growth: 62

8.1 Reduce Saline Intrusion by Surface Water

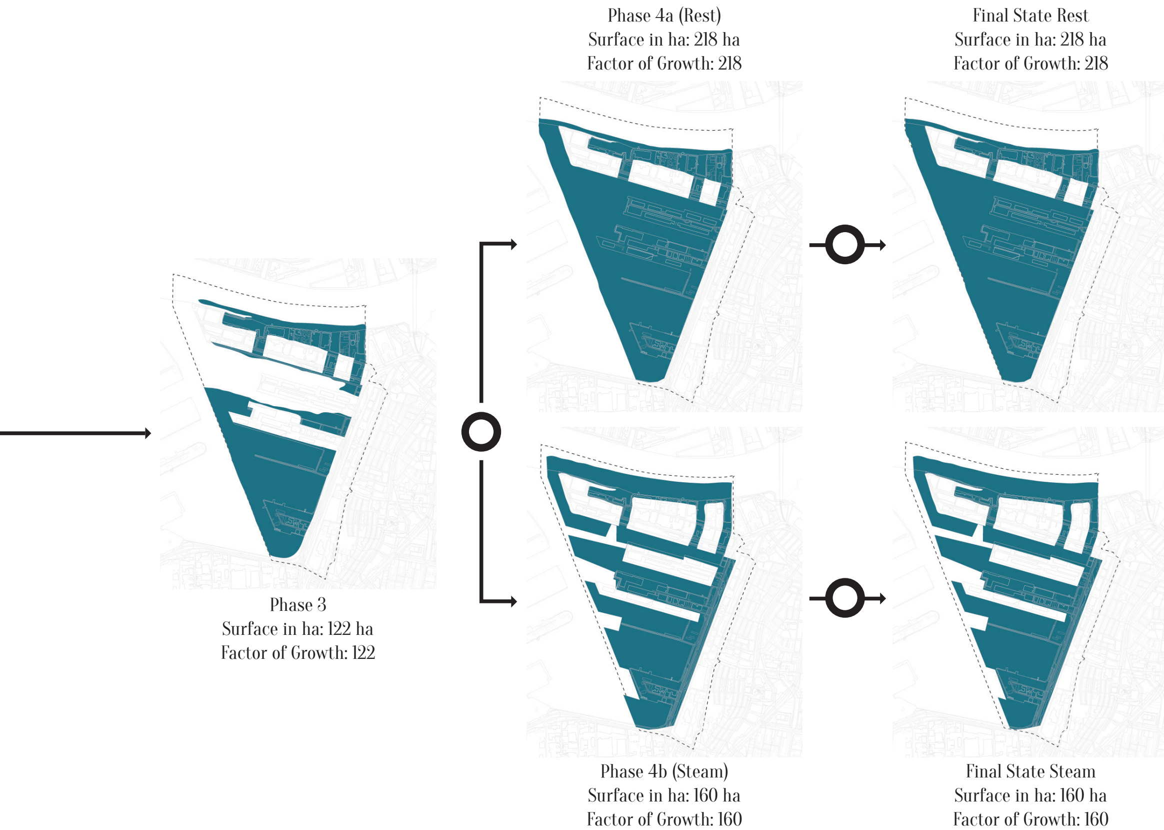
Area which can provide this surface: A gradient in the bottom of the basin pushes back the salt, which is provided by un-dredged water where sediment can settle and in tidal nature

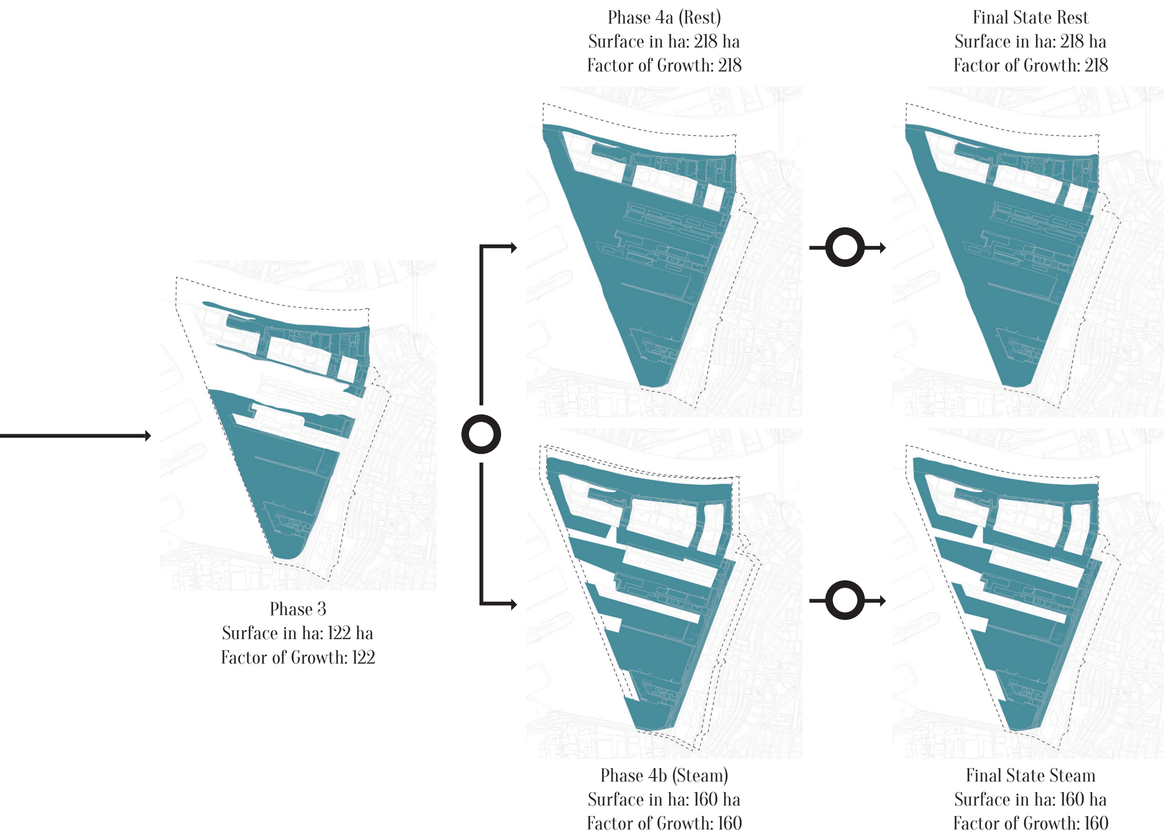
Key performance indicator: Surface of tidal nature and un-dredged water in ha

Existing Situation
Surface in ha: 0 ha

Phase 1
Surface in ha: 33 ha
Factor of Growth: 33

Phase 2
Surface in ha: 62 ha
Factor of Growth: 62


Phase 4a (Rest)
Surface in ha: 218 ha
Factor of Growth: 218
Final State Rest
Surface in ha: 218 ha
Factor of Growth: 218
Phase 3
Surface in ha: 122 ha
Factor of Growth: 122
Phase 4b (Steam)
Surface in ha: 160 ha
Factor of Growth: 160
Final State Steam
Surface in ha: 160 ha
Factor of Growth: 160


Phase 4a (Rest)
Surface in ha: 218 ha
Factor of Growth: 218
Final State Rest
Surface in ha: 218 ha
Factor of Growth: 218
Phase 3
Surface in ha: 122 ha
Factor of Growth: 122
Phase 4b (Steam)
Surface in ha: 160 ha
Factor of Growth: 160
Final State Steam
Surface in ha: 160 ha
Factor of Growth: 160

8.2 Reduce Saline Intrusion by Ground Water

Area which can provide this surface: The brackish seepage comes up in low located areas with a low ground water table, so increasing the ground water table in these areas reduces the saline intrusion by ground water.

Key performance indicator: Surface of seepage areas where ground water table is increased in ha

Existing Situation
Surface in ha: 0 ha

Phase 1
Surface in ha: 15 ha
Factor of Growth: 15

Phase 2
Surface in ha: 15 ha
Factor of Growth: 15

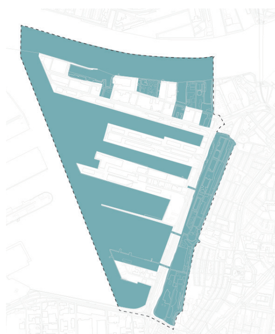
9.1 Temperature Regulation

Area which can provide this surface: All unpaved area

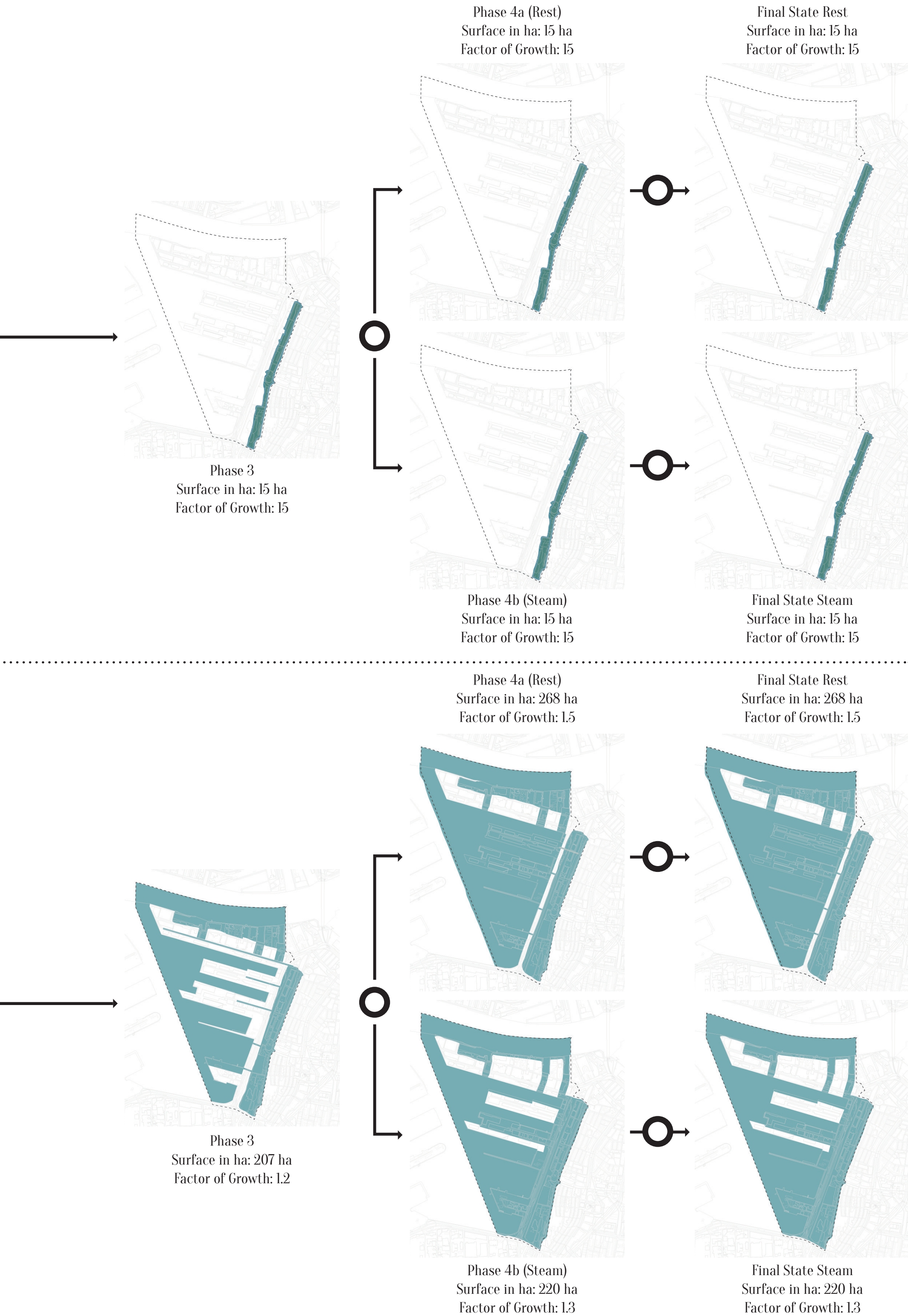
Key performance indicator: Surface of unpaved area in ha

Existing Situation
Surface in ha: 176 ha

Phase 1
Surface in ha: 176 ha
Factor of Growth: 1



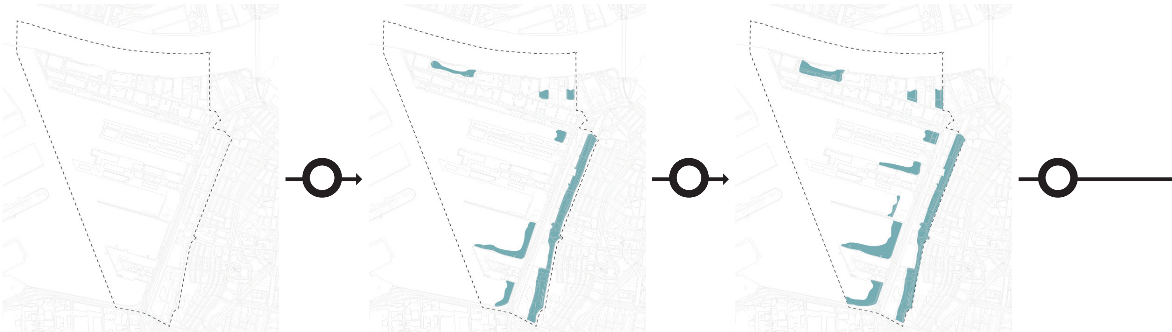
Phase 2
Surface in ha: 202 ha
Factor of Growth: 1.1


Phase 4a (Rest)
Surface in ha: 15 ha
Factor of Growth: 15
Final State Rest
Surface in ha: 15 ha
Factor of Growth: 15
Phase 3
Surface in ha: 15 ha
Factor of Growth: 15
Phase 4b (Steam)
Surface in ha: 15 ha
Factor of Growth: 15
Final State Steam
Surface in ha: 15 ha
Factor of Growth: 15
Phase 4a (Rest)
Surface in ha: 268 ha
Factor of Growth: 1.5
Final State Rest
Surface in ha: 268 ha
Factor of Growth: 1.5
Phase 3
Surface in ha: 207 ha
Factor of Growth: 1.2
Phase 4b (Steam)
Surface in ha: 220 ha
Factor of Growth: 1.3
Final State Steam
Surface in ha: 220 ha
Factor of Growth: 1.3

9.2 Air Purification

Area which can provide this service: All upgoing vegetation, such as alluvial willow foRest and reed and rush

Key performance indicator: Surface of area with upgoing vegetation in ha



Existing Situation
Surface in ha: 0 ha

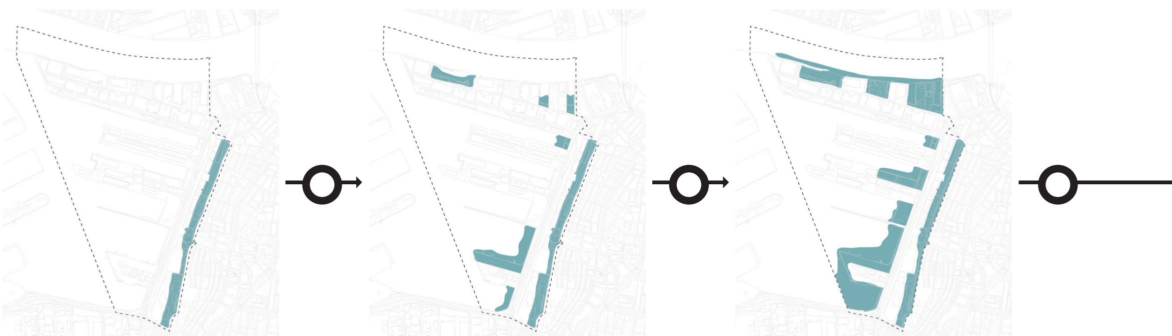
Phase 1
Surface in ha: 24 ha
Factor of Growth: 24

Phase 2
Surface in ha: 38 ha
Factor of Growth: 38

9.3 Carbon Sequestration

Area which can provide this service: All tidal (both mud flats and salt marshes) and fresh nature

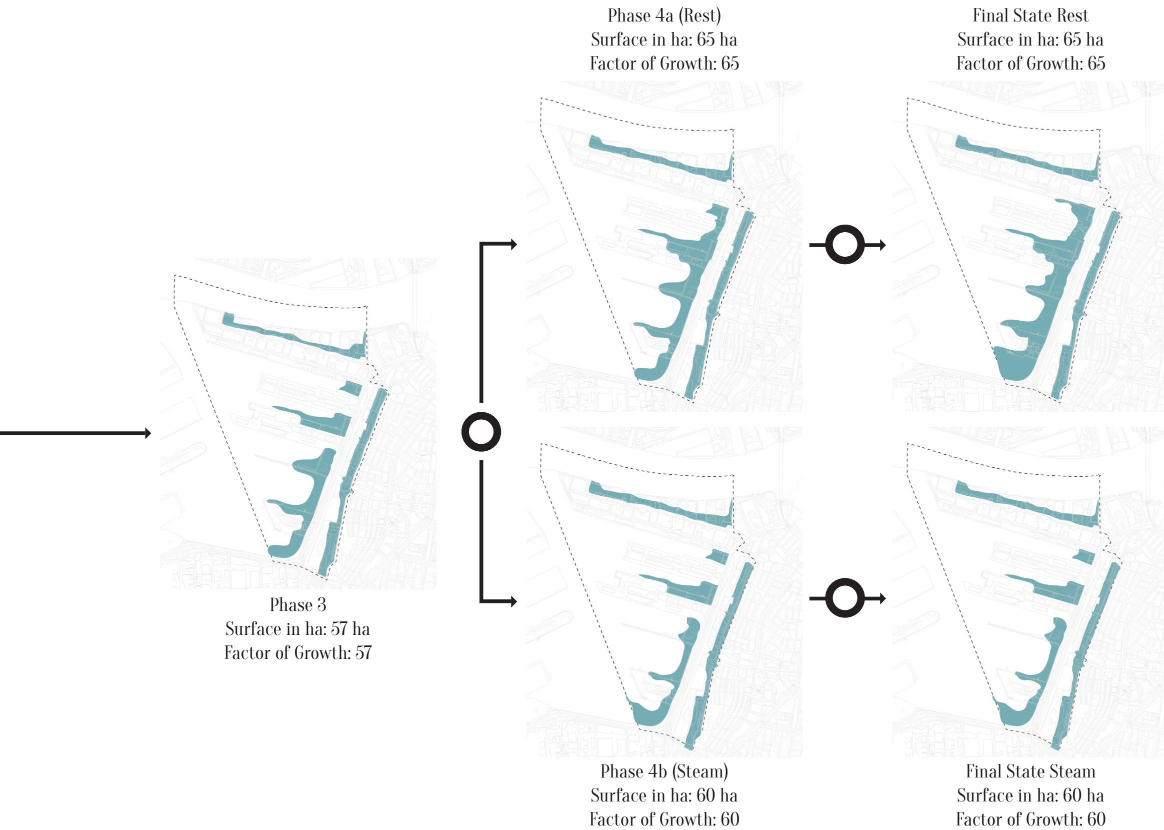
Key performance indicator: Surface of all tidal and fresh nature in ha

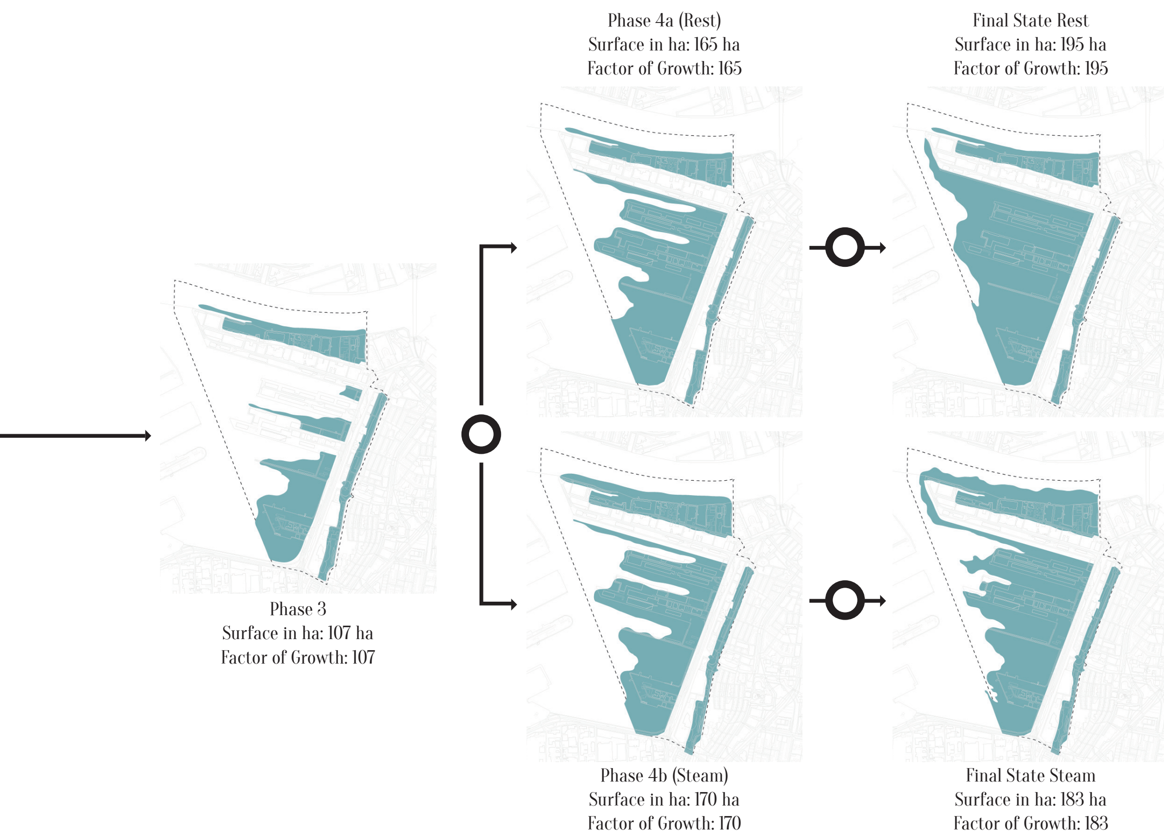


Existing Situation
Surface in ha: 15 ha

Phase 1
Surface in ha: 39 ha
Factor of Growth: 39

Phase 2
Surface in ha: 65 ha
Factor of Growth: 65


Phase 3
Surface in ha: 57 ha
Factor of Growth: 57
Phase 4a (Rest)
Surface in ha: 65 ha
Factor of Growth: 65
Phase 4b (Steam)
Surface in ha: 60 ha
Factor of Growth: 60
Final State Rest
Surface in ha: 65 ha
Factor of Growth: 65
Final State Steam
Surface in ha: 60 ha
Factor of Growth: 60


Phase 3
Surface in ha: 107 ha
Factor of Growth: 107
Phase 4a (Rest)
Surface in ha: 165 ha
Factor of Growth: 165
Phase 4b (Steam)
Surface in ha: 170 ha
Factor of Growth: 170
Final State Rest
Surface in ha: 195 ha
Factor of Growth: 195
Final State Steam
Surface in ha: 183 ha
Factor of Growth: 183